HANDBOOK ON
REPAIR AND REHABILITATION
OF
RCC BUILDINGS

सत्यमेव जयते

PUBLISHED BY

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CPWD Handbook on Repairs and Rehabilitation of RCC Buildings

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FOREWORD

CPWD, with a glorious history of more than 100 years in the field of built environment, is playing a lead role in our country in dissemination of knowledge relating to practices in building industry for engineering profession. It is actively involved in the development of infrastructure for the country and has to its credit successful completion of a large number of prestigious projects including bridges, flyovers, airports, roads and other buildings of national importance. CPWD publications are being used profusely by both public and private sector and they are reckoned as standard engineering practices. A vast number of technical publications have been released for the benefit of engineering community. Some of these are:

1) Manual on Planning and Design of Reinforced concrete multi-storeyed buildings – Vol. –I and Vol. –II. - 1976
2) Maintenance from Approach, Cause and Effect Study by Shri K S Narayanan
3) A Report of Documentation on Fire, Assessment of Damages and Repair of Vigyan Bhawan, New Delhi - 1993.
4) Guidelines and Space Standards for Barrier Free Built Environment for Disabled and Elderly Persons, 1998
5) Manual on Rainwater Harvesting, 2002

Buildings and other structures have a certain useful life, which depends on the specifications adopted. The large number of monuments, which are cherished heritage structures have stood well over a period of time. But some of these have shown signs of distress due to age, aggressive natural environment/ industrial pollution etc. Further, distress gets aggravated due to overloading/ misuse of buildings. A few buildings have also failed due to faulty design / construction. Thus, Repairs & Rehabilitation of buildings are of vital importance. The experiences gained by CPWD and other organisations in Repairs & Rehabilitation of RCC Buildings are presented in this Handbook. A panel of experts drawn from government departments, scientists, research organisations and consultants has ensured that the handbook will provide expert guidance in Repair & Rehabilitation work. An attempt has been made to comprehensively cover all aspects related to repair, rehabilitation and strengthening of RCC buildings at one place. I am sure this handbook will serve as a ready reference guide to all practicing civil engineers, academicians and students.

The initiative and efforts of Shri A K Sharma, Superintending Engineer and his team in Repairs & Rehabilitation Unit under the guidance of Dr A.V.Chaturvedi, ADG (Training) & Shri R Subramanian, Chief Engineers of CDO are commended. I express my appreciation for Shri S. L. Karunakaran, Chairman and all members of the Expert Committee for their valuable contribution in bringing out this handbook, which is first of its kind dealing with the vital area of Repair & Rehabilitation.

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PREFACE

Reinforced cement concrete (RCC) as a construction material has come into use for the last one century. In India, RCC has been used extensively in the last 50-60 years. During this period, we have created large number of infrastructural assets in terms of buildings, bridges, sports stadium etc., which are lifeline for the civilized society. These have been created with huge investment of resources. We cannot even dream of recreating such assets out of limited national resources. It is, therefore, essential to maintain them in functional condition. Since, deterioration of RCC is a natural phenomena and has started exhibiting in large number of structures, a systematic approach is needed in dealing with such problems. Identification of the causes of deterioration and consequent repair/rehabilitation strategy at optimum cost needs a scientific evaluation and solution.

It has been observed that the deterioration phenomena of RCC is not realized by majority of practising civil engineers. As a result, the factors considered necessary for durability of RCC buildings are many times not given due importance during construction and/or during maintenance. The durability provisions have been given emphasis in the revised 'Code of Practice on Plain and Reinforced Concrete' (IS:456-2000). In the international scenario also, deterioration of RCC had been drawing attention of the practising civil engineers for quite some time. They have accordingly, made certain advancements in the field of protection, repairs, rehabilitation, strengthening and retrofitting of the existing RCC structures taking advantage of the advancement in the materials science, more particularly the polymer science. The knowledge in this area among the Civil Engineers, in India is still at infancy stage and needs development and systematic dissemination. This Handbook is a pioneering attempt with this objective in view.

CPWD is a leading organisation practising in construction and maintenance of buildings for over a century. Having faced the problem of deterioration in RCC buildings under its maintenance, the need of specialised unit in the field of repair, rehabilitation and protection of existing buildings was felt and a unit was created on 1/1/96. Based on various investigative works carried out by this unit including remedial measures suggested & adopted for deteriorated buildings and study of literature available on the subject, this handbook has been prepared. The book covers the subject starting from causes of deterioration, investigative methods, design principles, selection criteria of repair materials & methods, guidelines for selection of consultant, short-listing of contractors and preparation of contract documents for repair/rehabilitation contracts including nomenclature and related specifications of commonly used repair items. A variety of case studies with photographs have also been included to facilitate the readers to imbibe a better understanding of the subject.

Initially, the structures deteriorate slowly due to cyclic temperature variations, overloading, physical causes & aggressive chemical attack due to environment etc. Later on, if not paid due attention, these deteriorate rapidly and fail to meet the functional requirement for its designed service life. Various causes of deterioration like original construction defects, chloride induced corrosion, carbonation of concrete, sulphate attack, cracking due to thermal gradient, plastic shrinkage cracks and foundation settlement etc. are discussed lucidly with the help of sketches in Chapter-2.

The first step in repairs and rehabilitation is the proper diagnosis for successful rehabilitation works. Chapter 3 deals with Non Destructive Evaluation (NDE) techniques, laboratory tests and Condition

Survey Techniques. Over forty tests have been enumerated for measurement of different properties grouped in four categories as given below:

a) Corrosion of embedded steel,

b) Concrete quality, durability and deterioration,

c) Concrete Strength

d) Structural Integrity

Details of commonly used tests for Non Destructive Evaluation (NDE) like Rebound hammer test, Ultrasonic Pulse Velocity (UPV) test, Capo / Pull out test, Core test, Chloride test, Carbonation test, pH measurement, Resistively test, Differential Thermal Analysis (DTA), etc have been dealt with. Symbols for recording distresses on building plans and worksheets have been given. Proforma for scientific analysis, planning and documentation has been developed which will go a long way in grouping / classification of damages. These in turn are useful tools in selection of the appropriate repair technique.

Chapter 4 deals with the analysis and design of repairs, which are quite different from the original design. For this purpose, repairs have been classified as active or passive depending upon the relieving or non-relieving of existing stresses & strains before carrying out the repairs. The types of stresses acting on the interface of substrate and repairs have been briefly discussed for a designer not to loose sight off during structural evaluation.

The compatibility of repair material with the parent material is an essential requisite for successful repairs. Chapter 5 covers cements, admixtures, additives, polymers and epoxies in detail specifying wide and varied application with their advantages as well as limitations. Attempt has been made to guide the readers to select the right type of material for a specific job. The directory of Indian manufacturers of repair materials and testing laboratories has been included for information of users.

The methods available for repair, rehabilitation and retrofitting are many. The chapter-6, which is on 'Repair, Rehabilitation and Retrofitting Methods' gives guidelines for selection of method from various repair options available to suit the performance requirement of repair system. More than twenty techniques for dealing with various types of distresses and other situations have been described. These generally cover concrete, RCC structural members like slabs, beams, columns, and foundations, repairs of cracks, strengthening of masonry, surface protection, reinforcement etc.

As the structural repairs have to be generally investigated by the consultants and executed through contractors, foolproof contract documents are basic necessity. Chapter-7 'Guidelines for Special Conditions of Contract' gives information for engagement of consultant and short-listing of contractors and also gives the checklist, so that none of the salient points are missed while preparing the contract/tender documents.

Chapter-8 and Chapter-9 give the nomenclature and related specifications of more than seventy items generally used in repairs and rehabilitation works. These have been grouped under ten subheads. The specifications are given in easy to follow step-by-step format for their fail-safe execution/application in the field.

An expert group in the field of repairs, rehabilitation and retrofitting, consisting of over fifteen experts drawn from Government and Non Government practising engineers/designers/consultant/leading scientists was constituted for finalisation of this Handbook drafted by the Repair & Rehabilitation

Unit of CPWD. This was done with a view to ensure that all aspects required are covered in such a Handbook in a lucid form for reference and adoption.

It is hoped that this handbook, which covers A to Z of Repairs and Rehabilitation, will be of immense use for the student community, Academicians, consultants, practising professional engineers / scientists involved in planning, design, execution, inspection and supervision, for proper Repair and Rehabilitation Management of Buildings.

The time for preparation of the book was rather tight and hence the aspect of retrofitting could not be dealt in detail. Since the subject is rather nascent in the country, it is proposed to update the Handbook every 3 to 5 years. If the readers wish to share their typical experiences in the form of case studies, they are welcome for inclusion in the updated versions. Comments and suggestions for improvement are welcome from the readers and users.

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CHAPTER 1

INTRODUCTION

1

INTRODUCTION

The whole professional life of engineers is based on team work rather than on personal competitiveness

...Freeman Dyson

Concrete construction is generally expected to give trouble free service through out its intended design life. However, these expectations are not realized in many constructions because of structural deficiency, material deterioration, unanticipated over loadings or physical damage. Premature material deterioration can arise from a number of causes, the most common being when the construction specifications are violated or when the facility is exposed to harsher service environment than those expected during the planning and design stages. Physical damage can also arise from fire, explosion – as well as from restraints, both internal and external, against structural movement. Except in extreme cases, most of the structures require restoration to meet its functional requirements by appropriate repair techniques.

1.1 An Overview of Present Repair Practices

Since 1950s, the construction activity in India has been increasing geometrically without matching increase in the availability of quality inputs, in terms of materials and skilled workmen. The gap between the quality planned and the quality achieved continues to become wider. The factors contributing to damages/distresses in buildings have, thus, become intrinsic right from the construction stage. Often these are concealed under external renderings and the defect takes time to manifest itself.

Construction documents contain adequate specifications and instructions required to execute quality works. However, they remain as written document without achieving the desired level of results, because of lack of understanding of their significance by the field engineers. Standard cube test results are taken as a measure of quality in the construction. Whereas the factors such as method of placing, compaction and curing of concrete, which have significant influence on the quality achieved in the hardened concrete, are given scant attention. Many a times, the quality of concrete as placed and hardened in position has no correlation to the cube test results, which are used for quality control measures.

Procedures, mandatory or otherwise, for periodic inspection of buildings and structures and documenting defects, like cracks, excessive deflections, corrosion of reinforcement etc., in logical manner, and recording of structural repairs already carried out, are generally not followed or maintained. In some buildings, only visual inspection is carried out for preparing maintenance budget estimates and this exercise is often left to the engineers who have no experience in such problems.

Concrete constructions require proper care in the form of regular maintenance. Buildings remain for several years without getting due attention. Water stagnation, paint pealing, plaster break- off, fungus growth, cracking of external rendering and cover concrete are common and widespread. Penetration of moisture into reinforced concrete components promotes corrosion process and further damages the concrete cover.

The engineers responsible for maintaining buildings often begin repair activity without adequate understanding of the factors responsible for the defects. The repairs strategy adopted is replacement of damaged materials without dealing with the real problems. Many engineers unintentionally attempt treating the symptoms, instead of dealing with the cause and effect phenomenon. Such an approach may offer a quick action with minimum inconvenience to the occupants. But in this process, there is a strong possibility that the source and cause for the distress remain unattended and continue to cause problem even after the superficial repairs have been executed. If structural defects are dealt with in this fashion, it remains only as defects camouflaged beneath finishes, which gives a false sense of safety to the occupants allowing the problem to continue without getting treated. A rational approach to any repair and rehabilitation work is to consider the source of the problem and the symptoms together.

1.2 Distress Identification

Before attempting any repair procedure it is necessary to have a planned approach to investigate the condition of concrete and reinforcement. While the diagnosis of damage or deterioration in some cases is reasonably straightforward, it may not be so in many cases. Particularly difficult are cases in which the cause and effect phenomenon cannot be readily explained or when prognosis in terms of long-term performance of restored structure is to be made.

This will require a thorough technical inspection and an understanding of the behaviour of the structural component, which is being repaired. Inspection calls for detailed mapping of affected areas, documentation of type and location of symptoms and their history and photographic evidences. It may also include the environmental factors, which are likely to accelerate the damage process. Existence of concealed ducts, water lines, wet areas require special attention. Some areas impose severe limitations on access to damaged areas. A comprehensive inspection data helps in making an effective strategy for repair and rehabilitation.

Non-destructive evaluation (NDE) of concrete and components are well known and extensively used. While they are very good tools for establishing quality levels in new constructions, applying these techniques to damaged structures requires certain level of experience and understanding of limitations of these methods. Solving the problem successfully is entirely dependent on the ability of a team of experts engaged to do this job. Both field and laboratory tests are available. It is important to select the appropriate Non Destructive Evaluation (NDE) techniques and location of investigation. This is a specialised job and requires sophisticated instruments and trained personnel. A single technique may not be adequate and a combination of techniques has to be adopted to get a truly representative data on the condition of the building.

Concrete normally provides excellent protection to reinforcing steel. Notwithstanding this, a large number of cases have been reported in which corrosion of reinforcement has caused damage to concrete structures within a few years from the time of construction. One of the most difficult problems in repairing a reinforced concrete element is to handle corrosion damage. Reinforcement corrosion caused by carbonation is arrested to a great extent through repairs executed in a sound manner. However, the treatment of chloride-induced corrosion is more difficult and more often the problem continues even after extensive repairs have been carried out. It invariably re-occurs in a short period of time. Repairing reinforcement corrosion involves a number of steps, namely, removal of carbonated concrete, cleaning of reinforcement, application of protection coat, making good the reduced steel area, applying bond coat and cover replacement. Each step has to be executed with utmost care. When chlorides are present in concrete, it is extremely difficult to protect reinforcing steel from chloride attack, particularly in cases where chlorides have entered through materials used in construction and residing in the hardened concrete. For such cases, new technologies are available which require specialists to execute the job.

1.3 Repair Management

Three distinct stages are to be recognized while taking up a repair job. The first stage involves documentation of damage, its type and extent, prognosis of repaired structure and recommendations on repair methodology. For major jobs it will be worth while to engage an independent consultant to do this job. The second stage requires preparation of detailed drawings, sketches, execution guidelines and notes, material and works specifications and tender document. The tender document should adequately cover various elements to the extent possible. Specific provisions in terms of material specifications should be included. It should clearly define modalities of payment, works measurements and records. This will facilitate in receiving a fair and competitive proposal for the repair works. Guidelines prepared for executing the job should be practical and flexible so as to encourage the ingenuity of the contractor executing the job. The third stage is actual execution of repairs. This is a specialised job and those who have the necessary expertise and resources in terms of tools and plants should be engaged. The supervising engineer should have a good understanding of the procedures and give an attentive supervision. In some cases it may become necessary to monitor the effectiveness of repairs by various tests before and after the repairs have been executed.

Various options in terms of techniques and repair materials are available for executing repair jobs. Selecting a most appropriate material and repair methodology is very important to achieve durable, effective and economic repairs. Matching the response of repaired sections with the main structure is an important task.Compatibility of materials and matching specifications are essential in any repair job. Just as building durable construction requires understanding of structural engineering, material science, and environment/ exposure conditions, repair jobs also require the same level of attention in these areas.

The buildings taken up for repair may have structural deficiency and in such cases it is necessary to consider provisions for strengthening through bracing and creating alternative load transfer framing to give additional reserve strength to the structure for adequate safety and serviceability response. If this aspect is overlooked, the symptoms are likely to reappear even after repairs have been carried out.

Familiarity with repair methodology and repair materials is very essential. General civil en1gineering practice does not offer much scope in this area. The engineer undertaking such specialised jobs should have good knowledge of new materials, repair methodologies, its limitation and the fundamentals of structural engineering to ensure safety and serviceability of the buildings during repair and thereafter.

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CHAPTER 2

CAUSES OF DETERIORATION AND DURABILITY ASPECTS

2

CAUSES OF DETERIORATION AND DURABILITY ASPECTS

All things are hidden, obscure, and debatable if the cause of the phenomna be unknown, but everything is clear if this cause be known

..Louis Pasteur

2.0 General:

Concrete is a composite material that consists essentially of a binding medium, within which are embedded particles or fragments of aggregates. However in cement concrete, which is relevant to RCC structures, the binding medium is the mixture of hydraulic cement and water.

All concrete in service will be subject to chemical and physical changes. A durable concrete is one in which these changes occur at a rate, which does not detrimentally affect its performance within its intended life. Leave it to concrete alone, the material remains by and large durable, but concrete alone cannot be utilised extensively for structural applications. It is the Reinforced Concrete (RCC), a composite structural material, which is utilised for variety of structural uses. But, it has been observed that RCC has not proved to be durable due to large number of factors, including variations in production, loading conditions in service life and subsequent attack by the environmental factors. However, a well constituted, properly compacted, and cured concrete used in RCC continues to be substantially water tight and durable as long as capillary pores and micro-cracks in the interior do not become interconnected pathways leading to surface of concrete. (Ref Fig 2.1(a) &2.1(b))

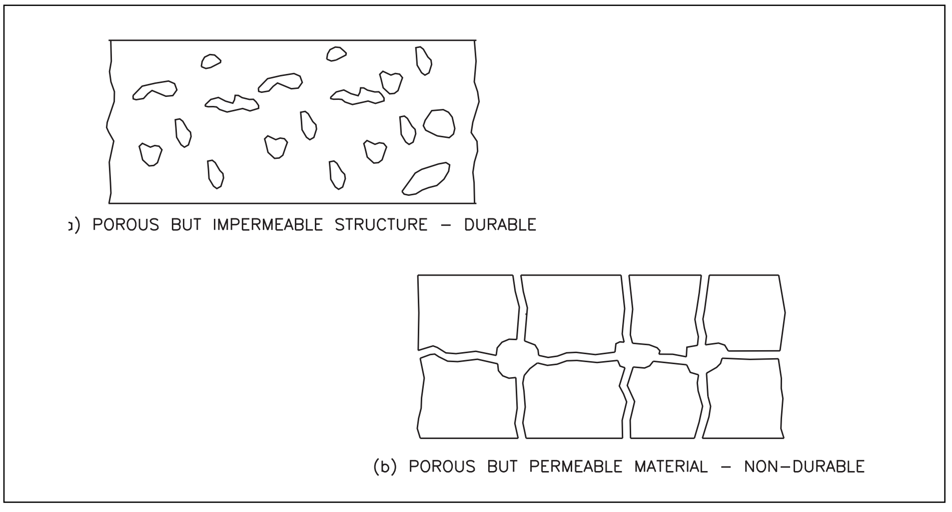


Fig 2.1: (a) Porous but Impermeable Structure (b) Porous but Permeable structure
Fig 2.1: Structure of Durable Concrete and Non-durable concrete

Case studies reported in the literature show that many reinforced concrete structures, within a life period of 15 years or so, suffered from of durability distress. The external symptom range from cracking to spalling of concrete, which frequently involved corrosion of reinforcement. The field cases included in Chapter 10 of this publication give further details on the magnitude of this problem. In almost all the field cases, penetration of water and /or aggressive chemicals during the service life of structures, is the primary reason for the problem. Addressing the issue of deterioration, carbonation, chloride ingress, leaching, sulphate attack, alkali-silica reaction and freeze-thaw are the known responsible natural causes. Out of these, the first three can all lead to corrosion of reinforcement. The general approach for durability is to demand impermeability of concrete as the first line of defence against any of the deterioration process. Damages due to other natural hazards including fire damage may not come under this category.

Although it is difficult to generalize the causes of deterioration due to interacting nature of various factors, efforts have been made to group the various types as physical and chemical. Because the micro-structure of concrete material is continuously changing in response to penetration of water, CO_2, oxygen and aggressive ions at a rate, which is influenced by local conditions of temperature, humidity and pressure, it would be difficult to make exact quantitative predictions of cause affecting service-life. Based on this simplification, few holistic models of deterioration of RCC have been illustrated, which represent a qualitative design approach for easy understanding of the contributing factors for deterioration and its mechanism.

2.1 Holistic Model of Deterioration of RCC

2.1.1 Model-1

According to this holistic model of deterioration of concrete shown in Fig 2.2, the deterioration process is considered in two stages. During the first stage, due to loading and weathering

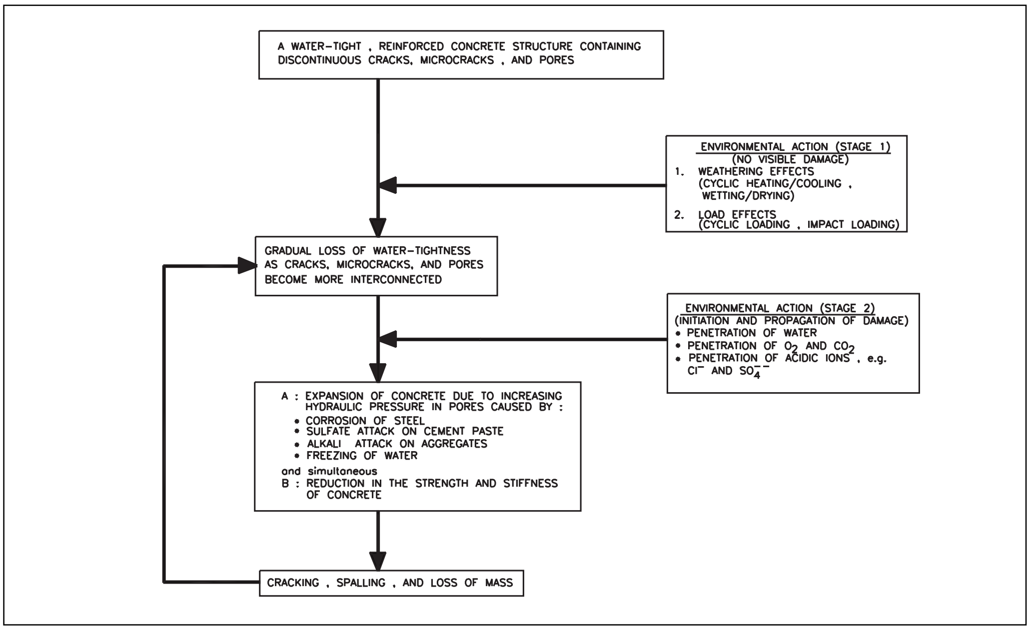


Fig 2.2: Holistic Model-I of Concrete Deterioration from environmental effects

(Source: P.K. Mehta, "Concrete Technology: Last, Present and Future," SP-144, American Centre Institute, Detroit, 1994)

effects (e.g. cycles of wetting & drying, diurnal & seasonal temperature variations, etc) the voids and micro-cracks in the interfacial zone between the cement paste and coarse aggregate or reinforcing steel become inter-linked. When the inter-linked network of micro-cracks gets connected to any cracks present at the concrete surface, this provides the primary mechanism of fluid transport into the interior of concrete. Once this happens, the penetrability of concrete increases greatly and the beginning of the second stage during which water, oxygen, carbon dioxide and acidic ions are able to penetrate easily into concrete. The presence of these elements facilitates various physical-chemical interactions as a result of which, the material eventually undergoes cracking, spalling and loss of mass resulting in partial loss of strength and stiffness.

2.1.2 Model-II

According to this concept as illustrated in Fig. 2.3 there are three stages, namely gradual loss of water tightness, initiation of damage and propagation of damage. During the stage 1 no noticeable weakening of the material occurs but some protective barrier is being broken down, such as the depassivation of the reinforcing steel by CO_2 or chloride penetration. While discussing this model, Prof Mehta says that the longevity of stage 1 can be manipulated through proper attention to the selection of materials, mixture proportions and concrete processing.

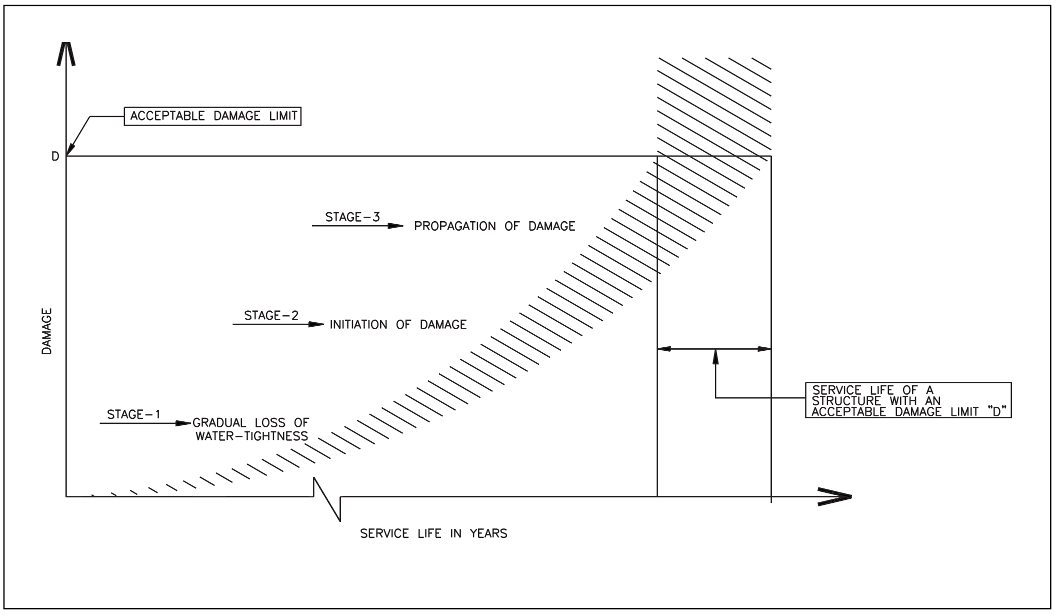


Fig. 2.3: Holistic Model-II of Deterioration of RCC

2.1.3 Model-III

Another model on deterioration of concrete, which is dependent on the important role played by water cement ratio (W/C), is illustrated in Fig 2.4. This offers an overall view on the co-existence of the following three principal elements.

(a) Interconnected porosity of Cement paste
(b) Exposure to aggressive agents/chemicals
(c) Intermittent presence of water

In absence of any of these three elements, damage to RCC will not occur. For example, even in a porous and/or micro cracked concrete, further deterioration can not occur, in absence of water/moisture even if there is a potential presence of environmental aggressive agent such as $SO4^{-2}$, Cl^{-}, CO_2. In absence of water/moisture, these aggressive ions cannot travel, through inter connected pores. Thus, neither sulphate attack on cement paste nor the corrosion of steel reinforcement can occur.

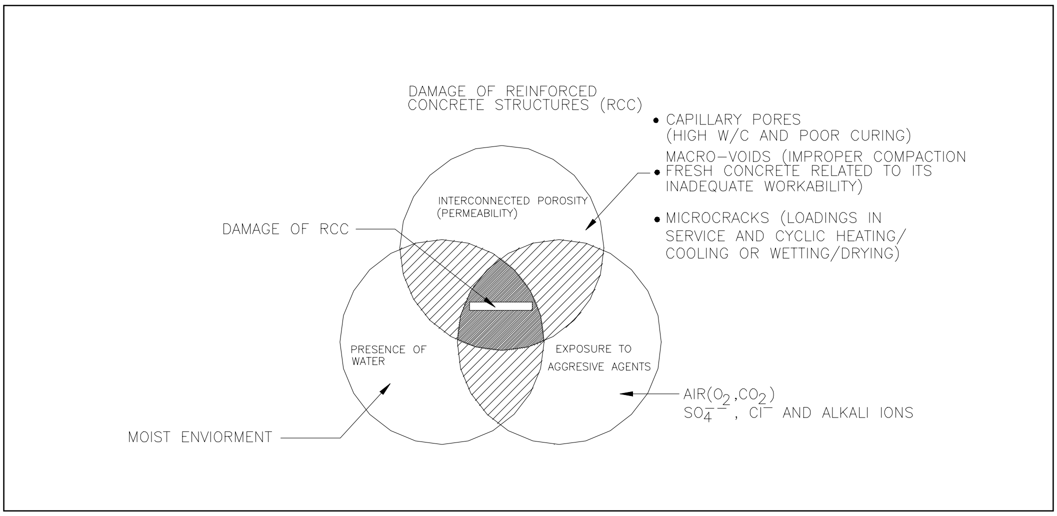


Fig. 2.4: Ternary Representation of the Damage to RCC

(Source: M. Collepardi, "A Holistic Approach to Concrete Durability—Role of Superplasticisers" Proc. of International Syuposium on Concrete Technology for Sustainable Development in Twenty-First Century, Hyderabad, India, Feb., 1999)

2.2 Permeability Of Concrete

As deterioration process in concrete begins with penetration of various aggressive agents, low permeability is the key to its durability. Concrete permeability is controlled by factors like water-cement ratio, degree of hydration/curing, air voids due to deficient compaction, microcracks due to loading and cyclic exposure to thermal variations. The first three are allied to the concrete strength as well. The permeability of cement paste is a function of water-cement ratio. This is well illustrated in Fig 2.5. Beyond 0.55 there is an asymptotic increase. Given good quality materials, satisfactory proportioning and good construction practice, the permeability (i.e. 'Interconnected Porosity') of the concrete is a direct function of the porosity and interconnection of pores of the cement paste. Interconnected Porosity is related to:

1.	Capillary Porosity	-High w/c ratio -Inadequate curing
2.	Air voids	-Improper compaction
3.	Micro cracks	-Loading effects -Weathering -Initial care -After care -Secondary effects

4.	Macro cracks	-Placement, -Hardening process -Intrinsic chemical attack -corrosion of reinforcement

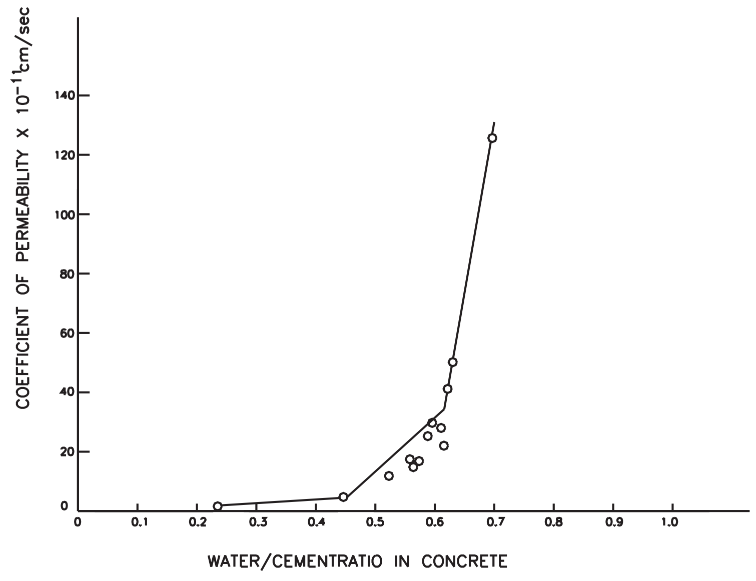


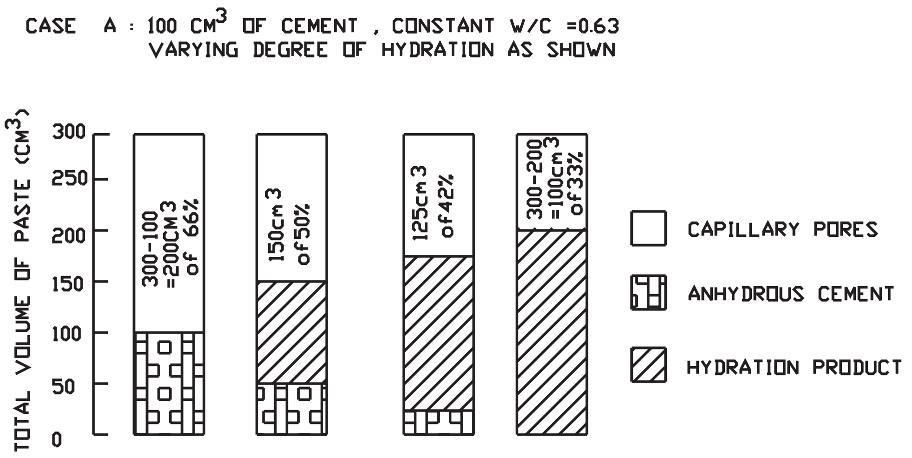
Fig. 2.5: Permeability of cement paste is a function of water-cement ratio

For understanding the permeable character of concrete, it is necessary to understand the mechanism of formation of pores, capillaries and air voids during hardening process due to hydration of cement paste. This is better understood by knowing the composition of cement and resultant hydration products after chemical reaction with water.

2.2.1 Capillary Porosity: The volume of hydrated cement product is significantly higher than the volume of its constituents (i.e., cement particles and water). As a result of hydration, increased volume of hydrated gel eventually fills part of capillary pore volume [Fig 2.6 (a)]. This helps in creating discontinuity in capillary pores. Whereas any lessening in the hydration process will not give the full benefit from this phenomenon.

It can be shown that 100 gm of anhydrous Portland Cement requires about 23 gm of water (a water/cement ratio of 0.23) after about a month's hydration under normal conditions. However, for achieving full hydration as well as to render the mortar/ concrete workable, excess water is required. This extra volume of water entrapped in the cement paste after completion of hydration leaves interconnected pores, called capillaries in hardened concrete, which become means of passage for external/environmental chemicals into the concrete. This porosity is termed as capillary porosity. The porosity obviously increases with the increase in w/c ratio [Fig 2.6(b)].

This approach is explained in simplified models in Fig 2.6(a) and 2.6(b) , wherein Case-A shows changes in permeability for constant w/c ratio under varying degree of hydration & Case-B indicates change in porosity at complete hydration for varying w/c ratio.



DAYS HYDRATED	NONE		7d		28d		1Yr.
HYDRATION DEGREE			50%		75%		100%

Fig. 2.6(a): Changes in capillary porosity with varying degree of hydration

(Source: Concrete—Microstructure, Properties and Meterials by P. Kumar Mehta & Paulo J.M. Mouterio)

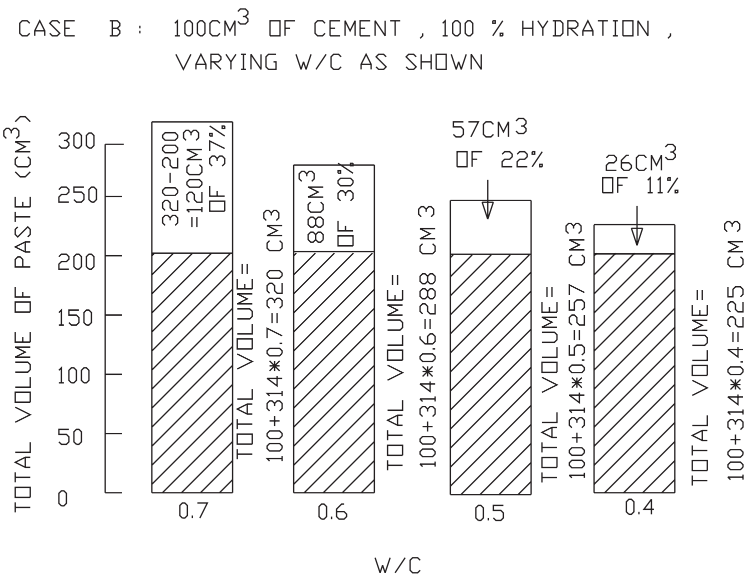


Fig. 2.6(b): Changes in capillary porosity with varying w/c ratio

(Source: Concrete—Microstructure, Properties and Meterials by P. Kumar Mehta & Paulo J.M. Mouterio)

Tables 2.1 and 2.2 illustrate the effect of curing time on capillary pores and the curing time required for various w/c ratios.

In a well constituted, adequately compacted & cured concrete with low water-cement ratio, volume of capillary pores gets reduced and become discontinuous due to expansive hydrated gel, which significantly reduces the permeability.

Table 2.1: Curing Time required for various water-cement ratios

Water-Cement Ratio by mass	Curing Time required for capillary discontinuity
0.4	3 days
0.45	7-days
0.5	14 days
0.6	6 months
0.7	1 year
>0.7	1 year

Table 2.2: Typical Reduction in permeability of cement paste with progress of hydration

(Source: T.C. Powers, L.E. Copeland, J.C. Hayes and H.M. Mann, J.ACI, Proc. Vol. 5, pp. 285-98, 1954)

Age (days)	Coefficient of permeability ($\times 10^{-11}$ cm /sec)
Fresh	20,000,000
5	4000
6	1000
8	400
13	50
24	10
Ultimate	6

2

2.2.2 Air Voids: Air voids (much larger than capillary pores) form due to inadequate compaction in the form of discrete air bubbles (as in air entrained concrete) of much larger size than capillary pores. These air voids may get inter-connected by capillary pores system.

2.2.3 Micro Cracks: During service life of a reinforced structure, it is subjected to various types of loading conditions (static and/or of cyclic nature) and also exposed to extreme exposure conditions of temperature variations (diurnal and seasonal). Micro-cracking combined with capillary porosity is generally responsible for ingress of aggressive chemicals in RCC.

- **Cyclic loading:** Fig 2.7 illustrates the crack propagation due to cyclic load in tensile zone of an RCC beam. The crack depths in structural members due to cyclic loading are higher than due to static loads of same intensity.

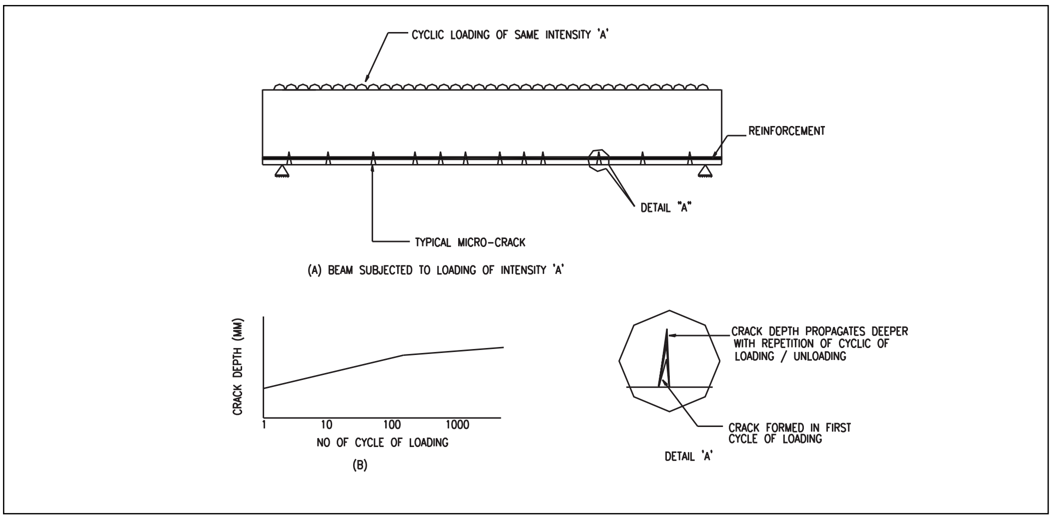


Fig. 2.7 Crack propagation in tensile zone of an RCC beam.

- **Differential Thermal Exposure:** The structural members having different thermal exposure conditions on the opposite faces, more particularly, those located on the exterior, are subjected to loading due to temperature gradient within the cross section. This is due to difference in temperature on the two faces of member during different times. As a result, tensile stresses in excess of tensile strength of concrete could develop across the cross section and result in formation of micro cracks. This process is cyclic due to *diurnal and seasonal* temperature variation conditions. Cyclic nature of loading is responsible for further increase as the crack depths propagate deeper with each cycle. Fig 2.8 illustrates the cyclic process of thermal loading of a structural member.

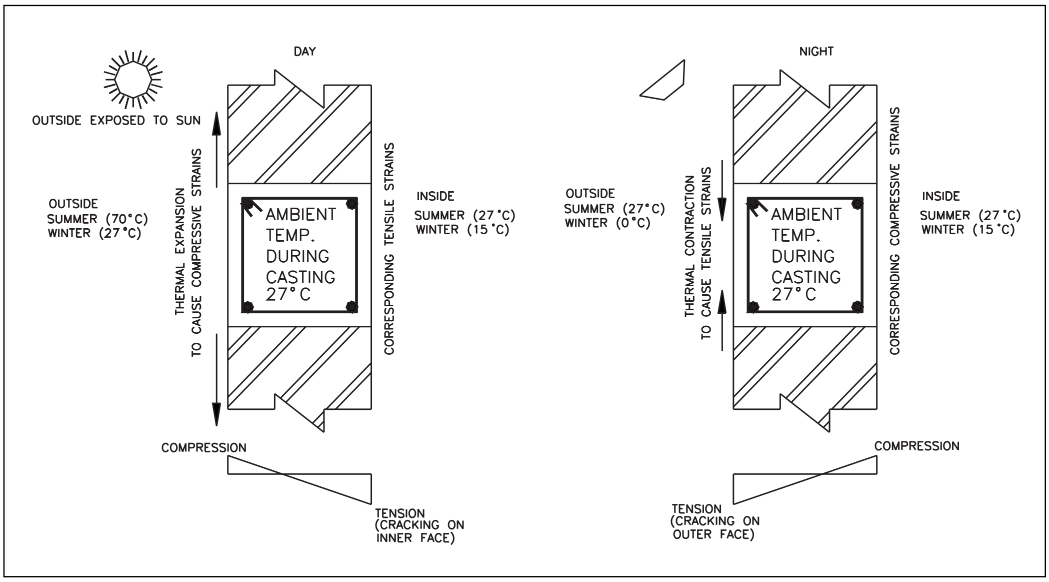


Fig. 2.8 Cyclic process of thermal loading of a structural member.

- **Other causes:** Besides above, several other factors and secondary effects would also cause micro-crack formation, which could be severe in special structures under special circumstances.

Initial and after care of the structure in the form of periodical painting, also plays an important role in controlling the adverse effect due to propagation of such micro-cracks.

2.2.4 **Macro Cracks:** Some minor cracking in concrete structures would occur within the normal practice. Proper design and detailing coupled with proper construction practice can control the crack widths. Any crack width, which allows aggressive chemicals to travel freely into the concrete, is termed as Macro Crack. The threshold limiting crack width has been defined by various codes of practices for RCC design. These vary from 0.1 to 0.3 mm. Any crack in concrete, which is wider than this, is likely to cause durability problems. Beeby has showed from his experimental and theoretical work that the relationship between corrosion and crack width either does not exist or, if it does, is not a significant factor compared with other variables such as the amount of cover and the quality of the concrete. Yet many others consider that even micro-cracking is responsible for easy ingress of aggressive deteriorating chemicals in to the cover concrete to adversely affect and cause depassivation to initiate corrosion of embedded steel reinforcement and acelerate the same with development of macro cracks. Macro cracking in concrete could be due to variety of reasons, which includes:

- Improper placement of concrete,
- Settlement cracks of fresh concrete,
- Cracking due to
  - intrinsic sulphate attack,
  - alkali aggregate reaction,
  - heat of hydration,
  - Increased volume of Corroded reinforcement exerting bursting pressure on concrete.
- Excessive Loading

2.3 Aggressive Deteriorating Chemical Agents

The deterioration of RCC is basically related to loss of water tightness of cover concrete and migration of aggressive chemicals through interconnected porosity, which in turn chemically attacks on its constituents i.e. hydrated cement gel, aggregate and the reinforcement as under:

(a) Corrosion of reinforcing bar
- Due to carbonation of concrete
- Due to ingress of chloride

(b) Sulphate Attack

(c) Alkali Silica Reaction (ASR)

2.3.1 Corrosion of reinforcing bars: Steel reinforcement in concrete is protected from corrosion by a combination of

- the formation of a passivating protective layer on steel surface due to chemical reaction under highly alkaline environment and
- the environmental protection provided by the concrete cover.

The hydration reactions of portland cements release allkalies giving it a high pH in the range of 12.6 to 13.5. Even though oxygen and moisture may reach the steel surface, it will not corrode and will remain passive as long as high pH is maintained and the cover concrete is intact. The two common conditions that lead to the loss of passivity of steel in concrete are

i. Reduction of alkalinity of concrete surrounding the steel with pH lower than 11 to 11.5

ii. Presence of chemicals (e.g. chloride ions), which destroy the passivity even while the alkalinity of surrounding concrete remains high.

Note: *Use of rusted reinforcement will promote further rusting since pre rusted surface will impede the passivation of steel substrate.*

The three elements needed (see Fig 2.9) for initiation of the corrosion of reinforcement bars are:

- De-passivation of Steel
- Oxygen
- Intermittent presence of water i.e. alternate wetting and drying

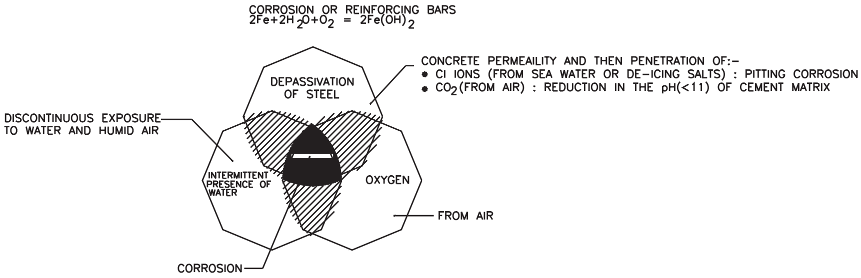


Fig. 2.9 Corrosion of reinforcement due to environmental elements
(Source: M. Collepardi, "A Holistic Approach to Concrete Durability—Role of Superplasticisers" Proc. of International Syuposium on Concrete Technology for Sustainable Development in Twenty-First Century, Hyderabad, India, Feb., 1999)

Carbonation: The alkalinity in concrete is provided by hydroxides of calcium, sodium and potassium present in the hardened cement gel. Permeation of carbon dioxide into concrete through interconnected pores and its reaction with these hydroxides causes chemical reaction as under:

$CO_2 + H_2O = H_2CO_3$(Acid)

$Ca(OH)_2 + H_2CO_3 = CaCO_3 + 2H_2O$

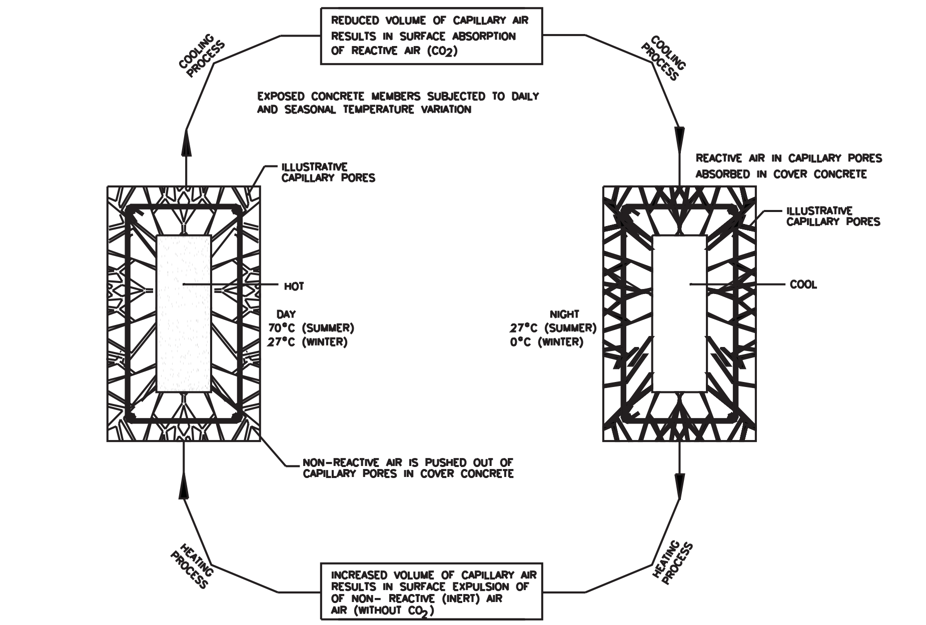
(Alkali) (Acid) (Salt) (Water)

Because of this reaction, the alkalinity of concrete gets reduced. This process is called Carbonation of concrete. Carbonation of concrete can be a problem in areas where the concentration of CO_2 is high and relative humidity is moderate (50-60%). Permeable concrete made with low cement content, high water—cement ratio, and inadequately moist-cured tend to suffer from serious carbonation even due to diurnal or seasonal temperature variations [Fig 2.10(a)]. Diffusion of gaseous products from environment (CO_2 and O_2) cannot occur or if occurs, at negligible rate in a fully and permanently saturated concrete. On the other hand, water is also needed for feeding the corrosion process. Therefore, discontinuous i.e. intermittent exposure to water (rain or wetting/drying cycle due to leakage from toilets) [Fig 2.10(b)] is the most favourable condition for corrosion of reinforcing steel. Once the passive film is destroyed, the affected portion of reinforcing steel is exposed to action of oxygen and water; consequently corrosion in reinforcement steel is initiated.

Localised rusting of reinforcement steel is represented as under:

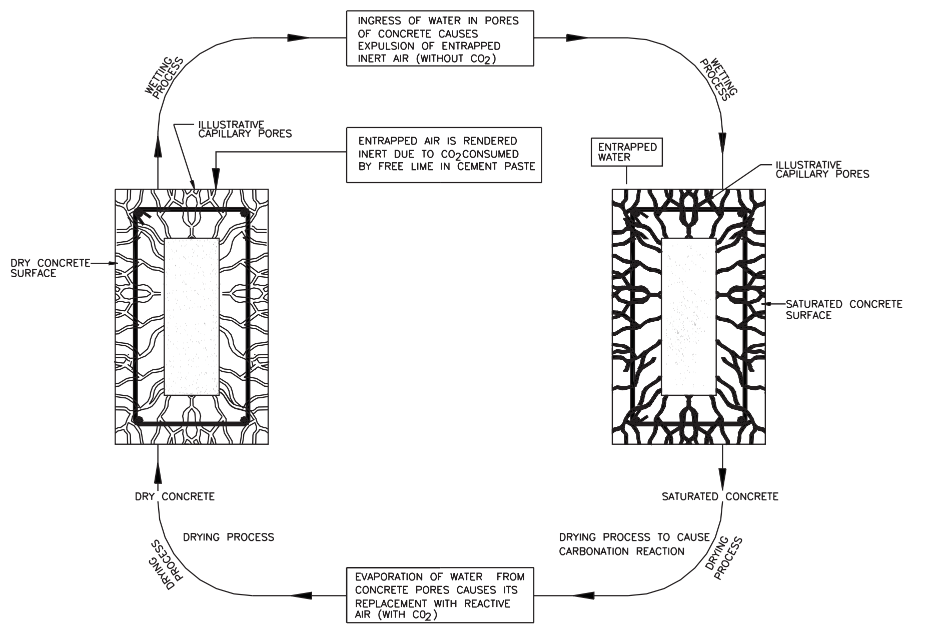
Anode reaction $Fe = Fe^{++} + 2e^-$

Cathode reaction $O_2 + 2H_2O + 4e^- = 4(OH)^-$ (Oxygen is reduced)



(a) . UNIFORM HEATING / COOLING CYCLE

FIG. 2.10(a) ACCELERATED CARBONATION PROCESS OF CONCRETE SURFACE



(b) ALTERNATE WETTING / DRYING CYCLE

FIG. 2.10(b) ACCELERATED CARBONATION PROCESS OF CONCRETE SURFACE

Chlorides: These may be present in the fresh mix or may penetrate from external source into the hardened concrete. Due to the deleterious effect of chlorides on the corrosion protection of the reinforcement, the chloride content of the mix is limited to certain values in relation to cement in almost all standards. During use of the structures, chlorides may penetrate into the concrete from various sources. The most important of these are sea water. Substantially greater amounts of chlorides may ingress into the hardened concrete via water transport mechanisms than via pure chloride ion diffusion. The rate of penetration depends both on the diffusion property of the concrete and on its binding capacity. The composition of binder plays important role for the penetration resistance of concrete than the amount of cement used and the water/cement ratio.

The parameters having decisive influence on the chloride-induced corrosion of the reinforcing steel are : chloride content at the steel surface; C_3A content in cement; addition of blast-furnace slag/fly ash/silica fume in mix; water cement ratio; concrete cover; temperature and relative humidity. The quality of the concrete cover is the dominant influencing variable for the corrosion rate in the crack zone. This is, however, true only of crack widths up to about 0.4mm. With larger cracks, crack width is of decisive importance, since a different corrosion mechanism is dominant in this situation. If the reinforcement detailing rules given in the codes are followed, it generally ensures that the crack widths are in the order of 0.3mm or less.

Lower the permeability of cover concrete, longer the time it takes for the penetration and depassivation of embedded steel to affect the RCC. A corrosion initiation period is thus, dependent on permeability of cover concrete. Deffusion of air and chloride ions cause carbonation and depassivation of steel. Oxygen available in the air becomes a feed for the corrosion process.

Water	Acts as electrolyte. A medium for penetration of harmful dissolved materials
Carbon Dioxide	Reduces Alkalinity of concrete – Results in destroying the passive film on the reinforcing steel reinforcement and thereby corrosion is likely to initiate.
Chloride	Destroys the passive film on reinforcing steel and initiates corrosion of steel .

2.3.2 Sulphate Attack: The term, sulphate attack, is generally used to mean the deterioration of concrete as a result of physical-chemical interactions between the minerals in hardened Portland cement paste and sulfate ions from the environment. Soils containing sulfates of calcium, sodium, potassium and magnesium are the primary source of sulfate ions in groundwater. A high sulfate content in water is generally indicative of the presence of magnesium and /or alkali sulfates. In combination with ammonium, chloride, nitrate and carbonate ions the sulfate ion attack is more severe.

The sulfate attack on concrete manifests itself in the form of expansion, cracking, loss of mass and/or disintegration. Expansion and cracking is generally associated with the product ettringite formed due to reaction between sulphate ions and the hydration products C_3A present in high quantity in Portland cement pastes. The ettringite formation could take place due to internally present sulphate ions or sulphate entering from external sources. In addition to ettringite, cement paste subjected to prolonged attack by aggressive sulfate solutions generally contain gypsum which forms as a result of progressive decomposition of calcium hydroxide and calcium silicate hydrates. This leads to a reduction of stiffness and strength, with eventual transformation of the material into a mushy mass.

For improved resistance to sulfate attack, a reduction in the porosity and consequently the coefficient of permeability, is more important than modification in the chemistry of cement. Addition of mineral admixtures, such as fly ash, ground blast furnace slag and silica fume have a beneficial influence on the sulfate resisting behaviour of concrete.

2.3.3 Alkali Silica Reaction: Chemical reactions between aggregates containing certain reactive constituents and alkalis and hydroxyl ions released by the hydration of cement can have a deleterious effect on concrete. When the aggregates in cement concrete contain reactive forms of silica, the phenomenon of chemical reaction is referred to as Alkali-Silica reaction (ASR). Expansion and cracking, leading to loss of strength, elasticity and durability are among the physical manifestations of ASR. Amorphous silica, microcrystalline and poorly crystalline silica, fractured or strained quartz and glassy silica are among the commonly known alkali-reactive forms of silica. Depending on the degree of disorder, porosity, particle size, and temperature, the dissolution of silica structure will gradually occur, followed by formation of a swelling-type alkali-silica gel, which can cause considerable expansion on water absorption. Deleterious expansion from alkali-silica reactions in field takes years to develop. Mineral admixtures, such as natural pozzolans, fly ash, silica fume, and ground granulated blastfurnace slag, when used as partial replacement in concrete, can be effective in suppressing the ASR expansion. Reports in the published literature by many investigators, confirm that, as a result of ASR, adequately reinforced concrete structures do not suffer any significant deterioration in mechanical strength. Another point to note is that expansion will not occur unless sufficient moisture is present in the environment.

2.3.4 Other Causes of Distress: The basic underlying cause of deterioration of RCC are covered in preceding part of this chapter. There could be a number of other causes like construction and/or design and detailing deficiencies, material & workmanship deficiencies and the effect of environment. The deficiencies could be due to extrinsic or intrinsic contributory factors as explained in Table given in the Appendix 2.1.

2.4 Durability Aspects:

Durability is defined as the continued ability of the structure to withstand the expected wear and deterioration and perform satisfactorily in the normal operating conditions through out its intended life without the need for undue maintenance. What is implied is that the designer should expect certain degree of deterioration during the service life and provide required design inputs to adequately control it. Design for durability is now highlighted in IS:456-2000 under a specific section. The code emphasizes the perceived concern about the durability of concrete structures in India with specific design recommendations to deal with corrosion of reinforcement besides dealing with other types of durability problems.

Based on simplified approach, most of the National codes of practice on concrete construction include specific clauses for ensuring durability of constructed facilities, addressing the issue under carbonation, chloride ingress, leaching, sulphate attack, alkali-silica reaction and freeze-thaw. The first three can all lead to corrosion of reinforcement, which can take place only when steel reinforcing bars get depassivated due to reduced pH on account of reduction of alkalinity of pore water of cement gel surrounding it. The alkalinity reserve of concrete is a function of proportions of hydroxides of Calcium, Potassium and Sodium present in the hardened concrete matrix, which in turn is directly related to quantity of cement. Higher the cement content, higher the reserve pH of concrete due to increased quantity of such hydroxides of Calcium, Potassium and Sodium. It is noteworthy that excessive quantities of cement content also lead to other related problems due to heat of hydration, shrinkage etc. For this reason, in the codes, the requirements on durability are expressed in terms of minimum cement content, maximum water/cement ratio, minimum grade of concrete and minimum cover to reinforcement. These design parameters are related to specific exposure conditions. The general approach is to demand impermeability of concrete as the first line of defence against any of the deterioration process. The parameters mentioned above play a significant part in enhancing the durability, a comprehensive approach to design reinforced concrete structures for durability should give equal attention to the type and quality of component materials, the selection of mix proportions, the control of processing conditions. The design and detailing aspects should aim at minimizing the size and number of joints and cracks due to thermal gradients, drying shrinkage, creep and loading.

☆ ☆ ☆

SUGGESTED FURTHER READING MATERIAL AND REFERENCES

1. Mehta, P. Kumar and Monteiro,Paulo J.M., CONCRETE-MICROSTRUCTURE, PROPERTIES AND MATERIALS, *Published by* :Indian Concrete Institute, Ocean Crest, 35, 3rd Maim Road, Gandhi Nagar, Adyar, Chennai-600020, India.

2. "Causes of distress & Durability Aspects of Concrete Structures" by S. Gopalkrishnan, Deputy Director & Head, concrete composites Laboratory, SERC, Madras 600113, presented during advanced cause on "Damage Assessment & Rehabilitation of Distressed concrete structures" at SERC Madras, December, 10-13, 1996.

3. "Durability of Concrete Structure, Investigation, repair, protection" by CEOFFMAYS., Gramfield (U.K.) (First edition 1992)

4. IS:456-2000 Code of Practice for Plain & Reinforced Concrete

5. Concrete Society Technical Report No 26, "Repair of concrete damaged by reinforcement corrosion" published by "The Concrete Society", Devon House, 12-15, Dartmouth Street, London.

6. ACI Manual of Concrete Part I Practice, ACI committee 116.

Appendix 2.1

INTRINSIC & EXTRINSIC CAUSES AND STAGES OF DISTRESS

CAUSE OF DISTRESS	INITIAL DAMAGE STAGE OF RCC	ACCELERATED DAMAGE STAGE OF RCC
CONSTRUCTION DEFICIENCY (INTRINSIC)		
PHYSICAL:		
(a) **High w/c Ratio**	**High capillary porosity** in cement paste which allows the aggressive chemicals from its environment to penetrate easily and allows the concrete/reinforcement to get affected at an accelerated rate and initiate the onset of corrosion.	1. Carbonation reaches reinforcement level to depassivate steel & initiate corrosion. 2. Increased volume of corrosion product exerts pressure on surrounding concrete. 3. Increased cracking of concrete allows easy permeation of atmospheric gases. 4. Accelerated corrosion to cause increased cracking, then spalling of concrete. 5. Corrosion reduces steel bar cross-section. 6. Corrosion product behind reinforcement pushes bar outward to make it buckle and fail in compression to cause collapse
(b) **Inadequate curing**	-Do-	
(c) **Poorly Graded Aggregates**	**Porous concrete due to Air voids** and allows the aggressive chemicals from its environment to penetrate easily and allows the concrete/ reinforcement to get affected at an accelerated rate and initiate the onset of corrosion.	Same as above
(d) **Inadequate compaction**	**Porous concrete due to Air voids** and allows the aggressive chemicals from its environment to penetrate easily and allows the concrete/ reinforcement to get affected at an accelerated rate and initiate the onset of corrosion.	Same as above
(e) **Shuttering Joints not Slurry tight**	**Honey combed concrete** due to bleeding when cement paste is replaced by air voids near surface and allows the aggressive chemicals from its environment to penetrate easily and allows the concrete/ reinforcement to get affected at an accelerated rate and initiate the onset of corrosion.	Same as above

Contd...

Appendix 2.1 *(Contd..)*

CAUSE OF DISTRESS	INITIAL DAMAGE STAGE OF RCC	ACCELERATED DAMAGE STAGE OF RCC
(f) **Cover Thickness being lesser**	Protective cover Thickness against external/environmental chemical attack reduced and allows the concrete/ reinforcement to get affected early.	Same as above
(g) **Wrong placement of reinforcement**	Cracking /crushing of concrete to cause macro-cracking and allows the aggressive chemicals from its environment to penetrate easily and allows the concrete/ reinforcement to get affected at accelerated rate and initiate the onset of corrosion.	Same as above
CHEMICAL:		
(a) **Chloride** infested beyond permissible limits either through construction water and/or aggregates	Depassivation of Steel reinforcement locally and formation of galvanic cells to initiate corrosion of bar	1. Chloride ion acts as current carrier in presence of water and causes localised corrosion of reinforcement. 2. Same as 2-6 above
(b) **Sulphate** being beyond permissible limits in construction water or aggregates or diffusion from adjacent environment	Formation of C_4A_3S, an expansive product to cause disintegration due to bursting force within hardened concrete (a slow process)	1. Bursting force in hardened concrete causes cracking and disintegration of concrete to make it weak in strength and more permeable 2. Same as Sl no 1 to 6 above
(c) **Reactive aggregates** containing amorphous silica or strained Quartz to cause Alkali-Silica Reaction (ASR)	Formation of expansive gel around aggregate particles in presence of water and disintegration of concrete due to bursting force in hardened concrete (a slow process)	1. Bursting force in hardened concrete causes cracking and disintegration of concrete to make it weak in strength and more permeable 2. same as Sl no 1 to 6 above
DESIGN DEFICIENCY (Intrinsic)		
(a) **Wrong assessment of design Loads**	**Deflection, Crushing/ Cracking of Structural Member** allows the aggressive chemicals from its environment to penetrate easily and allows the concrete/ reinforcement to get affected at an accelerated rate and initiate the onset of corrosion.	same as Sl no 1 to 6 above
(b) Factors like **shrinkage, thermal Movement, structural behaviour,** etc not considered	**Disintegration of Concrete, shrinkage cracks** allow the aggressive chemicals from its environment to penetrate easily and allows the concrete/reinforcement to get affected at an accelerated rate and initiate the onset of corrosion.	same as Sl no 1 to 6 above

Contd...

Appendix 2.1 (Contd..)

CAUSE OF DISTRESS	INITIAL DAMAGE STAGE OF RCC	ACCELERATED DAMAGE STAGE OF RCC
ENVIRONMENTAL (EXTRINSIC) PHYSICAL:		
(a) **Heating/ Cooling**	**Surface disintegration and micro-cracking** allows the aggressive chemicals from its environment to penetrate easily and allows the concrete/reinforcement to get affected.	same as Sl no 1 to 6 above
(b) **Wetting/ Drying**	**Increase in Capillary porosity due to leaching away of water soluble salts** results in depletion of water soluble calcium hydroxide reducing the alkalinity which further allows the aggressive chemicals from its environment to penetrate easily resulting the concrete/reinforcement to get affected at accelerated rate and initiate the onset of corrosion.	same as Sl no 1 to 6 above
(c) **Abrasion of Surface**	**Surface disintegration and reduced cover thickness** allows the aggressive chemicals from its environment to penetrate easily and allows the concrete/reinforcement to get affected at an accelerated rate and initiate the onset of corrosion.	same as Sl no 1 to 6 above
CHEMICAL EFFECT:		
(a) **Chloride attack** from sullage of Toilets, sea water, atmospheric gases, acids, etc	When chloride ions permeate and reach reinforcement level, **cause local depassivation of steel** bars and formation of galvanaic cells locally and initiate corrosion	1 Chloride ion acts as current carrier in presence of water and causeslocalised corrosion of reinforcement. 2. Same as S. No. 2 to 6 above.
(b) **Sulphate attack** from soil, sub-soil water, industrial waste/Gases, acids, etc	When permeate and react with calcium aluminate Hydrate (C-A-H) in cement paste, it forms expansive compound, which exerts bursting pressure to cause disintegration & cracking of concrete up to depth of permeation to allow the aggressive chemicals from its environment to penetrate easily and allows the concrete/reinforcement to get affected at an accelerated rate and initiate the onset of corrosion.	1. Bursting force in hardened concrete causes cracking and disintegration of concrete to make it weak in strength and more permeable 2. Same as Sl no 1 to 6 above

CHAPTER 3

CONDITION SURVEY & NON-DESTRUCTIVE EVALUATION

3

CONDITION SURVEY & NON-DESTRUCTIVE EVALUATION

All things are hidden, obscure, and debatable if the cause of the phenomna be unknown, but everything is clear if this cause be known

...Louis Pasteur

3.1 Condition Survey:

3.1.1. Definition:

Condition Survey is an examination of concrete for the purpose of identifying and defining area of distress. While it is referred in connection with survey of concrete and embedded reinforcement that is showing some degree of distress, its application is recommended for all buildings and structures. The system is designed to be used for recording the history of the project from its inception to completion and subsequent life.

3.1.2. Objective:

The objective of Condition Survey of a building structure is

a) To identify
   - causes of distress and
   - their sources;

b) To assess
   - the extent of distress occurred due to corrosion, fire, earthquake or anyother reason,
   - the residual strength of the structure and
   - its rehabilitability ;

c) To prioritise the distressed elements according to seriousness for repairs and

d) To select and plan the effective remedy.

"*Find the cause, the remedy will suggest itself*". Sometimes, the source of the cause of distress is different than what is apparently seen. It is, therefore, essential that the engineers conducting condition survey, determine the source(s) of cause so as to effectively deal with it and minimize their effects by proper treatment.

3.1.3. Stages:

Stages for carrying out Condition Survey, largely depend on field conditions, user habits, maintenance, etc, and have a direct relation with the pattern of distress, whether localised or spread over.

Condition Survey of a building/structure is generally undertaken in four different stages to identify the actual problem so as to ensure that a fruitful outcome is achieved with minimum efforts & at the least cost.The four stages of Condition Survey described in Fig3.1 are:

a) Preliminary Inspection,
b) Planning,
c) Visual Inspection,
d) Field and Laboratory testing

3.1.3.1. Preliminary Inspection:

A. The primary objective of the preliminary inspection is

1. To assess and collect following necessary information for a thoughtful planning before a condition survey is physically undertaken:

- Background history of the distressed structure
  - from the Owners/Clients;
  - from the occupants of building, general public, etc based on personal enquiries;
- Notes and records of earlier repairs, if carried out,
- All possible relevant data and information;

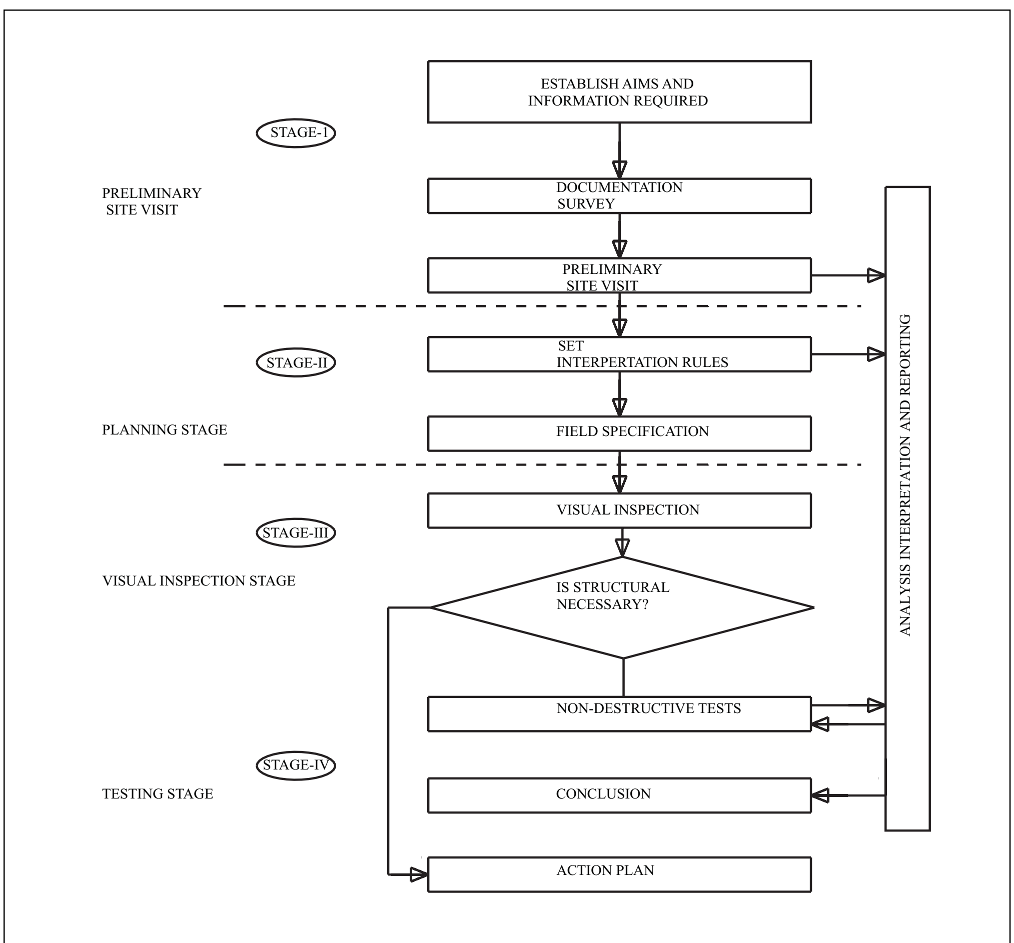


Fig.-3.1 Flowchart to illustrate the process of condition survey

- The practical restrictions in conducting field survey and devise methods to overcome the same;
- The safety requirements for condition survey team;
- Necessary site preparations including access scaffolds, working platforms, etc, if any;
- The extent and quantum of survey work;
- The approx. time required for survey;
- The requirement of
  - field-testing equipments,
  - tools for sampling.

2. To advise the client/owner of the building in regard to immediate safety measures, if considered necessary, to avert any mishap endangering life and structure.
3. To define the scope of work of field investigations in consultation with the Clients/Owners.

B. Basic Information Gathering: - A programme has to be evolved to obtain as much information as possible about the distressed structure at reasonable cost and in a reasonable time.Accordingly, the information required from the owner/client has to be listed out.Even though, many construction details and other related information may not be available with the owners/clients, yet as much as information and details as possible be gathered during the Preliminary Site Visit. Before undertaking a Condition Survey of a building/structure, the following essential information is required and be obtained from the clients/owners:

a) Period of construction;
b) Construction details including architectural, structural and as built drawings;
c) Exposure conditions of structure;
d) Designed use vis-a-vis present use of structure;
e) Previous changes in use, if any;
f) Record of structural changes made, if any;
g) Record of first occurrence of deterioration, if any;
h) Details of repairs, if carried out in the past;
i) Reports of previous investigations/condition surveys, if any;
j) Apparent cause of distress, as could be ascertained from the owner/client;
k) Photographs of distressed portions of structure.

A typicalProforma for collection of this information is given in Appendix 3.1**.** Study of such details and documents shall be done combined with the preliminary visit.It will give a fairly good idea of the distressed structure. The history-case file of distressed building/ structure with remedial actions taken in the past is important and more relevant. However, the information as listed above covering old drawings, record of past repairs/maintenance, change of use, modifications carried out, though very important, may not be available in certain cases.

C. Photographic Record: It is always necessary to carry a camera with flash during such ‘Preliminary inspection’ and take necessary photographs of the distressed structure and its members.

Preliminary Inspection and collection of data would be helpful in planning, the Condition Survey for field investigations. The symptoms of distress are related with the age of structure. This allows a reasonably sufficient understanding of the cause of distress for an experienced Rehabilitation Engineer.Table 3.1 gives such indicative details for guidance.

Table 3.1: Diagnosis of Defects and Deterioration

(Source: Testing of Concrete in Structures by J H Bungey et al)

Cause	Symptoms			Age of Appearance	
	Cracking	Spalling	Erosion	Early	Long Term
Structural deficiency	Yes	Yes		Yes	Yes
Reinforcement Corrosion	Yes	Yes			Yes
Chemical Attack	Yes	Yes	Yes		Yes
Frost Damage	Yes	Yes	Yes	Yes	
Fire Damage	Yes	Yes		Yes	
Internal Reactions	Yes	Yes			Yes
Thermal Effects	Yes	Yes		Yes	Yes
Shrinkage	Yes			Yes	Yes
Creep	Yes	Yes			Yes
Rapid Drying	Yes			Yes	
Plastic Shrinkage	Yes			Yes	
Physical Damage	Yes	Yes	Yes	Yes	Yes

3

3.1.3.2 Planning Stage

Planning stage involves preparation of field documents, grouping of structural members and classification of damage as under:

i) Preparation of Field Documents:

For condition survey, the following are required to be prepared:

a) Survey objective;

b) Scope of work;

c) Method of survey;

d) The field and laboratory testing requirements and field equipments & tools required for the same;

e) List of tasks and their sequence for condition survey together with a work schedule;

f) Required number of photo copy of available drawings;

g) Floor plans based on field measurements;

h) Work sheets and tables for recording in a logical manner all information, test results including field data gathered;

i) Previous Condition Survey results and Investigation Reports, if any;

j) Maintenance and repair records.

Work Sheets are documents in the form of floor plans, charts and statistical formats to record relevant data, observations, locations, quality, type and extent of damage etc. These have to be tailor- made for structural elements i.e. slabs, beams and columns of the project under investigation. Work Sheets are required for study of damage pattern and its extent as well as to work out Bill of Quantities of various repair items based on condition survey. The Work Sheets should contain:

- Plan of building at each floor with suitable grid pattern evolved to identify structural member in an RCC framed structure
  - with each structural element drawn to a convenient scale so as to record the visual observations on the floor plan itself using suitable notation.
  - The typical notations and their details used for recording field observations on each such plan. (Typical notations are given in Appendix-3.2) Any of the symptoms that cannot be reflected with notations could also be recorded in the form of a note.

ii) Grouping of the Structural members:

Soon after the preliminary site visit and on perusal of building plans, the structural members shall be grouped as per their type and based on similarity of exposure conditions for proper appreciation of the cause of distress. For example in a building subjected to normal environmental attack, the grouping could be done as under:

a) External columns/beams would be subjected to more severe environmental attack than the internal structural members of a building and could be grouped in two broad groups.

b) Even from amongst the external columns, those at corners or projected out are likely to be exposed more due to adjacent faces being exposed than those not at corners or un-projected columns. Hence to be grouped separately.

c) The members subjected to dampness/wetting/drying located in or around the toilet shafts are likely to undergo similar class of distress and be grouped separately.

d) Structural members with different protective finishes have to be grouped separately.

For assessment of the behaviour of the group as a whole, test results of RCC members in each of the groups so formed in a building have to be tabulated together in a Proforma (Appendix 3.3) for their interpretation.

iii) Classification of Damage :

Based on the preliminary data collected and site visit, the rehabilitation engineer should freeze the interpretation rules and subdivide the repair classification broadly in to five classes as ‘Class 0’ to ‘Class 4’ named as Cosmetic Repair, Superficial Repair, Patch Repair, Principal Repair and Major Repair.The classification given in Table 3.2, is generally considered sufficient for deciding the ‘Repair Requirements’ for carbonation induced corrosion damaged structure. This is just an indicative classification and the same may vary from case to case. It should be decided by the Rehabilitation Engineer before taking up detailed Condition Survey of the distressed structure in field.

3

TABLE 3.2 : Classes of Damage and Repair Classification

Class of Damage	Repair Classi-fication	General Observations on the Condition of Concrete	Repair Requirements
'Class O'	Cosmetic	Only final finishes disfigured. No structural distress observed.	Redecoration, if required
'Class 1'	Superficial	Final finishes/skin alone damaged. No structural cracks observed. Carbonation depths not yet reached reinforcement level.	Superficial repair of slight damage to non-structural finishes
'Class 2'	Patch Repair	Minor structural cracks observed and /or carbonation depths reached reinforcement level	Non-Structural or minor Structural Repair limited to crack sealing, restoring the lost cover concrete, if any, due to corrosion of reinforcement. Carbonation resistant surface protective coating, shotcrete or other repair material reinforced with nominal light steel fabric
'Class 3'	Principal Repair	Spalling of cover concrete, major structural cracks, including cracking along reinforcement due to corrosion or otherwise leading to substantial reduction of load carrying capacity.	Strengthening repair to reinforced concrete in accordance with the load-carrying requirement of the member. Concrete strength may be extremely low and reinforcement dia might have been significantly reduced requiring check by design procedure. Make up reinforcement may have to be provided in case of deficiencies due to deterioration
'Class 4'	Major Repair	Major structural loss necessitating replacement of structural member.	Major Strengthening repair ignoring the original concrete and reinforcement or demolition and recasting

3.1.3.3 Visual Inspection :

1. Visual examination of a structure is the most effective qualitative method of evaluation of structural soundness and identifying the typical distress symptoms together with the associated problems.
2. This provides valuable information to an experienced engineer in regard to its workmanship, structural serviceability and material deterioration mechanism.

3. It is meant to give a quick scan of the structure to assess its state of general health.
4. The record of visual inspection is an essential requirement for preparation of realistic bill of quantities of various repair items.
5. Experienced engineers should carry out this work as this forms the basis for detailing out the plan of action to complete the diagnosis of problems and to quantify the extent of distress.
6. Simple tools and Instruments like camera with flash, magnifying glass, binoculars, gauge for crack width measurement, chisel and hammer are usually needed. Occasionally, a light platform/scaffold tower can be used for access to advantage.

A. What to look for ?

- Though the record of visual inspection is required to be prepared for the structure as a whole for working out bill of quantities. But for analysis and identification of source of cause, focused work could be carried out on selected areas showing typical defects, but choosing these, as far as possible, from areas with simple access.
- One or more areas, apparently free from defect, would also be examined at this stage for simple comparison. This is required, because it is frequently found that by comparing good areas with bad, the reasons for the problems emerge.
- Preparation of good photographic record during such inspection is very important.
- The commonly observed order of deterioration of RCC structures due to ageing process is given in Table 3.3.

3

Table 3.3 : Commonly Observed Order of Deterioration of RCC Building

Commonly Observed Order	Location of RCC component
First	Wet / water stagnating areas with RCC elements located on external direct exposed walls/slabs and frequented with alternate wetting/drying cycle.
Second	Thin exposed non structural RCC elements e.g. chhajjas, railings, facias, fins etc
Third	Terrace RCC slab with ineffective insulation, water proofing and drainage systems
Fourth	Wet areas with RCC elements located on inner unexposed walls and frequented with alternate wetting/drying cycle
Fifth	Beams/columns with one face exposed direct to sun and rain and the other face unexposed.
Sixth	Beams/Columns exposed to rain and sun from all sides.
Last	Beams/Columns/Slabs located in the interior of building.

Note : These are indicative and based on assumptions that the quality of concrete is uniformly good or poor at all locations. May vary upon the degree of exposure, frequency of wetting/drying cycles.

A.1 Obstructions to Visual Inspection :

1. False ceiling, carpets, recently done paints, patch work repairs of plaster, re-plaster etc are likely to create obstructions to visual inspection. Such areas should be analysed and recorded with due care.
2. The access height from within and from outside during this inspection could also be a major problem.
3. Notes of these obstructions/limitations of visual inspection need to be recorded for taking into considerations while preparing the work details on repairs/ rehabilitation.

A.2 Structural System :

1. It is necessary that the engineer conducting visual inspection should have necessary familiarity with its structural system, structural behaviour and serviceability requirements.
2. One must look for its main framing system, bracings and alike. Thus, he should analyse the basic system bracing, structural stability and soundness of the structural system.
3. In case of non-availability of structural drawings, the existing framing, bracing and stiffness provisions have to be recorded during this inspection.
4. Malfunction, if any, due to structural deficiency should be identified with reference to material distress observed at site.

A.3 Leakage/Seepage due to Ineffective Drainage System :

1. Water stagnating areas in a structure attract dampness, leakage etc and are subjected to alternate wetting/drying cycle. Such areas are more prone to early corrosion of embedded steel reinforcement.
2. Concealed water supply and drainage lines are the general source attracting damage to the structure. Source of leakage/seepage due to concealed services has to be *identified, established and recorded* during the inspection.
3. Particularly at terrace floors of the building, dampness due to improper terrace treatment, its slope or inefficiency of rainwater disposal system may not be noticeable to the eyes but damage continues till spalling of cover concrete takes place. Hence efficiency of rainwater disposal system should be carefully examined during such inspection and a note to this effect be recorded.
4. Discolourations observations made during inspection should be marked on drawings and also taken as photographic records .

A.4 Types of Cracks and their pattern :

1. It is generally easy to differentiate various types of cracks and relate them with the cause of distress. The *location of cracks and their pattern*, etc give the first indications of the problem
2. Cracking & spalling, cracking & rust staining or rust staining are the visual indications of the corrosion of steel in concrete structures. Corrosion cracks are quite characteristic and distinct from those caused by other factors and such cracks run along the reinforcement location
3. Rust staining in freshly laid concrete is indicative of honeycombed concrete,

which could result in severe rusting and deterioration of concrete at a later date.

4. Cracks at right angle to main reinforcement are generally associated with structural deficiency.
5. A mesh pattern of cracks suggests drying shrinkage, surface crazing, frost attack or alkali-aggregate reaction (Fig 3.2)

Figure 3.3 and 3.4 give typical symptoms of distress due to corrosion of reinforcement in a concrete slab and beam respectively. Cracking along the bar can be an important indication that the reinforcements are subjected to corrosion.

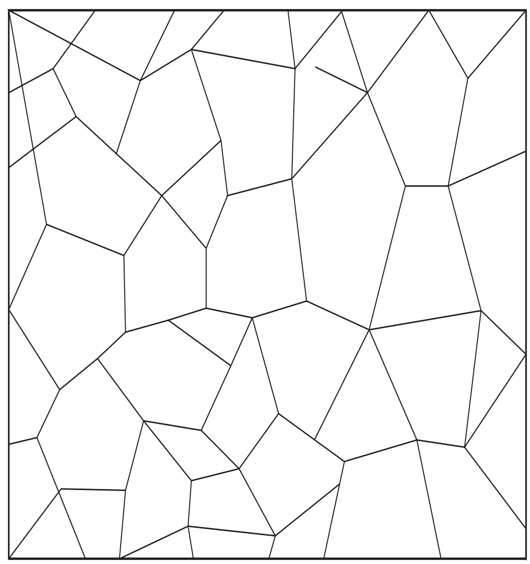


Fig.-3.2 Map' cracking typical of shrinkage crack etc. in concrete

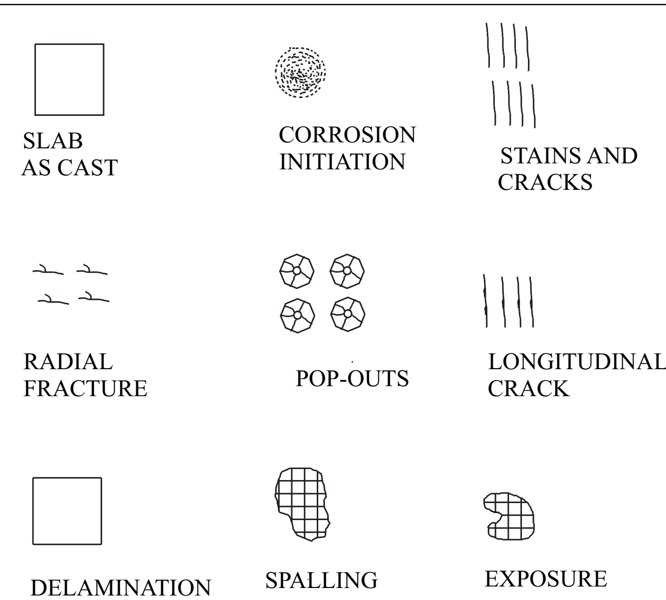


Fig.-3.3 Typical symptom of corrosion in a reinforced concrete slab

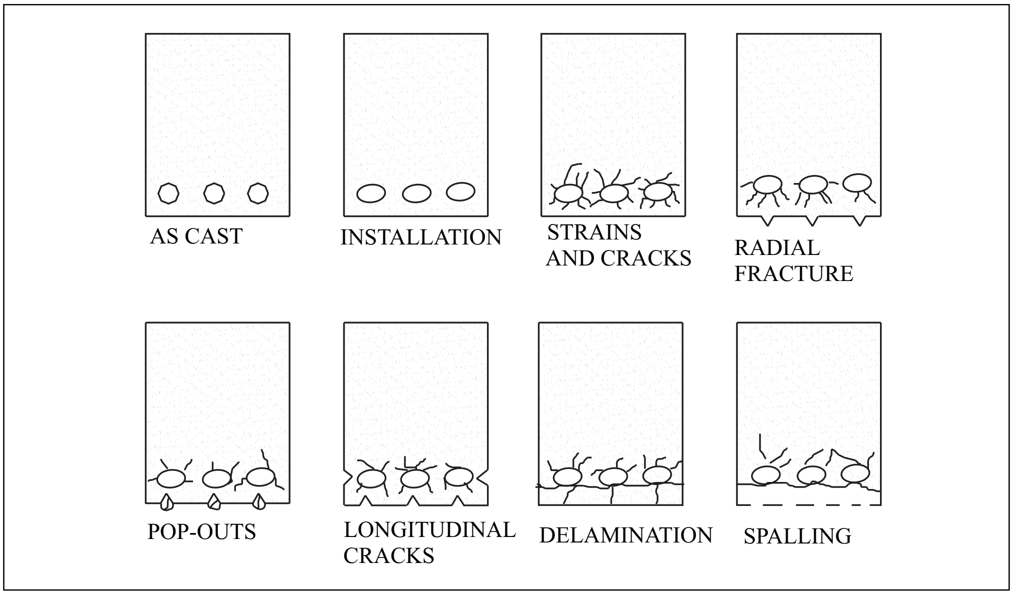


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Fig.-3.4 Typical symptom of corrosion in a reinforced concrete Beam

A.5 Colour & texture of concrete surface:

1. The texture of a concrete surface may indicate the possibility of a chemical attack and associated disintegration by leaching.
2. In fire damaged structure, the colour of the concrete gives an indication of maximum temperature level to which the surface had been subjected.

B. Worksheet

The visualinspection shall largely cover:

1. Recording of
   - Areas of high distress ;
   - Cracks & their location ;
   - Excessive deflection ;
   - Exposure conditions of various distressed areas ;
   - Moisture, leakage/ seepage & dampness locations ;
   - Abnormal vibrations in structure, if any ;
   - Algae, fungus growth and/or efflorescence etc and their locations ;
   - Photographic records, and
2. Identifying the areas of immediate concern.

Visual inspection would be documented in the form of Worksheets , photographic record etc for reference at a later date. Each worksheet shall :

1. Have unique identification for each of the structural members of the building covered by it.
2. Essentially cover the following in regard to observed defects:
   - Location,
   - Classification, and
   - The extent of spread.

3. Have notations for recording different types of defects, which could be suitably evolved by the rehabilitation engineer before taking up the condition survey. The suggested notations used for recording the defects on Work Sheets are given in Appendix 3.2

   The Worksheets (Fig. 3.5), besides being helpful in analysis for arriving at the cause of distress, would also be helpful for working out Bill of Quantities at a later date. All the defects noticed during visual examination are required to be plotted on Work sheet for a subsequent detailed study in combination with tabulated field & lab test results in proforma as per Appendix-3.3. This is necessary for determining the cause of deterioration.

The information obtained from visual inspection will determine whether there is need for further comprehensive investigation using more sophisticated testing techniques.

Visual inspection is, therefore, the best way of qualitative assessment of any structure.

3.1.3.4 Field/Laboratory Testing stage :

Objective :

1. It may neither be feasible nor is the practice to conduct field/laboratory testing on every structural member in an existing distressed building.
2. The field/laboratory testing of structural concrete and reinforcement is to be undertaken, basically for validating the findings of visual inspection.
3. These may be undertaken on selective basis on representative structural members from each of the various groups based on exposure conditions as explained in the preceding sections.
4. The programme of such testing has to be chalked out based on the record of visual inspection.

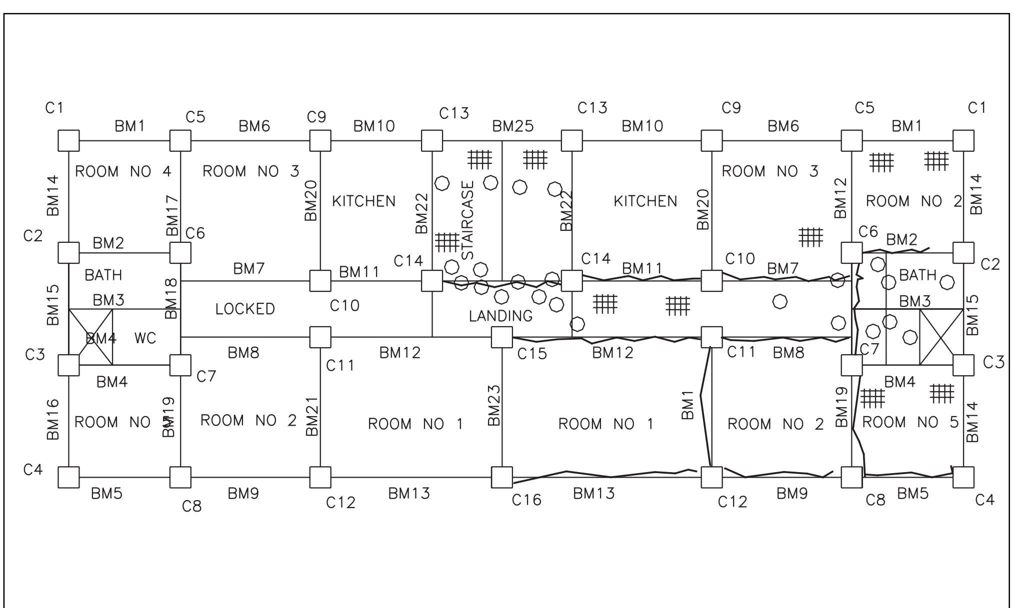


Fig.-3.5 A Typical Work Sheet

Table 3.4 gives the list of test methods that could be deployed for field/Laboratory testing during the course of investigations. A typical format for tabulation of the field test results/ observation is given in Appendix-3.3. NDE tests are frequently adopted during the process of condition survey

3

Table 3.4 : Principal Test Methods

(*Source: Testing of Concrete in Structures by J H Bungey et al*)

Property under investigation	Test	Equipment type
Corrosion of embedded Steel	Half Cell potential	Electrochemical
	Resistivity	Electrical
	Linear polarization resistance	Electrochemical
	A.C. Impedance	Electrochemical
	Cover depth	Electromagnetic
	Carbonation depth	Chemical/microscopic
	Chloride concentration	Chemical/electrical
Concrete quality, durability and deterioration	Surface hardness	Mechanical
	Ultrasonic pulse velocity	Electromechanical
	Radiography	Radioactive
	Radiometry	Radioactive
	Neutron absorption	Radioactive
	Relative humidity	Chemical/electronic
	Permeability	Hydraulic
	Absorption	Hydraulic
	Petrographic	Microscopic
	Sulphate content	Chemical
	Expansion	Mechanical
	Air Content	Microscopic
	Cement type and content	Chemical/microscopic
	Abrasion resistance	Mechanical
Concrete strength	Cores	Mechanical
	Pull-out	Mechanical
	Pull – off	Mechanical
	Break-off	Mechanical
	Internal fracture	Mechanical
	Penetration resistance	Mechanical
	Maturity	Chemical/electrical
	Temperature-matched Curing	Electrical/electronic
Integrity and Performance	Tapping	Mechanical
	Pulse-echo	Mechanical/electronic
	Dynamic response	Mechanical/electronic
	Acoustic emission	Electronic
	Thermoluminescence	Chemical
	Thermography	Infra-red
	Radar	Electromagnetic
	Reinforcement location	Electromagnetic
	Strain or crack measurement	Optical/mechanical/electrical
	Load test	Mechanical/electronic/electrical

3.1.4 Considerations for Repair Strategy :

In the Condition Survey Report, before arriving at the Repair Strategy, it shall include the following considerations:

1. Identification of the cause of problem and its source is the fundamental to the success or failure of the repair. A lack of attention at this point can put at risk the whole job.
2. For arriving at an effective and economical solution, systematic documentation of all observations is essential, which will greatly facilitate in diagnosing and making assessment of the extent of damage.
3. Available space and accessibility will determine the selection of repair method and repair strategy.
4. Accessibility to the areas identified for repairs needs consideration.
5. Depending upon the scope and scale of repairs, the repair strategy has to suit and dovetail the on-going activities in the building.
6. The prioritization of repairs and their sequencing are important components for deciding the repair strategy.
7. Major repair procedure may demand propping the structural members to relieve a part or full component of the load acting on the member. If the building requires extensive propping, vacating the building may become the pre-requisite.
8. Safety measures to prevent any immediate major mishap shall be prescribed without loosing further time.
9. The report should also include requirements on safety measures to be adopted during execution of repair jobs.

More experienced engineers should look in to special and peculiar distress problems For example, micro cracking or some other subtle defect could be the cause of carbonation and corrosion. Carrying out repairs to corrosion distress, missing the main cause, may simply mean that the problem recurs in a relatively short duration.

3.2 NON DESTRUCTIVE EVALUATION TESTS :

A number of non-destructive evaluation (NDE) tests for concrete members are available to determine in-situ strength and quality of concrete. Some of these tests are very useful in assessment of damage to RCC structures subjected to corrosion, chemical attack, and fire and due to other reasons. The term 'non destructive' is used to indicate that it does not impair the intended performance of the structural member being tested/investigated. The non-destructive evaluation have been broadly classified under two broad categories viz 'in-situ field test' and 'laboratory test'. These tests have been put under five categories depending on the purpose of test as under :

1. In-situ Concrete Strength
2. Chemical Attack
3. Corrosion Activity
4. Fire Damage
5. Structural Integrity/Soundness

Various non destructive evaluation tests commonly used under each of these categories have been listed out in Table 3.5 as under :

Table 3.5 : Commonly Used NDE Tests

Sl No	Test Method	Details
A.	**Insitu Concrete Strength:**	
1	Rebound Hammer Test	A qualitative field test method to measure surface hardnessof concrete
2	Ultrasonic Pulse Velocity	A qualitative field test by measurement of Ultrasonic Pulse Velocity (UPV)
3	Windsor Probe	A qualitative field test for assessment of near surface strength of concrete
4	Capo/Pull out test	-do-
5	a. Core cutting/ sampling	
	b. Lab Testing of Cores	Field cum lab test method for assessing quality of concrete as under: - strength - density - texture - permeability
6.	Load Test	A field test for assessing the load carrying capacity within the limits of elastic deformations
B.	**Chemical Attack**	
1	Carbonation Test	A field/lab test for assessment of pH of concrete and depth of carbonation
2	Chloride Test	A field/lab Test for assessment of total water/acid soluble chloride contents
3	Sulphate Test	A Lab Test for assessment of total acid/water soluble sulphate contents of concrete
C.	**Corrosion Potential Assessment**	
1	Cover-Meter / Profo-meter measurement (In-situ Test)	A field method for measuring -thickness of cover concrete -reinforcement diameter -reinforcement spacing.
2	Half Cell Method	A field method for Measuring/ plotting corrosion potential for assessing probability of corrosion
3	Resistivity Meter	A field method for assessing electrical resistivity of concrete to determine its corrosion resistance
4	Permeability a. Water b. Air	A field/Lab method for assessment of in-situ permeability of concrete due to water and air.
D.	**Fire Damage Assessment**	
1	Thermo-Gravimetric Analysis (TGA)	A laboratory test for assessment of temperature range to which concrete was subjected to
2	Differential Thermal Analysis (DTA)	A laboratory Test for assessment of qualitative & quantitative composition of sample of concrete
3	X-ray Diffraction (XRD)	To determine the extent of deterioration in concrete subjected to fire
E.	**Structural Integrity/Soundness Assessment**	
1	Ultra-sonic Pulse velocity Method	A field method for determination of discontinuities, cracks and depth of cracks
2	Radiography	For taking photographs showing details of inside of a concrete member, where other NDE methods are not suitable
3	Impact Echo Test	A field/laboratory test method to detect hidden damage andits extent.

3

3.2.1 Concrete Strength Assessment :

A. Objective:

1. Generally, in-situ non-destructive evaluation of concrete is to have an overall idea of the quality of concrete.
2. In some cases, a sufficiently accurate estimate of quantitative value of concrete strength is required for assessment of load carrying capacity of a structural member. The need for such an estimate may arise during evaluation of change in usage of structure, modification or extension of the original structure or damage due to fire, earthquake, etc.
3. Core cutting /sampling method, as at sl no 5 in Table 3.5 above, is done by extracting the concrete cores from the beams/columns/slab or any other structural members to determine the residual insitu strength, density & porosity /permeability of concrete in laboratory. This test, being semi destructive, is also time consuming. Hence it is used selectively in combination with other NDE qualitative test results, so as to validate and calibrate such other qualitative test methods used more commonly.

B. Limitations:

The accuracy is not very high as most of the non-destructive methods of evaluation of concrete strength are based on indirect measurement of concrete strength.

C. Selection of test, its location and number :

Out of test methods listed above, the choice is usually Schmidt Hammer and UPV for determining the insitu quality of concrete.The uses of other methods like pull out test/ capo test, windsor probe etc, being either time consuming &/or partially destructive, have not become popular in India. Hence UPV test has an edge over the Windsor Probe test & is most commonly employed. This method gives substantially reliable & adequate data for quality assessment of concrete.

The table 3.6 gives commonly used test methods indicating minimum number of test readings/samples, the percentage of confidence level, the speed of test, likely damage to concrete, reliability of strength calculation, and representative-ness of the test.
It would be prudent to have a combination of at least two methods for assessing the quality of concrete in addition to their correlation with concrete core results.

Table 3.6 : Strength Tests-Relative Merits

(Source: Testing of Concrete in Structures by J H Bungey et al)

Test Method	Minimum number of readings	Typical Coefficient of variation	Best 95% confidence level	Cost	Speed of test	Damage	Representativeness	Reliability of absolute strength correlations
General Applications:								
Cores Standard Cores (100 mm)	3	10%	±10%	High	Slow	Moderate	Moderate	Good
Smaller Cores	9	15%	±15%					

Contd.....

Table 3.6 : (*Contd...*)

Test Method	Minimum number of readings	Typical Coefficient of variation	Best 95% confidence level	Cost	Speed of test	Damage	Representativeness	Reliability of absolute strength correlations
Pull -out	4	8%	±20%	Moderate	Fast	Minor Surface Only	Near rate	Mode-
Pull-off	6	8%	±15% rate	Moderate	Mode-Surface	Minor rate only	Near	Mode-
Break-off	5	9%	±20% rate	Moderate	Mode-Surface	Minor rate only	Near	Mode-
Internal fracture	6	16%	±28%	Low	Fast Surface	Minor only	Near	Mode-
Windsor Probe	3	4%	±20%					
Comparative Assessment:								
Ultrasonic Pulse velocity	1	2.5%	±20%	Low	Fast	None	Good	Poor
Surface hardness	12	4%	±25%	Very low	Fast	Un-likely	Surface only	Poor

D. Examination of Variability:

1. Variability of test result depends on the NDE test method and shall vary with each type of method.
2. Obtaining strength of concrete by different methods and studying variability of average results can lead to wrong conclusions.
3. Insitu strength of concrete in a structural member also varies with the location.
4. Plotted histogram and contours of test results, give better idea of variability of concrete strength. These help in identifying the concrete from different sources/ batches for working out the coefficient of variation separately.

E. Analysis of Results:

1. The standard charts supplied by manufacturers or available in literature may not be valid for the site conditions.

2. Calibration curves for concrete strength assessment could be prepared by testing cores of standard size at a few locations and correlating the results of the other test methods with the core strengths.

3. Characteristic strength of concrete shall thus, be calculated from such calibration charts using statistical analysis.Minimum 50 readings are required for calculation of standard deviation. If the number of readings are not sufficient, the following values of standard deviation as per table 3.7 may be assumed .

4. The in-situ characteristic strength of the concrete may be obtained by using the well known relationship

$f_{ck} = f_{mean} - 1.64\ S$ Where, f_{ck} is the characteristic strength of concrete, f_{mean} is the mean strength and "S" is the standard deviation.

Table 3.7:Typical Values of Standard Deviation of Control Cubes and In-situ Concrete

(Source: Testing of Concrete in Structures by J H Bungey et al)

Material control and construction	Assumed std. devn. of control cube(s) , (N/mm^2)	Estimated std. devn.of in-situ concrete cube(s), (N/mm^2)
Very good	3.0	3.5
Normal	5.0	6.0
Low	7.0	8.5

Note : IS-456: 2000, Table 8, gives the assumed values ofstandard deviation for cube testing for different grades of concrete.Accordingly, highervalues for in-situ testing may be assumed.

3

3.2.1.1 Rebound Hammer Test :

The operation of Rebound Hammer (also called Schmidt's Hammer) is illustrated in Fig 3.6. When the plunger of rebound hammer is pressed against the surface of concrete, a spring controlled mass with a constant energy is made to hit concrete surface to rebound back. The extent of rebound, which is a measure of surface hardness, is measured on a graduated scale. This measured value is designated as Rebound Number (a rebound index). A concrete with low strength and low stiffness will absorb more energy to yield in a lower rebound value.

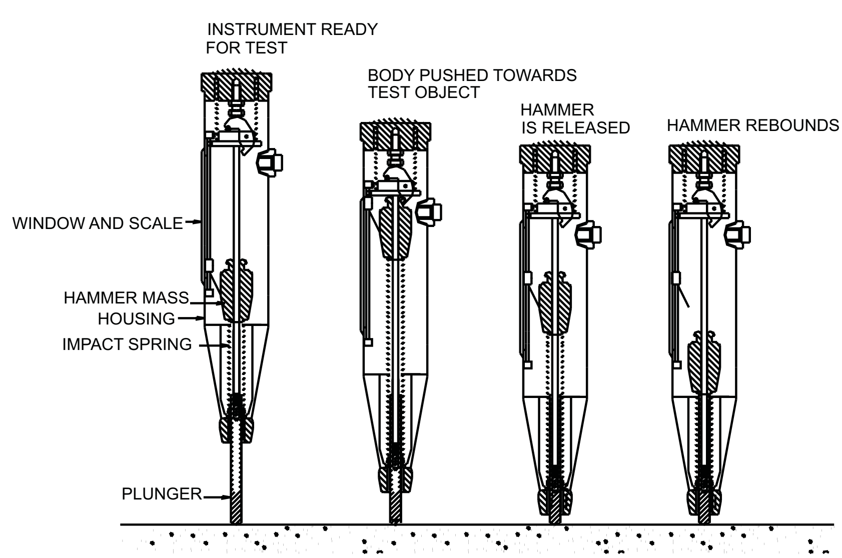
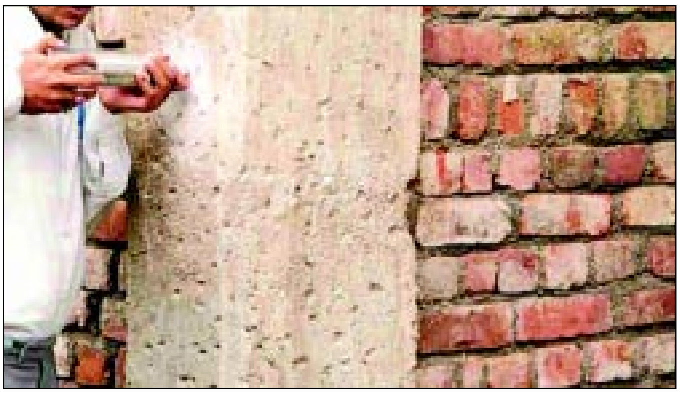


Fig.-3.6 Schematic diagram of operation of the rebound hammer



Rebound or Schmidt Hammer

IS 13311 Pt-2-1992 as well as BS: 6089-81 and BS: 1881:Pt-202 explains the standard procedure for test and correlation between concrete cube crushing strength and rebound number. The results are significantly affected by the following factors :

a. Mix characteristics :
   i. Cement type,
   ii. Cement Content,
   iii. Coarse aggregate type :

b. Angle of Inclination of direction of hammer with reference to horizontal (Fig 3.7)

c. Member Characteristics,
   i. Mass,
   ii. Compaction,
   iii. Surface type,
   iv. Age, rate of hardening and curing type,
   v. Surface carbonation,
   vi. Moisture Condition,
   vii. Stress state and temperature.

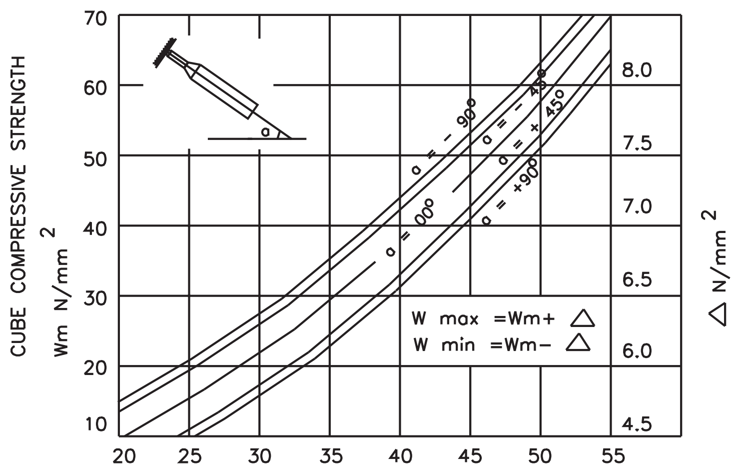


Fig.-3.7 Cube Compressive strength is N/mm^2 plotted against the rebound number

Since each of these may affect the readings obtained, any attempts to compare or estimate concrete strength will be valid only if they are all standardized for the concrete under test and for the calibration specimens.

A. Strength Assessment

This test is conducted to assess the *relative strength* of concrete based on the hardness at or near its exposed surface. Carrying of periodic calibration of rebound hammer using standard anvil is desirable. However for new concrete construction, rebound hammer is calibrated on concrete test cubes for a given source of constituent materials (viz. cement, sand and stone aggregate), this calibration data can be used with reasonable accuracy in arriving at equivalent in-situ cube strength of *relatively new concrete* (i.e. not more than three months old concrete). This calibration exercise may be carried out in a concrete lab by casting cubes of designed mix and testing these under controlled condition with rebound hammer as well as test to destruction in compression. Calibration graphs then can be drawn. Large number of readings are desirable to reduce the effects of variability in readings due to various localised as well as instrument factors. This method may give highly erroneous results for concrete whose surface is exposed to atmosphere for longer periods *say more than three months*. This is due to hardening of concrete surface due to carbonation, which may cause overestimation as much as 50% for old structure.Hence Strength assessment by Rebound Hammer Test should generally be restricted to relatively new structures only.

B. Survey of Weak & delaminating Concrete

As the test requires a flat surface and large number of readings to reduce variability, this test is not generally suitable for use on spalled concrete surfaces of distressed structures. However, comparison of Rebound numbers, which indicate the near surface hardness of the concrete, will help to identify *relative surface weaknesses* in cover concrete and also can be used to determine the *relative compressive strength* of concrete. Locations possessing very low rebound numbers will be identified as weak surface concrete and such locations will be identified for further investigations like corrosion distress, fire damage and/or any other reason including original construction defects of concrete. This survey is to be carried out on each identified member in a systematic way by dividing the member into well-defined grid points. The grid matrix should have a spacing of approximately 300mmx 300mm. Table 3.8 gives guidelines for qualitative interpretation of rebound hammer test results with reference to quality.

Table-3.8: Quality of Concrete from Rebound Values

Comparative Hardness

Average Rebound	Quality of Concrete
>40	Very Good
30-40	Good
20-30	Fair
<20	Poor and/or delaminated
0	Very Poor and/or delaminated

3.2.1.2 Ultrasonic Pulse Velocity (UPV) test

Ultrasonic scanning is a recognised non-destructive evaluation test to *qualitatively assess* the homogeneity and integrity of concrete. With this technique, following can be assessed.

1. Qualitative assessment of strength of concrete, its gradation in different locations of structural members and plotting the same
2. Any discontinuity in cross section like cracks, cover concrete delamination etc
3. Depth of surface cracks.

Ultrasonic Pulse Velocity instrument

This test essentially consists of measuring travel time, ‘*T*’ of ultrasonic pulse of 50-54 kHz, produced by an electro-acoustical transducer, held in contact with one surface of the concrete member under test and receiving the same by a similar transducer in contact with the surface at the other end. With the path length, ‘*L*’ (i.e. the distance between the two probes) and time of travel, T the pulse velocity ($V = L/T$) is calculated (fig 3.8). Higher the elastic modulus, density and integrity of the concrete, higher is the pulse velocity.The ultrasonic pulse velocity depends on the density and elastic properties of the material being tested.

Though, pulse velocity is related with crushing strength of concrete, yet no statistical correlation can be applied.

The pulse velocity in concrete may be influenced by :

a) Path length
b) Lateral dimensions of the specimen tested.
c) Presence of reinforcing steel
d) Moisture content of the concrete.

The influence of path length will be negligible provided it is not less than 100 mm when 20 mm size aggregate is used or less than 150 mm for 40 mm size aggregate. Pulsevelocity will not be influenced by the shape of the specimen, provided its least lateral dimension (i.e. its dimension measured at right angles to the pulse path) is not less than the wavelength of the pulse vibrations.For pulse of 50 Hz frequency, this corresponds to a least lateral dimension of about 80 mm. The velocity of pulses in a steel bar is generally higher than they are in concrete.For this reason, pulse velocity measurements made in the vicinity of reinforcing steel may be high and not representative of the concrete.The influence of the reinforcement is generally small if the bars run in a direction at right angles to the pulse path and the quantity of steel is small in

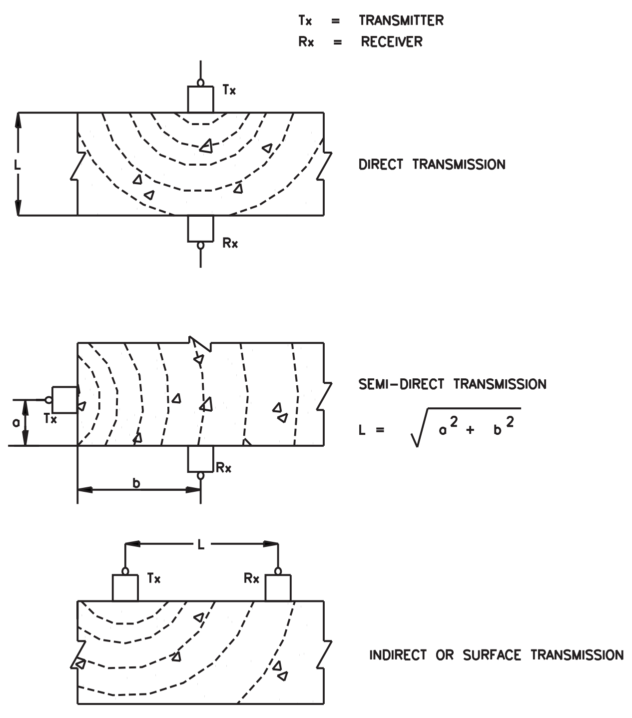


Fig.-3.8 Method of propogating and receiving pulses

relation to the path length.The moisture content of concrete can have a small but significant influence on the pulse velocity. In general, the velocity is increased with increased moisture content, the influence being more marked for lower quality concrete.

Measurement of pulse velocities at points on a regular grid on the surface of a concrete structure provides a reliable method of assessing the homogeneity of the concrete.The size of the grid chosen will depend on the size of the structure and the amount of variability encountered.

Table 3.9 : General Guidelines for Concrete Quality based on UPV

(Source: Indian Concrete Journal, June 1998)

Pulse Velocity	Concrete quality
> 4.0 km/s	Very good to excellent
3.5-4.0 km/s	Good to very good, slight porosity may exist.
3.0- 3.5 km/s	Satisfactory but loss ofintegrity is suspected
<3.0 km/s	Poor and loss of integrity exist

Table 3.9 shows the guidelines for qualitative assessment of concrete based on UPV test results. To make a more realistic assessment of the condition of surface concrete of a structural member, the pulse velocity values can be combined with rebound number. Table 3.10 shows the guidelines for identification of corrosion prone locations by combining the results of pulse velocity and rebound numbers.

Table 3.10 : Identification of Corrosion Prone Location based on Pulse Velocity and Hammer Readings

(*Source: Indian Concrete Journal, June 1998*)

Sl.No.	Test Results	Interpretations
1.	High UPV values, high rebound number	Not corrosion prone
2.	Medium range UPV values, low rebound numbers	Surface delamination, low quality of surface concrete, corrosion prone
3.	Low UPV, high rebound numbers	Not corrosion prone, however, to be confirmed by chemical tests, carbonation, pH
4.	Low UPV values, low rebound numbers	Corrosion prone-requires chemical and electrochemical tests.

Detection of defects

When an ultrasonic pulse traveling through concrete meets a concrete-air-interface, there is a negligible transmission of energy across this interface so that any air-filled crack or void lying directly between the transducers will obstruct the direct beam of ultrasound when the void has a projected area larger than the area of transducer faces.The first pulse to arrive at the receiving transducer will have been diffracted around the periphery of the defect and the time will be longer than in similar concrete with no defect.

Estimating the depth of cracks.

An estimate of the depth of a crack visible at the surface can be obtained by measuring the transit times across the crack for two different arrangements of the transducers placed on the surface. One suitable arrangement is one in which the transmitting and receiving transducers are placed on opposite sides of the crack and distant from it. Two values of 'x' are chosen, one being twice that of the other, and the transmit times corresponding to these are measured.An equation may be derived by assuming that the plane of the crack is perpendicular to the concrete surface and that the concrete in the vicinity of the crack is of reasonably uniform quality.It is important that the distance 'x' be measured accurately and that very good coupling is developed between the transducers and the concrete surface. The method is valid provided the crack is not filled with water.

3.2.1.3 Penetration Resistance ('Windsor Probe' and 'PNR Tester')

This technique offers a means of determining relative strengths of concrete in the same structure or relative strength of different structures. Because of the nature of equipment, it can not, and should not be expected to yield absolute values of strength. ASTM C-803 gives this standard test method titled, " penetration resistance of hardened concrete".

'***Windsor Probe***', as commercially known, is penetration resistance measurement equipment, which consists of a gun powder actuated driver, hardened alloy rod probe, loaded cartridges, a depth gauge and other related accessories. In this technique, a gunpowder-actuated driver is used to fire a hardened alloy probe into the concrete. During testing, it is the exposed length of probe, which is measured by a calibration depth gauge. But, it is preferable to express the coefficient of variation in terms of the depth of penetration as the fundamental relation is between concrete strength and penetration depth.

The probeshown in fig. No. 3.9 has a diameter of 6.3 mm, length of 73 mm, and conical point at the tip.The rear of the probe is threaded and screwed into a probe-driving head, which is 12.6 mm in diameter and fits snugly along with a rubber washer into the bore of the driver. As the probe penetrates into the concrete, test results are usually not affected by local surface conditions, such as texture and moisture content. However, damage in the form of cracking may be caused to slender members. A minimum edge distance and member thickness of 150 mm is required. It is important to leave 50mm distance from the reinforcements present in the member since the presence of the reinforcing bars within the zone of influence of the penetrating probe affects the penetration depth.

A ***pin penetration test device (PNR Tester)***, which requires less energy than the Windsor Probe System, is given in Fig no 3.10.

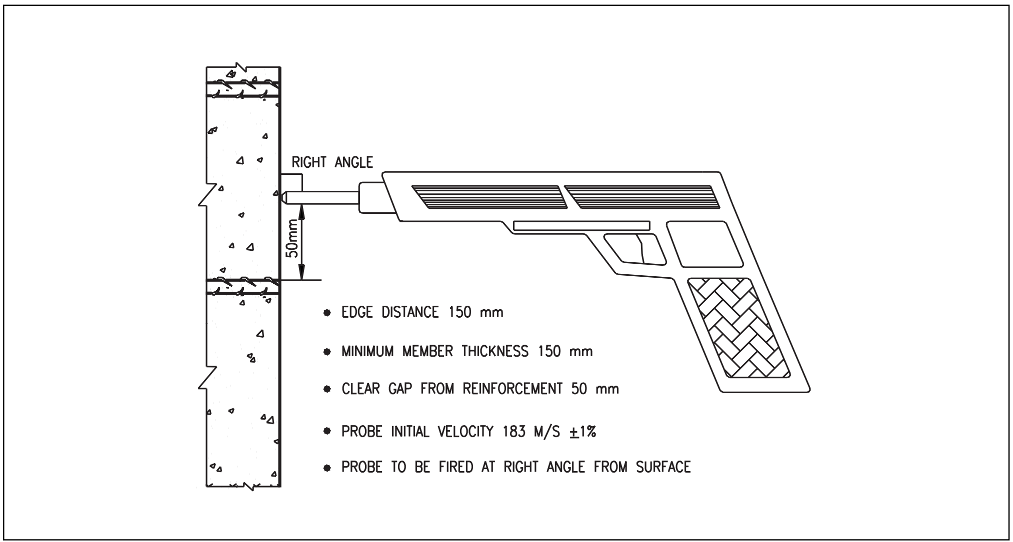


Fig.-3.9 Windsor Probe

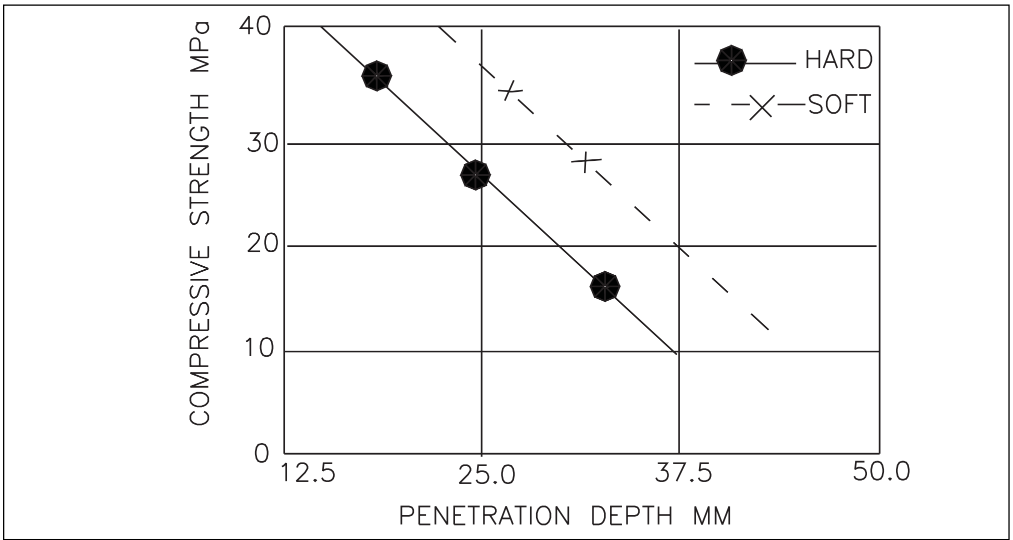


Fig.-3.10 PNR Tester

Being a low energy device, sensitivity is reduced at higher strengths. Hence, it is not recommended for testing concrete having strength above 28 N/sqmm. In this, a spring-loaded device, having energy of about 1.3% of that of Windsor Probe, is used to drive 3.56 mm diameter, a pointed, hardened steel pin in to the concrete. The penetration of pin creates a small indentation (or hole) on the surface of concrete. The pin is removed from the hole, the hole is cleaned with an air jet and the hole depth is measured with a suitable depth gauge. Each time a new pin is required as the pin gets blunted after use.

The strength properties of both mortar and stone aggregate influence the penetration depth of the probe in a concrete, which is contrastingly different than cube crushing strength, wherein the mortar strength predominantly governs the strength. Thus, the type of stone aggregate has a strong effect on the relation of concrete strength versus depth of penetration as given in Fig no 3.11

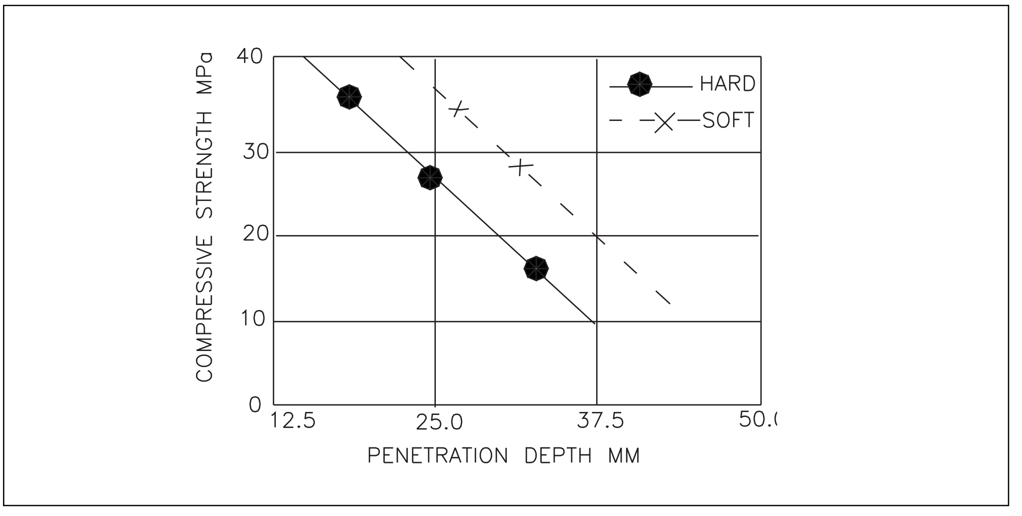


Fig.-3.11 Effect of aggregate type on relationship between concrete strength and depth of probe penetration

For two samples of concrete, with equal cube crushing strength, penetration depth would be more in the sample with softer aggregate than the one with harder aggregates. Correlation of the penetration resistance to compressive strength is based on calibration curves obtained from laboratory test on specific concrete with particular type of aggregates. Aggregate hardness is determined from standard samples provided along with the instrument. Aggregate size in the mix, also influences the scatter of individual probe readings. This technique offers a means of determining relative strengths of concrete in the same structure or relative strength of different structures. Because of the nature of equipment, it can not, and should not be expected to yield absolute values of strength. This test is not operator independent although verticality of bolt relative to the surface is obviously important and a safety device in the driver prevents, if alignment is poor.

It is claimed an average coefficient of variation for a series of groups of three readings on similar concrete of the order of 4% may be expected.It has been observed that ± 20% accuracy may be possible in strength determination of concrete. Fig 3.12 explains the approximate shape of failure during the test.

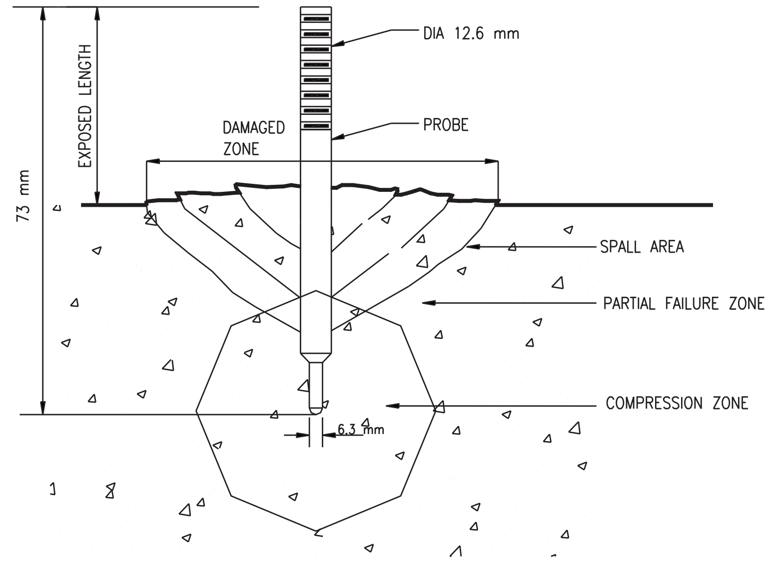


Fig.-3.12 Approximate shape of failure zone in probe penetration test

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3.2.1.4 Pullout (LOK) Test

The fundamental principle behind pull out testing with LOK-test and CAPO test is that test equipment designed to a specific geometry will produce results (pull-out forces) that closely correlate to the compressive strength of concrete. This correlation is achieved by measuring the force required to pull a steel disc or ring, embedded in fresh concrete, against a circular counter pressure placed on the concrete surface concentric with the disc/ring.

For hardened concrete, an expandable steel ring is used instead. This ring expands to fit a specially drilled hole and routed recessin the concrete. The first method, shown in figure 3.13 using the cast in steel disc, is called LOK test. The second method , shown in figure 3.14 using expandable ring, is called CAPO- test **(i.e. C**ut **A**nd **P**ull **O**ut **Test)** The diameter of

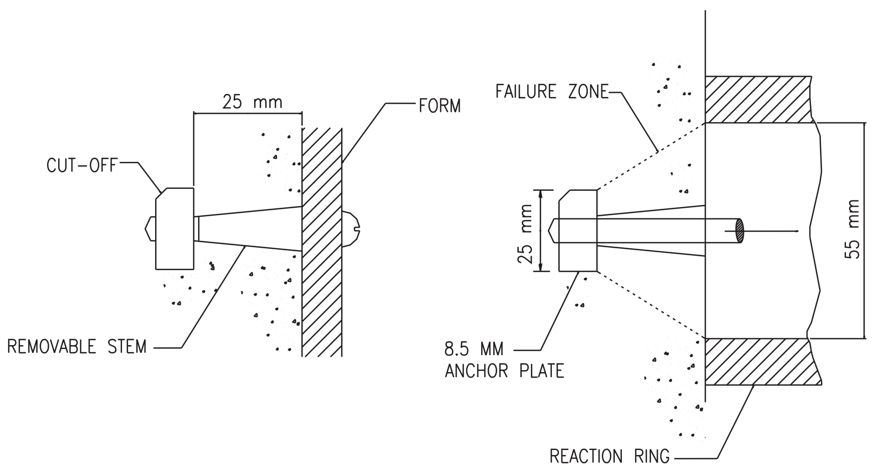

Fig.-3.13 LOK test insert

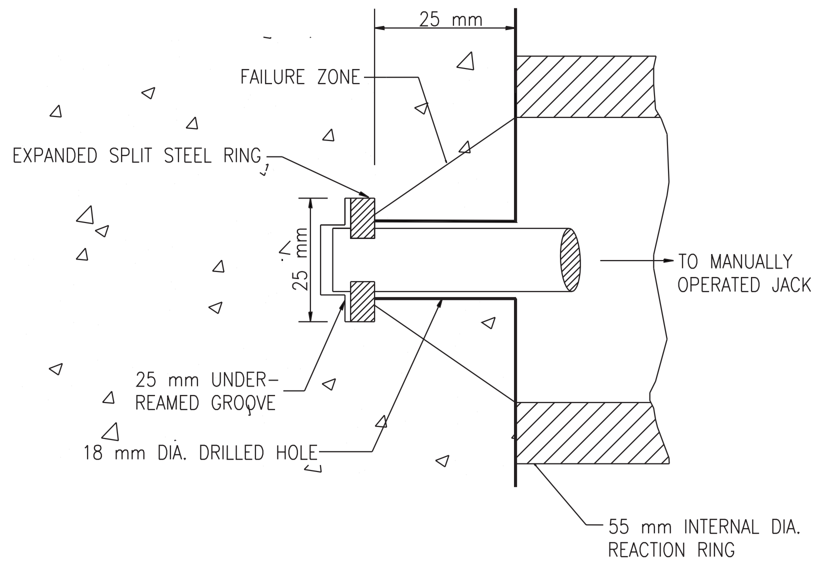

Fig.-3.14 CAPO test testing principle

both the disc and ring is 25mm. The distance to the concrete surface is also 25mm. The inner diameter of the counterpressure is 55mm.

The relationship between the pull-out force Fu in KN and compressive strength fc in MPa is given in figure 3.15

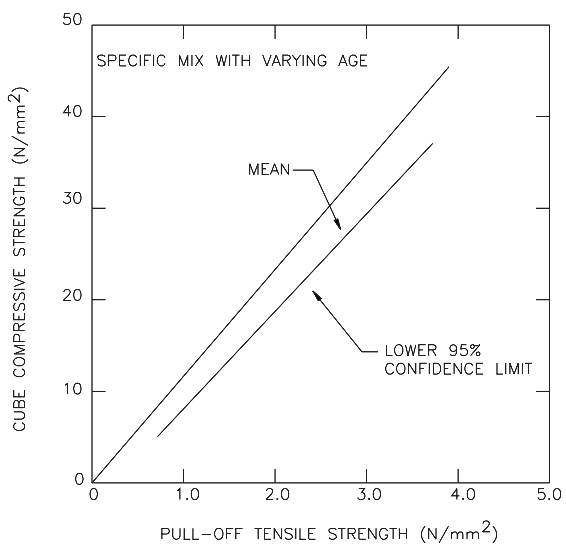

Fig.-3.15 Typical Pull out force Calibration Chart

By measuring the pull-out force of a cast-in disc or expanded ring, the compressive strength of in-situ concrete can be determined from the relationship in figure 3.16 to a great degree of confidence.

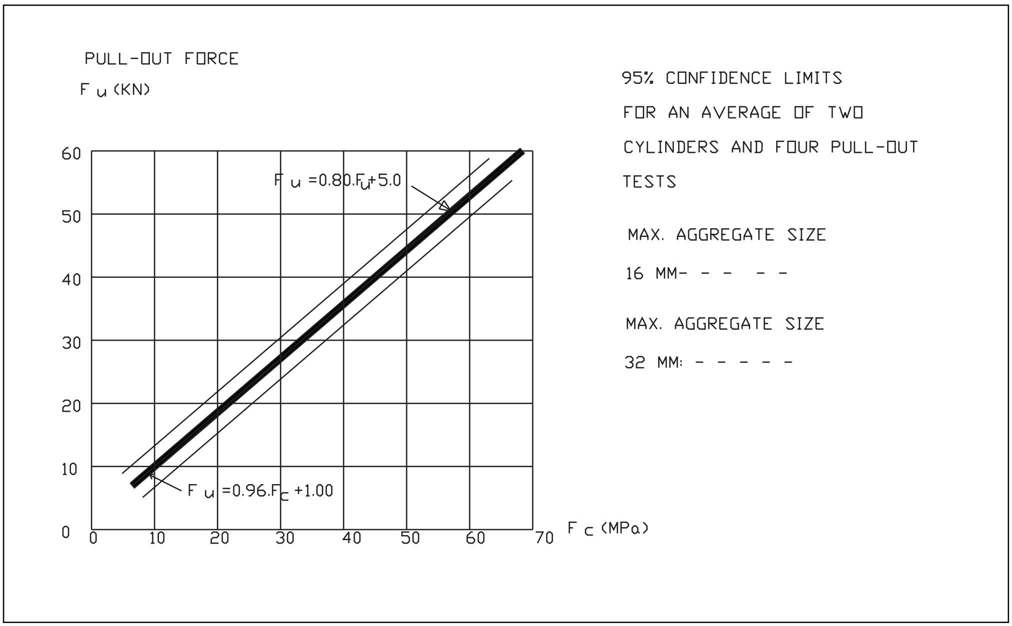

Fig.-3.16 Pull off force compressive strength relationship

The Pullout Test produces a well-defined failure in the concrete and measures a static strength property of concrete. The equipment is simple to assemble and operate.

As the insert is pulled out, a roughly cone shaped fragment of the concrete is extracted. The compressive strength, which is considered as an indicator of quality, is obtained from the calibration curves, prepared based on laboratory and field tests conducted on concrete cubes and pull out samples cast with various grades of concrete. In the test assembly, the embedment depth and the insert-head diameter have to be equal with inner diameter of the reaction ring could vary between 2 to 2.4 times the diameter of the insert-head. The apex angle of the conic frustom defined by the insert-head diameter and the inside diameter of the reaction ring can vary between 54^{O} to 70^{O}. The compressive strength can be considered as proportional to the ultimate pullout force. The reliability of the test is reported as good.

Since, the embedment depths of the commercially available metallic inserts is of the order of 25 to 30 mm, the test results cover a small portion of the near surface concrete located adjacent to the fractured surface and below the reaction ring. Thus, due to the inherent heterogeneity of concrete, typical average within-batch coefficient of variation of such pullout tests has been found to be in the range of 7 to 10% which is better than that of the standard cube/cylinder compression test. It is superior to rebound hammer and Windsor probe test because of greater depth of concrete volume tested. This test is not affected by, by type of cement and aggregate characteristics. However, this test is not recommended for aggregate size beyond 38 mm. The major limitation with this test is that it requires special care at the time of placement of inserts to minimise air voids below disc besides a pre-planned usage.

Pull out tests are used to:

i) Determine in-situ compressive strength of the concrete.
ii) Ascertain the strength of concrete for carrying out post- tensioning operations.
iii) Determine the time for removal of forms and shores based on actual in-situ strength of the structure.
iv) Terminate curing based on in-situ strength of the structure.

Here item no (i) only are of relevance for residual strength assessment of old & distressed structures. It can be also used for testing repaired concrete sections. These tests are divided under the following two categories:

a) Embedding an insert into the fresh concrete while casting and then pulling out with a jack (LOK test- LOK meaning "punch") after hardening after a specified period.
b) Insert fixed into a hole drilled into the hardened concrete and then pulling out with a jack (CAPO test- cut and pull out).This second method offers greater flexibility for conducting in-situ tests on hardened concrete of existing structures and is explained above in detail.

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After the concrete has fractured by this test, the holes left in the surface are first cleaned of the dust by a blower.It is then primed with epoxy glue and the hole is filled with a polymer-modified mortar immediately thereafter and the surface is smoothened.

3.2.1.5 Core Sampling and Testing

While rebound hammer, Capo/Pullout, Windsor probe and ultrasonic pulse velocity tests give indirect evidence of concrete quality, a more direct assessment on strength can be made by core sampling and testing. Cores are usually cut by means of a rotary cutting tool with diamond bits. In this manner, a cylindrical specimen is obtained, usually with its ends being uneven, parallel and square and sometimes with embedded pieces of reinforcement. The cores are visually described and photographed, giving specific attention to compaction, distribution of aggregate, presence of steel etc. The core should then be soaked in water, capped with molten sulpher to make its ends plane, parallel, at right angle and then tested in compression in a moist condition as per BS 1881: Part 4: 1970 or ASTM C 42-77. The core samples can also be used for the following:

Instrument showing core cutting

Concrete Core

- Strength and density determination
- Depth of carbonation of concrete
- Chemical analysis
- Water/gas permeability
- Petrographic analysis
- ASHTO Chloride permeability test

The strength of a test specimen depends on its shape, proportions, and size. The influence of height/diameter (H/D) ratio on the recorded strength of cylinder is an established fact. Strength of cores have to be related to the standard cylinder strengths i.e. for H/D ratio of 2. Thus, core should preferably have this ratio near to 2. For values of H/D between 1 and 2, a correction factor has to be applied. Cores with H/D less than 1 yield unreliable results and BS 1881: Pt 4: 1970 prescribes a minimum value as 0.95. The same Standard specifies the use of 150 mm or 100 mm cores. However, cores as small as 50 mm are also permitted in other standards. Very small diameter cores exhibit more variability in results than larger dia cores, hence their use is generally not recommended. The general rule adopted for fixing the core size, besides the H/D ratio, is the nominal size of stone aggregate and the dia should be not less than 3 times the maximum size of stone aggregate. For diameter of core less than 3 times the size of stone aggregate, an increased number of cores have to be tested.

Following are the factors, which affect the compressive strength of extracted concrete cores:

- *Size of Stone Aggregate:* If the ratio of dia of core to maximum size of stone aggregate is less than 3, a reduction in strength is reported. For concrete with 20 mm size aggregate, 50 mm dia core has been tested to give 10% lower results than with 100 mm dia cores.
- *Presence of transverse reinforcing Steel:* It is reported that the presence of transverse steel causes a 5 to 15% reduction in compressive strength of core. The effect of embedded steel is higher on stronger concrete and as its location moves away from ends i.e. towards the middle.However, presence of steel parallel to the axis of the core is not desirable.
- *H/D Ratio:* This has already been discussed above. However, its value should be minimum 0.95 and maximum as 2. Higher ratio would cause a reduction in strength.

- *Age of Concrete:* No age allowance is recommended by the Concrete Society as some evidence is reported to suggest that in-situ concrete gains little strength after 28 days. Whereas others suggest that under average conditions, the increase over 28 days' strength is 10% after 3 months and 15% after 6 months. Hence it is not easy to deal the effect of age on core strength.
- *Strength of Concrete:* The effect in reducing the core strength appears to be higher in stronger concretes and reduction has been reported as 15% for 40 MPa concrete. However, a reduction of 5 to 7 % is considered reasonable (concrete society Tech Report no. 11 "Council Core Testing for Strength"- The Concrete Society, 1987)
- *Drilling Operations:* The strength of cores is generally less than that of standard cylinders, partly as a consequence of disturbance due to vibrations during drilling operations. Whatever best precautions are taken during drilling, there is always arisk of slight damage.
- *Site Conditions vis a vis Standard Specimens:* Because site curing is invariably inferior to curing prescribed for standard specimens, the in-situ core strength is invariably lower than the standard specimen taken and tested during concreting operations.

3.2.2 Chemical Tests:

Chemical analysis of concrete can provide extremely useful information regarding the cause of causes of failure of concrete.The tests most frequently carried out are listed below :

1. Depth of carbonation
2. Chloride content
3. Cement content
4. Sulphate content
5. Type of cement
6. Alkali content

3.2.2.1 Carbonation Test

This test is carried out to determine the depth of concrete affected due tocombined attack of atmospheric carbon dioxide and moisture causing a reduction in level of alkalinity of concrete.A spray of *0.2% solution of phenolphthalein* is used as pH indicator of concrete. The *change of colour of concrete to pink indicates that the concrete is in the good health, where no change in colour takes place, it is suggestive ofcarbonation-affected concrete*.The test is conducted by drilling a hole on the concrete surface to different depths upto cover concrete thickness, removing dust by air blowing, spraying phenolphthalein with physician's injection syringe and needle on such *freshly drilled/ broken concrete* and observing the colour change. The depth of carbonation is estimated based on the change in colour profile.The pH value can also be determined by analyzing samples of mortar collected by drilling from the site, dissolving the same in distilled water and thereby titration in laboratory.

3.2.2.2 Chloride Content

Chloride content can be determined from broken samples or core samples of concrete.Primarily, the level of chloride near the steel-concrete interface is of prime importance. Chlorides present in concrete are fixed (water insoluble) as well as free (water soluble). Though it is the water soluble chloride ions, which are of importance from corrosion risk point of view, yet total acid soluble (fixed as well as free) chloride contents are determined and compared with the limiting values specified for the concrete to assess the risk of corrosion in concrete. The total acid soluble chlorides are determined in accordance with IS: 14959 Part III 2001, whereas for assessment of water soluble chlorides the test consists of obtaining the water extracts, and conducting standard titration experiment for determining the water soluble chloride content and is expressed by water soluble chloride expressed by weight of concrete or cement. The method gives the average chloride content in the cover region.Further, a chloride profile across the cover thickness will be a more useful measurement as this can help to make a rough estimate on chloride diffusion rate. One recent development for *field testing* of chloride content includes the use of chloride ion sensitive electrode.This is commercially known as "Rapid chloride test kit-4". The test consists of obtaining powdered samples by drilling and collecting them from different depths (every 5 mm), mixing the sample (of about 1.5 gm weight) with a special chloride extraction liquid, and measuring the electrical potential of the liquid by chloride-ion selective electrode.With the help of a calibration graph relating electrical potential and chloride content, the chloride content of the samples can be directly determined.

Based on the chemical analysis, corrosion-prone locations can be identified as per the guidelines given in Table-3.11.

Table-3.11 : Guidelines for Identification for Corrosion Prone Locations based on Chemical Analysis

(*Source: Indian Concrete Journal, June 1998*)

Sl.No.	Test Results	Interpretations
1.	High pH values greater than 11.5 and very low chloride content	No corrosion
2.	High pH values and high chloride content greater than threshold values (0.15 percent by weight of cement)	Corrosion prone
3.	Low pH values and high chloride content (greater corrosion prone than threshold values of chloride 0.15 percent by weight of cement	increased risk of corrosion

3.2.3 Corrosion Potential Assessment:

1)	Cover-Meter/ Profo-meter (In-situ Test)	Non-destructive method for measuring - thickness of cover concrete - reinforcement diameter - reinforcement spacing.
2)	Half Cell Method (In-situ Test)	Non-destructive method for measuring/ plotting corrosion potential for assessing probability of corrosion
3)	Resistivity Measurement (In-situ Test)	Non-destructive method for assessing electrical resistivity of concrete

4)	Permeability a. Water b. Air (In-situ Test)	Assessment of in-situ permeability of concrete due to water and air.
5)	Initial Surface Absorption (Lab Test)	An indicator of surface permeability

Half-Cell Potential measurement method is used for finding out the status of corrosion actively in the embedded steel.

3.2.3.1 Cover meter survey

The necessity to provide adequate cover thickness to control corrosion needs no emphasis.A cover thickness survey is useful to determine existng cover thickness in a specific location, where a damage has been identified and elsewhere, for comparison on the same structure.The cover thickness can be measured non-destructively using commercially known cover meters. The cover meters are also used to identify the location and diameter of rebar.COVERMASTER and PROFOMETER are the commercially available instruments, which are used to measure the cover thickness and rebar size. Table 3.12 shows how the cover meter readings are to be interpreted for corrosion assessment.

Cover meter or Profometer

Table 3.12 : Interpretation of Cover Thickness Survey

Sl.No.	Test Results	Interpretations
1.	Required cover thickness and good quality concrete	Relatively not corrosion prone
2.	Required cover thickness and bad quality cover concrete	Corrosion prone
3.	Very less cover thickness, yet good Quality cover concrete	Corrosion prone

3.2.3.2 Half cell potential survey

Corrosion being an electrochemical phenomenon, the electrode potential of steel rebar with reference to a standard electrode undergoes changes depending on corrosion activity.

A systematic survey on well-defined grid points gives useful information on the presence or probability of corrosion activity.The same grid points as used for other measurements, namely, rebound hammer and UPV could be used for making the data more meaningful.The common standard electrodes used are:

i) Copper - Copper sulphate electrode (CSE)

ii) Silver - Silver chloride electrode (SSE)

iii) Standard Calomel electrode (SCE).

The measurement consists of giving an electrical connection to the rebar and observing the voltage difference between the bar and a reference electrode in contact with concrete surface. [Fig 3.17(a)] Generally, the voltage potential becomes more and more negative as the corrosion becomes more and more active. However, less negative potential values may also indicate the presence of corrosion activity, if the pH values of concrete are less.

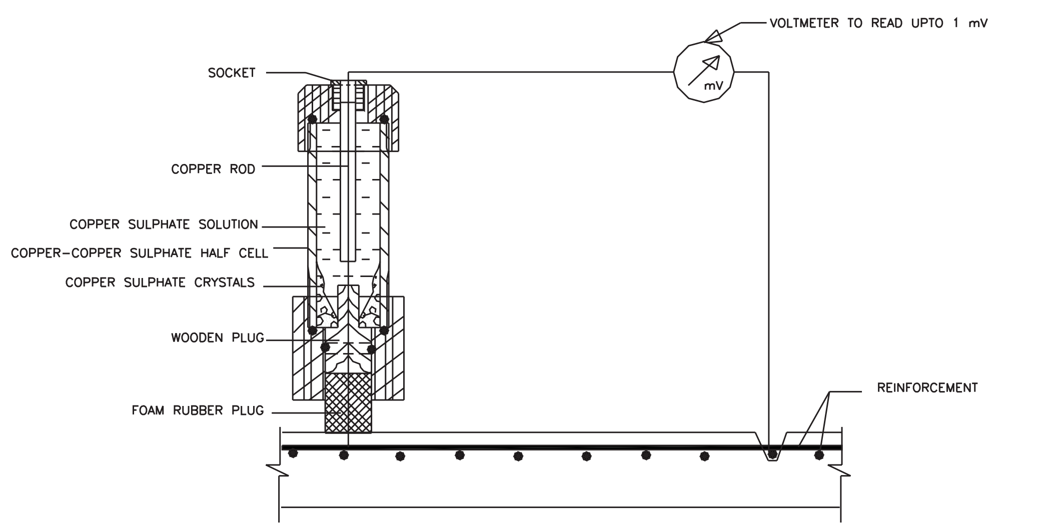


Fig.-3.17(a) Half Cell Potential Test

The general guidelines for identifying the probability of corrosion based on half-cell potential values as suggested in ASTM C 876 are given in Table 3.13

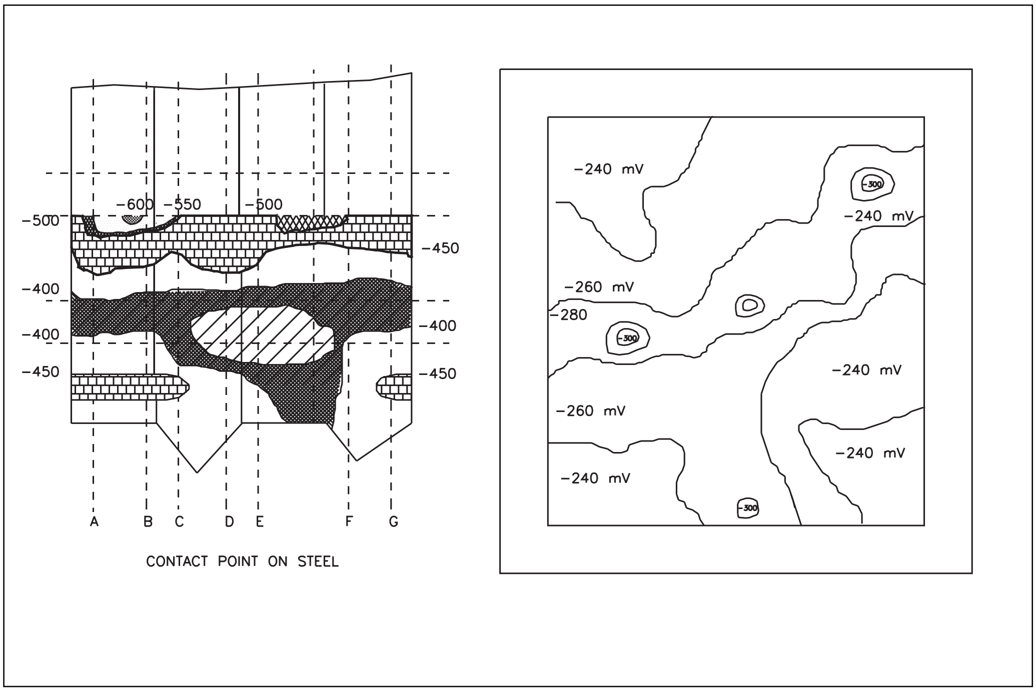
Table 3.13 – Corrosion Risk by Half Cell Potentiometer

(Source: Indian Concrete Journal, June 1998)

Probability of Corrosion being active	Half Cell Potential Reading Range	
	$Cu-CuSO_4$ Electrode	Silver-Silver Chloride Electrode
>95 percent	More negative than – 350 mV	More negative than – 700 mV
50 percent	- 200 to - 350 mV	- 500 to - 700 mV
<5 percent	More positive than – 200 mV	More positive than – 500 mV

In any case, the technique should never be used in isolation, but should be coupled with measurements of chloride content of the concretes and its variation with depth and also the cover to the steel and the depth of carbonation.

- However, a systematic "potential mapping survey" is considered to be more useful for on-site identification of the Corrosion State of rebars.This will facilitate setting out potential profile or potential contour.A typical potential contour is shown in fig 3.17 (b) and (c). Initially when potential surveying was introduced as per ASTM C876, each reading was interpreted in isolation and the numerical value was directly correlated to the degree of corrosion.Subsequently, this approach was realised to be erroneous because non-corroded steel can exhibit a wide range of potential values.It is now realised that *potential values should be assessed, not in isolation, but as a group and the inter-relationship of the potentials within that group should form the basis for interpretation.*Analysis of potential contour will generally consist of Identifying the locations with accumulated potential lines indicating to the corroding areas beneath.



(b) Shaded Mapping (c) Contours Plot

Fig.-3.17 (b) & (c) Typical Half Cell Potential Coutours

- Locating at a glance, the anodic areas identified by the gathering of isopotential lines having more severe potential gradient.
- Ascertaining whether or not a structure is actively corroding.

It is necessary to realise certain important parameters (listed below) which influence the measured potentials of the reinforcement.

i) The potentials of a rebar measured on the surface of, or within concrete may not be a true representation of the value at the surface of the steel

ii) The physical i.e. moisture content and chemical state of concrete i.e. presence of electrolyte ions can result in wide variation.

iii) The ohmic drop due to electrical resistance of the concrete also can induce variations

iv) With increasing concrete cover, the potential values at the concrete surface over actively corroding and passive slab become similar.

3.2.3.3 Resistivity Measurement

Resistivity Mapping:

The electrical resistance of concrete plays an important role in determining the quality of concrete from the point of view ‘corrosion susceptibility potential’ at any specific location. This parameter is expressed in terms of “Resistivity” in ohm-cm.

For general monitoring, a resistivity check is important because long-term corrosion can be anticipated in concrete structures where accurately measured values are below 10,000 ohm-cm.Further, if resistivity values fall below 5,000 ohm-cm, corrosion must be anticipated at a much earlier period (possibly within 5 years) in the life of a structure. Table 3.14 indicates the general guidelines of resistivity values based on which areas having probable corrosion risk can be identified in concrete structures.

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Table-3.14 : Corrosion Risk from Resistivity

(Source: Indian Concrete Journal, June 1998)

Resistivity ohm cm.	Corrosion Probability
Greater than 20,000	Negligible
10,000 – 20,000	Low
5,000- 10,000	High
Less than 5,000	Very High

The principle of resistivity testing in concrete is similar to that adopted in soil testing.However, when applied in concrete, a few drawbacks should be realised.The method essentially consists of using a 4- probe technique in which a known current is applied between two outer probes 100 mm apart and the voltage drop between the inner two elements at 50 mm spacing, is read off allowing for a direct evaluation of resistance R.Using a mathematical conversion factor, resistivity is calculated as per principle of four probe resistivity testing is illustrated in Fig 3.18.

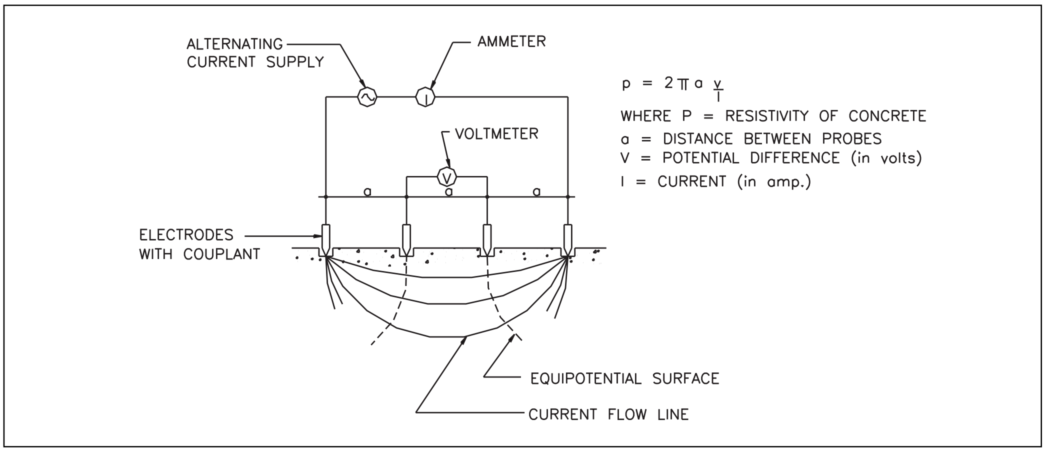


Fig.-3.18 Resistivity meter (4 probe system)

The following drawbacks are important to note while analysing and interpreting the resistivity values:

- The value obtained represents only the average evaluation over the depth regulated by the chosen probe spacing and not that of concrete at steel interface
- The resistivity of concrete varies with varying moisture conditions
- The instrument should have adequate 'IR' drop compensation for measurement.

Table 3.15 gives some guidelines for a qualitative identification of corrosion prone areas based on combined results of half-cell potential and resistivity.

Table 3.15 : Corrosion Probability based on Resistivity and Potential Mapping

Sl.No.	Test Results	Interpretations
1.	High resistivity greater than 10,000 ohm - cm and low potentials – more positive than – 200 mV (CSE)	No active corrosion-relatively cathodic
2.	Low resistivity below 10,000 ohm – cm and potentials between – 200 m V to -350 mV (CSE)	Initiation of corrosion activity – relatively anodic
3.	Low resistivity about 5,000 ohm – cm and potential – 200 mV to -350 mV (CSE)	Presence of corrosion activity – anodic
4.	Low resistivity below 5,000 ohm cm and potential more negative than – 350 mV (CSE)	High intensity of corrosion – fully anodic
5.	Higher potential gradient and high conductivity	High rate of corrosion

Measurement of corrosion rate:

In reinforced concrete structures, determination of actual rate at which the reinforcement is corroding assumes larger importance since the laboratory results are not directly applicable to field conditions.Another form of the polarisation method has been developed and is known as "Linear Polarisation Resistance" (LPR) method for the on-site study of corrosion rates of steel in concrete.The fundamental principle of linear polarisation is based on the experimentally observed assumption that for a simple model corroding system, the polarisation curve for few millivolts around the corrosion potential obeys a quasi-linear relationship .The slope of this curve is the so-called polarisation resistance "R_P". (ICJ 98, JUNE, 1998)

$R_P = (\Delta E/\Delta I)\Delta E0$

From this slope, the corrosion rate can be determined using stern- Geary equation

$I_{corr} = B/R_p$

Where, B is a constant which is a function of the Tafel Slopes and **ba, bc**, and determined from the formula given below:

B = [**ba. bc/ 2.3(ba + bc)]**

The value of B usually lies between 13 and 52 mV depending on the passive and active corroding system.For on-site measurements, the testing system consists of a potentiostat, counter electrode, reference electrode and the reinforcement as working electrode.This system is schematically illustrated in Fig 3.19.

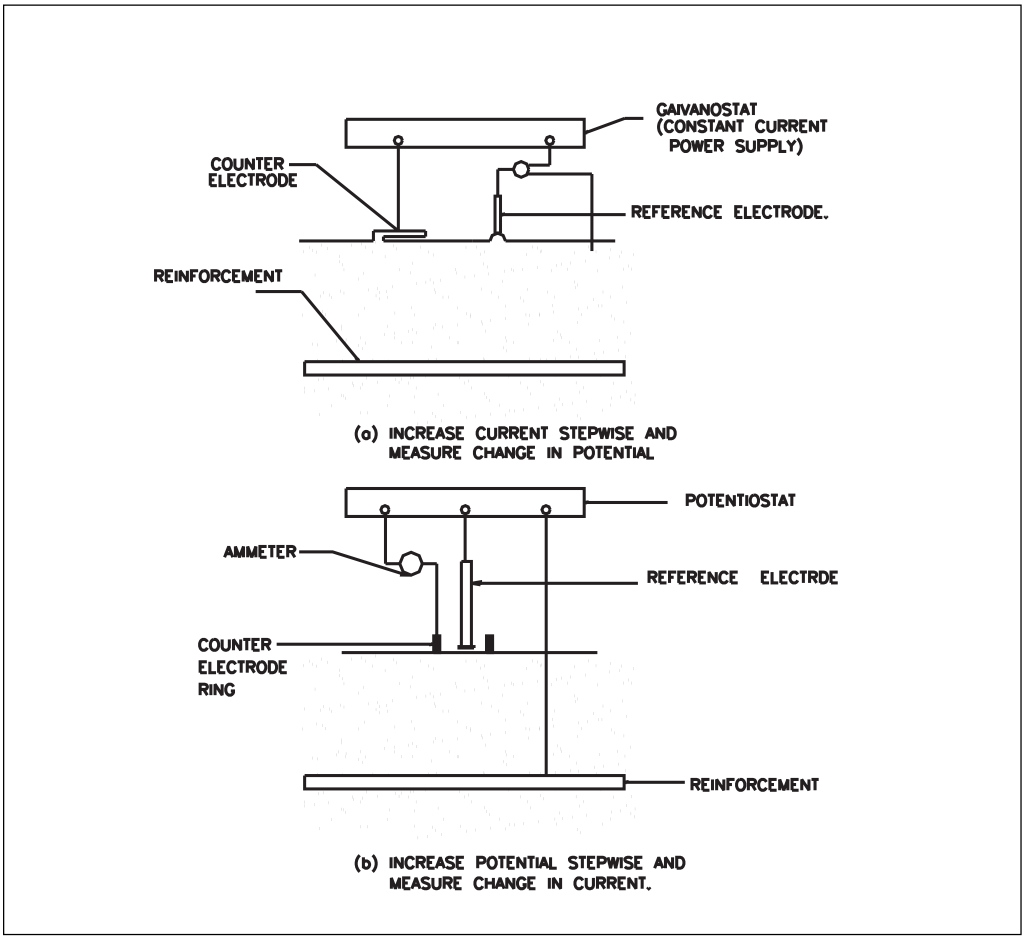


Fig.-3.19 Resistivity testing for concrete

A typical plot of linear polarisation curve is shown in Fig.3.20.

It is necessary that for measurements i n concrete, the potentiostat should have electronic ohmic compensation(IR drop) or otherwise, the value is to be obtained by calculation or separate experiments.

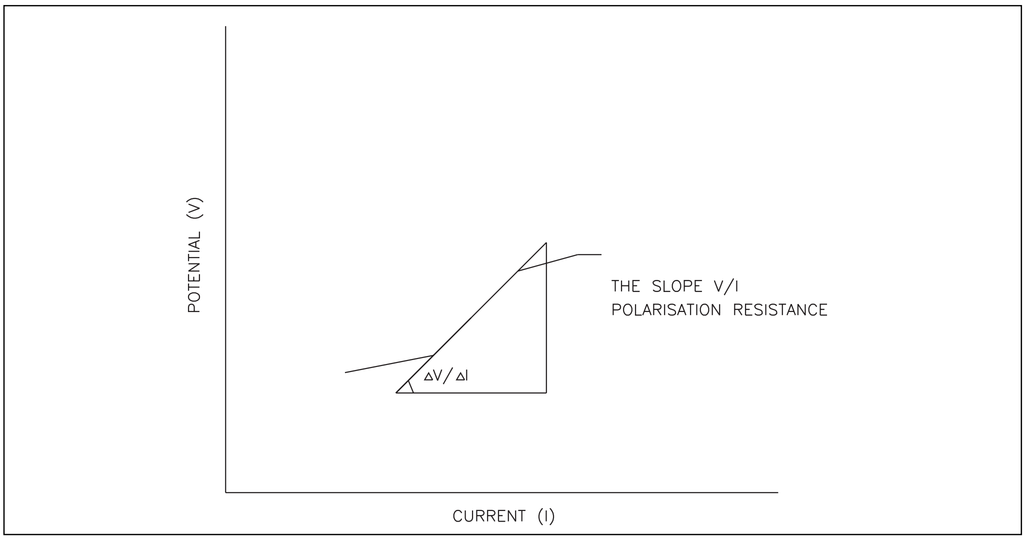


Fig.-3.20 Linear Polarisation Curve

3.2.4 Fire Damage Assessment:

1.	Differential Thermal Analysis(DTA)(Lab Test)	Assessment of qualitative & quantitative composition of sample of concrete
2.	X-ray Diffraction (XRD)(Lab Test)	To determine the extent of deterioration in concrete subjected to fire

3.2.4.1 Differential Thermal Analysis (DTA)

DTA is used to study the physical and chemical changes that occur in a material when it is heated so as to characterise the material. It is concerned with the rate of change of temperature of a sample as it is heated at a constant rate of heat flow.

The principle on which DTA is based is that when a material is slowly heated, its temperature rises but when the material undergoes any endothermic reaction viz. losing water, losing CO2, change in crystalline structure or decomposition, its temperature remains constant.

The results of DTA are presented in the form of DTA curves. The sample and an inert material are heated in separate crucibles and the difference of temperature between the two is recorded by means of thermocouples which generates an electrical signal whenever there is a temperature difference between the reference and the sample. When there is no endothermic reaction in the sample, there would not be any difference of temperature between the reference and the sample and hence, no electrical signal would occur. Any endothermic change would create a thermal differential and hence an electric pulse. The occurrence of this pulse appears as a peak in the DTA curve which is a plot.of temperature versus electrical signal generated. Advantage of DTA over TGA is that the changes not involving weight loss can also be detected.

By comparing the DTA curve of a sample with that for known compounds, qualitative composition of the sample can be judged. Quantitative composition of the sample can also be judged by measuring the size of the peak in the DTA curve. The peak size is directly linked with amount of heat involved in a transition.

If a concrete sample is analysed, endothermic peak due to Calcium hydroxide is found at 500°C. The peak due to conversion of silica occurs at 570°C. When various fire damaged samples of concrete are subjected to DTA, the presence of peak at 500°C indicates that Calcium hydroxide is present and that the sample has not been subjected to temperature more than 500°C. If peak of 570°C only is present, it means that silica conversion had not occurred in the sample and it was not subjected to temperature more than, 570°C. If no peak is there, it means that sample was subjected to temperature exceeding 570°C.

3.2.4.2 X-ray Diffraction (Xrd):

X-ray diffraction technique is based on the principle that a crystal of a substance has a unique diffraction pattern; When monochromatic X-ray beam falls on a crystal it gets reflected by the various crystalline planes. Interference occurs among the various reflected beams resulting in a diffraction pattern consisting of dark and bright fringes depending upon the phase difference among the interfering beams.

A crystal whose composition is unknown can be identified by obtaining its diffraction pattern and comparing it with diffraction patterns of already identified crystals. The diffraction pattern of a single crystal consists of a number of single spots but when powder sample is used, the diffraction pattern consists of a series of diffraction lines.

By this technique the size of crystal planes the molecular structure of the sample can be determined. It can also be found whether the sample is a single compound or consists of more than one compound. In case of polymers, degree of crystallinity can be found because the noncrystalline portion will scatter the x-ray beam to give a continuous background while the crystalline portion will give discontinuous diffraction pattern.

As regards to the assessment of fire damage, X-ray diffraction can be used to determine the extent of deterioration in concrete that has been subjected to fire. The temperature to which the damaged concrete has been subjected to can be determined by this method:

3.2.5 Structural Integrity/Soundness Assessment

3.2.5.1 Radiography:

This technique enables to take a photograph showing details of the inside of a concrete member. It is used to determine the location and size of reinforcement, to check for the existence of voids and areas of poor compaction in concrete where other NDE test methods are not suitable, such as massive old concrete structural units when being assessed for structural safety. It is also used for checking for voids in the grouting in prestressing ducts.

BS 1881: Part 205 gives detailed information/ recommendation for radiographic inspection of concrete.

The method uses sources of gamma rays for concrete up to about 500 mm thick and above this thickness, the standard recommends the use of high-energy X rays.

Due to the inherent danger of using gamma rays and high energy X rays, the use of this method is confined to investigation which justify the cost of the special precautions which have to be taken.

3.2.5.2 Impact-echo test:

Most recent Non-destructive evaluation technique based on use of transient stress waves, has been used for detecting flaws in many different types of structures including plate like structures, such as bridge decks, slabs and walls beams and columns, layered structures and hollow cylindrical structures. To detect hidden damage and determine the extent of damage inside a concrete cross section (delamination, Honey-comb, cracks etc.)

3.2.5.3 Dynamic Testing of Structures :

The dynamic characteristicsof structures depend on its stiffness and mass.Frequency of a structure gives a good indication of deterioration or improvement of its stiffness.The dynamic testing of a structure before and after repairs will give an idea of the deterioration of structures and effectiveness of the repairs.The different techniques available for dynamic testing of structures are following:

1. **Frequency Shift :** The method is based on the comparison of the natural frequency of the damaged structure with the undamaged structure.In the absence of the knowledge of the natural frequency of the undamaged structure an estimate has to be based on

theoretical computations.Care should be taken for the effect of non-structural members on the frequency. The frequency being a global property of a structure, this method cannot be used for locating the damage.

2. **Mode-Shape Change :** The change in mode shape is more sensitive to damage than the frequency. The damage location using mode-shape can be done without a prior knowledge of the undamaged structure or the theoretical calculations (West, 1984).An alternative to mode shape is to use derivatives of mode shapes such as curvature.
3. Change in Dynamically Measured Flexibility : The flexibility matrix of a structure can be synthesized using the frequency and mode shape in various modes.The flexibility matrix of the damaged structure compared with that of undamaged structure can indicate the damage. The same comparison before and after the repairs will indicate the effectiveness of repair.

In addition to the above-mentioned techniques a few techniques are available for continuous/periodic health monitoring of a structure. The problem with the dynamic testing is the absence of the knowledgeof the undamaged structure.However, the testing can be very; useful in assessing the effectiveness of repairs, as the testing can be done before and after the repairs.

3.2.6 Interpretation and Evaluation of Test Result Data

3.2.6.1 Establishing the problem, the probable causes and factors influencing the deterioration requires careful studies and analysis of the information gathered in the investigation stage which should be tabulated on a specific proforma to be prepared depending on the type of test data, information available for analysis.

3.2.6.2 This usually involves proposing a hypothesis and testing the resultant scenario against the observed facts. Two or three such hypothesis and scenario may be looked at and tested for their veracity against the available facts. Examination of available facts often reverse the need for further investigation to resolve the unanswered questions

3.2.6.3 Interpretation of test results.

Based on UPV Results:

a) **Uniformity of ultra-sonic pulse velocities throughout the structure** indicates that the concrete is likely to be of a uniform quality.This is a rare phenomenon in a poorly constructed building.However, uniformly low value would indicate low strength of concrete.

b) If the pulse velocities vary from one zone to another of a structure, but are reasonably uniform within each zone, there is probably a variation in the quality of concrete from one batch of concrete to the other that was used in construction.

c) If the pulse velocities vary randomly over a wide range throughout thestructure, the quality of concrete is not necessarily the only suspect. The very likely cause could be poor concreting, inadequate and non-uniform compaction, addition of extra water on site in uncontrolled quantities, and other construction related errors could lead to highly variable concrete.

d) Stripping of the plaster and exposing the concrete surface may visually indicate the poor quality of concrete by way its appearance.Segregation, honeycombing, loose concrete, powdery surface, cracks and presence of foreign material, one or all of them, may become visible when the plaster is stripped.

e) Micro cracking to various degrees in an under-designed or an over loaded structure in which there are zones of high-sustained stresses may also cause high variation in pulse velocities.A check of the actual loads on the structure and structural calculations will reveal zones of high-sustained stresses in the structure.Low pulse velocities have sometimes been mistakenly attributed to poor quality of concrete in the structure, though in reality low pulse velocities had been caused by micro cracking.

The engineer assessing the structure sometimes faces a dilemma when he is presented with a report on tests with many inconsistencies and unacceptable results.The fault may or may not lie with the testing agency.The following are some of the inconsistencies, which may make the test report inconclusive.

1) Low pulse velocities are accompanied by high core strengths;
2) Low probe penetrations are accompanied by low core strengths;
3) High core strengths are accompanied by low pulse velocities and high probe penetrations;
4) Other variations of the above;
5) Unacceptably low correlation coefficient.

The problem may arise due to inaccuracies in testing such as the following;

1) Inappropriate surface preparation for the non-destructive evaluationtests.
2) Applying too thick a coupling medium, which separates the surface of concrete from its contacting transducer, in the case of ultrasonic tests. For this reason, repeated readings of the transit time should be made while allowing the couplant to become thinly spread *until a minimum value of the transit time is obtained*.
3) Failing to detect reinforcement bars and ensuring that they do not lie in the path of the ultrasonic pulse, or ensuring that the presence of any steel is accounted for;
4) Measuring pulse velocities in zones of tensile stress or zones where compressive stress is too high for the quality of concrete; the influence is significantif the compressive stress is higher than 60 percent of the ultimate strength of the concrete;
5) Failing to ensure that the *drill is kept rigidly positioned* during coring, otherwise badly ridged or cored surfaces may be obtained with possible reduction in measured strength;
6) Failing to ensure that apparatus used in the various tests are performing satisfactorily;
7) Errors in measurements

It may not be possible to obtain sensible correlation curves for reasons other than testing procedures such as the following:

1) Poorly constructed structure with pockets of weak concrete, voids, cracks and foreign material scattered all over the structure;
2) Poorly designed and badly detailed structure with varying degrees of micro cracking and deterioration.

While it may be possible to get good correlation under controlled conditions in the laboratory, or for the concrete in a well designed and well constructed structure, it is often a problem in badly designed and badly constructed structures with highly varying conditions within the structure.

If the irregularities in test results are due to the testing procedure, these can be corrected and tests repeated.If the irregularities are due to other reasons, the assessor has to use a lot of judgement. He may decide to carry out a lot more tests on the critical members of the structure before coming to a conclusion on the condition of the structure.

3.3 Conclusion

In majority of cases, the causes of particular problem could be traced to the following, singly or in combination

1) Lower cover thickness over steel
2) Permeable cover concrete
3) High chloride levels
4) Alternate wetting and drying

It will be thus clear that the approach that should be adopted to control the future deterioration of concrete will depend on which of the above causes (or combination of causes) applies. The range of remedial solutions can vary from the minimal (patch repair of areas actually spalling) to the drastic (crust out completely & reinstate)

It is essential that all possible factors be noted during an investigation, so that unusual features of the environment or the concrete can be identified and the necessary solution sought.

☆ ☆ ☆

APPENDIX-3.1

Proforma For Planning Condition Survey Of Structure

Data- sheet

date :

Important

For proper investigation & selection of correct repair systems, it is desirable to furnish all possible information in detail as correctly as possible.

A. DATA

1. Name of the Project :
   a. Estimated cost :
   b. Location :
   c. Plinth area of Building :
2. Year of Construction :
3. Use of the Building
   a. Designed Use :
   b. Present Use :
   c. Any other change in Bldg use :
   d. Brief background history, if change in building use is involved :
4. a. Structural changes made in the past :
   b. If so, details of Changes carried out :
5. Year of first distress noticed :
6. Nature of distress noticed
   a. Any previous investigation done in the past :
   b. If so, copy of results of such investigation :
7. Any repair to concrete undertaken in the past. :
   a) If so, provide details
      1. Year of carrying out repairs
      2. Type of repairs
      3. Efficacy of repair
      4. Cost of repairs
8. Any investigation done in past
   a) If so, copy of the results of such investigation :
9. Type of cement used (OPC/PPC)/ SRC/ any other in original construction) :

10. Type of steel reinforcement used (Mild steel/Cold twisted steel/TMT /any other steel) :

11. Source of water used for original construction (Municipal water/Local bore well / Any other source) :

12. Chemical analysis results of water used for construction :

    pH Value :
    Chloride ppm :
    Sulphate ppm :

13. Source of sand and chemical analysis, if any, in regard to Chloride/ Sulphate contents :

14. Source of coarse aggregate including type of rock :

15. Photo of defective portions, if any :

16. Set of architectural drawings (to be enclosed) :

17. Set of structural drawings (to be enclosed) :

18. Details of any protective treatment used (during or after construction) :

B. TECHNICAL COMMENTS ON NATURE OF DISTRESS

1. Executive Engineers :

2. Superintending Engineers :

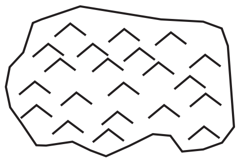
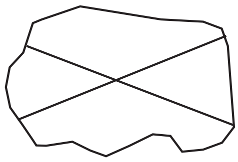
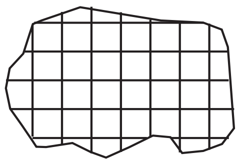
3. Chief Engineers :

Signature of Engineer-in-Charge

APPENDIX-3.2(A)

TABLE 3.2(A) NOTATIONS FOR SYMPTOMS OF DISTRESS OBSERVED VISUALLY FOR RECORDING ON SPREAD SHEET/FLOOR PLANS

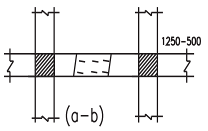
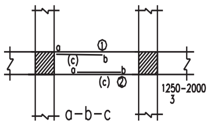
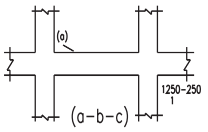
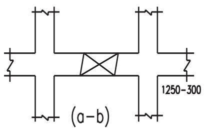
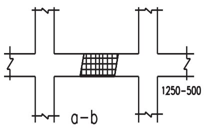
SLABS

S.NO.	SYMPTOM OF DISTRESS	NOTATION
1.	LOOSE COVER CONCRETE	
2.	SPALLED COVER CONCRETE WITH REINFORCEMENT NOT EXPOSED	
3.	SPALLED COVER CONCRETE WITH REINFORCEMENT EXPOSED	
4.	CRACK IN RCC SLAB	(b) b- LENGTH OF CRACK
5.	CRAZING CRACKS	

APPENDIX 3.2 (B)

TABLE 3.2(B) NOTATIONS FOR SYMPTOMS OF DISTRESS OBSERVED VISUALLY FOR RECORDING ON SPREAD SHEET/FLOOR PLANS

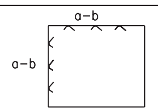
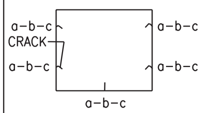
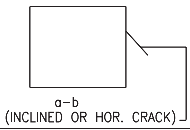
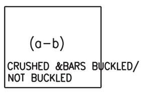
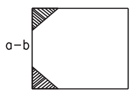
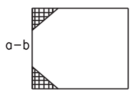
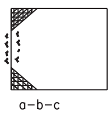
BEAMS

S.NO.	SYMPTOM OF DISTRESS	DIAGRAM	NOTATION
1.	LOOSE COVER CONCRETE		a- DISTANCE FROM LEFT FACE OF COLUMN b- LENGTH OF LOOSE COVER CONCRETE
2.	CRACK ALONG REINFORCEMENT IN THE SOFFIT OF BEAM		a- STARTING POINT OF CRACK FROM LEFT FACE OF COL./WALL b- LENGTH OF CRACK c- CRACK WIDTH IN MM
3.	DIAGONAL OR VERTICAL CRACK ON VERTICAL FACE OF A BEAM (CRACK TO BE SHOWN INCLINED OR VERTICAL AS THE CASE MAY BE)		a- STARTING POINT OF CRACK FROM LEFT FACE OF COL./WALL b- LENGTH OF CRACK c- CRACK WIDTH IN MM
4.	SPALLED COVER CONCRETE WITH NO EXPOSURE OF REINFORCEMENT		a- DISTANCE FROM LEFT FACE OF COLUMN b- LENGTH OF LOOSE COVER CONCRETE
5.	SPALLED COVER CONCRETE WITH REINFORCEMENT EXPOSED		a- DISTANCE FROM LEFT FACE OF COLUMN b- LENGTH OF LOOSE COVER CONCRETE

APPENDIX 3.2 (B)

TABLE 3.2 (C) NOTATIONS FOR SYMPTOMS OF DISTRESS OBSERVED VISUALLY FOR RECORDING ON SPREAD SHEET/FLOOR PLANS

COLUMNS

SL.NO.	SYMPTOM OF DISTRESS	DIAGRAM	NOTATION
1.	LOOSE COVER CONCRETE		a–STARTING HEIGHT FROM FL. b–VER.LENGTH OF LOOSE POSITION
2.	CRACK ALONG REINFORCEMENT		a–STARTING HEIGHT FROM FL. b–VER.LENGTH OF LOOSE POSITION c–CRACK WIDTH
3.	OTHER CRACK		a–STARTING HEIGHT FROM FL. b–VER.LENGTH OF LOOSE POSITION
4.	CRUSHING OF CONCRETE WITH MAIN REINFORCEMENT BUCKLED/NOT BULKED		a–LOCATIONS OF CRUSHING FROM FL. b–LENGTH OF CRUSHED POSITION
5.	SPALLED COVER CONCRETE WITH NO EXPOSURE OF REINFORCEMENT		a–HEIGHT OF STARTING PT. FROM FL. b–HEIGHT OF SPALLED AREA
6.	SPALLED COVER CONCRETE WITH REINFORCEMENT EXPOSED		a–HEIGHT OF STARTING POINT b–HEIGHT OF SPALLED AREA
7.	CRACK , SPALLED COVER CONCRETE WITH NO EXPOSURE OF REINFORCEMENT AND WITH EXPOSURE OF REINFORCEMENT		a–STARTING HEIGHT FROM FL. b–VER.LENGTH OF LOOSE POSITION c–CRACKS

APPENDIX 3.3

3

Typical Format for analysis of field test results
A. Concrete Strength assessment

Bldg Identification			Concrete Strength Assessment													General observation including priorisisation based on distress/deterioration	Reasons for distress with justification	Recommendation
Location of structural member			UPV meter		Schmidt Hammer			Core Test										
								Crushing Strength			Density Test			Petrographic Examination				
Group of Exposure	Member no.	Spread sheet reference No.	Velocity km/sec	Qualitative Grading	Rebound Numbers as recorded	Rebound Index	Qualitative Grading	Core Crushing strength	Equivalent cube strength	Qualitative Grading	Core Density	% age of standard density	Qualitative Grading	Visual observation of core	Qualitative Grading			

APPENDIX 3.3

Typical Format for analysis of field test results
B. Corrosion Assessment

Bldg Identification			Corosion Assessment														General Observation including priorisation based on distress/ deterioration distress/ deterioration	I Recommendations	Reasons for distress with justification
Location of structural member			Concrete Cover		Carbonation Depth		Half Cell Potential Test Ranges are 'A'=0 to (-) 200mV 'B'=(-)200mv to (-)350 mV 'C'=>(-)350mV			P^H of cover concrete	Chemical Test Results of Concrete		Reduction of Bar Diameter						
Group of Exposure	Member No	Work Sheet	Specified Thickness (mm)	Actual Measured Thickness (mm)	Depth of Carbonation measured (mm)	Whether reinforcement needs to be exposed all around	Potential Readings as observed	Number of readings falling in Ranges A,B&C	Probability of corrosion	Measured Value	Total Chlorides (% by weight of Cement)	Total Sulphate (% by weight of Cement)	Original Bar Dia (D_o)	Measured Bar Dia (D_2)	% age Reduction of X-sectional area	Whether addl reinforcement required (Y/N)?			
								A=? B=? C=?											
								-do-											

3

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34. IS:3085, 1965, "Method of Test for Permeability of Cement Mortar and Concrete", pp.3-10 ,BIS, New Delhi.
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CHAPTER 4

STRUCTURAL ANALYSIS AND DESIGN

4

STRUCTURAL ANALYSIS AND DESIGN

The definition of the problem becomes a major part of the innovation. A lot of solutions fail because they're solving the wrong problem.

...Elbert Einstein

4.1 General

Strength evaluation of an existing structure or its portion may be required if it is considered that there is:

a. Evidence of faulty design/construction
b. Structural deterioration due to ageing or otherwise
c. Need for changed use of structure for which it was not originally designed
d. New codal requirement to which the existing structure does not conform

4

Analysis and design process of a damaged structure has to be based on its actual existing condition. Before taking it up, the in situ properties of material used and its structural sizes have to be determined based on field investigations and measurements. Whereas, in case of new structures, option of alternative standard materials and structural sizes are open and the design process could be adopted to get the optimum results based on loads as per its design use.

Basic principles of analysis and design of a distressed structure are same as in case of new structures. However, these require extra inputs based on sound and experienced engineering judgment of the structure and its materials.

4.1.1 Reserve Strength

The old structures have reserve strength due to:

a. Increased strength of concrete with ageing, which needs to be established by actual assessment.
b. Conservative design approaches e.g. non-consideration of live load reduction factor etc.
c. Steel reinforcement provided is quite often more than the actual requirement.
d. Based on engineering judgment, some higher stresses could be permitted for short durations while carrying out repairs.
e. While taking the benefit of reserve strength, care shall however be taken, to ensure that the structure is not subjected to higher stresses so as to impair its stability.

4.1.2 Analysis necessary to Identify Critical Section

There is loss of capacity of structural member due to damaged concrete and/or reinforcement steel. The first step is the capacity determination of the structure by establishing the existing in situ cross-sectional details of damaged structural members and their material properties. The analysis of the structure can be done in accordance with the in-situ relative stiffness. If the deflections exceeds the permissible values, the same may be allowed with caution, provided modified serviceability criteria of appearance and efficiency is satisfied. The analysis should, however, identify the critical sections in the structure needing structural strengthening.

4.1.3 Active and Passive Repairs

It is essential to halt its further deterioration and undertake strengthening, if required, for additional anticipated loads. The repaired structure comprises of parent as well as new repair material. The repairs can be termed as *active* or *passive* depending on the load sharing mechanism of repair material and parent material. The *passive repairs* are those, which are applied on existing loaded structural members and are able to share only a part of subsequent additional loading. Whereas, in *active repairs*, the repaired structural member is initially unloaded to relieve it of loads before the application of repairs. This is done basically to ensure that the repair material and the parent material share the loads jointly.

The structural members can be repaired or strengthened for resisting excess shear and flexure by providing additional steel reinforcement, carbon fibre wraps/mesh, section enlargement, external pre-stressing, steel plate bonding etc. The sharing of load between old and new materials needs to be incorporated in the analysis and design. The type of stresses acting on the repair system are given in the Fig. 4.1.

4.1.4 Modeling of Repaired Composite Structure

The behaviour of the repaired composite structure is difficult to model due to unpredictable stress relieving and degree of integration with the existing structure. It will be necessary to make some rational assumptions based on sound engineering judgment.

The procedure detailed in the following sections can be followed for assessment, evaluation and design of repaired structures.

4.2. Structural System & Its Validatioin

The documents related to foundation conditions, soil report, analysis, design, execution and maintenance of work shall be gathered. The illustrative list is given in Chapter–3. As built architectural/structural drawings are essential for analysis and design.

It is necessary to check and validate the sizes of structural members duly making allowances for the finishes and damages. The diameter and location of reinforcement can be validated using available non-destructive bar locator (Cover master/bar locator, etc). The structural system can be developed based on the validated available structural/architectural drawings. Wherever such informations are not available, drawings based on actual measurement are to be developed.

4.3 Mechanical Properties of Materials

The steel reinforcement is relatively consistent in quality. The mechanical properties can be assessed based on the details available in the drawings or by exposing reinforcement at few places and taking samples for testing. The losses of cross sectional areas due to effect of corrosion etc. need to be ascertained.

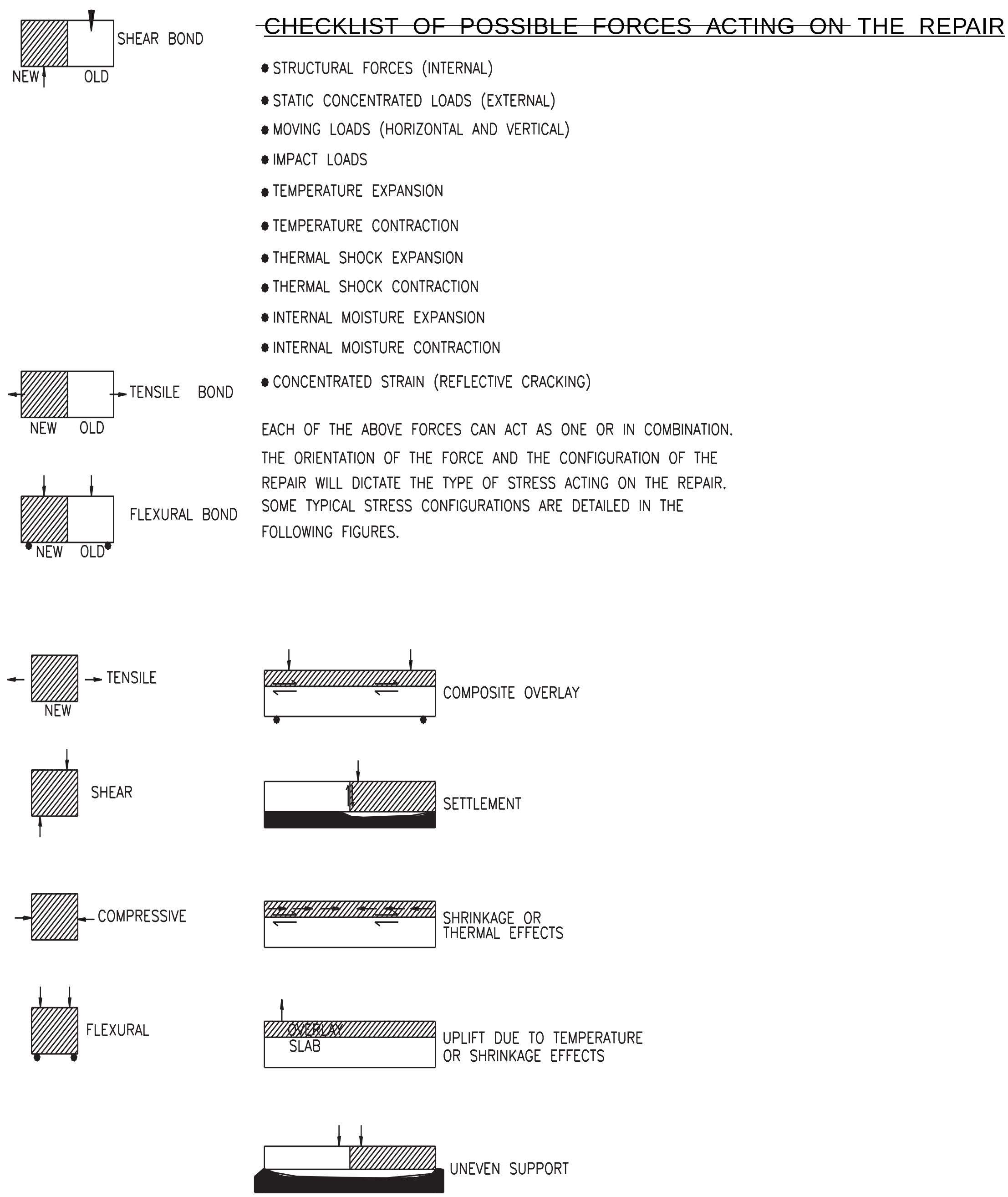

Fig. 4.1: Types of Stresses Acting on Reparis

(Source: 1. Peter H. Emmoms, "Concrete Repairs and Maintance Illustrated" Published by Galgotia, New Delhi, India.
2. Plum, D.R., "Materials–How to Select", Construction, Maintenance and Repair, November/December 1991, England).

The assessment of mechanical properties of concrete is rather elaborate and requires detailed investigations. The strength of the concrete can be evaluated by nondestructive methods like Ultrasonic Pulse Velocity Tests (UPV), Rebound Hammer Test etc. in conjunction with core test. Using the results of NDE investigations and methods of interpretation given in Chapter-3, the strength of concrete can be evaluated with certain degree of confidence.

4.4 Evaluation of Damage to Concrete/Reinforcement

The condition survey of the structure will give an idea regarding extent of damage to concrete due to spalling, original construction defects, loss of strength due to exposure to high temperature and also damage to reinforcement due to corrosion/fire. This can be done based on the field measurements. The observation of the structure can be mapped on a suitable format and the results incorporated in the analysis of structure.

4.5 Service Loads including due to Change of Building Use

Based on building use, its region of location and the related structural/architectural drawings, the design loads shall be worked out based on the applicable standards for earthquake and wind (refer IS: 875- Part 1 to 5 and IS: 1893). The loading as per original building use and also due to its changed use in the past and future, shall be ascertained and appropriately considered in the design process.

4.6 Evaluation of Building Configuration

The existing building may

a. Not comply with the requirements of current codal provisions of design and construction
b. Also require upgrading to satisfy the changed functional requirements.

These may necessitate structural modification. These could be identified based on the period of construction of the building and the then prevalent codal practices.

The configuration of the building in plan and elevation provide adequate information regarding structural dynamic response in the event of earthquakes etc. The locations of stress concentration need to be identified based on analysis of as constructed structure. These points of stress concentrations are to be examined in detail. The deficiency if any, in the original construction should be identified. Particular attention must be given to the non-structural/structural cracks in the structure to identify the cause of distress including improper construction joints / separation joints, if any.

4.7 Analysis and Design

Analysis and design of the building shall be done taking into consideration of:

a. Structural sizes and material properties established based on the investigations.
b. The reduction in member dimensions, changes in end conditions, the sequence of construction and subsequent changes in sizes of element, shall also be taken into account.
c. All the geometric & material characteristics and end conditions of the existing building while modeling the structure for analysis .
d. The theoretical model may be checked to compare the analytical results with the actual observations.
e. The structural safety and load transfer shall be ensured at all the stages of repair.

Some of issues to be considered in the analysis/design/repair process without compromising the stability of structure as a whole, are:

a. The removal of concrete during repair may reduce the effective size of the structural member and consequently affect its stiffness. Also the stability of the structure may be endangered due to transfer of load to adjoining members.
b. The removal of a structural member may increase the effective length of a compression member affecting its stability.
c. In case of indeterminate the beam / slab element, it may be safe to assume the member as simply supported in the design and proceed accordingly. It would also give flexibility during execution of repair work.
d. Effectiveness of fully exposed reinforcement in the structural member be assessed.

4.8 Load Tests for Flexural Members:

Load test in accordance to IS: 456-2000 shall be carried out for flexural members, in case of doubt regarding the capacity of repaired structural element. Before a load test is carried out,

a. Analysis shall be done taking into account the possible load transfer path.
b. The safety of the structural element and the personnel shall be ensured before allowing the load test.
c. Emergency support system shall be erected below the structure to face the situation of sudden deflection of a member or the structure.
d. The continuous monitoring of the flexural member, being tested, shall be done and behaviour compared with the expected results.

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Suggested further reading Material and References

1. IS:456, Indian Standard on Plain and Reinforced concrete-Code of Practice (Fourth Revision)
2. IS:875, Indian Standard Code of Practice for Design Loads other than Earthquake for Buildings and Structures Part 1 to 5
3. IS:1893, Indian Standard on Criterion for Earthquake Resistant Design of Structures
4. IS:4326, Indian Standard on Earthquake Resistant Design and Construction of Buildings- Code of Practice
5. IS:13920, Indian Standard on Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces - Code of Practice
6. IS:1905, Indian Standard Code of Practice for Structural use of Un-reinforced Masonry(Third Revision)
7. IS:3412, Code of Practice for Installation of Joints in Buildings
8. IS:2212 Code of Practice for Brickwork
9. SP:16 Design Aids to IS:456
10. SP:22 Explanatory Hand Book on IS:4326 & IS:1893
11. SP:24 Explanatory Hand Book on IS:456
12. SP:34 Handbook on Concrete Reinforcement Detailing
13. SP: 20 Explanatory Hand Book on IS:1905 & IS2212
14. ACI: 318, Building Code Requirements for Reinforced Concrete
15. Concrete Society Committee Report No.26
16. Concrete Society Committee Report No.33
17. ACI: 437, Strength Evaluation of Existing Concrete Buildings
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CHAPTER 5

SELECTION OF REPAIR MATERIALS FOR CONCRETE

5

SELECTION OF REPAIR MATERIALS FOR CONCRETE

The way my Dad always liked to put it was, that an engineers could find a way to do for one dollar, what everybody else could do for two.

..Jack Kilby

5.1 General

Selection of repair material is one of the most important tasks for ensuring durable and trust worthy repair. Though, the pre-requisite for a sound repair system is the detailed investigation and determining the exact cause of distress, yet an understanding of the process of deterioration of the repair materials (such as concrete and other auxiliary materials i.e. plastics, resins, etc) under service conditions is vital. Of course, availability of materials of relevance, equipment and skilled labour have to be explored before deciding upon the repair material.

The analogy for selection of repair material is similar to repairing of a torn garment with sound fibre/fabric but of similar performance characteristics (i.e. preshrunk and similar fibre/fabric) as that of the original garment. Had the patch repair been done with un-shrunk or dissimilar fibre/fabric, it would have inflicted a greater damage to the repaired garment due to its pulling away on a subsequent shrinking after washing. Exactly this is applicable to selection of materials for repair of concrete/plaster. Also the selection of the repair material has a chemical angle and the manufacturer's literature normally highlights the composition of the material rather than performance characteristics. Since, cementitious products have a tendency to shrink and hardening with age, it is essential that the repair material for repairing concrete or plaster should be of non shrink type and compatible with parent material.

5.2 Essential Parameters For Repair Materials

Besides being of compatible properties, repair materials for cement concrete/mortar shall also be easy to apply and require no attention after the repair has been applied. The essential parameters for deciding upon a repair material for concrete are :

- Low shrinkage properties
- Requisite setting/hardening properties
- Workability
- Good bond strength with existing sub-strate
- Compatible coefficient of thermal expansion
- Compatible mechanical properties and strength to that of the sub-strate
- Should allow relative movement, if expected, particularly in case of sealing of cracks or dealing with expansion joints.
- Minimal or no curing requirement
- Alkaline character
- Low air and water permeability
- Aesthetics to match with surroundings

- Cost
- Durable, non degradable or non-biodegradable due to various forms of energy, life, UV rays, heat etc
- Non-hazardous/non-polluting

5.2.1 Low Shrinkage

It is well known that the cementitious repair materials shrink with passage of time. Most of the shrinkage generally takes place in the initial period from the time of casting to 21 days. Therefore, cementitious repair material in its original form, if used for repair to concrete/ mortar, is likely to get either delaminated due to de-bonding or develop shrinkage cracks on its surface due to shrinkage strains and stresses. Shrinkage cracks so developed in the repair patch would allow the easy access of atmospheric air and water, which could be harmful for concrete and reinforcement.

It is, therefore, essential that the low shrinkage property of repair material shall be looked for while selecting a material for concrete repair. Cementitious materials need additional non-shrink compounds so as to be effective in achieving the desired property. Therefore, the formulation of the patch mortar incorporates, in the cement matrix, several special chemicals to mitigate the shrinkage. Using low cement content and low water cement ratio will also reduce the drying shrinkage.

5.2.2 Requisite setting/hardening Properties

It is desirable that the repaired structure shall be put to use at the earliest possible to reduce the down time of plant, machinery, building or road. It is, therefore, essential that repaired patch shall harden in the minimum possible time. However, in exceptional cases, it could also be essential to have the slow setting property as a desirable property for repair material. Such situation could be where more working time is required to work on repair materials or the repair process is intricate that more working time is required.

5.2.3 Workability

The repair material is to be applied by the field workers and hence its acceptability by them is very important. The property desired by the field workers is good workability. Hence optimum workability is to be achieved without sacrificing the other desirable properties by use of suitabile additives/admixtures.

5.2.4 Bond with the Substrate

The bond strength of repair patch with the substrate is essential to have a successful repair system. If it is felt that the bond strength of the repair material with the base material is inadequate or less than the strength of the base material, then some other suitable means could be explored to improve bond strength between repair material and substrate. These could be use of:

- Adhesive,
- Surface interlocking system, and/or
- Mechanical bonding

A variety of adhesives, in the range of epoxies, polymer modified cement slurries including unmodified polymer applications are available. The selection depends upon available open time for bonding etc, which are being specified for different applications. Surface interlocking system and methods of mechanical bonding are, however, detailed out in the subsequent chapter on Repair Methods.

5.2.5 Compatible Coefficient of thermal Expansion:

The difference in volume change because of temperature variation can cause failure either at the bond line or within the section of lower strength material. Therefore, in the areas exposed to temperature variations, the patches of repair should have same coefficient of thermal expansion to ensure that no undue stresses are transferred to bonding interface or the substrate. Due to similar coefficient of thermal expansion, cementitious materials are preferred over epoxy materials. Coefficients of thermal expansion of commonly used construction/repair materials are given in Table 5.1.

Table 5.1: Coefficient of Thermal Expansions of Commonly Used Building Materials

S. No.	Material		Co-eficient of thermal expansion in $10^{-6}/°C$
1.	Stones		
	(i)	Igneous rocks	8 to 10
	(ii)	Lime stones	2.4 to 9
	(iii)	Marbles	1.4 to 11
	(iv)	Sand & sand stones	7 to 16
	(v)	Slates	6 to 10
2.	Metals		
	(i)	Aluminium	25
	(ii)	Bronze	17.6
	(iii)	Copper	17.3
	(iv)	Lead	29
	(v)	Steel and iron	11 to 13
3.	Bricks and brickwork		5 to 7
4.	Cement mortar and concrete		10 to 14
5.	General purpose non-shrink concentitious micro-concrete (Renderoc RG)		10 to 12
6.	Polymers modified mortar/concrete		10-12
7.	Epoxy mortar/concrete		20-25

5.2.6 Compatible Mechanical Properties & Strength

The hardened material shall have compatible mechanical properties or rather slightly better strength than that of base material. This property is desirable to ensure uniform flow of stresses and strains in loaded structures. It is well known that the elastic modulus of two concretes would be different for different crushing strength so if repair concrete is having strength much different than the base, it could lead to non-uniform flow of stresses and may result in an early failure of the repair patch. For example, if M-20 grade of concrete has been used in original construction, the grade of the repair material shall neither be less than M-20 nor higher than M-25.

5.2.7 Relative movement, if expected

Particularly in case of sealing of such cracks where movement is expected or at expansion joints, the repair material selected shall be resilient and elastic to be able to absorb the anticipated relative movements of the structure without any signs of distress or crack.

5.2.8 Minimal or no curing Requirement

It is desirable that the repair material shall not have any curing requirement after the repair has been applied or even if it is required, it should be minimal to ensure that the repair patch hardens and attains the desired strength without much post-repair-care. Only epoxies don't need any curing. Other material applications need nominal to moderate curing, which need to be specified. Such materials have several other merits, which are to be kept in view, while making a selection. Curing compound can be applied over cementitious materials used for repairs but after examining its compatibility.

5.2.9 Alkalinity

In case of RCC, it is important to maintain the alkalinity of concrete around reinforcement with its pH above 11.5 from corrosion protection point of view. In this context, it is necessary for the repair material to have chemical characteristics such that it does not adversely affect the alkalinity of the base concrete at a later date. The chemical characteristics of the repair material and its after effect on the pH of RCC shall be examined beforehand. In addition, the pH of reinforcement protection applications, bonding coats and that of the repair material must also be similarly alkaline. This would ensure inbuilt compatibility.

5.2.10 Low air & water permeability

Permeable material allows easy permeation of environmental chemicals including carbon dioxide, water, oxygen, industrial gases/vapours etc. It is essential that repair materials should have a very low air/water permeability to provide protection to the reinforced concrete against ingress of harmful environmental chemicals.

5.2.11 Aesthetics

It is desirable that colour and texture of the repair material should match with the structure and give aesthetically pleasant appearance. If need be, this could be achieved through appropriate finishes.

5.2.12 Cost

Economics is important while considering various options for repair materials but cheaper repair material should not be selected at the cost of performance characteristics.

5.2.13 Durability & Bio non-degradability:

The repair material selected should be durable under its exposure conditions during the service life against chemical attack, resistant to any form of energy like ultra violet rays, infra red rays, heat etc and should be bio non-degradable.

5.2.14 Non-Hazardous / Non –Polluting :

The repair materials should not be hazardous to field workers. However adequate Safety measures are required to be taken for repair Materials, which are hazardous to workers involved with their application, etc. These should also be environment friendly.

5.3 Materials For Repair

Wide range of materials for repair of concrete is available differing in cost and their performance. Their application range covers:

- Materials for Surface Preparation
- Chemical Rust removers for corroded reinforcement
- Passivators for reinforcement protection
- Bonding Agents
- Structural Repair Materials,
- Non-structural Repair Materials,
- Injection grouts,
- Joint sealants,
- Surface coatings for protection of RCC

Products available in the market are generally in pre-proportioned and in pre-weighed packs together with accompanying instructions regarding mixing procedure, pot life, dosage and application procedure etc. It is desirable that the manufacturer indicates the generic name and proportion of the components in the products on the packs.

Though, these materials are being marketed under their brand names, yet these could be classified in the following categories:

- Premixed Cement concrete/mortars (modified with non-polymeric admixtures/additives).
- Polymers/latex modified cement additives for mortars/concrete/cement slurry [styrene butadiene rubber (SBR) latex, Poly (Vinylidene Chloride-Vinyl Chloride) (PVDC), acrylics and modified acrylics)]
- Epoxy resins
- Chemicals for corrosion inhibitor, removal of rust

5.3.1 Premixed Cement concrete/mortars

Though, the cement concrete and mortars are most natural repair materials for carrying out the repairs to RCC. Yet, they are not favoured as a repair material due to its inherent undesirable properties like drying shrinkage, slow setting, low workability, prolonged curing requirement, permeability, etc.

5.3.1.1 Cements:

Cement paste, being a binder in concrete or mortar holds fine aggregates, coarse aggregates and other constituents together in a hardened matrix. Cement forms one of the most basic material used for not only in new construction but also as repair material. Therefore, selection of the appropriate type of cement for new construction as well as repair work is important and determines the final efficacy and durability of the structure. The portland cements generally consist of Tricalcium silicate ($3CaO.SiO_2$), Dicalcium Silicate ($2CaO.SiO_2$), Tricalcium aluminate ($3CaO.\ Al_2O_3.Fe_2O_3$) and tetracalcium aluminoferrite ($4Cao.Al_2O_3$). These minerals are more often denoted as C_3S, C_2S, C_3AF, C_4A respectively. In addition to these minerals, OPC also contains about 60–70% free lime and small quantities of gypsum. The percentage of these minerals in OPC and their impact on cement properties are given in Table 5.2.

Table 5.2: Mineralogical Composition of OPC and Effect of Constituents on its Properties

Characteristics	C_3S	C_2S	C_3A	C_4AF
% by mass in OPC	30-55	20-50	7-12	6-11
Setting Time	Rapid	Slow	Rapid	-
% contribution to heat of hydration	30	10	58	2
Early Strength	High upto 7-14 days	Low upto 14 days	Gain upto 1 day	Nil
Long Term strength	Less Gain later	High gain later	Nil	Nil

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Various types of portland cements available are:

- 33 Grade Ordinary Portland Cement (IS: 269),
- 43 Grade Ordinary Portland Cement (IS: 8112),
- 53 Grade Ordinary Portland Cement (IS: 12269)
- Rapid Hardening Portland Cement (IS: 8041)
- Portland Slag Cement (IS: 455)
- Portland Pozzolana Cement (Fly Ash based) (IS: 1489 Pt-I)
- Portland Pozzolana Cement (Calcinated Clay based) (IS: 1489 Pt-II)
- Hydrophobic cement (IS: 8043)
- Low Heat Portland Cement (IS: 12600)
- Sulphate Resisting Cement (IS: 12330)

Types of cement to be used in a repair work depends on its suitability for the intended use. In general the following guidelines may be referred:

➢ **Ordinary Portland Cements (OPCs)** The IS:456 allows use of 33, 43 and 53 grade of OPC, where figures indicate the 28 days strength in N/mm^2. Grade 33 and 43 may be used for most of the repair purposes, if necessary with modification by suitable admixtures or additives. Whereas Grade 53 cement or a cement having still higher fineness could be more suited for injection grouting of cracks or honey combed concrete preferably with non-shrink admixture in suitable proportion.

  The hydrated gel of OPCs on its hardening has high pH, ranging from 12.5 to 13.5. As the threshold value for formation of γ-Fe_2O_3 passivating layer over steel is reported to be 11.5, these cements have an additional advantage of being used for passivating coats over reinforcing bars for their corrosion protection.

➢ **Rapid Hardening Portland Cements** gains strength more rapidly at early ages but has its ultimate strength comparable to OPCs. It is used where early strength is required.

➢ **Portland Slag Cements and Portland Pozzolana Cements:** Generally, such cements have low heat of hydration, better sulphate and chloride resistance and have low permeability. These are more suited for use in marine structures and in structures having contact with soils and water containing high percentages of sulphates and acids. These consist of OPC clinker and gypsum ground together with blast furnace Slag (Ground Granulated Blast Furnace Slag) or other pozzolanic material e.g. ground calcinated clay or fly ash conforming to IS: 3812. Ground slag or pozzolana, which by themselves do not possess any cementitious properties, but these, when in finely ground state, chemically react with free lime available in OPC cement paste in presence of moisture at ordinary temperature to form compounds possessing cementitious properties. This chemical reaction is initiated due to generation of free lime as a result of hydration of OPC. Substantial part of the free lime i.e. $Ca(OH)_2$ available in cement paste, which does not contribute towards strength development, is used up in hydration of ground slag or pozzolana present in finely divided form in cement. This results into a stable pore sealing product and contributes to delayed strength development even though the pattern of gain of strength is similar to that of OPC. Therefore, pozzolanas are being used as additives as partial substitute of OPC clinker from 20 to 35%. Presence of moisture is necessary for pozzolanic reaction, which is a delayed process. Therefore, adequate extended curing is required. Loss of free lime in pozzolanic reaction causes the pH of hydrated gel of cement paste to be lower than OPC, which is generally not more than 12 in such cements. There is evidenced that the blended cements with substantial contents of pozzolanic materials or blast furnace slag have reduced permeability to chlorides. On the other hand, the advantage of reduced permeability of such cement paste is not generally available in micro-cracked tension zones of flexural members, accommodating active steel reinforcement. So, from corrosion point of view of reinforcing steel, in flexural members, use of such cements may prove to reduce durability and in compression members with compression loads less than $0.2f_{ck}A_g$ and also for concretes of grades up to at least M30.

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- **Shrinkage Compensating Expansive Cements**: Shrinkage compensating expansive cements are used to minimize cracking caused by drying shrinkage in repair concrete in addition to its use in concrete structures. Drying shrinkage is the contraction caused by moisture loss from concrete. It does not include plastic volume changes that occur due to temperature change, structural loads, other chemical reactions or those before setting of concrete/mortar, when surface evaporation exceeds the concrete bleeding rate. These cements are designed to expand by small extent during the first few days of hydration. The extent of expansion intended is to approximately offset the amount of drying shrinkage anticipated in the concrete or mortar. The expansion is brought about by incorporating some specific compounds such as calcium sulphoaluminate, calcium aluminate and calcium silicate or other phases that, in presence of water, react to produce larger quantity of ettringite than is normally produced by Portland cements. The production of ettringite in the hardened concrete/mortar causes the concrete to expand. The expansive reaction essentially gets completed in first seven days. The value of expansion between 7 and 28 days is limited to be not more than 15% of the 7 day expansion.

  To achieve proper performance of shrinkage compensating expansive cements, inclusion of appropriate amount of reinforcing steel in concrete is necessary. For maximum expansion, additional moisture beyond that added as mixing water must be supplied during curing of the concrete to ensure that the desired amount of ettringite will be produced.

- **All other special cements** should be used for special purposes intended as per specialist's recommendations

5.3.1.2 Mineral Additives

Fly Ash (FA), Silica Fume (SF), Rice Husk Ash (RHA), Ground Granulated Blast Furnace Slag (GGBS) and metakaoline, which have good pozzolanic properties are being used as mineral additives in concrete and mortars with certain advantages in regard to their impermeability, resistance to leaching, resistance to chloride & sulphate attack and better crushing strength. As already explained, the pozzolanic reaction results in reduction of free lime and pH of hydrated cement paste. Such additives are to be used with caution, while repairing flexural structural members requiring protection of reinforcement against corrosion.

5.3.1.3 Chemical Admixtures

It is a material, other than water, aggregates, hydraulic cement, mineral additives and fibre reinforcement, used as ingredients of concrete or mortar and added to the batch immediately before or during its mixing to modify one or more properties of the repair concrete/mortar/ slurry in plastic or hardened state. As per IS: 9103, the admixtures are classified as under:—

- Retarding admixtures
- Water reducing admixtures
- Air entraining admixtures, and
- Super-plasticising admixtures

Dosage & Compatibility of Chemical Admixtures: It is important to note that the dosage of admixture varies depending upon the type & source of cement, aggregate and environmental conditions. It is, therefore, desirable to always determine compatibility of the admixture and its dosage experimentally before using the same in any work, to achieve the desired properties of repair mortar/concrete.. The manufacturer's literature, may however render preliminary guidance and should be treated as starting point for carrying out the test exercise for determining the optimum dosage of admixture.

5.3.1.4 Water Cement Ratio:

Water cement ratio plays a vital role in controlling shrinkage, water permeability, percentage of capillary pores and enhancing strength. As it is very difficult to control water cement ratio while producing concrete or mortars in scattered works, a mechanical control of quantity of water is essential to ensure consistently uniform quality of concrete/mortar batch after batch with the use of Mechanical Water Dozer. Details of the one developed by Central Design Organisation are given in Fig 5.1. The plasticisers and super plasticisers can be gainfully used to control water/cement ratio without any compromise on the workability.

5.3.2 Polymer Modified Mortars and Concrete (PMM/PMC)

The process technology of making the latex-modified mortar and concrete is similar to that of the conventional binding systems. Most polymers, such as latexes, are in the dispersed form. These are initially mixed in water in required proportion and then added to the cement mortar or concrete. The latex-modified mortar or concrete, are placed similar to normal concreting and cured under optimum conditions.

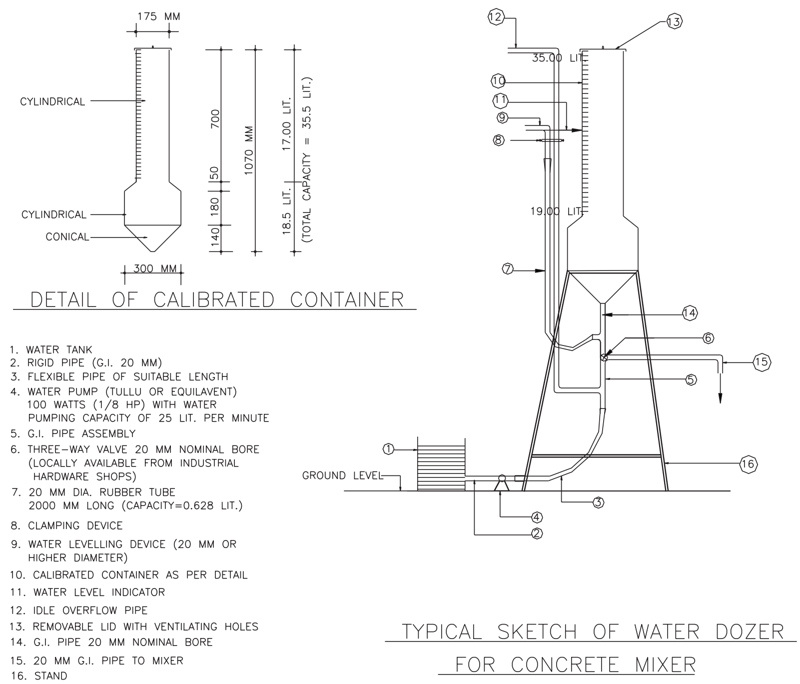

Fig 5.1 Mechanical Water Dozer

5.3.2.1 Materials:

The materials used in polymer modified systems are the same as those employed in normal mortar and concreting operations but for the latex/polymers, which is used as a modifier. However these are briefly described as under:

A. **Cements**: OPC is widely used for polymer modified mortars and concrete including all other portland cements depending upon their applications. However, air entraining cement are not used because air entrainment occurs due to latex addition.

B. **Aggregates:** The aggregates used for normal concreting operations are recommended for latex mixes. The aggregates should be clean, sound and of proper grading.

C. **Other Materials:** Alkali- resistant glass, steel polyamide, polypropylene, polyvinyl alcohol, acramide, and carbon fibers are used as reinforcements. Production of coloured latex mortars needs inclusion of pigments that are alkali resistant and weatherproof. They should also not interfere with the stability of latexes and hydration of cements.

D. **Polymers:** Polymers are long molecules, built by combination of single units called monomers. Polymers are essentially hydrocarbons. The process of conversion of monomers into polymer is called polymerisation. In civil engineering, polymers obtained from monomer at ambient temperature are important from practical point of view.

Polymer Latexes: Polymer Latexes consisting of very small diameter particles (0.05 – 5µm) emulsified in water are shown in Fig.5.2. Most of the commercially available polymer latexes for cement modification are based on elastomeric and thermoplastic polymers, which form continuous polymer films when dried. Out of the several types of PMM/PMCs produced, the latex modified mortars and concretes are by far the most widely used cement modifiers. It is important to note that the cement hydration is a continuous process. Latex modification of cement mortar and concrete is governed by both cement hydration and polymer film formation process in their binder phase. The cement hydration process generally precedes the polymer formation process. In due course, a co-matrix phase is formed by both cement and polymer film formation processes. This yields a monolithic interwoven matrix of solidified polymer and its continuous film with hydrated cement and this binds the aggregates strongly. Consequently, the properties of hardened cement mortar/concrete are improved.

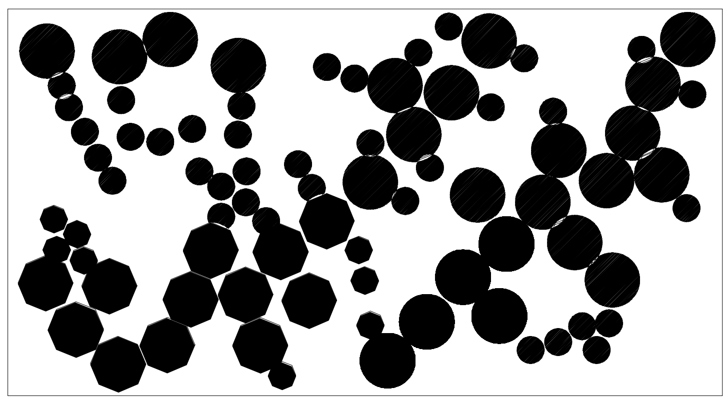

Fig 5.2 : SBR latexes for cement modifiers

Redispersible Polymer Powders: The principles of modification of cement mortars/ concretes is almost the same as that of the polymer latex modification except that it involves addition of redispersible polymer powders. Mostly these are used by dry mixing with cement and aggregate pre-mixtures followed by wet mixing with water.

Water Soluble polymers: These, being water soluble, are mainly used for improving workability of cement mortars and concretes and prevents "dry out" phenomenon due to increased viscosity of water phase in the modified cement mortar/concrete and a sealing effect due to formation of a very thin impervious film in them. In general these do not contribute to any improvement in strength of modified system. These are normally used at polymer: cement ratio less than 3% by weight. When added in powder form, , it is advisable to dry blend the polymer with cement aggregate mixture before adding water.

Liquid Resins: Liquid thermosetting resins are polymerisable low molecular weight polymers and pre-polymers. These are added to cement mortars/ concrete in a liquid form. Polymer content in cement mortars/concrete is generally higher than the latex system. In this modification, polymerisation is initiated in presence of water to form a polymer phase and simultaneously the cement hydration occurs. As a result a co-matrix phase similar to latex modified systems is formed and this binds the aggregates strongly. Consequently, the properties of hardened cement mortar/concrete are improved.

Monomers: Principles of modification of cement composites remain the same as that of the liquid resins detailed above except that here monomers are added instead of liquid resins. In such a case of modification, polymerisation and cement hydration takes place simultaneously at the same time during or after curing to make it a monolithic matrix, which binds aggregates. Generally, such a system of modification is not successful because of degradation of monomers by alkalis present in cement paste and interference of cement hydration and difficulty in uniformly dispersing monomers and other components during mixing..

5.3.2.2 Process of Polymer Modification in Cement concrete/mortar:

Polymer modified mortars and concretes (PMM/PMC) are prepared by mixing polymer in a dispersed, powdery or liquid form with fresh cement mortar and concrete mixture, subsequently cured. Polymers and monomers used as cement modifiers are shown in Table 5.3.

Polymers and Monomers for Cement Modifiers	-Polymer Latexes	-Elastomeric Latexes -Thermoplastice Latexes -Thermosetting Latexes -Bituminous Latexes -Mixed Latexes
	-Redispersible Polymer Powders -Water-Soluble Polymers -Liquid Resins -Monomers	

Table 5.3 Polymers and monomers for cement modifiers

Thus both, the particle dispersion of the polymer and the formation of polymer films are necessary for the composite mechanism of the latex-modified systems. The process of the polymer film formation on the cement hydrate is represented in Fig 5.3.

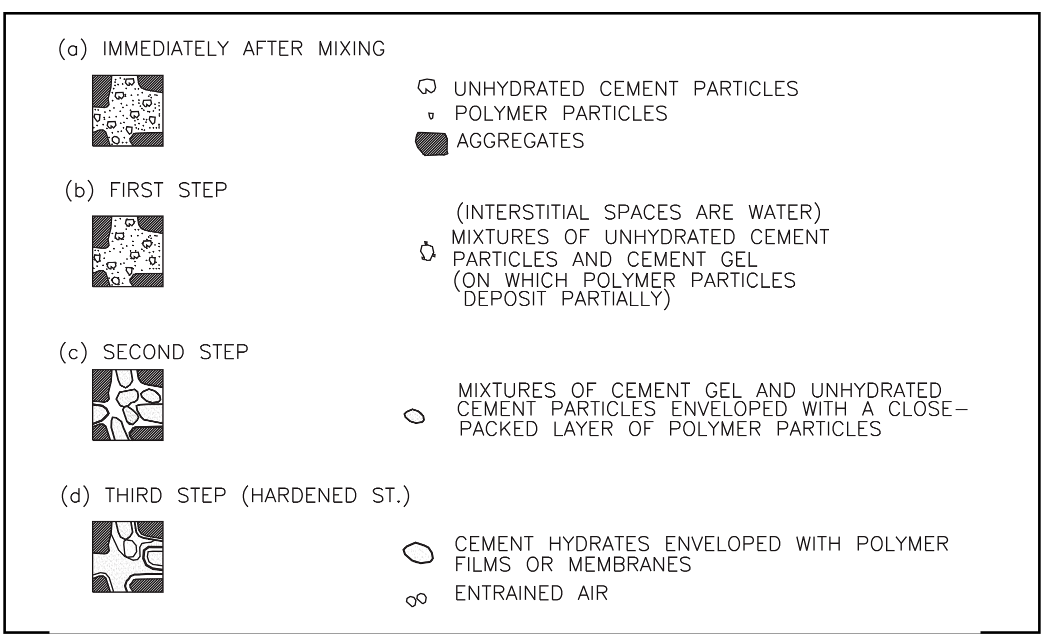

Fig 5.3: Simplified model of Process of Polymer film formation on Cement hydrates

(Source: Yoshikiko Ohama, "Handbook of Polymer-Modified concrete and Mortars" published by Noyes Publications, Park-Ridge, New Jersy, USA)

First Stage

In the first step, when polymer latexes are mixed with fresh cement mortar or concrete, the polymer particles are uniformly dispersed in the cement-aggregate paste phase.

Second Stage

In the second step, with drainage due to the development of the cement gel structure, the polymer particles are gradually confined in the capillary pores.

Final Stage

Ultimately, with water withdrawl by cement hydration, the close-packed polymer particles on the cement hydrates coalesce into continuous films or membranes, and the films or membranes bind the cement hydrates together to form a monolithic network in which the polymer phase interpenetrates throughout the cement hydrate phase. Such a structure acts as a matrix phase for latex-modified mortar and concrete, and the aggregates are bound by the matrix phase to the hardened mortar and concrete.

5.3.2.3 Composition of Polymers:

Polymer Latexes: The typical recipe of materials used for such emulsion polymerisation comprises of Monomers (100 pbw), Surfactant (1-2 pbw), Initiator (0.1-2.0 pbw), water (80-150 pbw) and other ingradients (0-10 pbw). These are charged in a reactor under constant agitation and heated to the required temperature. It is the initiator, which generates a free radical to cause the chain polymerisation of monomers to form polymer latex. A stripping process removes the unreacted monomers in the resultant latex. The latex is diluted or concentrated and a small amount of preservatives, stabilizers, antifoaming agents are added. However, natural rubber latex and epoxy latex is not produced by such process. The natural rubber latex is tapped from rubber plants and then concentrated to have appropriate solid contents.

Redispersible Polymer Powders: Redispersible polymer powders as cement modifiers are manufactured by a two step process. Firstly polymer latex is manufactured as raw material by emulsion polymerisation and then these are spray dried to get the polymer powders. Before spray drying the polymer latexes are further formulated with some ingredients as bactericides, spray drying aids and antifoaming aids. Anti-blocking aids such as clay, silica and calcium carbonate are added during or after spray drying to prevent “caking” of powders during storage.

Water Soluble Polymers: These are polyvinyl alcohol (PVA, poval) and the derivatives of cellulose including methyl cellulose (MC), carboxy methyl cellulose (CMC) and hydroxyethyl cellulose (HEC), polyethylene oxide, polyacrylamide, etc.

Liquid resins: In general, these are epoxy resin system used as cement modifier. It consists of two part system one as resin and the other as hardener or curing agent and essentially contain ‘anti-foaming agent’ to prevent excessive entrainment of air and ‘surfactants’ to effectively disperse the epoxy resin throughout the mortars or concrete.

5.3.2.4 General Requirements of a Polymer Latex:

The general requirements for polymer latexes as cement modifiers are as follows:

- Very high chemical stability towards the active cat-ions, such as calcium and aluminium, liberated during the hydration of cement.

- Very high mechanical stability during mixing, and in transfer pumps.
- Low air entrainment. This is generally achieved by addition of antifoaming agents during manufacture of polymer latexes. Excess of anti-foaming results into loss of adhesion to the substrate. The balance has to be judiciously maintained.
- No adverse influence on cement hydration.
- Formation of continuous films in mortar or concrete. High adhesion of the films to cement hydrates and aggregates.
- Very good water, alkali and weather resistance
- Thermal stability: In special cases dealing with higher temperatures

5.3.2.5 Classification of Polymer Latexes:

The polymer latexes are classified in to three categories as cat-ionic (negatively charged), an-ionic (positively charged) or non-ionic (not charged), which is governed by the type of surfactant used in production of latexes.

5.3.2.6 Properties of Polymer Latexes:

In general, polymer latexes are copolymer systems of two or more different monomers and their total solid content including polymers, emulsifiers, stabilizers, etc. is 40-50% by weight. Most of the commercially available latexes for cement have solid contents 40±3%. Higher percentage would adversely affect concrete compressive strength. These form continuous polymer films when dried. Most popular polymers are urethane, acrylics and modified acrylics. Polyvinyl acetates, styrene butadiene rubber (SBR), chloroprene rubber (CR) also called as neoprene, Poly Acrylic Ester (PAE), Poly (Ethylene Vinyl Acetate) (EVA or VAE), Poly (Styrene Acrylic Ester) (SAE) are being used in cementitious repair work. Typical properties of such polymers commercially available are given in Table 5.4. Polyvinyl acetate latex and polyvinylidene chloride and poly vinyl chloride latex are generally not recommended as cement modifiers because of poor resistance and chloride ions liberation.

All latex systems should ensure controlled foaming. Commercially available polymers for cement modification must contain proper amounts of appropriate anti-foaming agents. One should be able to use them directly for mixing without addition of anti foaming agent during such operation at site.

Table 5.4 provides typical properties of polymer latexes. Table 5.5 shows the quality requirements for the polymer latexes as specified in JIS 6203

Table-5.4: Typical Properties of Commercially available Polymer Latexes

(Source: *"Polymer Modified Concretes and Mortars" by Y Ohama***)**

Type of Polymer	Stabiliser Type	Appearance	Particle Size (mm)	Total Solids (%)	Specific Gravity (at 20°C)	pH (at 20°C)	Viscosity (at 20°C, cP)	Surface Tension (at 20°C), dyn/cm)
SBR	Non-ionic	Milky White	200	46.5-49.5	1.010	10.0-11.0	10-12	32
	An-ionic	Milky White	219	44.0-46.0	1.016	7.06	53	31
PAE	Non-ionic	Milky White	500	44.5-45.5	1.054	8.6-10.2	29	45
	Non-ionic	Milky White	500	44.0-46.0	1.054	9.4-10.0	1328	45
CR	Cat-ionic	Milky White	120	50.0	1.100	9.0	16	35
	Cat-ionic	Milky White	700	50.0	1.100	6.0	10	30
EVA	Non-ionic	Milky White	700	52.8	1.050	6.0	1100-1600	75
	Non-ionic	White	400	55.0	1.060	4.5-6.5	3000-7000	40-45
An-ionic	Milky White	300	50.0	1.127	5.0-7.0	5000	40	

Table 5.5 : Quality Requirements for Latexes (Polymer Dispersions for Cement Modifiers)

Kind of test	Test item	Requirement
Latex Test	Appearance	Exclusive of coarse particles, foreign substances and coagulants.
	Total solids	Not less than 35.0% and within +/- 1.0% of the value marked by the manufacturer
Polymer-Modified Mortar Test	Flexural strength	Not less than 40 kgf/cm^2 (3.9MPa)
	Compressive Strength	Not less than 100 kgf/cm^2 (9.8MPa)
	Adhesion	Not less than 10kgf/cm^2 (0.98Mpa)
	Water absorption	Not more than 15.0%
	Amount of water permeation	Not more than 30g.
	Length change	0 to 0.15 %

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5.3.2.7 Physical and Mechanical Properties of Polymer Modified Mortars/Concretes:

Admixing of polymer latex in cementitious mixtures modifies the following physical and mechanical properties:

i. **Workability:** Generally polymer mortars/polymers modified concrete (PMM/PMC) have better workability compared to conventional mortar/concrete.

ii. **Water retention:** PMM/PMC have remarkably improved water retention property over ordinary mortar/concrete. The water-curing requirement is substantially reduced and needs to be specified accordingly to suit the polymer type, its proportion and method of curing.

iii. **Bleeding and Segregation:** A better resistance to bleeding and segregation even though they have better flowability.

iv. **Increased Resistance to Crack Propagation:** Micro cracks occur easily in the ordinary stressed hardened cement paste. This leads to poor tensile strength and fracture toughness. Whereas, in the latex-modified mortar and concrete, it appears that the micro cracks are bridged by the polymer films or membranes, which prevent crack propagation and simultaneously, a strong cement hydrate-aggregate bond is developed.

v. **Strength:** PMM/PMC with styrene butadiene polymer (SBR) latexes have a noticeable increase in tensile and flexural strength but there is hardly any improvement in its compressive strength compared to ordinary mortar/concrete. An increase in the polymer content or polymer-cement ratio (defined as the weight ratio of the amount of total solids in polymer latex to the amount of cement in a latex-modified mortar or concrete) leads to increase in flexural tensile strength and fracture toughness. However, excess air entrainment and polymer inclusion cause discontinuities of the formed monolithic network structure, whose strength is reduced.

vi. **Chemical resistance of PMM/PMC:** This depends on the type of polymer, polymer cement ratio and type of chemicals. Most PMM & PMC with styrene butadiene polymers (includes other like modified acrylics etc.) are attacked by strong organic and inorganic acids and sulphate but these resist alkalis and salts other than sulphates. Their resistance to chlorides, fats and oils is also rated as good while they have a poor resistance to organic solvents.

vii. **Temperature effect:** The strength of PMM/PMC depends on temperature. They generally show a rapid reduction in strength with increase in temperature. Most thermoplastic polymers have a glass transition temperature of 80 deg. to 100 deg. Centigrade.

viii. **Shrinkage:** The drying shrinkage of PMM/PMC may be larger or smaller than that of standard mortar or concrete depending on type of polymer and polymer: cement ratio used. More is the polymer ratio, lesser is drying shrinkage.

ix. **Water proofing Quality or permeability:** PMM/ PMC have a structure in which the larger pores are filled by polymer or these are sealed by continuous polymer flow. The sealing effect and porosity due to the polymer films or membranes formed in the structure also provides a considerable increase in water proofness or water tightness as well as resistance to chloride ion penetration, moisture transmission, carbonation and oxygen diffusion chemical resistance, and freeze-thaw durability. Such an effect is promoted with increasing polymer- cement ratio upto a certain level of polymer loading.

x. **Adhesion or bond strength:** A very useful aspect of PMM/PMC is their improved adhesion or bond strength to various sub-strata compared to conventional mortar/ concrete.

xi. **Abrasion Resistance:** PMM/PMCs have abrasion resistance better than the conventional mortar/concrete.

xii. **Durability and non-degradability:** Generally these materials are bio non-degradable after total polymerization takes place. However, certain polymers tend to disintegrate under any form of energy like ultra violet rays, heat etc. Particularly "styrene" based materials are reported to undergo such rapid disintegration and degradation and hence advised to be avoided. Whereas "acrylate" based materials are accepted due to their non-degradable and robust properties.

5.3.2.8 Mix Proportioning:

Most of the cement mortars' proportion for polymer modification used is in the range of 1:2 to 1:3 (Cement- fine aggregate ratio). The polymer latex (solid contents) : cement ratio by weight ranges from 5 to 20 % by weight. Whereas water/cement ratio is of the order of 0.30 to 0.60 depending upon the required workability. The standard mix proportions are shown in Table 5.6.

The mix proportions for most latex modified concretes can not be easily determined in the same manner as that of latex modified mortars. Because of many factors in design. Normally the polymer latex : Cement ratio ranges from 5% to 15% and water cement ratio from 0.30 to 0.50.

Table 5.6: Typical Applications and Standard Mix Design of Latex Modified Mortars

(Source : "Polymer modifed concrete and mortars"…………Y.Ohama)

Application	Location of work	Standard Mix Proportions (By weight) Cement	Sand	Latex (Solid contents)	Thickness of Trowelling or coating (mm)
Paving Materials	Floors for general houses, ware house, office and shops, toilet floors, etc	1	3	0.2-0.3	5-10
Flooring	Passengers, stairs, chemical plants, railway platforms, roads, garages, etc	1	3	0.3-0.5	10-15
Water Proofing Material	Concrete roof decks, mortar and concrete block walls, water tanks, swimming pools, septic tanks, silos, etc	1	2-3	0.3-0.5	5-20
Adhesive	Adhesives, when flooring materials, walling materials, heat insulating materials, etc are bonded to concrete floors and walls	1	0-3	0.2-0.5	-
	Joining new concrete to old concrete or new mortar to old mortar	1	0-1	Over 0.2	-
	Repair Cracks	1	0-3	Over 0.2	-
Anti corrosive lining	Effluent drains, chemical factory floors, grouting for acid proof tiles, septic tanks, foundation for machinery plants, floor for chemical laboratories, pharmaceutical warehouses, etc	1	2-3	0.4-0.6	10-15
Deck covering	Internal and external ship decks, bridge decks, train or car floors, foot bridge decks, etc	1	2-3	0.9-1.0	1-2
		1	3	0.4-0.6	5-6
		1	3	0.5-0.6	3-4

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5.3.2.9 General Guidelines & Precautions for use of polymer modified cement Mortar/ concrete

- The speed and time of mixing should be properly selected to avoid unnecessary entrapment of air.
- The PMM/PMC have excellent adhesion even to metal and hence all equipment should be washed immediately after use.
- For resurfacing, flooring and patching, all loose and non-durable materials including laitence must be removed either by sandblasting, wire brushing and blowing with compressed air. The cleaned surface should be thoroughly wetted well before placement of PMM/PMC. Before application, surface should be in saturated dry (wet but no standing water) condition.
- The choice of type of PMM/PMC depends on thickness of coating to be applied.
- It is advisable to finish the surface by trowling 2-3 times. Over trawling is not advisable.
- PMM/PMC should never be placed below 5^{o} C and above 30^{o} C. The surface of newly placed material should be protected from rainfall or other source of water. The surface should be immediately covered with burlap or plastic sheet.
- In large area of application, it is advisable to provide joints of 15 mm width at intervals of 3-4 meter.
- Curing under water immersion or under wet condition is detrimental to PMM/PMC. It should be moist cured for 1-3 days followed by curing at ambient temperature. Steam curing is not recommended.

- Polymers and Latexes are non-toxic and safe for handling.
- Polymers should be stored in a cool dry room & should not be kept in exposed areas.
- Polymers should be mixed with cement slurry or mortar in the proportions recommended by the manufacturers for various uses.

5.3.2.10 Fields of Application:

A. Structural repairs to RCC: PMM/PMC are used to make up the damaged/lost cover concrete due to their better bond with substrate, including the reinforcement.

B. Ultra Rapid Hardening Polymer Modified Shotcrete:

Ultra Rapid Hardening Polymer Modified Shotcrete system can be classified in to two categories:

— One, which uses a polymerisable monomer that reacts with Ordinary Portland cement at ambient temperature. This system is used as repair and protective material for concrete structures with leaking and flowing water. It uses magnesium acrylate monomer and its setting time can be controlled within few seconds or less. Fig 5.4 represents a schematic diagram of this shotcrete system.

— Second, which uses ultra rapid hardening cement concrete with SBR latex and is often used for urgent construction and repair works.

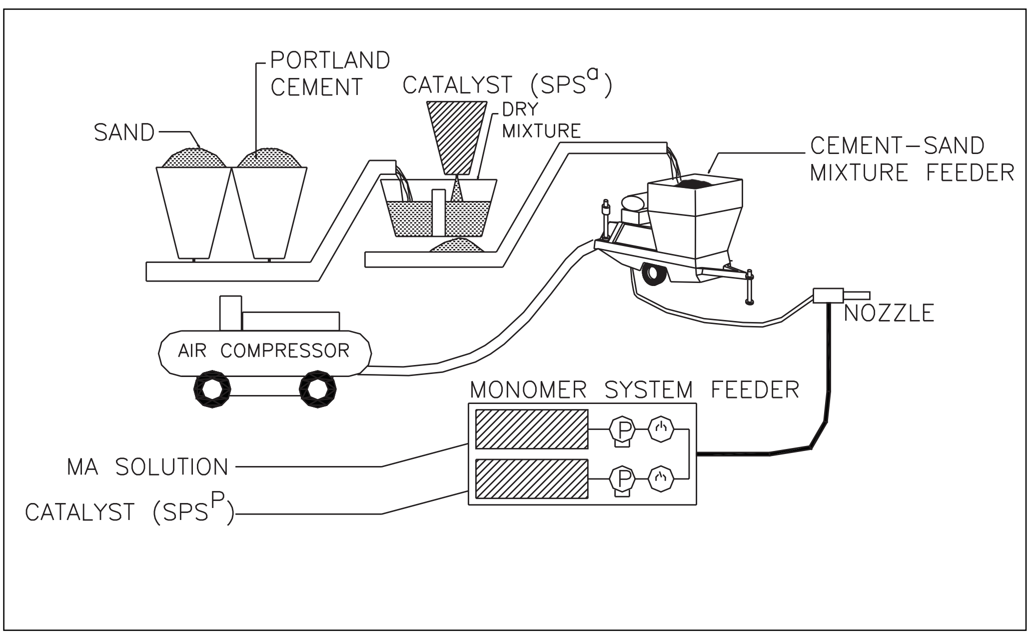

Fig 5.4: Schematic Diagram of Ultra-rapid hardening polymer modified shotcrete

(Source : Y. Ohama, "Handbook on Polymer Modified conrete and Mortars")

C. Polymer Ferrocements:

For the purpose of improving the flexural behaviour and durability of conventional ferrocement, polymer-ferrocements have been developed using latex modified mortars instead of ordinary cement-sand mortars. Use of SBR and EVA modified mortars is found to be very effective in improving their flexural behaviour, impact resistance, drying shrinkage and durability. Incorporation of short fibres such as steel and carbon fibres in the latex modified mortars is found to be further effective in improving such characteristics.

D. Anti Washout Underwater Concrete:

The major requirements from anti-washout under water concrete are anti washout or segregation resistance, flow ability, self-leveling ability and bleeding control. Anti-washout admixtures are water-soluble polymers and are classified in two types as *Cellulose-type* polymers such as MC and HEC and Poly-*acryl amide and poly acryl amide-sodium acryl ate.* These are added at polymer-cement ratios of 0.2% to 2.0% during mixing of the ordinary cement concrete. The water soluble polymer bonds to a part of mixing water by hydrogen bonds in the concrete and disperses in a molecule form in the mixing water. As a result, the mixing water is confined in the network structure of the dispersed polymer and becomes very viscous. The very viscous water envelops cement and aggregate particles to impart an anti-washout character to concrete.

E. Protective Anti Corrosive and Water Proofing Coatings:

Hydrated type flexible water proofing materials are polymer modified pastes or slurries with very high polymer: cement ratios of 50% or more and have been widely used as liquid applied water proofing membrane materials, repair materials, etc. The constituents normally comprise of Portland cement, silica sand, water and polymer latexes such as SBR, PAE, EVA, SAE, epoxy and asphalt latexes besides some other additives. Thickness of such water proofing membranes is 2 to 4 mm and is generally available in pre packaged type products. The performance advantages of such membranes are:

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- Safe application due to no organic solvent system.
- Convenience of application as it does not require the surface to be dry.
- Good adhesion with the cementitious, metallic and most other substrates.
- Excellent elongation, flexibility and crack resistance.
- Good water proofness.
- Resistant to carbonation and chloride ion penetration.

PAE modified water proofing materials appear to have excellent elongation and water resistance. Crack bridging capacity of such flexible membranes is being successfully tested in Germany.

An interesting water proofing material, which solidifies in water has recently been developed in Japan for tunnels and dams. It has a potential as a shock absorbing, water proofing backfill material.

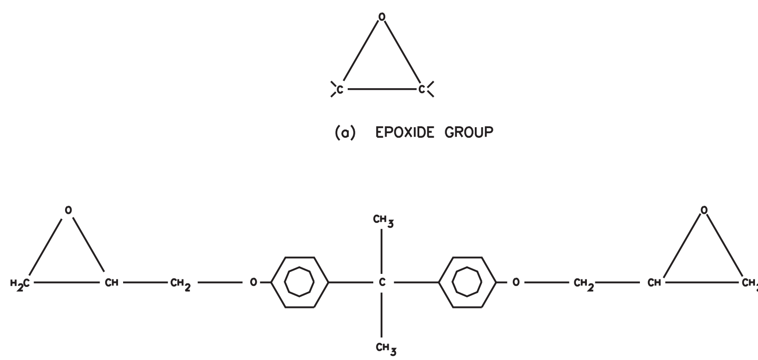
F. Bond Coats (Structural Adhesives) and Grouts: Polymer modified cement mortars as well as slurries are used as bond coats and grouts due to their very good adhesive qualities on cementitious as well as metallic surface.

5.3.3 Epoxies and Epoxy Systems including Epoxy Mortars/Concretes:

5.3.3.1 Epoxies

Epoxies also come in the category of polymers but in the case of epoxies, the polymerisation process takes place when two materials called the epoxy resin and hardener come in contact by thoroughly mixing in specified proportion. The epoxy resin materials have good mechanical strength, chemical resistance and ease of working. These are being used in civil engineering for high performance coatings, adhesives, injection grouting, high performance systems, industrial flooring or grouting etc.

A. Epoxy resins: These are characterized by a three membered ring known as epoxy/ epoxide / oxirane or ethoxyline group refer Fig.5.5 (a). On an average it contains more than one epoxide group per molecule. Basic epoxy resin used in the building industry is "**D**i**G**lycidyl **E**ther of **B**isphenol-**A**" (DGEBA) and can be represented as given in Fig. 5.5(b). In its simplest and most standard form epoxy resin is the condensation product of bisphenol-A and epichlorohydrin. Depending upon the amount of excess of epichlorohydrin to bisphenol-A used in the manufacturing process, epoxy resins ranging from low molecular weight liquids to high molecular weight solids can be obtained. However, basic resin of this type is not suitable for many applications because of its higher viscosity. Modification of basic resin is therefore, necessary to achieve the required wet-ability, curing rate and numerous other properties in addition to lower viscosity.



(b)

FIG. 5.5

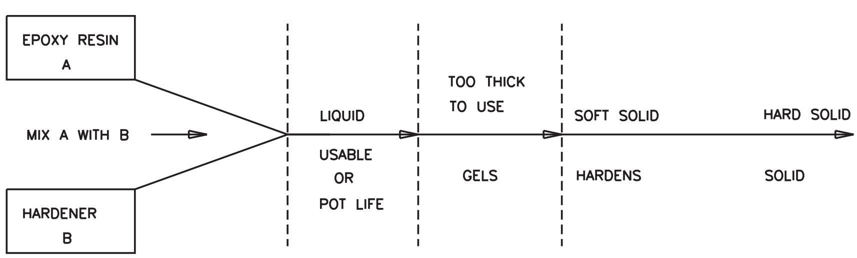


FIG. 5.6 PROCESS OF SETTING

B. Epoxy hardener (Curing Agent) : The proper choice of a hardener/curing agent can be as important as the choice of resin itself, both playing a significant role in determining the extent and nature of inter molecular cross linking. This curing agent, commonly called as hardener, combines with the epoxy resin and changes it from a liquid to a solid. The process of setting, together with the terminology often used is illustrated in Fig-5.6 Out of a vast number of compounds, most commonly used curing agents are aliphatic and aromatic amines and polyamides and their adducts, which form room temperature curing compositions relevant to construction applications. The aromatic polyamine curing agents react faster than the aliphatic polyamines. The properties of some common nitrogen containing hardeners are given in **Table – 5.7.** **Aliphatic amines** are used as such or in adduct form for ambient temperature curing. They have critical mix ratios, toxicity, high vapour pressure and brushing tendency. **Aromatic amines** are solid at room temperature. Adducts of these along with accelerators like sali-cyclic acid are used for ambient temperature curing. **Polyamides** are used as such or in adduct form with or without accelerator for ambient temperature curing. The chief advantages are low toxicity, convenient mix ratio and good flexibility. The main disadvantages are high cost, high viscosity and poor resistance against heat and solvent compared to amine cured system. Some other resins/ elastomers such as phenol formaldehyde resin, thermosetting acrylics, isocynates and polysulphides are also used as co-cross linking agents (10–50% by wt. of total resins) with amines to obtain the desired properties of the finished products. They are mostly used for corrosion resistant linings, food and beverages containers / tank coatings, kitchen appliance coatings etc.

Table 5.7 Prperties of nitrogen-containing harnders

(Source: B. Singh, etal "Epoxy Resins in Civil Engineering, ICJ January 1995 Vol 69. No 1. pp 13.21)

Type	Polyamide (A)	Amine adduct	Polyamide (B)	Low viscosity polyamide	Aromatic amine adduct
Viscosity (25°C MPa s)	10-20	3,000-5,500	9,000-16,000	3,000-4,500	6,000-20,000
Amount recommeded, (gm. eq/epoxide)	16-20	40	110-190	140-200	100-120
Nature	sl. Volatile, irritant	less volatile	non volatile, not strong smelling	non volatile, not strong smelling-	non volatile non smelling
Haze or blush	Marked	V. Slight	Almost nil	almost nil	Nil
Flexibilty and impact resistance	Poor	Poor	Good	Good	Better than amines amine adducts
Chemical resistance	Better	Better	Good	Good	Excellent
Water resistance	Moderate	Moderate	Good	Good	Excellent

5.3.3.2 Modified Epoxy Systems

A. **Diluents:** These are used for lowering the viscosity and improving handling characteristics. Diluents are classified as:

Reactive Diluents, which are mostly low molecular weight glycidyl ethers with low viscosity, which reduce the cross link density of the system. Because of their low viscosity, other cyclo aliphatic resins have also been used with the liquid diglycidyl ether resins or with solid epoxidised novolac resins.

Non reactive Diluents such as toluene, xylene and other aromatic hydrocarbons can bring about significant reduction in the viscosity of low molecular weight resins. The casting have inferior chemical resistance and if it is heat cured, the diluent can be volatile and cause blow holes and bubbles.. A popular non reactive diluent is dibutylpthalate, used as a concentration of 15 to 17% with a liquid resin.

B. **Coal Tar Epoxy System :** Coal Tar epoxy resin combinations with polyamine hardener have been widely used as water resistant protective coatings for ships and other marine structures. Coal Tar plays an important part in the improvement of corrosion resistance of epoxy resin system. It is Coal Tar/Epoxy in proportion of 40 : 60., which has been reported to give optimum results under aggressive environment.

C. **Rubber Modified Epoxy System:** This system is used to improve the draw back of brittleness and low elongation of unmodified epoxy resin based on bisphenol-A and epichlorohydrin with hardeners such as polyamines and anhydrides. The incorporation of small amount of elastomer particles promote absorption of strain energy by interactions involving craze and shear formation. Craze formation is promoted by 1- 5 micron particles and shear formation by 0.5 micron particles. Systems possessing both small and large particles provide maximum toughness. The most widely used toughner in epoxy resin is a liquid carboxy terminated butadiene- acrylonitrile.

D. **Epoxy Phenolic Interpenetrating Polymer Network Systems**: Interpenetrating Polymer Networks (IPN)s are relatively novel types of polymer alloys consisting of two or more polymers in network forms, at least one of which is synthesized and/or cross linked in the immediate presence of the other. Polymer phases are devoid of chemical linking between them interwoven to each other and help together by permanent entanglements. An indigenous attempt has been made to modify epoxy resin with a low cost, locally available phenolic resin to obtain optimum properties with the added advantage of cost performance ratio benefits. Two different resins (1. Medium viscosity epoxy resin based on epichlorohydrin and bisphenol as base and an aromatic amine adduct as the cross-linker and 2. Phenolic resin obtained from an indigenous phenol with its cross-linker) were mixed in different ratios and cross-linked simultaneously by a separate non interfering mechanism. These are used with advantage in coatings for protection of concrete structures and steel reinforcement bars against corrosion due to their good resistance to chlorides and chemicals. The elongation of its film increases to 17.5 percent as against 5 percent in case of neat epoxy resin systems allowing it to be used over steel reinforcement even at higher fatigue limits. Tables 5.8 compare properties of neat epoxy and IPN coatings. The IPN polymeric systems thus, obtained were evaluated for various physico-mechanical properties, using standard methods of testing. The properties of neat epoxy and IPN coatings

Table 5.8: Properties of Neat Epoxy Coatings vis-à-vis IPN Coatings

(Source: Aggarwal L.K. "IPN protective coating for enhancing the durability of concrete structures"— ICJ July 1996, Vol. 70, No. 7, pp 367-370)

Sl. No.	Property	Test Results Neat Epoxy Coating	IPN Coating
1	Tensile Strength, Kg/cm^2	220.000	243.00
2	Elongation, percent	5.00	17.50
3	Hardness, Shore D	85.00	83.00
4	Specific permeability, mg/cm^2-mm-24 Hrs	0.2043	0.140
5	Shear Strength, Kg/cm^2	53.600	77.000
6	Vicat Softening Point, ^{O}C	43.00	64.00
7	Coefficient of thermal expansion, ^{O}C	1.714×10^{-5}	0.90×10^{-5}
8	Adhesion with concrete, Kg/cm^2 to surface	30.000	30.000
9	Scratch Hardness, 1500 g load	No failure	No failure
10	Salt Spray Test, 1000 Hr	No corrosion Spots	No corrosion Spots
11	Impact Test, falling Weight Method	No failure	No failure
12	Scrub Resistance, 10,000 cycles	No failure	No failure

E. **Epoxy Mortar and Concrete:** Epoxy resins are used with aggregate (silica sand) to produce epoxy mortar or epoxy concrete, which is used for structural repairs of concrete, RCC besides its use in new construction in industrial flooring, foundation grouting, roads etc. They are normally used where volume of materials is not large and where rapid curing can be obtained. The rate of curing epoxy mortar is directly dependent on the ambient temperature. In cold weather, small patches of mortar can be easily heated artificially to provide a rapid cure. Clean, dried, specially graded silica sand is used as filler with a resin- hardener mixture. Addition of sand helps in reducing shrinkage, improves abrasion, thermal shock resistance and lower thermal coefficient of expansion making it nearer to concrete. The optimum resin; sand ratio for maximum strength is reported to be 1:7

F. **Composite Fibre System:** The system comprises of a fiber reinforcement layer that is wrapped to the exterior surface of the structural element to be retrofitted. The fiber composite reinforcement layer consists of at least one fabric layer that is located within a resin matrix. The primary fibres are oriented in a desired direction with reference to the axis of the structural element concerned. The composite reinforcement layer provides a quick, simple and effective means for increasing the resistance of the structural element to failure during the application of loads. All the components of the composite (epoxy, fabric etc.) shall be fully compatible and supplied by a supplier that is competent in the technology, design, installation and materials of the composite system.

5.3.3.3 Precautions to be taken:

Epoxies are generally toxic in nature and these require lot of care in their handling. The special care required to be taken during their mixing and applications are as under:

i. They should not come in contact with the skin. Workers should be provided with rubber gloves.

ii. The utensils/ equipments used for the mixing resin and hardener should be cleaned immediately after their use.

iii. The pot life of the mixed epoxy is generally very limited, ½ to 2 hours. It should be finally applied as adhesive within pot life period. Therefore, material should be prepared just sufficient to cover the area within the pot life period as recommended by the manufacturers.

iv. The epoxies are generally used as an adhesive to act as bond coat between the old concrete and repaired concrete. The epoxies have a glass transition range at temperatures at 60 to 80^{o} C depending upon the epoxy type. Therefore, they should not be used in the exposed environment.

v. Epoxies have much higher bond strength than other polymers, but at the same time, these are costlier.

5.3.3.4 Field of Applications:

A. **Anti Corrosive and Water Proofing Protective Coatings:**

Fusion Bonded Epoxy Powder Coatings(FBEC) as well as *IPN Coatings* are being used for protection to reinforcing bars against corrosion in RCC structures located in highly aggressive environment. FBEC process provides a tough film, which can withstand bar bending without cracking, whereas IPN coatings are used for new constructions for in situ coatings to steel reinforcement.

IPN coatings are also used as surface coatings for RCC structures for arresting further carbonation of cover concrete or other chemical attack by sealing their surface against ingress of environmental aggressive chemicals and their consequential attack on concrete.

Epoxy coatings in conjunction with epoxy grouting have been used to render leaking roofs, toilets, bath rooms as impervious. However, their use in exposed locations directly exposed to sunlight is to be avoided.

Polyurethane Coatings: Polyurethane Coatings are used as Surface Coatings on exposed RCC Structures as they have excellent UV resistance. These coatigns have good elasticity and abrasion resistance also. These are used as such or as a finishing coat over other coating systems.

B. Bond Coats (Structural Adhesives) and Grouts: Epoxies are used as bond coats and grouts due to their excellent adhesive qualities on cementitious as well as metallic surface.

C. Structural repairs to concrete: Due to excellent Mechanical properties and bond characterstics with most of the materials epoxy mortars/concrete are used to make up the damaged or lost cover concrete etc.

5.3.4 Polyester Resins

5.3.5 Surface Coatings

5.3.5.1 Essential Parameters for coatings

Protective coatings over structural concrete should necessarily possess following properties:

1. Posses excellent bond to substrate
2. Be durable with a long useful life normally 5 years.
3. Little or no colour change with time.
4. Little or no chalking.
5. Should have maximum permeability to allow water vapour escape from concrete substrate.
6. Should have sufficient impermeability against the passage of oxygen and carbon dioxide from air to concrete.
7. Should be available in a reasonable range of attractive colours.

5.3.5.2 Types of surface coatings

The surface coating could be classified as ;

1. Solvent based coatings
2. Solvent free coatings
3. Water borne coatings
4. Reinforced coatings (preferred for repairing
   Badly damaged liquid Retaining structures)

Table 5.9: List of various types coatings and their pefrormance characterstics

Coating Type	Characterstics
Epoxy coatings and modified epoxy coating such as coal tar epoxy, epoxy-phenolic (IPN etc.)	Excellent adhesion to concrete, abrasion impact resistant, Impermeable to organic and inorganic chemicals water and chloride ions. Excellent resistant to corrosion & steel reinforcement. Generally used for internal applications
Chlorinated rubber coatings	Resistant to heat, sunlight and weather, moderately resistant to acids, alkalis. Not recommended for immersed conditions. Adhesion to concrete is good.
Acrylic Coatings	Higher permeability, a life of three years may be possible
Polyurethane coatings	Excellent UV resistances abrasion and cracking resistance, has high elasticity and resistance to biological department.
Bitumen or Tar Products.	Provide excellent protection; however aesthetics is affected
Products based on cement sand and asphalt	Showed satisfactory performance for more than six years in tropical marine atmosphere at exteme exposure condition.
Vinyl copolymer resin paints	Showed satisfactory performance
a) Polyvinyl Alcohol	Adhesion to concrete is good, Moderately resistant to water and mild aggressive chemicals, Good, flexibility, hardness and abrasion resistance.
b) Polyvinyl Chloride	Adhesion to concrete is very poor. Excellent acid resistance Not suitable on moist surface.
c) Polyinylidene Chloride	Bonding to concrete is poor. Impact resistance is also poor.
Polyvinyl acetate	Because of its tendency to reemulsify on contact with water, it is suitable only where the concrete will remain permanently dry.
Polyvinyl butyrol	Outstanding abrasion, resistance, toughness, flexibility, water and heat resistance
Rubber and resins a) Chlorinated Waxes	Excellent water resistance and good abrasion resistance, Adhesion to concrete is good. Fade under sunlight.
b) Polyrene Butadine	Excellent resistance to both strong and weak acids as well as strong alkalis, oil grease and water exterior durability is good fade under sunlight.
c) Chlorosulphonated polythlene resins	Good flexibility, excellent weather resistant and good chemical resistant.
Neoprene Coatings	Excellent Weather resistant
Alkyd – isocyanate	Often recommended on concrete as a first coat or as a medium coat system and fails to function under extreme weather conditions.
Polyester-isocynate polyurethanes	Generally not recommended as the first coat on concrete because with residual alkalinity on concrete, such a polymer may undergo saponification reactions. The coating may break into powder (especially with aroma) ?
Alkyd and oil based paints	Not recommended over concrete surface
Phenolic paints	Not recommended due to poor alkali resistance
Oil based and olcoresinous Paints	Not recommended due to softening and blistering the alkaline environment.
Surface water proofers like silicones, soaps, wax, oil etc.	Not satisfactory

Coating Type	Characterstics
Coating for steel bridges	Best performing low volatile organic compound with zinc rich (organic and inorganic) Primers. Best performing carrier coating systems- three coat acrylic coating, an epoxymastic urethane, an epoxymastic/water borne epoxy enamel and a three coat water borne styreo acrylic.
Maitenance painting jobs on bridges a) Long oil alkyd coatings with red led	Performance not satisfactory
b) Aluminium fix epoxy mastic system	Successful performance
c) A moisture cured urethane system	Successful performance

5.4 Conclusions: The material selection for structural reparis and protective coatings is an intricate process which may put a practising Engineer in a difficult situation hence.for guidance regarding selection of proper concrete repair material/coating material, the following tables 5.10 and 5.11 may be referred. Product Guide on Constructions & Repairs Chemicals given in Appendix 5.1 provides information on commercially available products and Appendix 5.2 provides addresses of manufacturers of such products. Appendix 5.3 provides list with addresses of reputed laboratories where such products could be tested. These are given for ready reference and convenience of readers.

Table 5.10: MATERIALS SELECTION FOR CONCRETE REPAIR

(Source: Concrete society report No. 26. "Repair of concrete damaged by reinforcemnt corrosion)

Possible material for repair	Spalling over large areas			Spalling over small areas		Crack sealing	Structural Crack repair	Bond-ing aids
	Cover (mm)			Cover (mm)				
	>25	12-25	6-12	12-25	6-12			
Concretes Sprayed concrete or cement-sand mortors	*							
Polymer-modified cementitious mortars		*		*				
Epoxy resin mortars			*		*			
Polyester resin mortars					*			

Moisture tolerant epoxy resins								*
SBR, acrylic and copolymer emulsions						*		*
Low-viscosity polyester and acrylic resins						*		
Low- viscosity epoxy resins							*	
PVAc bonding aids	Not recommended for external repairs							
PVAc-modified mortars	Not recommended for external repair							

TABLE – 5.11: SELECTION OF MATERIAL FOR INJECTION

(Source: SURLAKAR, SAMIR, Rehabilitation of Structures-Criteria for material selection-ICJ January 2000, Vol 74, No1 pp 31-37)**)**

Type of Cracks	*Width,*	*Movement mm*	*Water*	*Type of material*	*Mode of application and/or principle*
Shrinkage cracks in concrete	≤ 0.2	No	No	Two-component epoxy injection	Surface treatment which works through capillary action
Shrinkage cracks in plaster	≤ 0.2	No	Generally not	One-component flexible paint or acrylic base	Coat with roller or brush
Structural cracks in concrete, brickwork	0.2-1	No	No	Two component epoxy low viscosity	Low pressure injection, shorter cracks with high pressure injection
Structural cracks in concrete, brickwork	1-2	No	No	Two component epoxy injection and solvent free epoxy	Low pressure injection
Structural cracks in concrete brickwork	2-5	No		Solvent free epoxy thicotropic	Low pressure injection, with hand pump
Structural cracks in concrete brickwork	≥ 5	No	Dry/wet	Polymer modified cement based grout	Grout with injection grout or hand pump
Structural cracks in concrete brickwork	≥15	No	Dry/wet	Non-shrink grot	Cut and fill non-shrink mortar
Moving cracks in concrete, brickwork	0.2-1	Due to temperature changes	Dry/wet	Two component polyurethane injection injection and flexible paints when wet joints, primary injection with polymer gel forming	High pressure injection with (low pressure injection also possible)then coat with roller/brush
Butt joint in pres-tressed concrete (coupling joints)	0.2-2	Vibration	Dry/wet	Two component polyurethane injection and joint sealant, when wet joint, primary injection with polyurethane gel forming	For joints pressure injection, for floors, seal joints with sealant guns or spatulas
Moving cracks in concrete, brickwork and floors	≥ 2	Vibration	Dry/wet	Sealant on different basis including flowable grades	Sealant gun or spatuals; for horizontal surface flowable grade of joint sealant can be used.

Appendix 5.1

Product Guide on Construction and Repair Chemicals

Contents

Product Guide on Construction and Repair Chemicals

1. This is just a compilation of extract of information supplied by the manufacturers
2. CPWD owns no responsibilty for the correctness of data given in this product guide.
3. The products have been classified with indicative limitations for user guidance.
4. The list is not comprehensive as information about all products manufactured in the country could not be obtained due to paucity of time.
5. The manufacturers' name given in abbreviated form shown within bracket as (MANUFACTURER) against each product is to be correlated to complete name and address given at the end of this appendix.
6. Different abbreviations and units have been used by the manufacturers in their product information. The possible explanations are: 'bwoc'- 'by weight of cement'; 'w/w'- 'weight by weght'; 'pbw'- 'parts by weight'; 'gm'-'gram' etc

Sl. No.	Proprietary Name of Product—(Abreviated Name of Manufacturer)	Manufacturer's Specific Remarks and its recommended Dosage /Coverage wherever made available

1 **INJECTION GROUTS** (Seals Cracks in Concrete & other building materials by Injecting under pressure)

a **EPOXY BASED INJECTION GROUT** (*Low pot life, non-resistant to ulitrea violet exposure and high temperatures,* Non-shrink, flowable, effective in sealing cracks, excellent bonding with almost all building materials, good chemical resistance)

1	EPOIN-AG-(AG)	1.05kg/litre
2	CERAscreed EP(LV)-(CERA)	1 litre / 2 kg
3	MASTER- GROUT EP - 150-(CHOKSEY)	Approx. density 1.08 kg/ litre. Low viscosity. It is also used for filling base plates & bolt pockets.
4	CICO POXY-21-(CICO)	
5	Quickmast 231-(DON)	
6	Expacrete SNE1-(ESSEN)	
7	FLOWGROUT EPLV-(FAIRMATE)	Suitable for damp or dry surfaces
8	Conbextra EP10-(FOSROC)	Low creep characteristics under sustained loading. Crack width range 0.25 to 10 mm
9	Groutfast (GREENSBORO)	1950 kg/cum
10	EPCO KP/HP-250 SLV-(KRISHNA)	
11	MC DUR 1264-(MC)	2 kg Resin:1 kg hardener. It can penetrate into concrete upto 0.25 mm
12	OMAIPLAS 501-(OM)	Base & Catalyst 1:0.5 Proportion.
13	OMAIPLAS 901-(OM)	Base & Catalyst 1:1 Proportion. For grouting of concrete or masonry structures under water.
14	Pidigrout EG-2-(PIDILITE)	1010 kg/cum
15	Pidigrout EG-3-(PIDILITE)	2150 kg/cum
16	Roff Crackfill EP (Two pack Epoxy)-(ROFFE)	
17	EUCO INJECTION RESIN-(STP)	
18	SUNEPOXY 368-(SUNANDA)	SUNEPOXY 368 & Hardner (3:1) - High Gel time
19	SYSTEM - I GY-257: Aradur -840 100:50 pbw (VANTICO)	Medium Viscosity 2000-3000 mPa at 25^o C
20	SYSTEM - II GY-257:Aradur -21 100:21 pbw (VANTICO)	Very Low Viscosity 150-130 mPa at 25^o C
21	SYSTEM - III GY-257:Aradur -54 100:50 pbw (VANTICO)	Low Viscosity 400-800 mPa at 25^o C
22	SYSTEM-IV Py-340-2:Aradur-54:Aradur-2958 100:38:4 pbw -(VANTICO)	Water based low viscosity System-Ideal for sealing of under ground structures. Develops Excellent Bond even in wet conditions.

Contd...

Appendix 5.1 *(...Contd)*

Sl. No.	Proprietory Name of Product—(Abreviated Name of Manufacturer)	Manufacturer's Specific Remarks and its recommended Dosage /Coverage wherever made available
23	Araldite GY 257 Aradur - 840 Quartz Sand Mix no.10- 100:50:400-800 pbw -(VANTICO	400 pbw Quartz Sand gives flowable Mortar and 800 pbw Quartz sand will give tampable Mortar System gives excellent mechanical properties and is tested for dimensional properties.
b	**ACRYLIC POLYMER BASED INJECTION GROUT**(Possess improved flexural and tensile properties, resistance to cracking, segregation, improved impermeabilitrey, chemical resistance, rapid setting, Shrinkage may reduce/increase , resistance to corrosion of Steel, Dynamic load/vibrations resistant)	
1	CICO NON SHRINK POLY- MERIC GROUTING COMPOUND (NSPGC)-(CICO)	Used as admixture in neat cement/ cement-sand grout, Dosage : 1 to 2 kg per 50 kg Cement.. To be used within 30 minutes from the time of production
2	Emcekrete -(MC)	Apporx. 2 kg per litre
3	OMAICRYL-(OM)	Omaicryl+Water+Cement mixed in 1:1:2.
4	Pidigrout 10M (PIDILITE)	2200 kg/cum Non-shrink grout
5	Roff Hygrout (Powder)-(ROFFE)	Expanding in nature.
c	**LIGNOSULPHATE BASED INJECTION GROUT ADMIXTURE** *(Lowers viscosity of cement slurry, compensates drying & plastic shrinkage)*	
1	INTRAPLAST EP-(SIKA)	0.6-1.0% by weight of cement.
2	CICO GROUT E1-(CICO)	As per manufacturer's instruction
3	FAIRADD-(FAIRMATE)	200 gm per 50 kg bag of cement.
d	**INJECTION GROUTS WITH UNDISCLOSED BASE** (Disadvantages/advantages cannot be generalised)	
1	ASIAN Super Grout-(ASIAN)	2300kg Grout Powder /CuM-Non-shrink cement grout
2	CERA Grout-(CERA)	26 litre / bag
3	MASTER- GROUT CNS - 50-(CHOKSEY)	Approx. 2180kg/m3. Mix 5.4 litre water with 30 kg of powder W/P=0.18.
4	Flogrout 40-(DON)	Yield:25kg +4.25 litre of water yield 13.0 litreres
5	Flogrout 60-(DON)	Yield: 25kg + 3.75 litrere yield 12.8 litreres
6	Polygrout-(ENEM)	2 kg/litre of grout
7	Flowcable 50-(MBT)	0.2% - 0.5% w/w of cement Expands up to 4 %. 28 day strength > 65 Mpa
8	Masterflow IN-(MBT)	Premixed. 28 day strength > 65 Mpa
9	SUNPLEX-(SUNANDA)	330 gm SUNPLEX per bag cement Expanding admixture & free from chlorides
2	**Rust Convertors/Removers for Reinforcements**	
a	**ACRYLIC POLYMER BASED Rust Convertor for Steel surface**	
1	RESIKON RSK-(ANUVI)	Converts rust to chemically stable chelate compound. Coverage: 150 - 200 sqft per kg
b	**RUST REMOVER** WITH MISCELLENOUS/ UNDISCLOSED BASE	
1	AMCOR RR-(ANUVI)	Removes rust & phosphatises iron metal.. Coverage: 15 sqm per kg
2	Cleancrete-(ASIAN)	Coverage: 6 – 9 sqm/litre.
3	FM RUST REMOVER-(FAIRMATE)	To protect deposition of rust by eliminating existing rust. The coverage rate will depend upon the degree of contamination
4	Feo Vert-(KRISHNA)	Rust converting Primer. Coverage: 9 - 10 sqm/litre./ coat.
5	Pidicrete URP and pidiclean RR-(PIDILITE)	SBR Based- Clean Rusted Reinforcement with Pidiclean RR and apply bond coat of 1-part cement and 1-part URP
6	Protekta Recor-(TECH)	Lignosulphate based admixture. Coverage: 100gm per bag of cement
7	Roff Rust Clear (Liquid)-(ROFFE)	Easy, economical & eco-friendly removal of rust. Coverage: 30 sqft per litre.

Contd...

Appendix 5.1*(...Contd)*

Sl. No.	Proprietory Name of Product—(Abreviated Name of Manufacturer)	Manufacturer's Specific Remarks and its recommended Dosage /Coverage wherever made available
8	Roff Rust Clear ZR (Liquid)-(ROFFE)	Easy removal of rust. Anti-corrosive as well as primer coating of zinc to prevent future rusting. Coverage: 40 sqft per litre.
9	RUSTICIDE-(SUNANDA)	Direct easy application. Single liquid component free from chlorides & phosphates.
10	Concressive ZR(MBT)	7.5 sqm/lir

3 Corrosion Inhibitors as Admixture in Concrete/Mortar
(Effective in preventing rust of embedded reinforcement.

1	FAIRCRETE C-(FAIRMATE)	Integral corrosion inhibitor.

4 Passivating/Protective/Bond Coats on Reinforcement

a **EPOXY BASED** Passivating/Bond Coat (*protect reinforceemnt from Chloride attack and other chemical)*

1	FRIAZINC R-(SIKA)	Zinc- rich system . Coverage:150g/sqm/coat.
2	ICOSIT K25 I/3-(SIKA)	Zinc- rich system . Coverage:175g/sqm/coat.
3	Nitozinc Primer-(FOSROC)	Zinc- rich system . Coverage: 4.5 sqm per litrere
4	IPNet RB-(KRISHNA)	Coverage: 12 litrere/ton for 16 mm bar diameter
5	Dr.fixit Epoxy Zink primer-(PIDILITE)	Zinc- rich system
6	CORRO BOND-(STP)	Coverage: 200gm/sqm
7	SHALIZINC PRIMER-(STP)	Coverage: 100gm/sqm

b **ACRYLIC POLYMER BASED Passivating Coat** (Protects Steel against corrosion. Provides impervious layer,high Alkalinity & Good adhesion It is a co-polymer of various acrylic monomers and it is solvent based.)

1	RESIKON COASTAL-(ANUVI)	Proportion: 2:1 ratio (OPC:RESIKON COASTAL)
2	Cempatch R-(DON)	Coverage: 1 kg pack covers 50 kg of 12mm dia Steel
3	SIKA RUSTOP(two-component, liquid& powder)-(SIKA)	Coverage: 110 gm./running metre for 10 mm. Dia rod.
4	POLYALK FIXOPRIME-(SUNANDA)	Proportion: POLYALK FP & Cement in ratio 1:1.25
5	Protekta -M-(TECH)	Coverage: 40 -50 sqft

c **SBR BASED Passivating Coat,** (May degrade over long periods.Protects Steel against corrosion. .Provides impervious layer, high Alkalinity & Good adhesion.)

1	POLYCRYLE-(GREENSBORO)	Coverage: 100 to 300 per sqm.
2	Roff Bond Repair (Liqiud)-(ROFFE)	Coverage: 60 sqft per litrere

d **LIGNOSULPHATE BASED** Passivating coat

1	Protekta GAC -(TECH)	Creamy consistency., brush applied over cleaned reinforcement. Coverage: 20-25 running feet

e **WITH UNDISCLOSED BASE Passivating Coat** (Excellent weather resistance, anti corrosive coating for Steel and reinforcements.)

1	NR-900-(ASIAN)	Coverage: 10kg/cum of conc.
2	SAFECORE R-(FAIRMATE)	Coverage: 2 kg + 1 litre Pack will cover 100 kg Steel of 12mm dia.
3	POLYDEE -RC-(GREENSBORO)	Coverage: 80 to 150 ml/sqm
4	SIKA RUSTOP-(SIKA)	Two component Liquid and Powder. Coverage: 110 gm/running metre for 10 mm dia rods
5	Renderoc Galvashiekd XP-(FOSROC)	Ligno-sulphate based. Coverage: One unit for 2 running metre of reinforcement bar
6	POLYPROOF-21 (Microfine Powder Concentrate)-(GREENSBORO)	Coverage: Coverage: 0.2% by weight of cement

Contd...

5

Appendix 5.1*(...Contd)*

Sl. No.	Proprietory Name of Product—(Abreviated Name of Manufacturer)	Manufacturer's Specific Remarks and its recommended Dosage /Coverage wherever made available
5	**Bonding Coats** (Applied by brush or spray. Bonding Agent for old concrete with newly poured concrete)	
a	**EPOXY BASED** Bonding Coat, *(Low pot life.*Excellent bonding under dry conditions, high mechanical proprerties *)*	
1	EPOBOND-AG-(AG)	Excellent bonding under dry & wet Conditions both. Coverage: 0.200 to 0.300 kg per sqm
2	Bond-Aid-(ASIAN)	Dilution 1:3. Coverage: 30-35sqm/kg
3	CERAbond-EP-(CERA)	Excellent bonding under dry & damp Conditions both.Coverage: 2.5 sqm/kg
4	MASTER - BOND - EP-(CHOKSEY)	Excellent bonding under dry & damp
5	CICO BOND EPO-(CICO)	Use this mixed material within 30 minutes after mixing.. Simple air curing for 7-days Coverage : Three pack 2.5 sqm per kg Two pack 2 to 2.5 of mixed material.
6	Quickmast 108-(DON)	Two part, pre packaged can be applied on damp surfaces. Coverage: Approx 0.3kg per sqm..
7	Conbond SNE-(ESSEN)	Coverage: 2 - 4 sqm per kg
8	FAIRBOND EP-(FAIRMATE)	Cures even on damp surfaces. Coverage: 0.3 kg/ sqm.
9	Nitobond EP-(FOSROC)	Allows concreting upto 10 hrs at 20o C and upto 6 hrs at 30o C. Coverage: 2.2 sqm per kg
10	Epibond-(KRISHNA)	Coverage: 3 - 5 sqm / litrere on level surface.
11	Concresisve 1414-(MBT)	Conforms to ASTM. Coverage: 2-2.7sqm/kg
12	MC DUR 1200-(MC)	Coverage: Approx. 500-550 gm/sqm
13	Pidipoxy EBA-(PIDILITE)	Coverage: 3 – 4 sqm /kg
14	Roff Concrete Bond GP (Liquid)-(ROFFE)	Coverage: 30 sqft per litrere
15	SIKA HIBOND -(SIKA)	Coverage: 0.2 kg to 0.5 kg per sqm
16	EUCO 352-(STP)	Coverage: 4-6sqm/kg
17	SUNEPOXY 358-(SUNANDA)	Proportion: Sunepoxy 358 & Hardner in ratio 1:0.5
18	Protekta Bond-(TECH)	Coverage: 4-5 sqft
19	SYSTEM - I GY-250 Aradur -830 Aradur -850 Aradur -825 Silica Flour-(VANTICO)	Concrete to be poured within tacky period, which is 1 hr at 25-30o C. Mixing Ratio: 100parts by weight:20parts by weight(pbw)
20	SYSTEM - I I GY-257 Aradur -840-(VANTICO)	Concrete to be poured within tacky period, which is 1 hr at 25-30o C. Mixing Ratio: 100pbw:50pbw
21	Araldite GY-257 Aradur-450 Aradur-2958 -(VANTICO)	Develops Excellent bond even in wet conditions. Concrete to be poured within tacky period, which is 1 hr at 25-30o C. Mixing Ratio- 100pbw: 30pbw: 9pbw
b	**ACRYLIC POLYMER BASED** Bonding Coat (Good bonding between old and new concrete. UV resistant, non-re-emuslifiable, resistant to water penetration, no rebound loss, high flexural strength)	
1	RESIKON 400-(ANUVI)	2:1 ratio (OPC : RESIKON 400) .
2	Cempatch Primer-(DON)	Coverage: 1kg pack covers 3 to 4 sqm.
3	Conbond SNA-(ESSEN)	Coverage: 5 - 6 sqm per litrere
4	EL-Monobond-(KRISHNA)	Coverage 3 to 4 sqm. per coat
5	MC BONDAID PLAST-(MC)	Coverage: 8-10 sqm/kg
6	High Bond-40-(NEELAM)	Coverage: 250gm./sqm.
7	OMAICRYL-(OM)	Dilute with water 1:1. Bonds old concrete surface with fresh mortar. Coverage: 8 to 9 sqm per kg
8	Pidicrete MPB -(PIDILITE)	Coverage: 8-10 sqm /kg (by spray)
9	FLEXCON-(STP)	Coverage: 10sqm/titre
10	Protekta -400-(TECH)	Produces highly flexible membrane. Coverage: 12 -15 sqft (slurry) a 1.5-2mm thick
c	**SBR BASED Bonding Coat** (May be non-resistant to UV exposure and could degrade over long periods. Improves bonding, reduces cracking, wear resistant , improves tensile flexural strength, chemical resistant.)	
1	BONDCRETE-AG-(AG)	Coverage information not supplied by firm
2	CERAlatex SBR-(CERA)	Coverage: 8-10 sqm/litrere

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Appendix 5.1 *(...Contd)*

Sl. No.	Proprietary Name of Product—(Abbreviated Name of Manufacturer)	Manufacturer's Specific Remarks and its recommended Dosage /Coverage wherever made available
3	POLYDEE-MC -(GREENSBORO)	Coverage: 2 kg per bag cement
4	Rheomix 141-(MBT)	Compressive strength upto 40 Mpa. Coverage: 5-7 kg per bag of cement
5	Roff Bond Repair (Liqiud)-(ROFFE)	Coverage: 35 sqft per litrere
6	SIKA LATEX POWER(Liquid product)-(SIKA)	Coverage: 3 kg to 6 kg per 50 kg bag of ratio SLP:W = 1:4 to 1:8 by vol.
7	Protekta -500-(TECH)	Coverage: a 12-15 sqft (slurry) a 5-2 mm thick
d	**WITH UNDISCLOSED BASE Bonding Coat,** (Excellent interfacial bonding, Easy to use,Hacking totally eliminated)	
1	HACK AID PLAST-(TECH)	Ready to use by brush
2	Ashford Formula-(JB)	40 sqft. to a litre. on fresh concrete floor.

6 **PLASTICISERS** (Reduces water demand upto 15 % for same level of workabilitrey to result in higher strength, Increased flowabilitrey/workabilitrey for same w/c ratio to allow it to be placed without vibration at poorly accessible locations, essentially needed for producing higher grades of concrete)

Sl. No.	Proprietary Name of Product—(Abbreviated Name of Manufacturer)	Manufacturer's Specific Remarks and its recommended Dosage /Coverage wherever made available
a	**ACRYLIC POLYMER BASED** PLASTICISER(Excellent abrasion resistant, wearing coat of bridge slabs, repair of abraided surface of concrete roads. Industrial flooring)	
1	OMAICRYL-(OM)	Dosage: 10% to 20% bwoc
b	**WITH UNDISCLOSED BASE PLASTICISER**	
1	POLYPROOF-22 (Liquid)-(GREENSBORO)	1 to 5% by weight of cement
2	Stanro SPS-(NEELAM)	0.5 to 1% by wt. of cement.
3	CICO PLAST-A-(CICO)	Optimum Dose: 1000 ml per 50 kg Cement.- Range : 700 to 1500 ml per 50 kg Cement.
4	Roff Plasticiser-330 (Liquid)-(ROFFE)	140-280 ml per 50 kg bag of cement
c	**MELAMINE BASED** PLASTICISER	
1	CICO PLAST - AF-(CICO)	It acts only to prevent harmful effects of frost on green concrete. Dosage : 0.5 to 1.5 litre per 50 kg bag of count.
d	**NEPTHALENE BASED PLASTICISER**	
1	Cemwet Sp-I-(ASIAN)	0.4-2% by wt.of cement
2	CICO PLAST AEP-(CICO)	Normally with the 300 kg of cement/cum, Zone II sand, 20 mm aggregate, 150ml is sufficient to get 4 to 5% air at 30 Deg C. Range : 100 ml to 200 ml per 50 kg cement.
3	CICO PLAST MMF-(CICO)	Used for pumped concrete. Dosage : 300 ml per 50 kg cement. Range : 200-1000 ml per 50 kg
4	Pidicrete CF 21-(PIDILITE)	Dosage: 100-500 ml per bag of cement
5	SIKA PLASTOCRETE SUper .-(SIKA)	Marked with IS:9103 & conforms to IS:2645. No added chlorides and sulphates. Dosage: 0.2% by wt. of cement i.e. 100 gm per 50 kg bag of cement.
e	**LIGNOSULPHATE BASED PLASTICISER**	
1	RESIKON 130-(ANUVI)	100 - 500ml per 50kg cement
2	PLASTAID-(ENEM)	Dosage: 0.25 kg per bag of cement
3	BLOCKSAVER-(ENEM)	Dosage: 0.25 kg per bag of cement
4	Conflow SNP1-(ESSEN)	Gives high density concrete. Dosage: 0.10 to 0.25 litres per 50 kg cement
5	FAIRCRETE N -(FAIRMATE)	Dosage: 100 ml to 250 ml per 50 kg bag of cement
6	Pozzolitreh 300 R-(MBT)	Dosage: 0.1-0.3%
7	PLASTIMENT BV40-(SIKA)	Dosage: 0.2-0.8% by wt of cement
8	EUCON WR-(STP)	Dosage: 0.4% bwoc

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Appendix 5.1 *(...Contd)*

Sl. No.	Proprietory Name of Product—(Abreviated Name of Manufacturer)	Manufacturer's Specific Remarks and its recommended Dosage /Coverage wherever made available
7	**Super Plasticisers** (Reduces water demand by 15-30% for same level of workabilitrey to result in higher strength, Increased flowabilitrey/workabilitrey for same w/c ratio to allow it to be placed without vibration at poorly accessible locations, essentially needed for producing higher grades of concrete)	
a	**MELAMINE BASED SUperPLASTICISER**	
1	RESIKON SP120 M-(ANUVI)	Dosage: 100 - 500ml per 50kg cement
2	Supercon 100-(KRISHNA)	Dosage: 0.5% to 4% by weight of cement
3	Roff Superplast - 820 (Liquid)-(ROFFE)	Dosage: 250 — 600 ml per 50 kg bag of cement
4	SIKAMENT 320-(SIKA)	Dosage: 0.6-2.0% by wt of cement.
b	**NEPTHALENE BASED SUperPLATICISER**	
1	RESIKON SP-110-(ANUVI)	Dosage: 100 - 500ml per 50kg cement
2	Cemwet SP-3000-(ASIAN)	For pumping concrete. Dosage: 0.4-2% by wt.of cement
3	MASTER- PLAST SPL-2-(CHOKSEY)	Conforms to IS:9103, BS-5075-Part-3, ASTM-C-494 Type F. Non-foaming, non-toxic, Does not contain any chlorides or nitrates, can be used at high dosage without affecting setting time of concrete to get higher workabilitrey. Dosage: 0.200 to 1.200 litrere per 50 kg
4	OMAI SPNF-(OM)	Dosage: 0.5 to 1% by weight of cement
5	Roff Superplast-410 (Liquid) -(ROFFE)	Dosage: 300—500 ml per 50 kg bag of cement
6	SIKAMENT 170-(SIKA)	Dosage: 0.5-2.0% by wt of cement
7	EUCON 37-(STP)	Dosage: 6-2% by weight of cement(bwoc)
8	POLYTANCRETE- NGT-(SUNANDA)	Dosage: 150ml to 400ml per bag of Cement
9	Protekta -T -(TECH)	Dosage: 500gm per bag of cement
c	**LIGNOSULPHATE BASED SUPER PLASTICISER**	
1	CICO - MS-(CICO)	Ideal for underground structures, parking, bridge decks. Dosage : 3 to 10% by weight of cement.
2	FAIRFLO-(FAIRMATE)	Dosage: 300 ml to 600ml per 50 kg bag of cement
3	Pidicrete CF-(PIDILITE)	Dosage: 100-500ml per bag of cement
4	Roff Superplast -320 (Liquid)-(ROFFE)	Dosage: 250 - 500 ml per 50 kg bag of cement
d	**WITH UNDISCLOSED BASE SUPER PLASTICISER**	
1	POLYPLAST-HW/HL-(GREENSBORO)	Dosage: 0.3% to 2%
8	**Shrinkage, Reducing/Compensating Compounds**	
a	**ACRYLIC POLYMER BASED** Shrinkage, Reducing/compensating compound (Crack filling abilitrey, non shrink, reduced creep and shrinkage,resistant to frost and fire damage.Dimensional stabilitrey,excellent abrasion resistant)	
1	MC Sunfilla-(MC)	Crack filling abilitrey, non-shrink, resists further crack growth. Dosage: 1.5 kg/sqm/mm thickness
2	MC Einpresshilfe EH-(MC)	permanent expansion, reduced creep & shrinkage. Dosage: 0.5 to 1% of cement weight
3	OMAICRYL-(OM)	Dosage: 10% to 20% by weight of cement
4	Roff Grout Mix (Powder)-(ROFFE)	Non-shrink cement slurry. Dosage: 500 gm per 50 kg bag of cement.
b	**SBR BASED** Shrinkage, Reducing/compensating compound	
1	POLYDEE-MC -(GREENSBORO)	Anti shrink compound/ concrete. Dosage: 2 kg per bag cement
c	**NEPTHALENE BASED** Shrinkage, Reducing/compensating compound	
1	Fluid-X-(ASIAN)	0.5 by wt. Cement
2	OMAI SPNF-(OM)	0.5 to 1% by weight of cement
3	INTRAPLAST EP-(SIKA)	0.6-1.0% by wt of cement.

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Appendix 5.1 *(...Contd)*

Sl. No.	Proprietory Name of Product—(Abbreviated Name of Manufacturer)	Manufacturer's Specific Remarks and its recommended Dosage /Coverage wherever made available
d	**LIGNOSULPHATE BASED** Shrinkage, Reducing/compensating	
1	RESIKON PLASTERAID -(ANUVI)	100 -300ml per 50kg cement
e	**WITH UNDISCLOSED BASE** Shrinkage, Reducing/compensating compound	
1	CERA Expan 250-(CERA)	Dosage: 225 gm for 50kg cement
2	Conbex 100-(FOSROC)	Dosage: 225 gm per per 50 kg cement
3	OMAIPLAS 801-(OM)	Dosage: 5% to 20% weight of cement
4	SHALIGROUT IP-(STP)	Dosage: 1% bwoc
5	Protekta AC1-(TECH)	Dosage: 1.4 litre per bag of cement
6	Protekta -DX-(TECH)	Dosage: 100gm per bag of cement
7	Floadd-(DON)	Yield : 36 litreres when 20 litreres of water added
8	GROUTFAST Cementitious-(GREENSBORO)	2250 kg/cum
9	SUNPLEX-(SUNANDA)	330 gm SUNPLEX per bag cement
9	**Self Flow Micro Concrete** (Highly fluid, non shrink, self compacting concrete with very high early and ultimate strengths.,excellent adhesion, used for structural repairs like Jacketting, patch repair, retrofitting of RCC, grouting fondations, anchor bolts)	
a	**EPOXY BASED Self Flow Micro Concrete** (May not be suitable in exposed location, at high temperatures or where temperature variation range is large. Excellent mechanical properties and bonds with almost all building materials.Suitable for sealing crack surface defects, concrete repair, thin jackets, thin film bonding, assembly of prestressed concrete segmental units and segmental bridge construction.)	
1	Araldite GY 257 Aradur - 840 Quartz Sand Mix no.10- 100:50:400-800 pbw -(VANTICO)	400 pbw Quartz Sand gives flowable Mortar and 800 pbw Quartz sand will give tempable Mortar System gives excellent mechanical properties and is tested for dimensional properties.
2	CICO POXY SBA-(CICO)	Coverage : 1.7 kg of mixed material for 1 mm thickness per sqmr.
3	Repcrete SNE1-(ESSEN)	Coverage : 16 kg gives 8 litreres of volume after mixing
b	**ACRYLIC POLYMER BASED** Self Flow Micro Concrete	
1	MC Floorpatch-(MC)	Ideal for repair of blow holes in Industrial floors. Coverage: 1.5 kg/sqm/mm thickness
2	MC Floor level-(MC)	1.5 kg/sqm/mm thickness
c	**SBR BASED** Self Flow Micro Concrete (*May be effective in exposed locations and degrade over long durations*, Used for Micro concrete/ retrofitting, jacketting **)**	
1	POLYDEE-MC -(GREENSBORO)	2 kg per bag cement
d	**LIGNOSULPHATE BASED Self Flow Micro Concrete** (Self compacting concrete,anti washout,non shrink microconcrete for underwater repairs. High strength and fast setting,non-shrink,improved impermeabilitrey & chemical resistant)	
1	Renderoc RG-(FOSROC)	Anti washout for under water repairs Coverage : 1950 kg/cum
2	Renderoc UW-(FOSROC)	Coverage : 12 litreres yield per 25 kg bag
3	POLYCRETE -(SUNANDA)	Coverage : Ready to use .Mix 12.5% to 13% water.
e	**WITH UNDISCLOSED BASE Self Flow Micro Concrete**	
1	POLYGROUT-(ENEM)	Coverage: 2 kg per litre volume of grout Also used for grouting Machine Foundations, bolts, anchors.with positive expansion
2	EUCOCRETE-(STP)	Coverage : 2000 kg/cum
3	CERA Microconcrete-(CERA)	Coverage : 13.5 litree / kg
4	Cempatch N-(DON)	Conforms to BS-6319 Part-2-1983, BS 6319 Part-7-1985. Coverage : 25 kg pack Yields 11.1 litrere
5	Cempatch HM-(DON)	Yield: 25 kg + 4.25 litrere water. Yields 13.5 litrere.
6	Repcrete SNC-(ESSEN)	Coverage : Gives 12 litrere volume after mixing with water
7	CEMSCREED HM(F)-(FAIRMATE)	Information not supplied by firm

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Appendix 5.1*(...Contd)*

Sl. No.	Proprietory Name of Product—(Abbreviated Name of Manufacturer)	Manufacturer's Specific Remarks and its recommended Dosage /Coverage wherever made available
8	Supercon UW-(KRISHNA)	Effectively fills cavities under water. Coverage : Information not supplied by firm
9	Emacco S 66 CT-(MBT)	Coverage : Information not supplied by firm
10	Roff Crete Repair (Powder)-(ROFFE)	Can be used in less thickness. Coverage : 24.5 litrere per 50 kg bag of cement
11	SIKA MICROCON- CRETE - HS-(SIKA)	Coverage : 2000 kg/cum

10 **Polymer/Epoxies in Repair Mortar/Concrete** (May not be suitable at high temperatures. Improved bonding with substrate and imperviousnes, to be applied in thin layers, Excellent mechanical properties)

a **EPOXY BASED Repair mortar/Concrete** (May not be suitable in exposed location, at high temperatrures or where temperature variation range is large. Excellent mechanical properties and bonds with almost all building materials)

1	Araldite GY 257 Aradur - 840 Quartz Sand Mix no.10- 100:50:400-800 pbw -(VANTICO)	400 pbw Quartz Sand gives flowable Mortar and 800 pbw Quartz sand will give tempable Mortar System gives excellent mechanical properties and is tested for dimensional properties.
2	Bond-Aid-(ASIAN)	Can be applied on wet surfaces. Dilution 1:3. Coverage: 30-35sqm/kg Dosage: 2-3 cum per kg
3	Emacco S 88 CT-(MBT)	Premixed
4	Concressive 2200-(MBT)	Coverage: 3kg/sqm

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b **ACRYLIC POLYMER BASED Polymer in Repair Mortar/Concrete** (May not be suitable at high temperatures. Used as an admixture by weight of cement. Improves bonding and flexural tensile strength. Reduces Chloride ingress and water absorption. Resistant to UV Radiation.Suitable for Exterior use, abrasion and impact resistant, chemical attack, non-toxic, resists fungus and micro-organism growth, protects Steel reinforcement, Chloride free, can be used in wet areas)

1	RESIKON 400-(ANUVI)	Dosage: 5 -15 % of cement depending on application
2	CERA Poly Crackfiller-(CERA)	Dosage: 40 rm/kg to fill V groove of 6mm
3	CERA Patchcrete-(CERA)	Dosage information not supplied by firm
4	ELASTOCRETE-(CHEMLINE)	Dosage: 1.5 sqm per 2 coats 0.6mm thickness per coat
5	ELASTOCRETE-(CERA)	Dosage: 1.2 sqm per 2 coat thickness of per coats 2 mm
6	MASTER- CRETE M-81-(CHOKSEY)	Coverage: 4-4.5 sqm./ 3 kg mix per coat . Mix M-81:OPC (1:2)
7	Setcrete SB-(DON)	Coverage: 0.5 kg of SB +1 kg of OPC cement for one sqm. 15 kg of Setcrete SB for 50kg of cement.
8	FAIRCRETE SB (L)-(FAIRMATE)	
9	CEMSCREED R-(FAIRMATE)	Coverage: 5 to 7 sqm.
10	Nitobond AR-(FOSROC)	Coverage: 10 % by wt of cement
11	Monobond-(KRISHNA)	Dosage: Appox. For Mortar 10 to 15 % parts by weight.
12	MC Floorpatch-(MC)	Coverage: 1.5 kg/sqm/mm thickness
13	MC Floor level-(MC)	Coverage: 1.5 kg/sqm/mm thickness
14	OMAICRYL-(OM)	Dosage: 10% to 20% by weight of cement
15	Roff Supercrete (Liquid)-(ROFFE)	Dosage: 6-10 % of cement
16	SIKA TOP 77-(SIKA)	6% by wt of cement.
17	POLYALK EP 25-(SUNANDA)	Composition: POLYALK EP & cement as 1:0.5
18	Protekta Flexphalt-(TECH)	Used as flexible membrane and gives total water protection. Coverage: a 15-20 sqft
19	Protekta Flexjoint-(TECH)	Coverage: a 15-20 sqft can be higher depends on the surface
20	Protekta STG-(TECH)	Information not supplied by firm
21	Protekta Crack Filler -(TECH)	Information not supplied by firm

c **SBR BASED Polymer in Repair Mortar/Concrete** (Liable to be affected by UV exposure and at high temperatures, could degrade over long durations. Good bonding, reduces cracking, abraison resistant, water resistant, resistant to cracking , resistant to chemical attacks, improves imperviousness and tensile strength)

1	BONDCRETE-AG-(AG)	Information not supplied by firm
2	Nitobond SBR-(FOSROC)	Information not supplied by firm
3	POLYDEE-MC -(GREENSBORO)	Dosage: 2 kg per bag cemt
4	Rheomix 141-(MBT)	Dosage: 5-7 kg per bag of cement

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Appendix 5.1 *(...Contd)*

Sl. No.	Proprietory Name of Product—(Abreviated Name of Manufacturer)	Manufacturer's Specific Remarks and its recommended Dosage /Coverage wherever made available
	5 Nafufill SBR-(MC)	Dosage: Varies according to field of application
	6 Roff Bond Repair (Liquid)-(ROFFE)	Dosage: Dosage: 3 - 5 % of cement
	7 SIKA LATEX POWER(Liquid product)-(SIKA)	Dosage: 3 kg to 6 kg per 50 kg bag of ratio SLP:W = 1:4 to 1:8 by vol.
	8 SBR LATEX-(STP)	Dosage: AS per litreREATURE
	9 POLYALK -SB-(SUNANDA)	Dosage: POLYALK SB,Cement & Quartz Sand as 1:5:15 by wt.
d	**FIBRES BASED** Polymer in Repair mortar/Concrete (Provides resistance to crack formation etc.)	
	1 CERA Fibercrete-(CERA)	
	2 SMASHTOUGH-(ENEM)	Coverage: 2 kg per litrere volume of mortar
e	**WITH UNDISCLOSED BASE Polymer in Repair Mortar/Concrete**	
	1 REPAID-(ENEM)	Coverage: 2 kg per litre volume of mortar
	2 OMAIPLAS 801-(OM)	5% to 20% weight of cement
11	**Quick Setting Compounds** (Rapidly sets concrete/mortar to yield early strength)	
a	**EPOXY BASED Quick Setting Compounds**	
	1 GROUTFAST-(GREENSBORO)	Structural Grouting/ RCC Cracks, Renderings, non-shrink. 1950 kg/cu.m.
b	**ACRYLIC POLYMER BASED** Quick Setting Compounds	
	1 MC Fix ST-(MC)	Depends on application
c	**MELAMINE BASED** Quick Setting	
	1 Cemwet-ACC-(ASIAN)	Chloride free high early strength. Dosage: 1-1.5kg by wt. Of cement
d	**NAPTHALENE BASED** Quick Setting Compounds	
	1 OMAI SPNF-(OM)	Good workabilitrey, flowabilitrey, pumpable concrete, reduces w/c ratio. Dosage: 0.5 to 1% by weight of cement
e	**LIGNOSULPHATE BASED** Quick Setting Compounds	
	1 Patchroc-(FOSROC)	2000 kg/cum
	2 QS-530-(NEELAM)	1:3 with cement
f	**WITH UNDISCLOSED BASE** Quick Setting Compounds	
	1 CERA Polymortar-PE-(CERA)	Resistant to oil, grease and chemicals. Dosage: 2.6 litrere / 4 kg; 13 litrere / 20 kg
	2 CERA Anchorset-(CERA)	High pullout stength achievement. Dosage: 0.5 litre per kg
	3 CICO No.2 & 2A-(CICO)	Profusely water leaking locations in concrete. Final setting time 20-40 secs for CICO no 2. Dosage: Approx. 20 litrere per 50kg cement
	4 CICO NO.3 (CB) CICO NO.3A(CF)-(CICO)	For masonry, rock tunnels for moderate leakage. Dosage: Approx. 12 litrere per 50 kg cement or 16 to 17 kg per 50 kg cement
	5 CICO SHOT P (Powder)-(CICO)	Mixed with dry cement for shotcreting/gunite and water proofing applications. Dosage : 1.5 kg to 2 kg per 50 kg cement.
	6 CICO SHOT LP 100 (Liquid)-(CICO)	Mixed in mixing water for shotcreting/gunite and water proofing applications. Normal Dosage : 1.5 to 2 litres. per 50 kg cement.
	7 CICO SHOT L 100-(CICO)	Mixed in mixing water for shotcreting/gunite and water proofing applications. Normal Dosage : 1.5 to 2 litres. per 50 kg Cement.

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Appendix 5.1*(...Contd)*

Sl. No.	Proprietory Name of Product—(Abreviated Name of Manufacturer)	Manufacturer's Specific Remarks and its recommended Dosage /Coverage wherever made available
8	SPRAYCRETE-(FAIRMATE)	For dry mix shotcrete application. Dosage: 2% to 5% by weight
9	SPRAYCRETE L-(FAIRMATE)	For wet mix shotcrete applications. Dosage: 2% to 5% by weight
10	FAIRCRETE NC-(FAIRMATE)	Improves frost resistasnce. Dosage: 1 to 2 litres.per 50 kg bag of cement
11	Conplast Sprayset Powder-(FOSROC)	Allows higher buildup thickness. Dosage: 4% to 6% by wt of cement
12	OMAIPLAS 801-(OM)	Dosage: As per reqd. acceleration.
13	OMAIPLAS 801-(OM)	Hardens within 3 to 15 minutes. Dosage: 5% to 20% weight of cement
14	Roff Hyplug (Liquid)-(ROFFE)	Instant setting mortar. Dosage: 15 litrere per 50 kg bag of cement
15	SIGUNIT POWDER 1 (SIKA)	For Dry shotcreting. Dosage: 2-3% by wt of of cement.
16	SIGUNIT L .-(SIKA)	For Wet shotcreting. Dosage: 5-6% by wt of cement
17	DAM IT-(STP)	Information not supplied by the manufacturer
18	CERA Plug-(CERA)	Information not supplied by the manufacturer
19	RAPIDFAST-(GREENSBORO)	Dosage: 1-5% by wt. of cement.

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12 **Retarder** (To extend the initial and final setting time)

a **SBR BASED Retarder** (May not be suitable for locations, which are exposed or subjected to high temperatures. May degrade over long durations. watertight- ness, good bond, impact & flexural tensile strength, improve chemical resistance.)

1	SIKA LATEX POWER (Liquid product)-(SIKA)	Dosage: 3 kg to 6 kg per 50 kg bag of ratio SLP:W = 1:4 to 1:8 by vol.

b **MELAMINE BASED Retarder (Increases workability, reduces water cement ratio.)**

1	FAIRFLO RM-(FAIRMATE)	Dosage: 200 ml to 800 ml per 50 kg

NAPTHALENE BASED Retarder (reduces water cement ratio, workability retaintion for longer period)

1	FAIRFLO S -(FAIRMATE)	Dosage: 200 ml to 800ml per 50 kg bag of cement
2	EUCON 537-(STP)	Dosage: 0.6 - 1.5% bwoc

c **LIGNOSULPHATE BASED Retarder** (Increases setting time, cold joints can be avoided, requires less curing, improves impermeabilitrey)

1	CICO-PLAST-R-(CICO)	With OPC for M 25 grade concrete and 3 hours retardation normal dosage : 200 ml per 50 kg Cement. Range : 150 ml to 300 ml per 50 kg cement.
2	RETAID-(ENEM)	Coverage: 0.14 kg per bag of cement
3	Pozzolitreh 300 R-(MBT)	Dosage: 0.1-0.3%
4	EUCON 537-(STP)	Dosage: 0.6 - 1.5% bwoc

d Retarder WITH UNDISCLOSED BASE

1	Roff Retard - 310 (Liquid)-(ROFFE)	Dosage: 140-420 ml per 50 kg bag of cement
2	Protekta -DX-(TECH)	Dosage: 100gm per bag of cement
3	CemwetSRA -(ASIAN)	Dosage: 0.05-0,2%by wt.ofcement
4	POLYPLAST-R-(GREENSBORO)	Dosage: 1 to 2%

13 **Curing Compound** (It prevents premature water loss.. Stops dusting in floor, curing compound. can be applied at difficult locations, on vertical surfaces, roads, runways, external floors, dams)

a **LIGNOSULPHATE BASED** Curing Compound

1	CICO CUREFREE (WP OR C)-(CICO)	Coverage : 2.5 to 5 sqm per litre depending on surface texture.
2	CICO RITECURE-(CICO)	Coverage : On Steel troweled surface 7-10 sqm/litrere; On wood troweled surface 5-7 sqm/litrere.

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Appendix 5.1 *(...Contd)*

Sl. No.	Proprietary Name of Product—(Abreviated Name of Manufacturer)	Manufacturer's Specific Remarks and its recommended Dosage /Coverage wherever made available
b	Curing Compound **WITH UNDISCLOSED BASE**	
1	Setcrete 8-(DON)	Coverage : 5 to 6 sqm per litre
2	Setcuro WB-(DON)	Coverage: 5 to 6m sqm per litre
3	FARICURE RA-(FAIRMATE)	Coverage: 4 to 5 sqm. per litre.
4	Roff Cure WB-White (Liquid)-(ROFFE)	Coverage: 50 sqft per litre
5	Curewell-WB-(ASIAN)	9 to 10sqm/litre
6	Curaid SN2-(ESSEN)	4 to 6 sqm per litre
7	POLYCURE-(GREENSBORO)	NA
8	Ashford Formula-(JB)	40 sqft. to a litrere on fresh concrete floor.
9	Masterkure 106-(MBT)	
10	EUCOSIL-(STP)	5-8 sqm/litre
11	MASTER- CURE WB1 &WB2 *WB-1(clear) *WB-2(white)-(CHOKSEY)	4-6 sqm per litre/ coat
12	MASTER- CURE RB1&RB2 *RB-1-clear resin based *RB-2 -white Aluminized synthetic resin based-(CHOKSEY)	Depends on requirments within the range of 0.1-0.2 kg per sqm
14	**Shuttering Oil**	
a	**UNSPECIFIED BASE Shuttering Oil**	
1	SETRELEASE RU-(FAIRMATE)	20 to 60 sqm. per litre.
2	POLYDEE-RL-(GREENSBORO)	NA
3	Roff Shutter Release (Liquid)-(ROFFE)	300 sqft per litre
b	**LIGNOSULPHATE BASED** Shuttering Oil **(**Fair laced concrete)	
1	CICO LEASE-(CICO)	Coverage : On Steel : 25 to 60 sqm/litre. On Timber : 15 to 30 sqm/litre.
2	ASIAN MRA-(ASIAN)	30-40sqm/litre
3	POLYDEE-RL-(GREENSBORO)	NA
4	Rheofinish 202-(MBT)	Brush/Spray Applied. Coverage upto 65 sqm per litres
5	EUCOSLIP-(STP)	12-18 sqm/litre
6	MASTROL- MRA-(CHOKSEY)	30- 80 sqm/ litre.
7	MASTROL- WD-(CHOKSEY)	*Plywood- 90-110sqm *Steel 130-170sqm
15	**Floor Hardners**	
a	**EPOXY BASED FLOOR HARDNER (Excellent abrasion resistance and other mechanical properties)**	
1	**Primer :** Araldite GY-257 Aradur-840 **Mortar:** Araldite GY 257 Aradur - 840 Quartz Sand Mix **Seal Coats (2)** :Araldite GY-257 Aradur-840 -(VANTICO)	**Primer:** 100 pbw :50 pbw **Mortar:** 100pbw:50pbw:800pbw **Seal Coat:** 100pbw:50pbw Heavy duty industrial floor topping.
2	Araldite GY-257 Aradur-2963 or Aradur XY-54 Silica Flour Quartz Sand Flow Control Agen Antifoaming Agent Pigment Paste -(VANTICO)	Self levelling multilayer system with good aesthetics for Industrial flooring. Composition: 100pbw: 45pbw: 50pbw: 30pbw: 240pbw: 2pbw: 2pbw: 3pbw
3	Araldite GY-257 Aradur-2963 -(VANTICO)	Industrial surface coating with good aesthetics. Composition: 100pbw: 45pbw:
b	**ACRYLIC POLYMER** BASED FLOOR HARDNER	
1	Protekta Senfloor -(TECH)	Resistant to acid, alkali, organic solvents. Suitable for Industrial floors. Coverage: 30 sqft.per kg
2	ELASTOCRETE-(CHEMLINE)	To produce high strength polymer floor topping and thin section screeds.

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Appendix 5.1(...Contd)

Sl. No.	Proprietory Name of Product—(Abreviated Name of Manufacturer)	Manufacturer's Specific Remarks and its recommended Dosage /Coverage wherever made available
c	**LIGNOSULPHATE BASED** FLOOR HARDNER **(**It provides the hardest surface to floors and pavements**)**	
1	CICO SURFACE HARDENER-(CICO)	For heavy duty industrial floors Coverage: 2 kg per sqm for 13 mm thickness of topping . For light duty floors1.Coverage: 1.5 kg per sqm for 13mm thickness .
2	CICO FLORTOP-E-(CICO)	From moderate to heavy duty floors coverage: 2 kg per sqm to 5 kg/sqm
d	FLOOR HARDNER **WITH UNDISCLOSED BASE**	
1	SUperSCREED -P-(ENEM)	Coverage: 3.3 kg pack per bag of cement
2	POLYDEE-FT-(ENEM)	Coverage: 4-7kg/sqm
3	SURFLEX-(STP)	Coverage: 3.5kg /sqm
4	Protekta Guard-(TECH)	Coverage: 30 sqft per kg
5	Ironate-A-(ASIAN)	Coverage: 1.5-5.5kg/sqm
6	FAIRTOP -(FAIRMATE)	Coverage: sprinkling rate 5 kg per sqm. on a green concrete.
7	POLYDEE-FT-(GREENSBORO)	Coverage: 4-7kg/sqm
8	Ashford Formula-(JB)	Coverage: 40 sqft. to a litre. on fresh concrete floor.
9	Hard Top-70-(NEELAM)	Coverage: 3.5 to 9 kg/sqm.
10	Super Magnum Floor-(NEELAM)	
11	Rofflor DURA -999 (Powder)-(ROFFE)	Coverage: Lt Duty.3.5 kg/ sqm, Med Duty 5.0 kg/sqm Heavy Duty 7.0 kg / sqm
12	SHALIHARD-(STP)	Coverage: 250gm /sqm
13	TECH FLOOR HT - 200-(CHOKSEY)	TRAFFIC *HEAVY 7 kg/sqm *MEDIUM 5 kg/sqm *LOW 3 kg/sqm
16	**Water Proofing Compounds** *(*Surface coatings as well as Integral Water Proofing Compound)	
a	**EPOXY BASED** Water Proofing Coating *(*Seals pores & network of fine cracks, good bonding, withstands positive water pressure, resists chemicals aggression*)*	
1	TECHOXY-(STP)	Can be applied on damp surfaces. Coverage: 7-8 sqm./kg per coat
2	CHOKSEYS COAL TAR -EPOXY-(STP)	Resistant to UV exposure. Coverage: 4-4.5 sqm./litre per coat
3	CICO AQUAPOXY-(CICO)	Can be applied on damp surfaces. Coverage: 3 to 4 sqm per kg of mixed material per coat
4	POLYDEE-10 TAR POLYMER -(GREENSBORO)	Coverage: 0.3-0.5kg/sqm
5	OMAIPLAS EP-101-(OM)	Coverage: 4 to 6 sqm/set in 2 coats.
b	**ACRYLIC POLYMER BASED Water Proofing (Good bonding with concrete, metallic, CERAmic surfaces.,crack resistant, flexible, elastomeric, anti-carbonation, UV resistant & breathable)**	
1	RESIPOLYPROOF-(ANUVI)	Proportion: 1 : 1 ratio (OPC : RESIPOLYPROOF). 1kg OPC + 1kg Polyproof covers appx.4 sqm
2	ELASTOCRETE-(CHEMLINE)	Coverage: 1 sqm of 1mm thick- coat
3	CICO ACRYL-(CERA)	Coverage: 1 kg per 50 kg cement.
4	CICO DURAFEX OR FLEXICOAT-(CERA)	Coverage: Minimum 4.5 kg to 3 kg per sqm along with non-woven polyester fabric and 1 kg to 1.6 kg per sqm in 2 coats without polyester fabric.
5	TAPECRETE P151-(CICO)	Proportion for PMC Slurry for 1 coat : Tapecrete P 151-0.25kg ; Cement 0.5kg PMC Slurry for 2 coat Tapecrete P151- 0.4kg; Cement 0.8kg PMC Brush Topping 1.5mm thick /sqm Tapecrete P151-0.67kg; Cement - 1.3kg; Silica sand 1.3kg For PMC Filler & Mortar the mix ratio can be approx.as follows : Tapecrete P151- 1kg; Cement-2 kg; Graded sand -5.6kg
6	Aquacoat SNF-(ESSEN)	Coverage: 1 kg to 3 kg per sqm
7	Master Seal 550-(MBT)	Flexible up to 5%. Bnd strength upto 1.2 Mpa. Coverage: 1.8 kg per sqm

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Appendix 5.1*(...Contd)*

Sl. No.	Proprietory Name of Product—(Abreviated Name of Manufacturer)	Manufacturer's Specific Remarks and its recommended Dosage /Coverage wherever made available
8	BPG-700-(NEELAM)	Coverage: Depending upon the width & depth of the Sealant
9	OMAICRYL-(OM)	Coverage: 10% to 20% by weight of cement
10	OMAISEAL-703-(OM)	For cracks/joints upto 10 mm width. Coverage: 25 Rmt/kg
11	Roff Hyfex (Liquid)-(ROFFE)	Single component, highly flexible. Coverage: 5 sqft per kg
12	Roff Hyguard EX (Powder & Liquid)-(ROFFE)	Flexible. Coverage: 6 sqft per kg
13	Roff Supercrete (Liquid)-(ROFFE)	Coverage: 25 sqft per litre
14	EUCO ELASTIC PLASTER[-(STP)	Coverage: 2kg /sqm
15	POLYALK WP-(SUNANDA)	Proportion: POLYALK WP & cement in the ratio 1:1.5
16	Protekta EJR-(TECH)	Developed for expansion joints. Can withstand positive and negative hydrostatic pressure.
17	Protekta Micro Emulsion-(TECH)	Neutral, alkali stable. Coverage: 30-40 sqft

c **SBR BASED Water Proofing** (May not be suitable for locations, which are exposed or subjected to high temperatures. May degrade over long durations., Good bonding, reduces cracking, abraison resistant, water resistant, resistant to cracking , resistant to chemical attacks, improves imperviousness and tensile strength)

1	BONDCRETE-AG-(AG)	Information not supplied by firm
2	MASTER- BOND SBR-LATEX-(CHOKSEY)	Information not supplied by firm
3	POLYDEE-SG -(GREENSBORO)	Coverage: 0.3 to 0.5 kg/sqm
4	Roff Bond Repair (Liquid)-(ROFFE)	Coverage: 30 sqft per litre
5	SIKA LATEX POWER(Liquid product)-(SIKA)	Coverage: 3 kg to 6 kg per 50 kg bag of ratio SLP:W = 1:4 to 1:8 by vol.

d **FIBRES BASED** Water Proofing*(*Eliminates cracking of plaster.*)*

1	Krifib-(KRISHNA)	125 gm / bag of cement.

e **MELAMINE BASED Water Proofing (Properties are enhanced due to reduction in water demand)**

1	CICO No.1-(CICO)	Dosage: Approx. 1.5 kg per 50 kg Cement for 1:6 or leaner mortar mix; 1 kg per 50 kg Cement for 1:4 or richer mortar mix. For concretes with cement content upto 350 kg/cum., 1.5 kg/50 kg of Cement, For concretes with cement contents above 350 kg/cum. 1 kg/50 kg cement.

f **NEPTHALENE BASED Water Proofing (Properties are enhanced due to reduction in water demand)**

1	RESIKON LWP-(ANUVI)	Dosage:Coverage: 100- 300ml per 50kg cement.
2	CICO SUper-(CICO)	Dosage: 150 ml/50 kg of cement.
3	CICOPLAST-N-(CICO)	Normal dosage 500 ml/50 kg Cement. Range : 150 ml to 300 mil per 50 kg Cement.
4	Cemwet-AEA-(SIKA)	Dosage: 70-75m/bag
5	SIKA PLASTOCRETE SUper - marked with IS:9103 & conforms to IS:2645.-(SIKA)	Dosage: 0.2% by wt. Of cement i.e. 100 gm per 50 kg bag of cement.

g **LIGNOSULPHATE BASED Water Proofing (Properties are enhanced due to reduction in water demand)**

1	CICO POLYGROUT-(CICO)	As the volume to be sealed is not known the consumption is not predictable. However, about 25% of the volume to be sealed is the required consumption of POLYGROUT.
2	Conflow SNW1-(ESSEN)	0.10 to 0.20 litres per 50 kg cement
3	FAIRCRETE RMW-(FAIRMATE)	Dosage: 100 ml to 250ml per 50 kg bag of cement. Ideal Dose: 150 ml per 50 kg bag of cement.
4	Thioflex 600-(FOSROC)	

h **WITH UNDISCLOSED BASE** Water Proofing Advantages/disadvantages cannot be generalised in absence of the base material of the products.

1	SUperSCREED -P-(ENEM)	Dosage: 3.3 kg pack per bag of cement
2	FAIRPLAST IP-(FAIRMATE)	Dosage: 200 gm. per 50 kg bag of cement
3	SUper-SIL-(NATIONAL)	Dosage: One kg covers 35-40 square feet. On primer coat of white cement

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Appendix 5.1 *(...Contd)*

Sl. No.	Proprietory Name of Product—(Abreviated Name of Manufacturer)	Manufacturer's Specific Remarks and its recommended Dosage /Coverage wherever made available
4	B.Guard-(NEELAM)	Dosage: 2-2.5 sqmt./kg
5	Stanro IW-4-(NEELAM)	Dosage: 0.2% of cement wt.
6	OMAIPLAS 801-(OM)	Dosage: 5% to 20% weight of cement
7	Pidiproof LW-(PIDILITE)	Dosage: 200ml per bag of cement
8	Roff Hyproof (Liquid)-(ROFFE)	Dosage: 140 ml per 50 kg bag of cement
9	NOLEEK POWER - marked with IS:2645-(SIKA)	Dosage: 1% by wt. of cement, i.e.500 gm per 50 kg bag of cement.
10	SIKA DAMPROF (Liquid product)-(SIKA)	Dosage: 50 ml. to 100 ml (Diluted version, dilution ratio = SD:Water=1:10 by vol.) per hole.
11	Protekta -SP2-(TECH)	Dosage: 200 gm per bag of cement
12	Protekta -G-(TECH)	Dosage: 30-40 sqft
13	Cemwet-WPCC-(ASIAN)	Dosage: 150gm/bag of cement
14	TECH-REPEL- WB-(CHOKSEY)	Dosage: Dilute 1 litre.with 20 litre.water. *1000 sqft./litre. per 21 litre. Diluted per coat.
15	TECH- FORCE-(CHOKSEY)	Dosage: 1-1.5 sqm./kg per coat withstandsnegative w.p. upto 1 kg/csqm, use 1-3 coats
16	POLYMOD -AP-(CHOKSEY)	Dosage: 1.1-1.5 sq mtr.of memb-rane will cover 1 sqmtr. Area
17	Aquarepel SN1-(ESSEN)	Dosage: 8-10 sqm per litrere
18	POLYDEE-10 TAR POLYMER -(GREENSBORO)	Dosage: 0.3-0.5kg/sqm
19	Sifumex 100 D-(KRISHNA)	Dosage: 1% to 2% by weight of cement.
20	Rheomac 707-(MBT)	Dosage: 0.32% v/w of cement
21	Aquaep-(NEELAM)	—
22	Multiseal-(NEELAM)	Dosage: Depending upon the width & depth of the Sealant
23	OMAIPLAS-AB-(OM)	Dosage: 1sqm per kg in 2 coats
24	Roff AEA - 310 (Liquid)-(ROFFE)	120- 280 ml per 50 kg bag of cement
25	POLYDEE-AEA-(GREENSBORO)	1 to 2%

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17 **Air Entraining Agents** (Increases frost resistance, resistant to de-icing of salts, improves workabilitrey and durabilitrey.)

1	Roff AEA-310 (Liquid) (ROFFE)	Dosage: 120-280 ml per 50 kg bag of cement
2	Cemwet-AEA-(ASIAN)	Nepthalene based. Dosage: 70-75 m/bag
3	POLYDEE-AEA-(GREENSBORO)	Dosage: 1 TO 2%

18 **Anti Carbonation Protective Coating on Concrete**

a **EPOXY BASED** (Likely to be adversely affected at high temperatures as well as under UV exposure. High adhesive , excellent dimensional stabilitrey, abilitrey to cure dry conditions, good chemical resistance, excellent mechanical properties.)

1	EPOBOND-AG-(AG)	Adhesion under dry and wet condition. Coverage : 0.200 to 0.300 kg per sqm
2	CICO POLYCOTE-(CICO)	Resilient and flexible membrane. Coverage : 3 to 4 sqm per kg Of mixed material which should be used within 30 minutes after mixing. The coverage depends on the surface textgure of the surface of application.
3	CICO POLYCOTE 1100-(CICO)	No priming, single coat application. For all type of exposed, buried or immersed concrete and Steel surfaces. Coverage : 2 to 6 sqm per kg of mixed material.
4	CICO POXY NS-(CICO)	Applied on dry & cleaned surface over a zinc rich primer coat-ing.. Coverage : 3-5 sqm/kg Depending on the surface texture.
5	Quickmast 405-(DON)	Tar extended epoxy coating. Coverage : 1 kg covers 1.6 to 2 sqm for 2 coats
6	Quickmast 173-(DON)	Epoxy primer. Coverage: 4 to 6 sqm per Lt for 2 coats
7	SAFECORE EP (F)-(FAIRMATE)	High build solvent epoxy coating over Quickmast 173 primer. Coverage : 12- 14 sqm.per 5 kg Pack per two coats.

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Appendix 5.1(...Contd)

Sl. No.	Proprietory Name of Product—(Abreviated Name of Manufacturer)	Manufacturer's Specific Remarks and its recommended Dosage /Coverage wherever made available
8	Waterseal-(KRISHNA)	Foodgrade non-toxic coating for water tanks/treatment plants. Coverage: 5-6 sqm./litre
9	Roff Tuff Coat (Liquid)-(ROFFE)	Coverage : 40 sqft per kg
10	SHALIPOXY PB-(STP)	Coverage : 4 sqm/kg
11	SHALIPOXY CTE-(STP)	Coverage : 5sqm /kg
12	System-I: Araldite GY-250 Aradur-830 Aradur-850-(VANTICO)	Proportion: 100pbw:45pbw:15pbw
13	System-I I: Araldite GY-250 Aradur-2969 -(VANTICO)	Proportion: 100pbw: 60pbw
14	System-I I I Araldite GY-257 Aradur-840 -(VANTICO)	Proportion: 100pbw: 50pbw
15	System-IV Araldite GY-255 Aradur-45 -(VANTICO)	Water impermeable coating/ Coaltar epoxy. Proportion: 100pbw: 100pbw

b **ACRYLIC POLYMER BASED Anti Carbonation Coating** (Likely to be adversely affected at high temperatures. Used as an admixture by weight of cement. Very good adhesive , excellent dimensional stabilitrey, good chemical resistance, protects against corrosion, allows surface to breath).

1	RESIKON 400-(ANUVI)	Coverage : 1 : 1 ratio (OPC : RESIKON 400)
2	ACRYCRETE-AG-(AG)	Coverage : 4.25 sqm./23kg /3mm THICK
3	CERA Infraguard-S-(CERA)	Coverage : 4-5 sqm/kg
4	FUTURA- 5-(CHOKSEY)	Coverage : 8-9 sqm. per litreer/coat
5	CICO SEALOCOTE-(CICO)	Coverage: 4 to 5 sqm per kg In two coats depending on surface texture.
6	TAPECRETE MARINE COATING-(CICO)	One cubic meter of Marine Coating required the following : Marine coating :446 kg —Portland cement: 858 kg— Fine Silica sand:858 kg For a 2mm thickness of coating the requirement will be about 4 kg of the three component of Marine Coating/ per sqmr. The generally applicable thickness ranges from 0.8 to 10mm. The corresponding requirement can be worked out from the 2mm thickness value.
7	Repcoat-(DON)	Coverage: 3.5 to 4sqm per kg for 2 coats
8	WATERGUARD -(FAIRMATE)	Coverage: 16.5 sqm. to 25 sqm.
9	Monopol 456-(KRISHNA)	Coverage: 4.0 sqm - 6.0 sqm./ litre / coat.
10	Master Seal 550-(MBT)	Two component. No site mixing. Flexible upto 5%. Coverage: 1.8 kg per sqm
11	Master seal 300H-(MBT)	Flexible. Can bridge crack up to 5 mm. Coverage: 1 to 1.6 litrere per sqm.
12	OMAICRYL-(OM)	Coverage: 3sqm/kg/3coats.
13	ICOSIT ELASTIC (I)-(SIKA)	Coverage: 250g/sqm/coat.
14	Protekta Flexstone Coat-(TECH)	Water clear transparent. Coverage: 10-15 sqft. depents on the surface

c **SBR BASED Anti Carbonation Coating** (May not be suitable for locations, which are exposed or subjected to high temperatures. May degrade over long durations.Improves bonding with hardened concrete,reduces cracking , abraison resistant).

1	BONDCRETE-AG-(AG)	
2	Rheomix 141-(MBT)	5-7 kg per bag of cement

d **LIGNOSULPHATE BASED** (Arrests dust / din accumulation, preserve natural colour, hydrophobic,provides excellent barrier to carbondioxide chlorides, sulphates and water inside.i) Highly resistant to UV rays and long term weathering.).

1	CICO PEL-W OR SIPEL-(CICO)	6 to 10 sqm per litre, depending on porsity of the sub-stratam.
2	Dekguard S & Dekguard Primer-(FOSROC)	3 sqm/litre
3	BPG-600 -(NEELAM)	200-400 gm./sqm.

e **Protective coating on concrete WITH UNDISCLOSED BASE** (Advantages/disadvantages cannot be generalised in absence of the base material of the products)

1	POLYDEE-ADG-(GREENSBORO)	Coverage: 0.3-0.5kg/sqm

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Appendix 5.1 *(...Contd)*

Sl. No.	Proprietory Name of Product—(Abreviated Name of Manufacturer)	Manufacturer's Specific Remarks and its recommended Dosage /Coverage wherever made available
2	Bondfit-8000-(NEELAM)	Coverage: 1.2 to 2 sqm./kg/coat
3	TECH-REPEL- WB-(CHOKSEY)	Coverage: Dilute 1 litre.with 20 litre.water. *1000 sqft./litre. per 21 litre. Diluted per coat.
4	POLYDEE-ADG-(GREENSBORO)	Coverage: 0.3-0.5kg/sqm
5	SIlitreEX (Colourless liquid Repellent)-(GREENSBORO)	Coverage: 200 to 300 gm/sqm only one coat can be applied.
6	OMAIPLAS-AB-(OM)	Coverage: 1 sqm per kg in 2 coats
7	OMAICRYL + OMSIPLAS AB-(OM)	

19 Protective coat on Steel

a **EPOXY BASED Protective coat on Steel (Non-resistant to UV radiation, exposed locations and high temperatures. Protects Steel against corrosion. Zinc rich primer to avoid corrosion. Anti-corrosive, chemical resistant, W/P, good bonding)**

1	AMCOR PR-(ANUVI)	Should be covered with mortar, concrete or paint for durabilitrey. Coverage: 16-18 sqm per kg
2	EPOBOND-AG-(AG)	Good for dry and wet conditions. Coverage: 0.200 to 0.300 kg per sq m
3	CERA Zinc ZR (CERA)	Zinc rich primer. Coverage: 4-5 sqm/kg
4	CICO POXY FC (CICO)	Applied in dry condition after surface cleaning. Coverage 6-8 sqm/kg Depends on sub-strate
5	Quickmast 405-(DON)	High build tar extended coating. Coverage: 1 kg covers 1.6 to 2 sqm for 2 coats
6	Quickmast 471-(DON)	High build solvent epoxy coating.needs Quickmast173 primer. Coverage: 1 kg covers 1.6 to 2 sqm for 2 coats
7	Procoat SNZ-(ESSEN)	Good for marine environment. Coverage: 6 - 10 sqm per litre
8	SAFECORE EP (S)-(FAIRMATE)	Coverage: 12 - 14 sqm. per 5 kg Pack per two coats DFT: 175 microns.
9	Corroseal ZR - (KRISHNA)	Coverage: 3 - 5 sqm / litre on level surface.
10	MC DUR ZKE-(MC)	Coverage: Approx. 100-300 gm/sqm
11	MC DUR ZKE-(MC)	Approx. 100-300 gm/sqm
12	Roff Pitch Coat (Liquid) (ROFFE)	Coverage: 20 sqft per litre
13	SHALIPOXY PB-(STP)	Coverage: 4 sqm/kg
14	SHALIPOXY CTE-(STP)	Coverage: 5sqm /kg

b **ACRYLIC POLYMER BASED Protecting coat on Steel** (Likely to be adversely affected at high temperatures. Used as an admixture by weight of cement. Seals the surface against humidity, carbonation & corrosive atmosphere Excellent breathabilitrey Fills pores, honeycombs and voids to give uniform surface)

1	ACRYCRETE-AG- (AG)	Coverage: 4.25 sqm./23kg /3mm THICK
2	FLEXCRETE-AG -(AG)	Coverage: 2.5 TO 3.0kg/ sqm/1.5 TO 2 mm
3	TAPECRETE MARINE COATING- (CICO)	One cubic meter of Marine Coating required the following : Marine coating :446 kg Portland cement: 858 kg Fine Silica sand:858 kg For a 2mm thickness of coating the requirement will be about 4 kg of the three component of Marine Coating/ per sqmr. The generally applicable thickness ranges from 0.8 to 10mm. The corresponding requirement can be worked out from the 2mm thickness value.

c **WITH UNDISCLOSED BASE Protective coat on Steel** (Advantages/disadvantages cannot be generalised in absence of the base material of the products)

1	POLYDEE -RC -(GREENSBORO)	Coverage: 80 to 150 ml/sqm
2	SUPER-SIL - (NATIONAL)	Coverage: One kg covers 35-40 square feet. On primer coat of white cement
3	NICON-(NATIONAL)	Coverage: One kg covers 250 square feet.
4	Cinter Flux-20(NEELAM)	Coverage: 0.5 kg/sqm./coat
5	DERUSTER-(OM)	Coverage: 10 sqm/kg/coat.

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Appendix 5.1 *(...Contd)*

Sl. No.	Proprietory Name of Product—(Abreviated Name of Manufacturer)	Manufacturer's Specific Remarks and its recommended Dosage /Coverage wherever made available
6	OMAISOL-(OM)	Coverage: 10 sqm/kg/coat.
7	OMAI ANTI-CORR-(OM)	Coverage: 8 sqm/kg
8	NR-900-(ASIAN)	Coverage: 10kg/cum of conc.
9	POLYDEE-10 TAR POLYMER-(GREENSBORO)	Coverage: 0.3-0.5kg/sqm

20 Acid Resistane Enhancer

a **EPOXY BASED Acid Resistane Enhancer** (Acid resistant coating for concrete and Steel (Non-resistant to UV radiation)*Excellent bonding and adhesion under dry and wet conditions both. Outstanding chemical resistance such as sulphuric acid, methyl, ethyl, ketones and methanol etc.)

1	EPOBOND-AG-(AG)	0.200 to 0.300 kg per sq m
2	TECH FLOOR SL - 2-(CHOKSEY)	0.25 -0.30 sqmr./kg mix with 2 mm.thickness
3	Quickmast 401-(DON)	1 kg covers 1.4 to 1.8 sqm. for 2 coats
4	Quickmast 402AR-(DON)	1 kg covers 1.4 to 1.8 sqm. for 2 coats
5	SAFECORE UlitreACOAT-(FAIRMATE)	9 -10 sqm. per 5 kg pack for two coats.DFT:400-500 microns
6	Nitomortar S-(FOSROC)	8 litre yield per 16 kg pack
7	Top Cinter-48 Epoxy-(NEELAM)	200 gm./sqm./coat
8	Roff Tuff Coat-HD (Liquid)-(ROFFE)	20 sqft per litre
9	SHALIPOXY FC-(STP)	250gm /sqm
10	SHALIPOXY ARC-(STP)	4 sqm/kg

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b **WITH UNDISCLOSED BASE Acid Resistane Enhancer** (Anti corrosive,100 % Inorganicpaint,non fading,insulating property,permits breathing,anti fungus and algae. reflects Infrared and Ulitreaviolet rays, water proofing characteristics)

1	POLYDEE-ADG-(GREENSBORO)	0.3-0.5kg/sqm
2	SUPER-SIL-(NATIONAL)	One kg covers 35-40 square feet. On primer coat of white cement
3	EUCON CIA-(STP)	1.6% bwoc
4	Accidet-X-(ASIAN)	16 litre liquid in50kg powder
5	POLYDEE-ADG-(GREENSBORO)	0.3-0.5kg/sqm

21 Anchoring

a **EPOXY BASED Anchoring**

1	CICO POXY EW-N-(CICO)	Density : 1.10 kg/litre. Consumption rate depends on the internal condition of the structure.
2	CICO POXY EW 1000-(CICO)	Depends upon the area to be sealed.
3	CICO RESIFIX-(CICO)	The number of capsules to be used is dependent on the pull out force. The capsules are manufactured in wide range of diameter between 25 to 40 mm and in 3 different lengths. The borehole diameter is about 8mm bigger than the anchor bolt diameter. In general, for 12 t pullout force, 3x30mm dia x 300mm length capsules are sufficient.
4	GROUTFAST-(GREENSBORO)	1950 kg/cum.
5	E 3 G-(STP)	—
6	Lokset L / S / P-(FOSROC)	Yield per 5 kg pack is 2.5 litres
7	CICO GROUT GP-(CICO)	Yield : 1800-2000 kg of dry powder grout mix per cum. of grout depending on flowabilitrey requirement and gap.
8	CICO FAST/ NORMAL SETTING HIGH STRENGTH CEMENT CAPSULES-(CICO)	The capsules are manufactured in variable length and diameter depending on customer's demand. The number of capsules to be used depends on the length of embeddment of the the anchor bolts which in turn depends on the design pull out force. The diameter of the bore hole is about 10-12 mm more than the diameter of anchor bolitre
9	ANCHORGROUT-(FAIRMATE)	
10	Rockset-(ASIAN)	32mmX300mm length
11	Roff Grout -GP (Powder)-(ROFFE)	0.028 m3 per 50 kf bag of cement

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Appendix 5.2

List of Material Manufacturers / Suppliers & their Addresses

Sl No.	Abreviated Name	Name of Manufacturer/ Dealer	City	PIN	Phone No.	Fax No.
1	AG	A.G. Devlopers Private Limited, B-283, 1st Floor, Saraswati Vihar, Delhi-110034, Emai: agechem@mantraonline.com	NEW DELHI	110034	7014140, 7022213	7028293
2	ANUVI	Anuvi Chemical Private Ltd.G-212, Godavari, Iind Floor, Laxmi Industrial Premises, Pokharan Road No. 1, Vartak Nagar, Tane-406606, maharastra, India	THANE	406606	022-5392219(O)	022-5392461
3	ASIAN	Asian Laboratories India, 88, New Okhla Indl. Complex, Scheme 1,DSIDC shed, Phase II,New Delhi email: asianlab@mantraonline.com	NEW DELHI	110020	6918093, 6836392	6316063
4	CERA	Cera-Chemical Pvt. Ltd., 71-C New Avadi Road, Kilpauk, Chennai-2 e-mail:cerachem@vsnl.com, web:www.cerachemindia.com	CHENNAI	600002	6453498, 6441013	044-6446104
5	CHEMLINE	Chemline India Limited. (Construction Chemical Divn.) F-1, Sarda chamber-ICentral Market, Prashant Vihar Rohini, DELHI - 110 085 (INDIA) e-mail:chemline@nda.vsnl.net.in	NEW DELHI	110085	11-7864419/20, 7566965, 7871304	011-7566966, 7862992
6	CHOKSEY	Choksey Chemical Pvt.Ltd., 111-Industrial Area, Sion, Mumbai-400022. Email-contact@chokseychem.com http//www.chockseychem.com.	MUMBAI	400022	4090124, 4040127, 4090325	22-4072949
7	CICO	CICO Technologies Limited, A- 9 Chitranjan Park (LGF), Outer Ring Road, New Delhi-110019, Email: cicodel@nda.vsnl.net.in, Web site: www.cicogroup.com	NEW DELHI	110019	6420544, 6235335	6221055, 6489365
8	DON	Don Construction Chemical India Ltd., No. 4, II Block Chowdhary Complex, 5th Street, Nandanam Extension, Chennai-600035. Email dccil@ vsnl.com , utechindia @epatra.com	CHENNAI	600035	4331817, 4335345	044-4338272
9	ENEM	Enem Polymers, 8, Sanket Colony, Vedant Nagari, Karvenagar, Pune email - enem@bom3.vsnl.net.in	PUNE	411 052	020-5461501	020-5431189
10	ESSEN	Essen SUPPLEMENTS India Ltd, Plot No. 35, Samrat Colony, West Marredpally, Secunderabad-26.	SECUND-RABAD	500026	040-7700300,	7808889
11	FAIRMATE	FAIRMATE Chemical Pvt Limited, 8/1, SAI Sudha, Arunoday Society, Alkapuri, Vadodra-390007, Email: faimate@lwbdg.lwbbs.net, Web Site: www.faimate.com	VADODRA	390007	0265-331193, 330803	0265-338733
12	FOSROC	Fosroc Chemicals (India) Limited , Hafeeza Chambers, II floor, 111/74,K.H.Road, Banglore-560027 e mail: fosroc@fosrocindia.com Web site: www.fosrocindia.com	BANGLORE	560027	(080) 2225495, 2240018, 2240120	(080) 2233474
13	GREENBORO	Greensboro Polychem Private Ltd. 199, Defence Colony Flyover Market, New Delhi-110024, email:greensboro@vsnl.com, info@buildingclinic.com Website www.123polydee.com www.buildingclinic.com	NEW DELHI	110024	4329335, 4316209, 4319123	11-4319123

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Appendix 5.2 *(...Contd)*

Sl No.	Abreviated Name	Name of Manufacturer/ Dealer	City	PIN	Phone No.	Fax No.
14	JB	J. B. Associates, Construction Chemical Company, 135 Arjun nagr, Kotla Muarakpur, Opp. Defence Colony, New Delhi-110003, email: ashfordformula@vsnl.net.in, web site:www.ashfordformula.com	NEW DELHI	110003	4625997, 4632541	4618346
15	KRISHNA	Krishna Conchem Products Pvt. Ltd. 1 & 2, Bldg No.6, Sector No.3, M.B.P Mahape, Navi Mumbai. email: kcppl@vsnl.com, Web site: www.krishnaconchem.com	MUMBAI	400 705	022-772923/24	022-7782808
16	MBT	MBT India, 704, Krishna Govinda Towers, Sector-4, Sanpada, Navi Mumbai, 400703, email: enquire@mbt-india.com, Web: www.mbt-india.com , Master Builders technology (MBT) India Pvt. Ltd, 1403, Vikram tower, 14th Floor, 16 Rajendra Place, New Delhi-110008 email mbt@mantaonline.com	MUMBAI	400703	022-619992/3, 011-5819390, 5825540	022-7619242, 011-5819391
17	MC	MC. Bauchemi (India) Pvt.Ltd., 201, Vardhaman Chambers Sectors-17, Vashi, Navi Mumbai-400703, Email mcbindia@vsnl.net.in, www.mc-bauchemieindia.com	MUMBAI	400703	7893867, 7895231, 7842827, 7893876.	7845265, 7843870.
18	NATIONAL	National Industries Company, 432, Naigaun Cross road, I st Floor, Wadala, Mumbai-email: des@vsnl.com	MUMBAI	400031	022-4121176	022-4148196
19	OM	Om Agro industrial Plastics Pvt.Ltd. OM AGRO INDUSTRIAL PLASTICS PVT.LTD., 6, Sarvodaya Industrial Estate, Mahakali Caves Road, Andheri (East), MUMBAI - 400 093. E-mail : omagro@bom5.vsnl.net.in E-mail : omagro@vsnl.com	MUMBAI	400093	820 28 75 820 85 41, 823 00 31	91-22-422 94 82
20	PIDILITE	Pidilite Industries Ltd, Ramakrishna Mandir Road, PB No. 17411, Andheri East, Mumbai-59, Web sitewww.pidilite.com E mail pnad@pidilite.com	MUMBAI	400059	8357560, 8357534, 8357527	
21	ROFFE	Roffe Construction Chemical Pvt.Ltd., 45/A, Mittal Tower, Nariman Point, Mumbai-400021 Email-roffe@roffe-in.com www.roffe-in.com.	MUMBAI	400021	022-2040264, 6132434,	022-2042254, 6116057
22	SIKA	Sika Qualcrete Ltd, 620, Diamond Harbour Road, Commercial Complex-II, Kolkata-700034, (An ISO 9001 Company) Email sika.cal@gncal.global.net.in Web site: www.sikaqualcrete.com	KOLKATA	700034	4466594 4466958, 4472448	033-468-8688/ 2665
23	STP	STP Limited, (speciality Chemicals & Additive Division, 16, NGN Vaidya Marg (Bank Street), Fort mumbai-400023 email: mumbai@bom.stp.co.in, www.stpltd.comSTP Limited, Plot No.M6-M9, Cuncolim Indl.Estate, Cuncolim, Salcete, Goa-403 703, Ph 403703	MUMBAI	400023	022-2664643/ 2313/1407	022-2663599
24	SUNANDA	Sunanda Speciality Coating Pvt Limited, 2, Anik Court Pandurang Naik Marg , Mahim, Mumbai-16 Email: sscpl1@bom5.vsnl.net.in, Web site: www.sunandchemcals.com	MUMBAI	400016	022-4464870, 4459251	022-4456050

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Appendix 5.2 *(...Contd)*

Sl No.	Abreviated Name	Name of Manufacturer/ Dealer	City	PIN	Phone No.	Fax No.
25	TECH	Tech-Dry (India) Private limited, 769, Ground Floor, Ist Cross, 1st Stage, Indiranagar, Bangalore-560038, Email Surendra@blr.vsnl.net.in	BANGLORE	560038	5255406, 5255294	5289159
26	VANTICO	Vantico Performance Polymer Pvt. Ltd. Off Aarey Road, Goregaon (E), Mumbai-400063. Ph: 022-8403221 , 307 , Padma Tower-II, Rajendra Place, New Delhi-110008.	MUMBAI	400063	022-8403221	011-5734745
27	NEELAM	Neelam Building Protection System Ltd., SCO 861, Chandigarh-Kalka Road, Manimajra (Chandigarh)-, Tel Fax: E-mail: nbps_ltd@yahoo.com,Contact person :	Chandigarh	160101 734469,	0172-	734301

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Appendix 5.3

List of Material Testing Laboratories

1 National Chemical Laboratory, Poona
2 National Test House, Alipore, Kolkata
3 National Test House, Chennai
4 Central Building Research Institute (CBRI), Roorkee, U.P.
5 Nation Council of Cement and Building Materials, 34 Km Mathura Road, Ballabhgarh, Faridabad, Harayana
6 Central Soil and Material Research Station (CSMRS), Hauzkhas, New Delhi
7 Structural Engineering Research Centre, P.O. Taramani, CSIR Campus, Chennai
8 Indian Institute of Chemical Technology, Hydrabad
9 Indian Istitute of Technology, Guwahati
10 Indian Istitute of Technology, New Delhi
11 Indian Istitute of Technology, Roorkee
12 Indian Istitute of Technology, Kharagpur
13 Indian Istitute of Technology, Mumbai
14 Indian Istitute of Technology, Chennai
15 Indian Istitute of Technology, kanpur
16 Indian Istitute of Technology, Varanasi
17 Shri Ram Institute of Industrial Research(Pvt) , 19, University Road, Delhi-110007,E-mail: delhi. Srifir@axcess.net.in Web Site: Sridhhi@nda.vsnl.net.in
18 Structural Designers & Consultants Pvt.Ltd. 1008/9, 10th Floor, Raheja centre, Nariman Point, Mumbai-400021. Tel: 2833506 (5lines) Fax: 91-22-287 59 85 Gram:STRUCTWEL E-Mail: structwl@bom3.vsnl.net.in Web:http://www.structwel, com.
19 AIMIL LTD (pvt), Mathura Road, New Delhi. Ph:6950012; 6950001-09, Fax: 6950011

CHAPTER 6

REHABILITATION AND RETROFITTING METHODS

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REHABILITATION AND RETROFITTING METHODS

Concepts are extremely useful... but concepts change and change very fast. What remains are the facts, the experimental facts.

..Imre Lakatos

6.1 General:

The decision to repair or replace a structure or its component can be taken only after consideration of likely service life of the structure is established based on the technical & economic evaluations. Once a decision, based on preliminary investigations, is taken to carry out the repairs, proper diagnosis, identification & extent of distress in structural members has to be correctly assessed. A detailed methodology should be developed, which should include available

- Methods of repair &
- Repair materials

Thus, a repair strategy can be adopted, keeping the objective in view. This shall be based on evaluation and available alternative methods of repair & material. Priority should be assigned to

- Repair of structural defects to ensure safety of the structure and
- Protection of the structure from further deterioration.

The selected method of repair should achieve one or more of the following objectives:

- Reinstate the structural integrity of the member by restoring or increasing its strength & stiffness.
- Prevent the ingress of distress promoting agents such as moisture, chlorides and carbon dioxide to improve durability.
- Maintaining the aesthetics/appearance of concrete surface.

6.2 Repair Options:

Depending upon the specific condition of deteriorated structure, the option of the repair methods could be one or more of the following:

- Grouting & crack repair
- Patch Repair
- Replacement of structurally weak concrete
- Replacement of spalled, and/or delaminated concrete
- Replacement of carbonated concrete surrounding steel reinforcement
- Cleaning and passivating the corroded steel reinforcement
- Concrete overlays with normal, low or highly fluid concrete, latex modified concrete & corrosion protection such as jacketing etc.

- Re-alkalisation of carbonated concrete.
- Electro-chemical removal of chloride from concrete
- Water proofing and/or protective coating.

6.3 Performance Requirements of Repair Systems

- Strength, Serviceability and Durability
- Protection of steel
- Bond with parent surfaxce
- Dimensional stability
- Resistance to environmentally induced damage.
- Ease of application
- Appearance

6.4 Important factors to be considered for selection of repair methods:

- Type and extent of distress
- Location of distress
- Environmental exposure
- Availability of skill
- Availability of time and access for repairs.
- Appearance
- Cost

6.5 Repair Stages

- Concrete Removal and Surface Preparation
- Fixing suitable formwork
- Bonding / passivating coat and repair application

6.5.1 Concrete Removal and Surface preparation

The general procedure for marking area to prepare the surface of spalled area for carrying out repairs is illustrated in Fig 6.1.

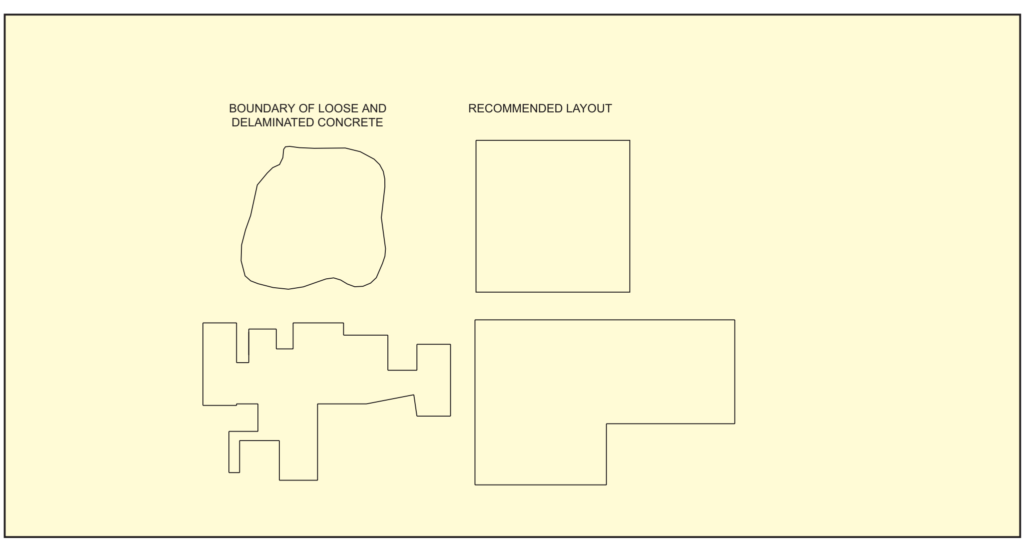


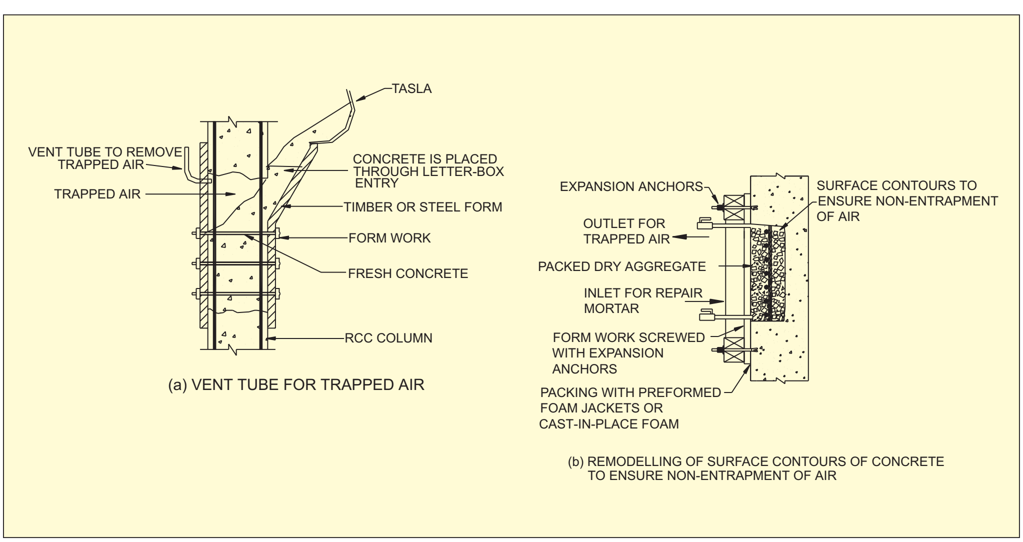
Fig 6.1 Recommended Layout of Surface Repairs

Prior to preparation of concrete surfaces, exposed reinforcement should be inspected for access clearance, cross-sectional area and location. Reinforcing bars must be further exposed if the remaining concrete is de-bonded from the reinforcing steel. Removal must be continued to completely expose the bar if more than half of a reinforcing bar perimeter has been exposed. For completely exposed reinforcing bars, a minimum average clearance of 25 mm or nominal maximum size of aggregate plus 5mm, whichever is greater, must be provided between the reinforcing bar and surrounding concrete. A structural engineer should be consulted if the cross-sectional area of an individual bar has been reduced by 15 percent or more or if two adjacent bars have been reduced by 10 percent or more. Out-of-plane and loose reinforcement should be secured in its design location.

The process of Surface preparation is illustrated stepwise (Step 1 to 3) in Fig 6.16. The general procedure in preparing concrete and reinforcement surfaces for optimum bonding is to sandblast the surfaces and then remove dust and debris by air blasting, low-pressure water blasting, or brooming. If the damage is due to corrosion, a suitable coating may be considered after removal of total rust from its surface to protect the exposed reinforcing steel. Final inspection of the prepared area including remedying any deficiencies should be completed just prior to batching the repair material.

6.5.2 Form work

If repairs are required on vertical or overhead surfaces and if the repair material is likely to sag, formwork will be required. Prior to installing forms, the concrete surface must be inspected for any surface contours that could result in air being trapped during concrete placement or pumping. If air is likely to get trapped, concrete must be removed to change the contour, or vent tubes must be installed. Formwork should be secured to the concrete with expansion anchors of standard makes etc. Installed form anchors should be pre-tested for slippage. Preformed foam gaskets or cast-in-place foam may be required to provide a watertight seal between the concrete and form surfaces (Fig 6.2).



(a) VENT TUBE FOR TRAPPED AIR

(b) REMODELLING OF SURFACE CONTOURS OF CONCRETE TO ENSURE NON-ENTRAPMENT OF AIR

Fig 6.2 Form Work

6.5.3 Apply Bonding Coat and Repair Application:

These shall be carried out as per the repair method/system selected based on engineering judgment considering various options available as under:

- Filling of cracks with cement and/or resin based grout
- Injecting grout into a mass of dry aggregate.
- Poured concrete
- Pre-packed concrete
- Dry packing
- Sprayed concrete (shotcrete), etc

Repair and Strengthening Methods/Systems be in three groups

- Materials
- Methods
- Systems

The repair materials have been separately dealt in Chapter-5. Repair methods and repair systems are described herein below:

6.6 Repair Methods:

The various repair methods are available for carrying out the structural repairs to a distressed structure. The basic methods, which could be used singly or in combination of more than one are briefly described in the following subsections. For detailed specifications and stepwise sequence of operations, Chapters 8 and 9 and relevant references given at the end of this chapter could be referred.:

6.6.1 Repairs using Mortars:

Mortar repairs are the most common form of repairs being resorted to in the field without knowing the limitations of such repairs in structural rehabilitation/strengthening. A variety of mortars are available for carrying out repairs of a structure, these are explained with their limitations and areas of application in the following subsections:

6.6.1.1 Portland Cement Mortars: Structural repairs with Portland cement mortar shall be made only if specifically approved by the Engineer-in-charge. Approval for hand-applied cement mortar repairs will be given only for very small repair areas, not associated with critical performance of the structure. When approved, Portland cement mortar may be used for repairing defects on exposed, new concrete surfaces only. Such repairs are applied only if the defects are small and are too wide for dry pack and too shallow for concrete replacement and only if the repairs can be completed within 24 hours of removing the forms. Portland cement mortar shall not be used for repairs to old or existing concrete or for repairs that extend to or below the first layer of reinforcing steel.

Portland cement Mortar shall consist of Ordinary Portland Cement Grade 43, clean water and clean graded sand. The proportion of Portland cement and sand shall preferably be in the same proportion as used in preparation of parent concrete. All materials of mortar mixtures and their application techniques shall be in accordance with relevant specifications.

6.6.1.2 Polymer Modified Cement Mortars are used for repairs on old hardened concrete for repairing defects on exposed concrete surface only. For larger repair areas with thickness in excess of 50 mm, concrete, as repair material, is a better option. For thicker applications, over larger areas, it is desirable to use appropriate reinforcing mesh fixed with U-nails. These shall use Polymers admixed in specified proportions, based on selection criterion given in Chapter 5. Other materials shall be same as in Portland Cement Mortars stated above. However, these shall follow the given relevant specifications, if specified.

6.6.1.3 Epoxy Mortars: These mortars consist of resin, hardener and silica sand and are applied over an epoxy bonding coat over old hardened concrete surface.. These mortars attain strength in few hours. These mortars have very high strength and are abrasion resistant, water resistant and can be used in few millimeter thickness overlays. These are used for repairs at locations where

- It is difficult to use epoxy bonded concrete,
- Depth of repair is less than 40 mm or
- Repair areas are small (less than 0.1 sqm) and few in number.

When depth of repair exceeds 15 mm but is less than 40 mm, the build up of patch repair over large areas shall be in layers using appropriate reinforcing mesh fixed with U-nails or shear keys.

6.6.2 Dry Pack and Epoxy Bonded Dry Pack:

The Dry Pack Repair technique is application of dry cement sand mix . It consists of cement and clean sand (in proportion 1:2.5) with just enough water to be able to form a ball by hand. It is immediately packed into place before the bond coat has dried or cured, with suitably shaped hardwood dowel and hammer in 8 to 10 mm thick layers **(**Refer Fig 6.3).

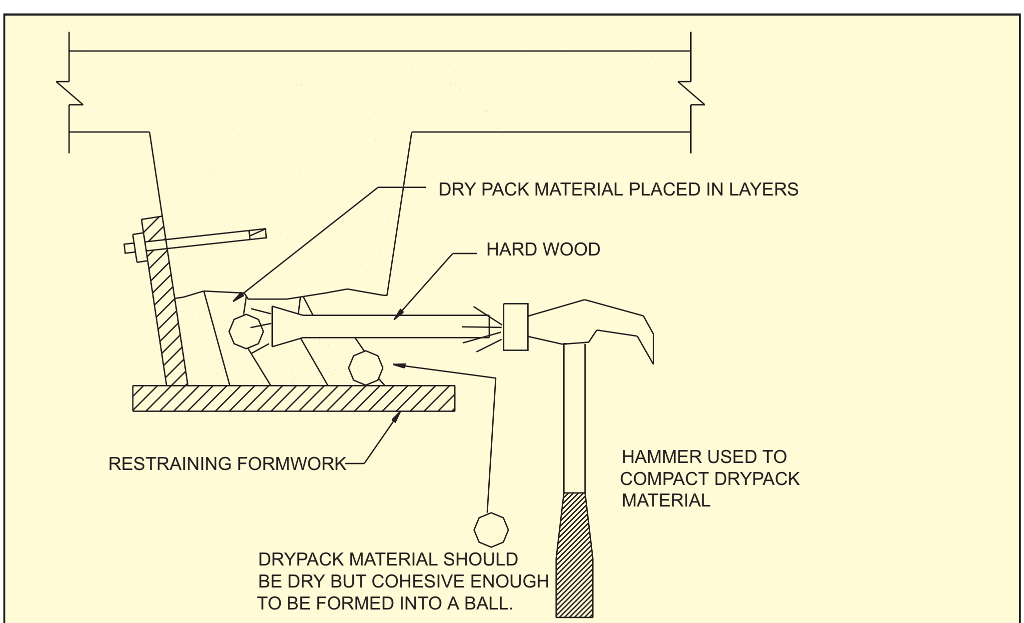


Fig 6.3 Dry Packing

If the epoxy is used as bonding material between the repair material and the substrate, the method is termed as Epoxy Bonded Dry Pack. Its application shall be limited to areas that are small in width and relatively deep but not less than 25 mm in depth.. The application areas include core holes, holes left by removal of form-ties, cone-bolts, she bolt holes, narrow slits for critical repairs or for repairs expected to be exposed to severe service conditions. Dry pack shall neither be used for shallow depressions where lateral restraint cannot be obtained nor for filling behind steel reinforcement.

6.6.3 Pre-Placed Aggregate Concrete (PAC):

Pre-placed aggregate concrete (PAC) is concrete that is made by forcing grout into the voids of a mass of clean, graded coarse aggregate densely pre-packed in formwork (Refer Fig 6.4). PAC is used where placing conventional concrete is extremely difficult, such as where massive reinforcing steel and embedded items are present, in underwater repairs, concrete and masonry repair, or where shrinkage of concrete must be kept to a minimum.

For the purpose of this repair method, grout typically consists of sand, cement, pozzolana, plasticiser/ super-plasticiser and an air entraining agent (for anticipated freeze & thaw problem, if required). The pozzolana and the plasticiser/super plasticiser are used to impart flowability to the grout. The coarse aggregate is washed to remove all fines and screened just prior to placement. Grout is then injected through forms to provide the cementing matrix. Grouting is begun at the bottom of the pre-placed aggregate.

Characteristics of the grout are affected by the water content, sand grading, cement, pozzolana and the types & amount of admixtures. For each design of grout mixture,

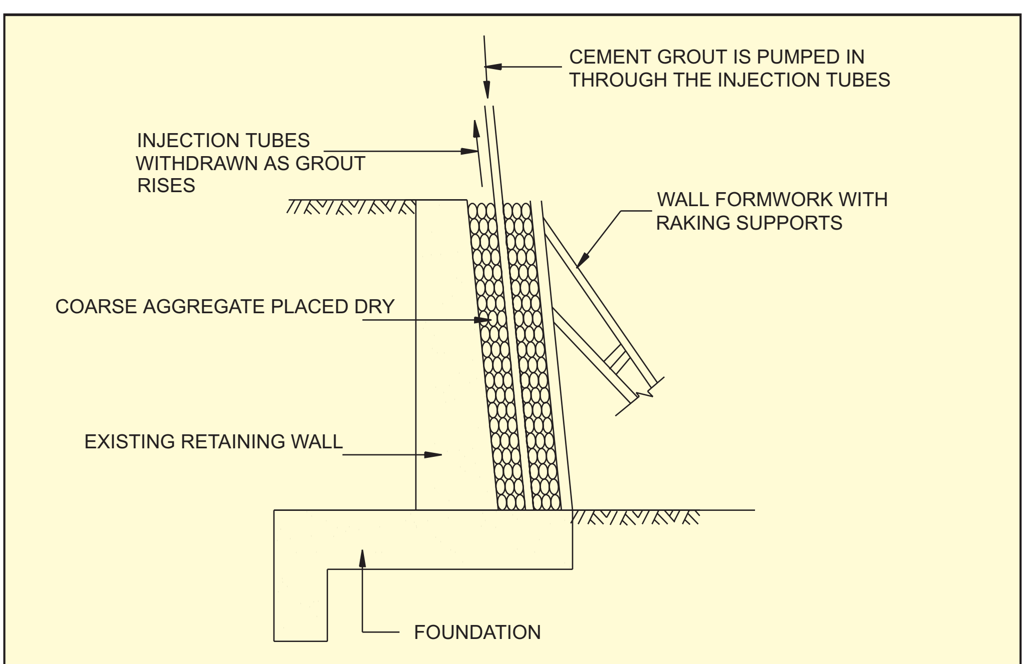


Fig 6.4(a) Preplaced Aggregate Concrete Repair to Concrete Wall

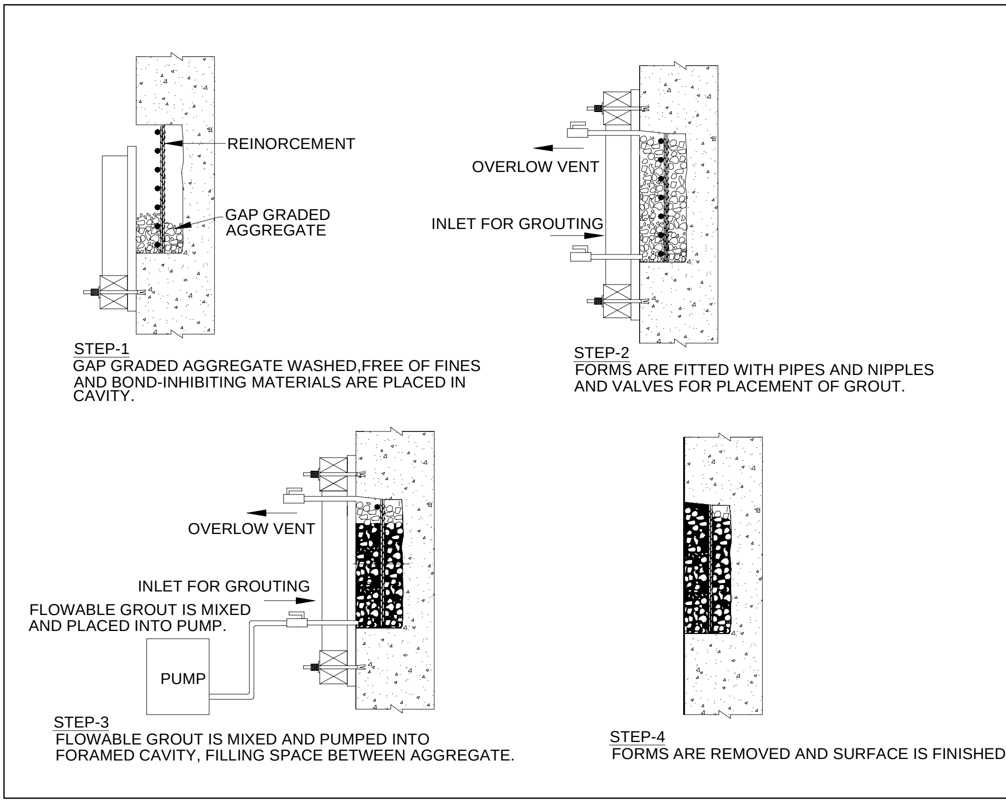


Fig 6.4(b) Preplaced Aggregate Concreting

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there are optimum amounts of fillers and admixtures to produce the best pumpability or consistency. Proper proportioning for the structural grout mix components is necessary to get the required strength and durability of the finished pre-placed aggregate concrete. Trial mix design is necessary for each job.

In underwater repair, injection of grout at the bottom of the PAC displaces water, leaving a homogenous mass of concrete with minimum of paste wash out. In such applications, addition of anti wash admixtures minimizes the paste wash out. For underwater PAC, the quality of underwater should also be tested to determine its influence on PAC over a period of time for taking appropriate corrective action.

6.6.4 Shotcrete

Shotcrete is defined as pneumatically applied concrete or mortar placed directly on to a surface. The shotcrete shall be placed by either the *dry mix* or *wet mix process*.

The *dry mix* process (Fig 6.5) shall consist of

- Thoroughly mixing the dry materials,
- Feeding of these materials into mechanical feeder or gun,
- Carrying the materials by compressed air through a hose to a special nozzle,
- Introducing water at nozzle point and intimately mixing it with other ingredients at the nozzle;
- Jetting the mixture from the nozzle at high velocity on to the surface to receive the shotcrete.

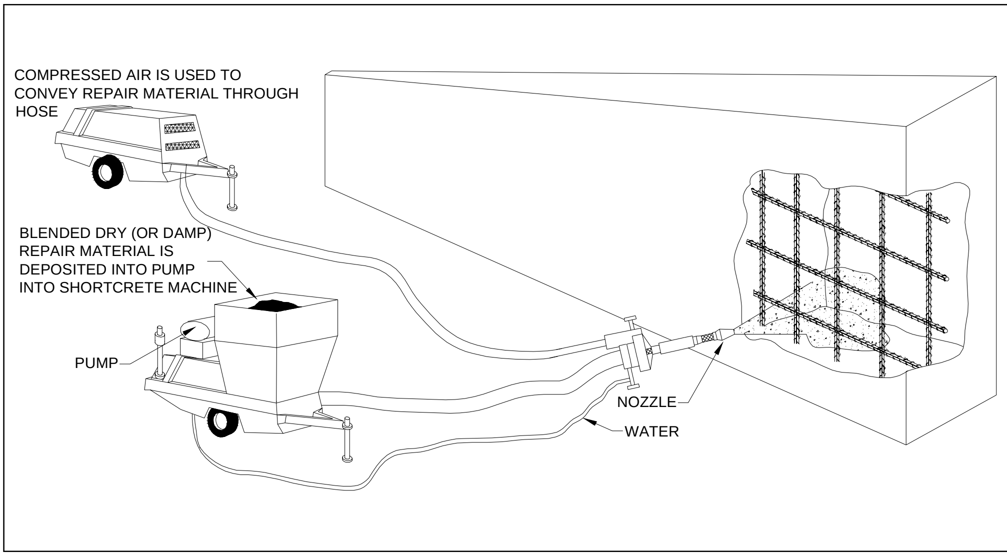

Fig 6.5 Dry Mix Shortcrete

The *wet-mix* process (Fig 6.6) shall consist of

- Thoroughly mixing all the ingredients with the exception of the accelerating admixture, if used;
- Feeding the mixture into the delivery equipment;
- Delivering the mixture by positive displacement or compressed air to the nozzle;
- Jetting the mixture from the nozzle at high velocity on to the surface to receive the shotcrete.

If specified, fibres of steel, poly propylene or other material, as may be specified, could also be used together with the admixtures to modify the structural properties of the concrete/mortar being placed in position.

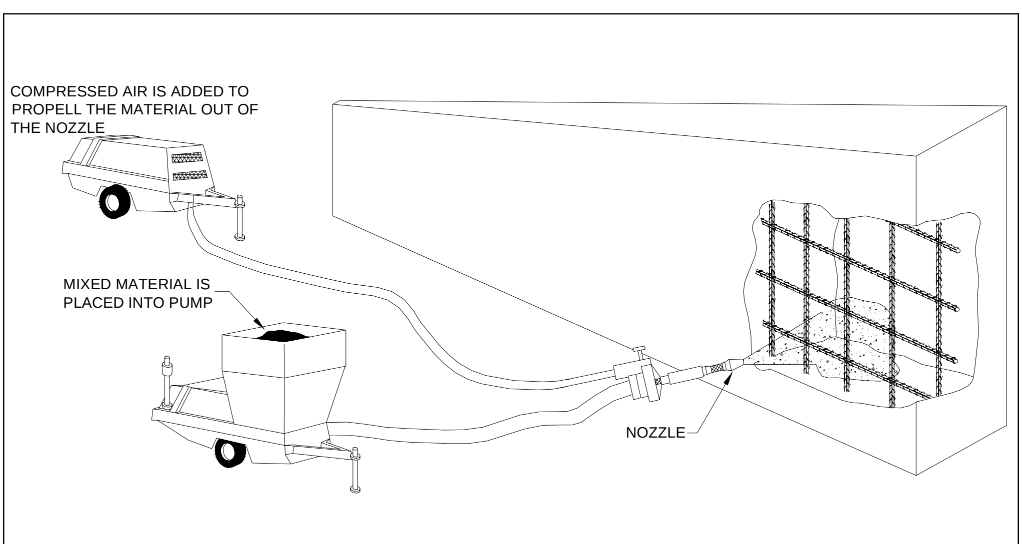

Fig 6.6 Wet Mix Shortcrete

6.6.5 Concrete Replacement:

It should be used on areas of damaged or unacceptable concrete greater than 0.1 sqm. having a depth greater than 150 mm or a depth extending 25 mm below or behind the back-side of reinforcement. Concrete replacement shall also be used for holes extending entirely through concrete sections and for longer areas of repair greater than 100 mm in depth when the concrete to be repaired is less than 7 days old. Epoxy bonding agents, latex bonding agents, dry neat cement, cement paste or cement and sand mortar shall not be used to bond, fresh concrete to concrete being repaired by this method.

6.6.6 Epoxy Bonded Concrete:

It is defined as freshly mixed portland cement concrete that is placed over epoxy resin bond coat on existing hardened concrete. This method should be used when the depth of repair is 40 mm or greater. It will be necessary to provide suitable reinforcement as per design requirement. In addition, epoxy bonded shear keys may also be used for shear transfer through the interface.

6.6.7 Silica Fume Concrete:

Silica fume concrete is a portland cement concrete with silica fumes used as an effective Pozzolana material in quantities not exceeding 10% by weight of cement. The mix shall invariably involve use of super-plasticisers. It may be used where a high strength repair concrete of low permeability is the requirement. If the depth of repair is at least 50 mm but less than 150 mm, epoxy-bonding agent to bond fresh silica fume concrete to parent concrete shall be used.

6.6.8 Polymer Concrete System:

Methyl Methacrylate (MMA) and Vinyl Ester Resin are commonly used polymer systems. These materials may be used for patches, overlays, grout pads, and embedment of slits, gates, and similar structures in concrete members. This system generally consist of

- 100% reactive monomer or resin system (only reactive solvents are permitted),
- Inhibitors to prevent premature polymerization of the resin or monomer system, which are normally added to the monomer by the acrylic manufacturers and require no site mixing, whatsoever.
- Promoter in very small quantity to decrease decomposition rate of the initiator
- The initiator to initiate polymerisation process. Its quantity is directly proportional to the rate of curing of the polymer concrete.
- Aggregates
- A compatible primer to be applied to the surface of concrete to be repaired.

The physical properties (e.g. compressive, tensile, flexural strength and modulus of elasticity) of cured repair materials so produced are very high.

6.6.9 Strengthening concrete by Surface impregnation using Vacuum Methods :

The surface impregnation is based upon first creating a partial vacuum within the concrete and then introducing a repair material i.e. the resin of very low viscosity into the cracks, voids, micro cracks and capillary system. The resin so impregnated fills the cracks, including micro cracks down to a width of 5 microns. Upon curing, the repair resin bonds the fractured and fissured matrix into a monolithic structural member of exceedingly high strength. Partial vacuum creation and introduction of repair resin are achieved by maintaining vacuum with the porting devices in the fracture or surface being repaired, connected to the vacuum source. The partial vacuum pressures are, thus, applied to the enclosed system. The repair resins are introduced, while maintaining the negative pressures, to fill the major cracks, interconnected cracks & voids and micro cracks. The concrete matrix, including the voids within fracture, is impregnated with the repair resin materials. This method can also be made applicable to stone or masonry structures.

The advantage lies in moisture evacuation along with any deleterious gases and/or materials from the concrete matrix of the fracture wall surfaces. The concrete drying process can be monitored by using in-line hydrometers installed in the special vacuum tubing.

The vacuum process offers the following advantages over pressure injection methods.

- Repairs can be completed in a relatively shorter period of time with no sacrifice to the quality of the repair.
- Repairs could be cost effective.
- Efficient and complete filling of existing fractures, interconnected fractures and voids and the complete filling of micro fractures.
- Total absence of pressure pockets ensures and facilitates deeper fill of repair resin.
- Evacuation of moisture from the interior concrete matrix of the fracture.
- No possible extenuation of the damage due to absence of applied pressures.
- Ability to introduce ultra – low viscosity materials into the fracture areas.
- Improved bonding due to lack of air bubbles normally associated with low viscosity, low specific gravity repair resins.
- Continued corrosion of reinforcement would be significantly diminished because of the evacuation of, and sealing out of moisture from the treated concrete matrix.

A. Using Methyl Methacrylate (MMA)

In the vacuum system, the requirement is of impregnating concrete with a Methyl Methacrylate (MMA) based monomer catalyst system followed by in-situ polymerization of the monomer by heat. MMA is low viscosity high strength material suitable for vacuum injection processes. Its viscosity is 5-15 cps with superior physical properties, flexibility and superior bonding and wetting properties.

B. Using Expanding Vinyl Ester Gel

These are low viscosity gels, which are water-soluble acrylic monomers. The gel is used for injection and sealing of joints and cracks against water leaks. Due to its ultra low viscosity, it has a very low flow resistance and is able to permeate into the smallest hairline cracks and capillaries. Thus, it seals them reliably and permanently. When it contact with water, it swells to double its volume while retaining its shape. This process is purely physical and reversible. As a result of this unique property, the material will retain its self healing property even when in a dry condition.

These processes involve unique materials and hence need specialist advice and close supervision in their field applications.

6.6.10 Thin Polymer Overlays:

Thin polymer overlays are used to improve the abrasion resistance and for creating waterproofing barriers on the surface and act as protective coatings. These are applied in less than 10 mm thickness. It is quite suitable for improving surface characteristics and also it acts as protective coating. It generally comprises of

1 One coat of primer and
2 One or more coats of sealant.

The primer coat shall consist of vinyl ester resin, initiator and promoter. Each coat of sealant shall consist of the same material as in the primer but with the addition of silica filler, titanium dioxide pigment and carbon black pigment.

6.6.11 Thin Epoxy Overlay:

These are used to improve the abrasion resistance of surface and for creating waterproofing/protective coating. Thin epoxy overlays are applied in 2 to 3 mm thickness. It generally comprises of resin and hardener. The strength gain is much faster than polymer overlays. There are several types for epoxy overlays available to suite different performance requirement. Epoxy overlays require protective coating in exposed locations subjected to ultra violet exposure.

6.6.12 Resin/Polymer modified Cement Slurry injection:

One of the most prevalent techniques used for repairing cracks is by injection of different types of materials depending upon the nature of the defect. The selection of material for injection requires thorough understanding of the property of that repair material and the functions that such a repair has to perform. In all cases, it is imperative that the cause of cracking is properly determined, otherwise, the selection of material could be totally faulty. The selection criteria of injection material is given in Table no. 5.11 in chapter- 5.

The method of crack repair by injection grouting is indicated in fig 6.14 & 6.15. The materials and step wise sequence of carrying repair are given in detail in chapter 8 & 9 for various applications.

6.6.13 Protective Seal Coats on the Entire Surface

These are defined as liquids that are applied to the surface of hardened concrete to prevent or decrease the penetration of liquid or gaseous media, such as water, aggressive solutions, gases like carbon dioxide, etc during the service exposure conditions. Patch repairs carried out on patch work basis and wherever polymer modified cementitious mortars or epoxy mortars are used, the chemical effects are not anticipated. However to protect the remaining areas from the environmental attacks and to avoid subsequent repairs in such areas, application of seal coats becomes necessary. Generally, these protective seal coats are suitably pigmented so that besides protection, aesthetics of the structure can also be taken care of simultaneously. Various coatings like polyurethane, epoxy, alkyds, chlorinated rubbers, acrylic emulsions can be used for the purpose however, the selection should be done considering the following points:

- Adhesion to surface

- Compatibility with the alkalinity of surface
- Coating should be impermeable enough but simultaneously, it should permit evaporation of moisture from concrete mass.
- Resistance to various aggressive environmental chemical attacks
- Expected life of the treatment
- Capacity to cover surface irregularities
- Ease of application and aesthetics

After considering all these parameters, appropriate coating material can be selected. Generally, water based coatings are preferred over solvent based.

There are number of properietory as well as other systems for providing surface coatings to the hardened concrete surface and have been dealt in detail in chapter 8 & 9. Also some commercially available products have been listed out in Appendex 5.1.

6.6.14 Ferro-cement:

Ferro-cement is a thin wall type composite, having a total thickness ranging between 12 to 30 mm. It is composed of hydraulic cement mortar reinforced with a minimum two layers of continuous and relatively small diameter orthogonally woven wire mesh separated by 4 to 6 mm dia galvanised spacer wires**.** The cement mortar is admixed with plasticisers and polymers for sealing pores. The wire mesh is mechanically connected to the parent surface by U-shaped nails fixed with suitable epoxy bonding system. The mesh may be made of hot dip galvanised MS wire or some other metallic or suitable material. Special technique for compacting ferro-cement layer is used with the help of orbital vibrators to ensure proper encapsulation of wire mesh in mortar.

It is a durable composite material, in which shrinkage cracks are distributed uniformly due to the presence of closely spaced, thin woven galvanized wire mesh. It is coupled with excellent corrosion resistance and impermeability to the ingress of water.

This repair technique is used for providing protective reinforced membrane for rehabilitation of distressed RCC structures. This acts as a protective layer against the vagaries of the environment. It is also used as a water proofing technique over reinforced concrete shell structures and RCC slabs as it provides impermeable thin membrane, which prevents seepage and leakage of water.

6.6.15 Plate bonding

Plate bonding is an inexpensive, versatile and advanced technique for rehabilitation, up gradation of concrete structures by mechanically connecting MS plates by bolting and gluing to their surfaces with epoxy as shown in Fig 6.7. Plate bonding can substantially increase strength, stiffness, ductility and stability of the reinforced concrete elements and can be used effectively for seismic retrofitting.

In this method the bolts, which are first used to hold the plates in position during construction, act as permanent shear connectors and integral restraints. The bolts are also designed to resist interface forces assuming the epoxy glue used as non-existent assuming it as destroyed

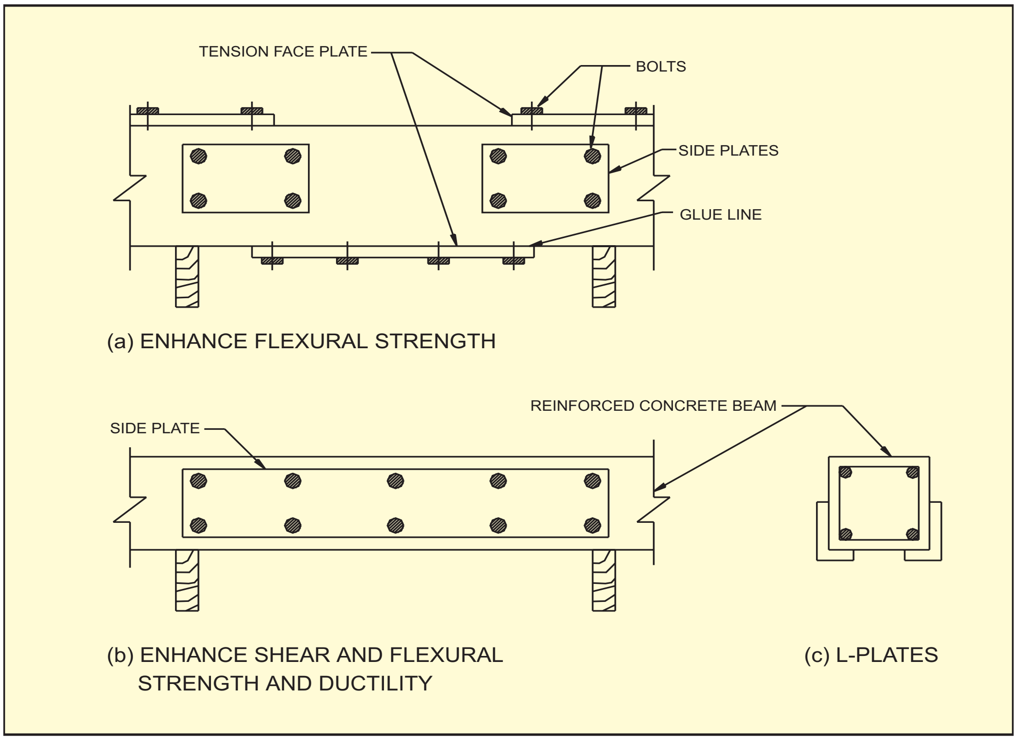

Fig 6.7 Tension Face Plates

by fire, chemical break down, rusting or simply bad workmanship. Since epoxy is prone to premature debonding, use of mechanical anchorage along with epoxy bonding is considered more reliable.

Since the steel plates are unobtrusive, with this technique original sizes of the structural members are not increased significantly. This method is preferred where enlargement of the members is going to affect the headroom, existing windows, doors and other fixtures.

6.6.16 RCC Jacketing

Reinforced concrete jacketing increases the member size significantly. This has the advantage of increasing the member stiffness and is useful where deformations are to be controlled. If columns in a building are found to be slender, RC jacketing provides a better solution for avoiding buckling problems. Design for strengthening/repair work is based on composite action between the old and the new work. Strain compatibility calculations may have to be carried out carefully giving due account to factors such as creep. As the new jacket is to behave compositely with the parent member, the new jacket can take additional loads only with the increase in the stresses & strains in the old one. The problem arises if the;

- Old concrete has reached limiting strain and is not likely to sustain any more significant strain
- Old concrete is weak and porous and started deteriorating due to weathering action and corrosion of reinforcement.

The question then arises as to whether the composite action should be abandoned and the new jacket (plate or RC) designed to carry the entire load. It is perhaps best to design the strengthening in this manner, but detailing must be right to ensure transfer of load to the new jacket, if the old concrete fails. It is however, necessary to ensure perfect bond also between the old and new concrete by providing shear keys and effective bond coat with the use of epoxy or polymer modified cement slurry giving strength not less than that of new concrete.

Plate bonding and RC jacketing are the common methods of strengthening RCC structures (detail procedure and stages given in Fig 6.8). The cost difference between the two methods is not significant. A choice has to be made between the two methods based on actual needs and the suitability of each method with respect to the structural /architectural and other details of buildings.

6.6.17 Propping and Supporting:

Problem arises in deciding on propping and supporting the structure to give relief in stresses and strains in some of the existing weak members being strengthened. Mere vertical props

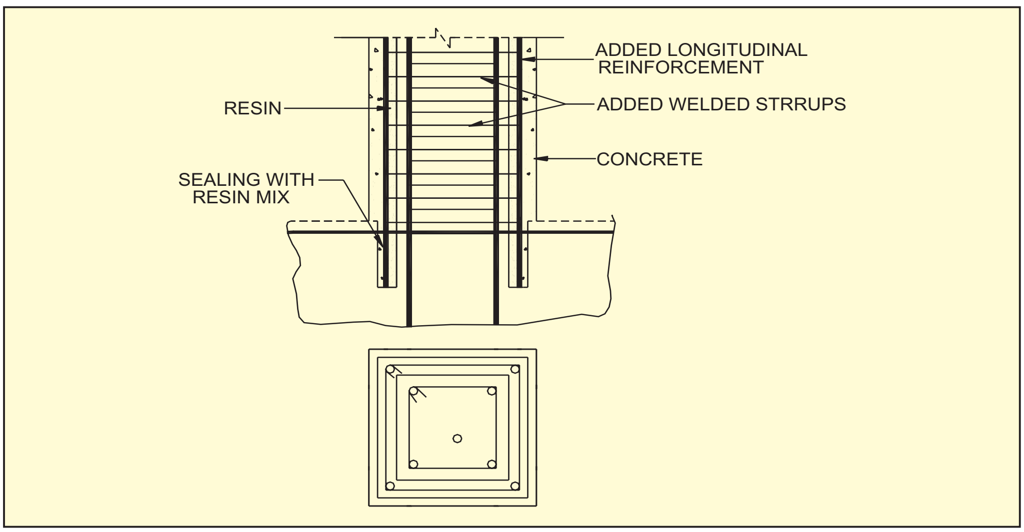

Fig 6.8(a) Column Strengthening Concrete Jacket

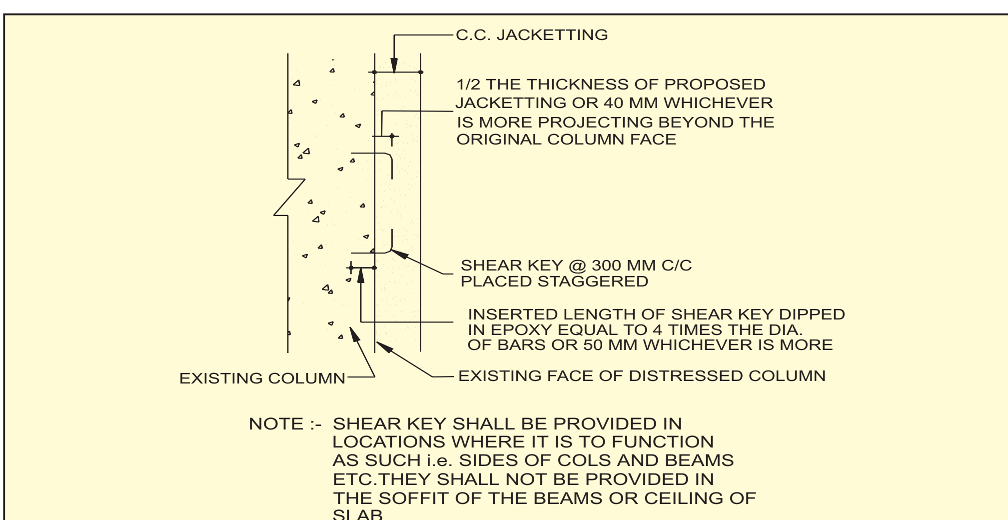

Fig 6.8(b) Details of Shear Key Bars

sitting on some beams & slabs may not be enough.

Diagonal bracing to transmit the loads to the adjacent columns should also be considered. The first item of schedule in Chapter 8 has been prepared which may be read in conjunction with its related specifications in Chapter 9 and Fig 6.9

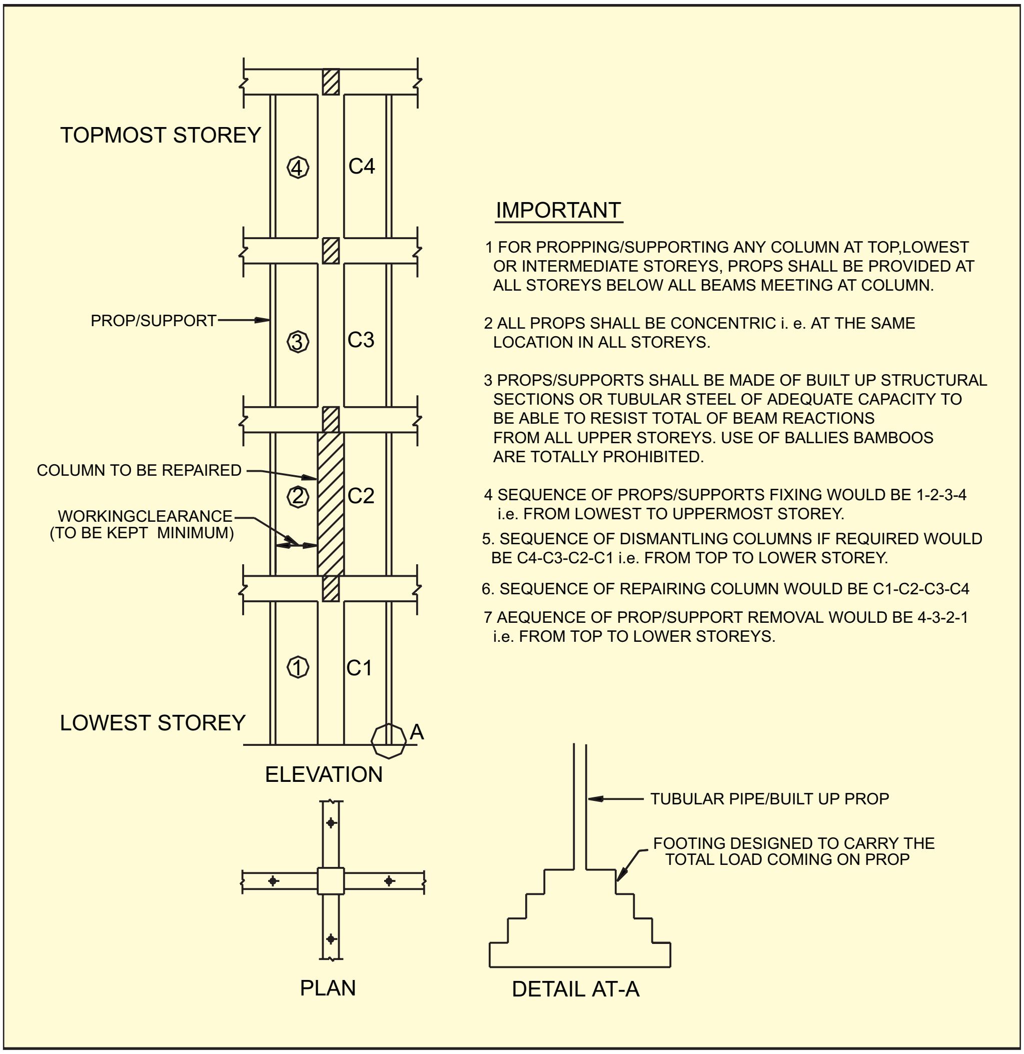

Fig 6.9 Typical Arrangement For Propping & Supporting a Column to Releive at Form Load

6.6.18 Fibre Wrap Technique:

The fibre wrap technique, also known as Composite Fiber System is a non-intrusive structural strengthening technique that increases the load carrying capacity (shear, flexural, compressive) and ductility of reinforced concrete members without causing any destruction or distress to the existing concrete. (Refer Fig 6.10)

There are two systems followed in adopting this technique:

a. Bi-directional Woven Fabric: This system comprises of woven fabric presoaked in specially formulated epoxy and applied over prepared surface after application of epoxy primer. Woven fibre fabric is composed of bi-directional high strength fibers that are

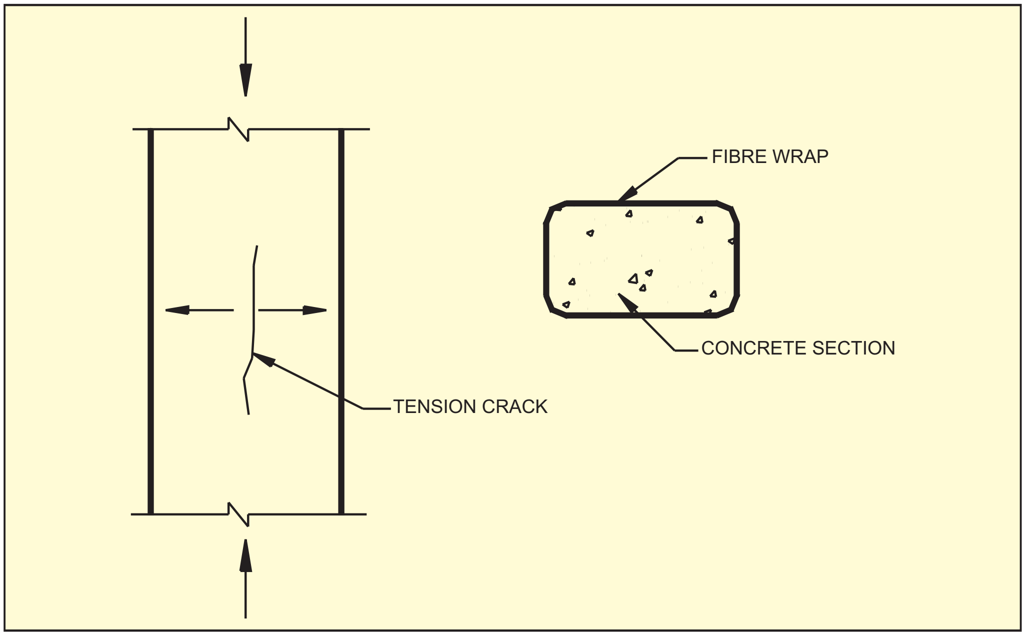

Fig 6.10 Fibre wrap technique for improving load carrying capacity of a column.

combined with specially formulated epoxy in a pre-determined proportion to form a composite-Material. This composite material is wrap applied onto the reinforced concrete or steel member requiring strengthening or protection and left to cure at ambient temperature. The subsequent layer/s of unidirectional fibre fabric could be applied after giving the required overlap along the direction of fibres as per design requirements

b. Uni-directional E-glass Fibres: This system comprises of precut unidirectional E-glass fibre wrapped over epoxy primer applied prepared surface of member requiring structural strengthening and/or surface protection. Subsequent to its wrapping, it is saturated with epoxy using rollers and stamping brushes manually to remove air bubbles, if any and left to cure at ambient temperature. The subsequent layer/s of unidirectional fibre fabric could be applied after giving the required overlap along the direction of fibres as per design requirements.

Though the underlying principle of the above two methods is more or less identical, but the application techniques and basic materials adopted are at slight variance. Each of the above systems has their own merits.

Enhancement in lateral drift ductility and horizontal shear carrying capacities of a concrete member can also be obtained by confinement of the member by this method. The flexural, shear and axial load carrying capacities of the structural members can be enhanced by appropriate orientation of primary fibres of the composites. The resulting cured membrane not only strengthens the reinforced concrete member but also acts as an excellent barrier to corrosive agents, which are detrimental to concrete and the reinforcement. Ingress of water, oxygen and carbon dioxide through the external surface of concrete member is prevented by the application of composite jacket.

The system is useful for its structural enhancement and protection capabilities under severe environmental conditions. It can be used for retrofitting of a wide variety of structures that include bridges, flyovers, chimneys, water tanks, buildings, large diameter pipes, industrial plants, jetties, sea-front and underwater structures

6.6.19 Foundation Rehabilitation Methods:

The methods to repair and rehabilitate a structure having foundation distress generally involve shoring & underpinning work for structures that are out of plumb, or are sensitive to effects of small settlement etc.

A. Shoring: Before any shoring work is commenced, the building should be carefully surveyed & record of levels, cracks & tilts kept. The observations should be continued throughout the period of shoring & under pinning and till the time when detectable measurements have ceased. The terminology used is:

1. **Raking shores** with the angle of shores generally 60^{o} to 75^{o} are usually used where external support is necessary. In case, the feet of raking shores are to be kept free, then flying shores can be provided which strut against another structure or wall.
2. **Flying shores** merely provide a restraint against building or tilting.
3. **Dead shores** are verified struts bearing on the ground at the required distance & supporting the vertical load of a wall wherever required in conjunction with flying shores or horizontal ties.

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The level of raking shores & flying shores are so arranged as to bear on the wall at floor *or ground* with a firm bearing. Folding wedges should be inserted at the foot of shores to take up yielding if any, of the ground & elastic shortening of the struts. Columns can be shored up individually by needle beams. The needle system has to be properly designed to suite the particular requirements. Suitable placing of jacks for exerting upward pressure can also be planned & designed.

B. Underpinning: If underpinning is necessary to arrest settlement, it is essential that the underpinned foundation should meet the requirements of correct allowable bearing pressures. Depending on the cause of settlement, shallow underpinning may be satisfactory in some cases, whereas in some cases the underpinning has to be taken down to a deeper & relatively incompressible stratum. Underpinning material are *metals* in case of comparatively shallow underpinning. Underpinning by piles or piers is suitable, only if the new bearing stratum is deep.

- **Underpinning piles** are normally provided in pairs, one on each side of the load bearing walls or in groups around the sides of columns.
- **Micro-piles** are a useful means of underpinning. They can be installed from the ground surface without deep excavation and the equipment in installing the piles is suitable for working in confined spaces. The rotary drilling results in less damage & loss of ground, as compared to the percussion method.
- **Proprietary jacked piles** with pre-cast segments are another means of underpinning. In the proprietary ‘pretest’ methods of underpinning the underlying ground is preloaded before the load of the structure is finally transferred by means of jacking between the tilted existing structure & the

new underpinning. There are various patented systems of jacking, involving interconnection of jacks with centralised pumping plant etc.

- **Underpinning by injection of the ground with cement or chemicals** to fill voids or to permeate and strengthen the ground is sometimes used. Various forms of grout can be introduced into granular soils or cavernous rock formations to increase their strength to reduce their compressibility grouts, however, cannot be induced to permeate clays or clayey silts, though by means of high injection pressure and using closely spaced points the **"hydro-fracture" technique** can be used to uplift the mass of clay or self & thereby provide a means of raising a structure. However, it may be worthwhile in many cases to take the foundation down to a deeper & more incompressible stratum say by piles rather than try to compensate & stop the settlement by grouting.

At the end, it is worthwhile bearing in mind that a foundation is not an entirely nor an end in itself. The ability to discern differences in type of framing etc. , is also an essential attribute of an expert investigator. In certain, cases, the results of fresh site investigates would indicate that the settlement may continue but at a deceasing rate. In that case, a possible solution could be to keep on monitoring and when the rate of settlement has decreased sufficiently, the building could simply be "patched up".

It is worth noting that damage investigations include both the design & operation (or lifetime usage) assessment, which involve "looking backwards in time" as are time dependent. As stated earlier the concept of time scale is important. In any case, for a good & effective damage investigation, proper causation statement are essential. They need to cover information about the damages, technical details, facts about what & when precise explanation of the causes of damages etc. causation is about opinion & fact meshed together so that they explain what happened. There must be clarity and it must be based on evidence. This will then load to the appropriate repair & rehabilitation strategy, always bearing in mind that foundation is not an isolated entity but a part of the structure as a whole.

6.6.20 Chemical and Electro-Chemical Methods of Repair

Chlorides are the most difficult to deal with by any other methods of repair except the electro-chemical methods. The chlorides could be introduced in the concrete either through ingredients of concrete during its making or during its service life from the environment to which the structure is exposed. These methods have also been used for realkalisation of concrete in contact with steel reinforcement with some success and have enhanced life of structures by few years. Though the electro-chemical methods are not very commonly used methods for buildings, yet these have been tried on limited scale and with success. Whereas these methods have been very successfully used for underground structures, where sufficient moisture and grounding medium is available.

A. Cathodic Protection:

As the steel reinforcements embedded in concrete undergoes corrosion due to an electrochemical process taking place within the concrete, micro and /or macro galvanic cells are formed due to various factors related to both concrete as well as steel. Thus, corrosion current flows form one region of the steel reinforcement called anode to another region of the steel reinforcement called cathode. Concrete due to pore-water present in it, acts as the conducting medium for this corrosion process.

Normally the region where there is relatively high concentration of chloride salts (coupled with a lowering of alkalinity due to carbonation) acts as anode where corrosion occurs. The region where there is relatively lower level of chloride contamination (alkalinity is also maintained relatively at a higher level) acts as cathode of the galvanic cell where oxygen reduction reaction occurs. At the anode, iron goes into solution as ferrous ions as follows:

$$Fe = Fe^{++} + 2\,e^{-}$$

At the cathode, hydroxyl ions are produced as follows:

$$O_2 + 2H_2O + 4e = 4\,OH^{-}$$

Under micro galvanic process, tiny anodes and cathodes are formed and they also shift positions leading to general corrosion. Under macro-galvanic process, anodes and cathodes operate at a macro level.

Principle of Cathodic Protection:

The principle of cathodic protection is nothing but applying a direct current (DC source) in opposition to corrosion current. While applying cathodic protection, the entire steel reinforcement network is made as cathode while a more active engineering metal (Zinc, aluminum or magnesium) system (sacrificial anode) or an inert metal system (impressed current anode) is made as anode. However, zinc, aluminum or magnesium have been employed either as sacrificial or impressed current anode. A wire mesh of titanium substrate insoluble anode in conjunction with a suitable rectifier system has been widely used.

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After extensive research and testing it has bee established that the only rehabilitation technique that has proven to stop corrosion in salt contaminated bridge decks regardless of the chloride content of the concrete is the cathodic protection. Once chloride entered into concrete, other rehabilitation techniques such as overlays, sealers and water proofing membranes were found no longer effective.

Cathodic protection as applied to buildings:

a. Impressed Current Technique:

Even though cathodic protection technique has been adopted in bridges and parking garages, it has been tried in buildings only to a very limited extent. This is mainly due to the following reasons.

a. Buildings are normally exposed to open dry atmosphere and as such are not conducive to adoption of this technique.
b. Dry atmosphere coupled with high electrical resistivity of concrete make it difficult to effectively apply and maintain cathodic protection.
c. Buildings may not need such sophisticated approach
d. Initial investment cost being comparatively higher, cost benefit ratio might not be favourable.

b. Sacrificial Anode System:

However, when one considers cathodic protection as a fool-proof technique particularly for chloride contaminated concrete, it is quite feasible to install a sacrificial anode system, which will work out to be quite economical. It has recently been shown that reinforced concrete exposed to ambient condition under high humid condition can be cathodically protected. The prerequisite is an ion conductive backfill to be inserted between the anode and the concrete.

Sacrificial anodic protection for RCC buildings will therefore consist of the following:

a. Strip or mesh type sacrificial anode (based on zinc or aluminum or magnesium alloys)
b. Ion conductive backfill (hydro-gel or polymer system)
c. Embeddable reference electrodes (maintenance free electrodes)
d. Shielded electrical leads to be taken from anodes embedded steel reinforcements and embedded reference electrodes.

The ion conductive backfill should be capable of maintaining conductivity even under ambient exposure conditions.

The criterion of cathodic protection is based on four hour potential decay. A decay of 150 to 250 mV might be needed depending on the field conditions. This can be periodically monitored using a hand held high impedance multimeter. Otherwise, this sacrificial system does not require any major maintenance work till the expiry of design life.

Advantages of Cathodic Protection:

The major advantages of cathodic protection system as applied to reinforced concrete;

(i) chloride ions move away from the steel reinforcement as they are drawn towards the externally placed anode.

(iii) Passivation of steel reinforcement gets strengthened due to build up of alkalinity at the cathode (production of OH^- ions)

B. Chloride Removal

The chloride ion attacks the passive layer, even though there is no drop in pH. Chlorides act as an electron carrier to become a catalyst to corrosion. Chloride ions are not consumed in the process, but help to break down the passive layer of iron oxide on the steel. These allow the corrosion process to proceed quickly.

"Chloride threshold" for corrosion, is given in terms of the *chloride/hydroxyl ion ratio*. When the chloride ion concentration exceeds 0.6 of the hydroxyl ion concentration, then the protective passive layer over the steel reinforcement breaks down. This approximates to a concentration of 0.4% chloride by weight of cement. The approximation is because:

(a) Concrete pH varies with the cement powder and the concrete mix. A little pH change causes an appreciable change in OH^- concentration and therefore, the threshold moves radically.

(b) Chlorides can be bound chemically by aluminates available in hydrated cement paste and physically by absorption on the pore walls. This removes them (temporarily or permanently) from the corrosion reaction.

(c) In very dry concrete corrosion may not occur even at very high chloride concentration as the water, presence of which is essential for ionic movement, is missing.

(d) in saturated concrete corrosion may not occur even at a very high chloride concentration as the oxygen, an essential ingredient for corrosion activity, is missing.

Process

In the process of chloride removal, an external anode is temporary attached to the concrete surface and the reactions are driven by a DC power supply. Chloride ions are negatively charged and the electrochemical process can be used to repel the chloride ion from the steel surface and move it towards an external anode.

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One essential requirement for the success of electrochemical treatment is good electrical continuity to ensure that current flows from the anode to all areas of steel. Electrical continuity must be checked and, if necessary, established in all applications of these techniques. If there is any discontinuity, current will short circuit the concrete pore structure and the ions will not flow.

Anode types

The most popular anode is the coated titanium mesh used for chloride removal. This is placed inside a cassette shutter. Where the shape of the member is especially difficult, a sprayed papier-mache system can be applied over the anode, soaked with the electrolyte.

When to Stop Process

End point determination can be by several means:

(a) **Point of diminishing returns-** When resistance goes up, amount of chloride removed goes down. Similarly when the current is small then also the amount of chloride removed is small. Under such situations, it is switched off. Switching off for about a week will bring the system resistance down. But how much more chloride is removed by allowing "rest" periods is not known.

(b) **Direct measurement-** Take samples from the concrete and when an agreed level is reached, stop. This assumes that good sampling is possible and the samples are representative.

(c) **Indirect measurement**- Sample the anode system and or electrolyte. When chloride level is either at a plateau or an agreed level stop. This assumes good sampling.

(d) **Experience of charge density needed** – Measure charges passed (ampere-hours per square metre), and when an agreed limit is reached, switch off.

It is of course impossible to remove all the chlorides from the concrete. The area immediately around the steel reinforcement is almost chloride free, but farther away there is less effect. This is particularly true behind the steel. Chloride removal will deplete the amount of chloride immediately in contact with the steel reinforcement, and will replenish the passive layer. Field data shows that this is effective for at least six years, but for how much longer is uncertain. The results suggest about 10 years, but only real experience will show that.

One implication of the amount of chloride which can be removed is that if large amounts of chloride have penetrated beyond the steel reinforcement or were cast uniformly into the concrete, then chloride removal will only effect the chloride level in the "cover concrete". The chlorides in the bulk of the concrete will then diffuse back around the steel and the corrosion may eventually be re-established. When the process is carried out, the steel is polarized for some time, perhaps a year, making half cell potential testing difficult to interpret. The charge on the steel means, however, that chloride ions will be repelled by the charge during this time.

Side Effects

Passing large amount of electricity through concrete can have effects upon its chemistry and therefore, its physical condition. There are two known side effects of chloride removal as follows.

- The first is the acceleration of alkali silica reactivity (ASR)
- Reduction in bond at the steel concrete interface.

C. Realkalisation:

Realkalisation is non Destructive Electrochemical Treatment to restore the alkalinity of carbonated concrete to prevent further corrosion of reinforcement.

In this process, instead of breaking and mechanically replacing a sound but carbonated concrete, pH of such concrete is increased to more than 12 initially, which favours the passivation of steel reinforcement with a final value greater than 10.5, which is considered sufficient to maintain the passivity of reinforcement.

It is indeed an electrochemical process as is the reinforcement corrosion. The corrosion reaction consists of an anode and a cathode reaction. The anode reaction causes the steel reinforcement to be dissolved and occurs at sites where concrete has lost its corrosion protective nature. Simultaneously, the cathode reaction produces hydroxyl ions at other sites along the steel reinforcement. While the anode reaction has harmful nature, cathode reaction improves the corrosion protection of steel.

Process:

Realisalisation is performed by applying an electric field between the reinforcement in the concrete and an anode system consisting an anode mesh embedded in an electrolytic reservoir and temporarily placed on the concrete surface. The system is schematically presented in fig….. During the treatment, electrolyte, which is sodium carbonate solution, is transported in to carbonated concrete as symbolized by the penetrating front. The dominant transport mechanism may vary, but electro-osmosis and migration of ions are the two main contributors. Simultaneously, electrolysis at reinforcement surface produces alkaline environment, symbolized by a passive barrier around the reinforcement.

6.7 Repair/Rehabilitation Strategies:

A number of options are available for giving a relief to a distressed structure, which could cover any of the following:

- Reduction of dead/live loads
- Repair/strengthening of Columns, beams and slabs
- Improving the compressive strength of concrete.
- Attending to Cracks and joints
- Improving the masonry structure to be able to resist earthquake forces
- Providing protective cover against the aggressive deteriorating chemicals

6.7.1 Stress Reduction:

Stress Reduction: The reduction is another method of providing relief to the distressed structure. This can be achieved by-

- Reducing dead load and live loads;
- Replacing heavy solid partitions with lightweight partitions;
- Enlarging openings by removing filler walls;
- Reducing numbers of stories;
- Changing the building use to a lower classification of loading;
- Span reduction of beams by providing struts etc;

Installation of shear movement joints in a continuous spans at points of zero moment.

6.7.2 Repair/Strengthening Columns, Beams and slabs:

These form the basic structural elements in most of the building structural systems, which are deteriorated and require attention to improve the load carrying capacity. Their structural modification or strengthening would give the required relief to the structure and enhance its performance as under:

- **Columns**: The strengthening of columns may be required for the following
  - **a. Capacity:** The load carrying capacity of the column can be enhanced by section enlargement. Different types of arrangement for section enlargement are shown in Fig. 6.11
  - **b. Ductility/confinement:** The ductility of the column can be enhanced by providing additional tiles, steel plate bonding, and fibre wrap.

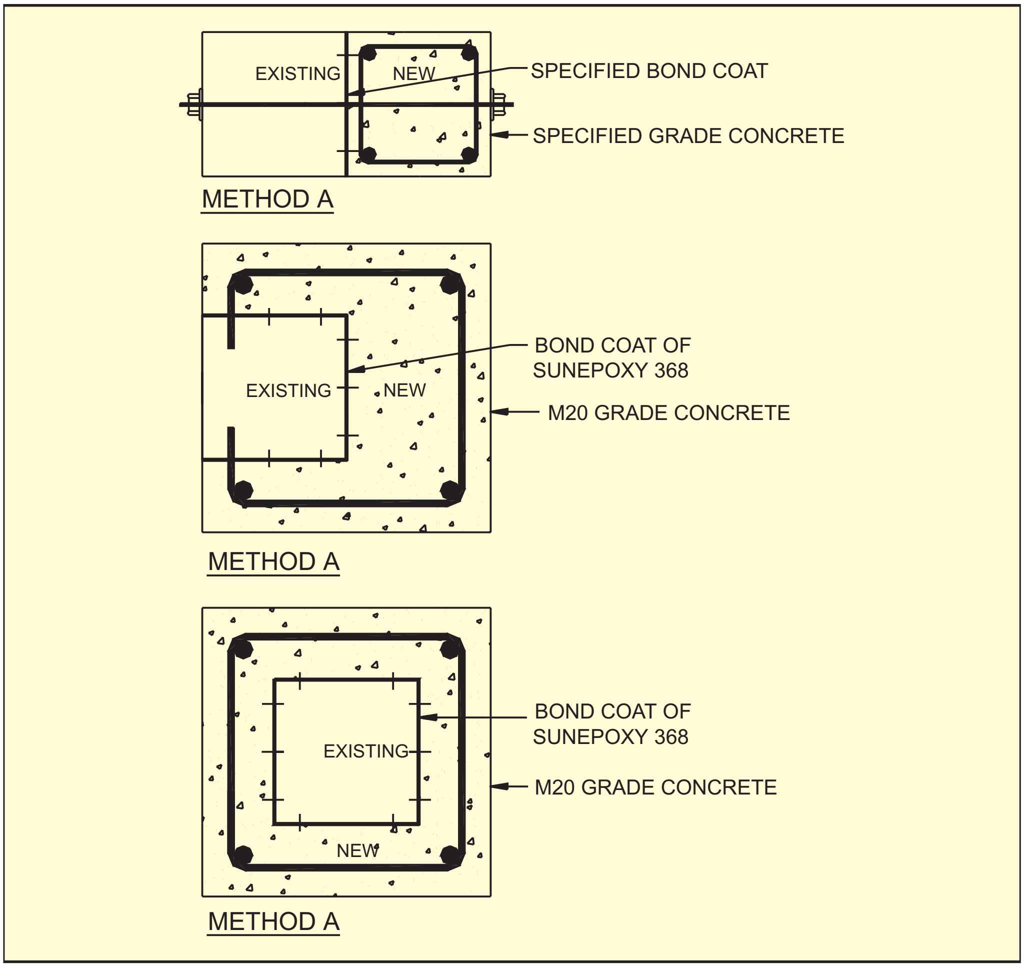

Fig. 6.11 Column Compressive Strengthening by Section Enlargement

c. **Joints:** The joints play crucial for resisting earthquake forces. The joints can be strengthening by enlargement, jacketing by steel collar and fibre wrap.

- **Beams:** These can be strengthened for:

a. **Flexural Strength:** The flexural strength of the beam can be enhanced by

i. Section enlargement in compression,

ii. Additional reinforcement in the tension. Caution shall be exercised to ensure that section is not over reinforced while providing additional reinforcement to compensate loss of reinforcement due to corrosion etc.

iii. The provisioning for enhanced tensile strength if being undertaken, this should be accompanied with corresponding increase in compression as well .Due to such increased flexural capacities extra shear capacities required to ensure ductile behaviour during earthquake shall also considered for provision.

iv. MS plate bonding

v. High Strength Fibre Fabric Wrap Technique (without section enlargement)

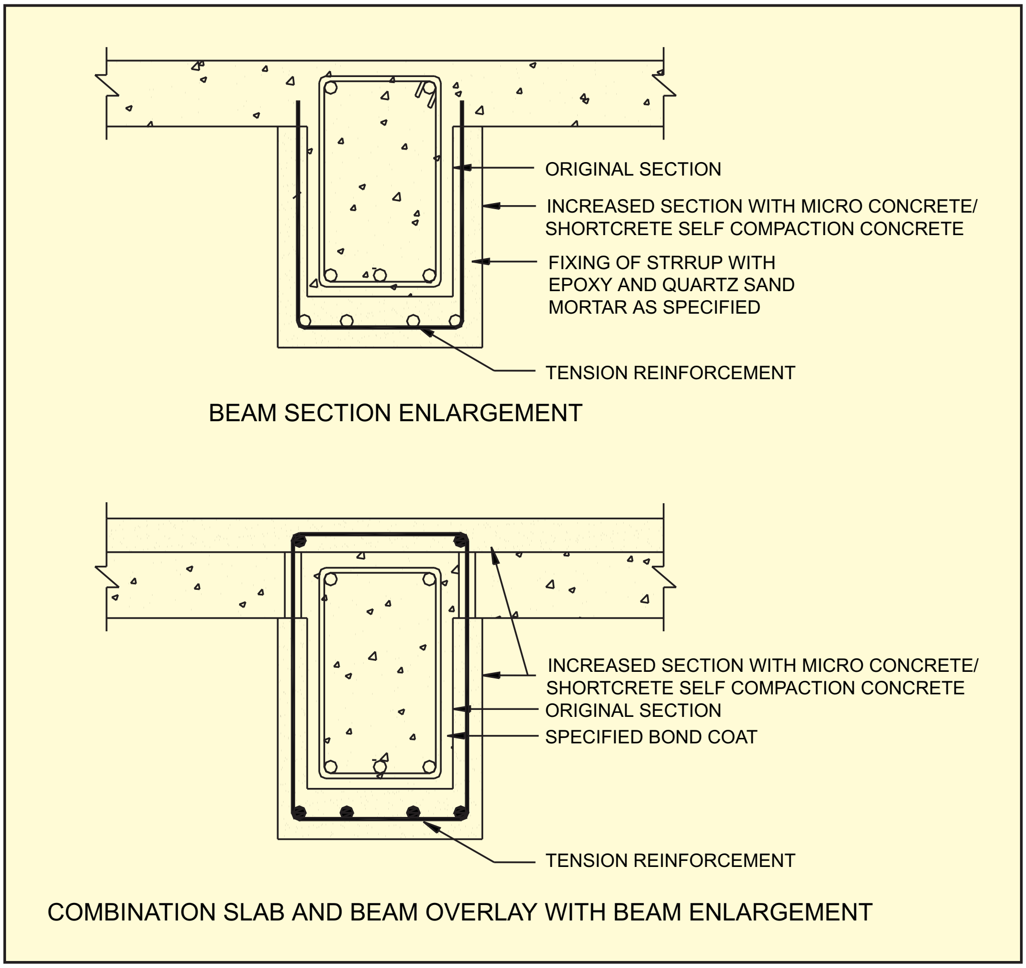

Fig. 6.12 Beam Strengthening : Concrete Overlay And Section Enlargement

b. Shear Strength: The shear strength of the beam can be enhanced by any of the following:

i. Section enlargement
ii. Shear ties anchored in compression zone of beam.
iii. Post tension strap around the section
iv. Diagonally anchored bolts (the holes are drilled perpendicular to the possible shear cracks)
v. MS Steel plate bonding
vi. Fibre wraps

- **Slabs:** The performance of the slab can be improved by providing overlays (in case of negative moment deficiency) or underlay (in case of positive moment deficiency). The addition of overlay/underlay will also increase the stiffness of the slabs and control the excessive deflections problems. The slabs are generally safe in shear and as such no need is likely to occur for shear strengthening except flat slabs near column capital.

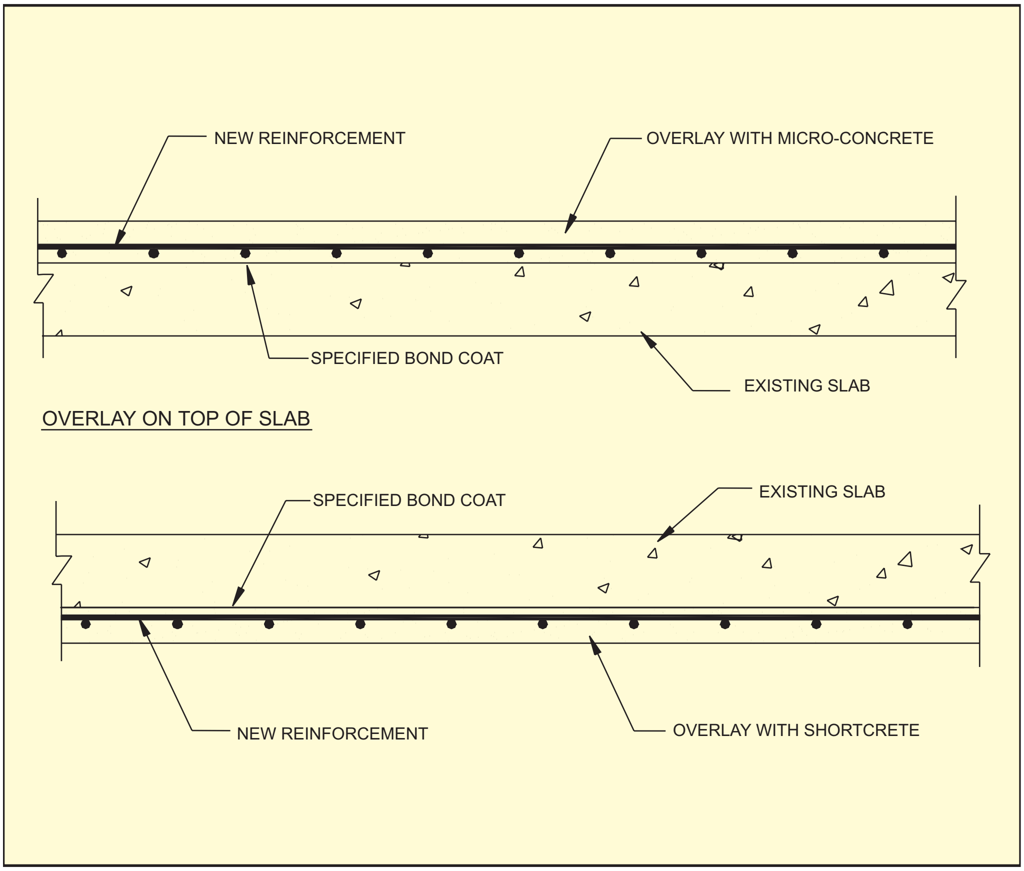

Fig. 6.13 Slab Strengthening : Concrete Overlay

Structural repairs to Columns/beams/slabs due to corrosion of reinforcement are most frequented in the normal practice. The step by step sequence of repair stages have been given in Annexure 6.1 for structural repairs to RCC columns, beams and slabs under different conditions of deterioration

6.7.3 Compressive Strength of Concrete: The concrete strength can be enhanced substantially by impregnation with specific polymers. The process has already been explained under section 6.5.9

6.7.4 Cracks/Joints: The concrete and masonry are weak in tension. The cracks indicate the tensile failure of the material. The cause of cracking should be examined in detail and remedial measures taken accordingly. Inactive (i.e. non-moving) cracks in masonry can be repaired by stitching. Grouting with non-shrink grouts also repairs these types of cracks. The active cracks required for accommodating thermal movements shall be repaired by suitably locating the expansion joints and filling them with flexible materials like poly-sulphides, bituminous fillers etc.

6.7.5 Masonry: The masonry may be required to be strengthened for resisting earthquake forces by external pre-stressing, splint and bandage methods. The techniques are explained in IS: 13935-1993

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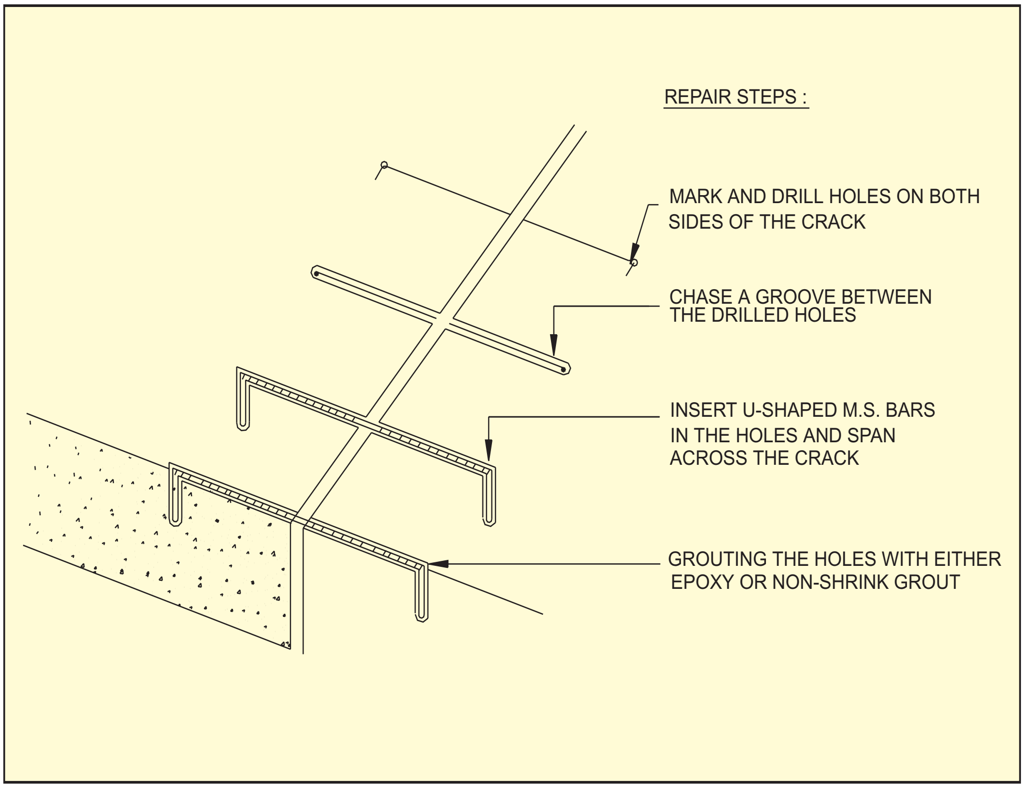

Fig. 6.14(a) Stitching Method of Rapairing Wall/Slab Cracks

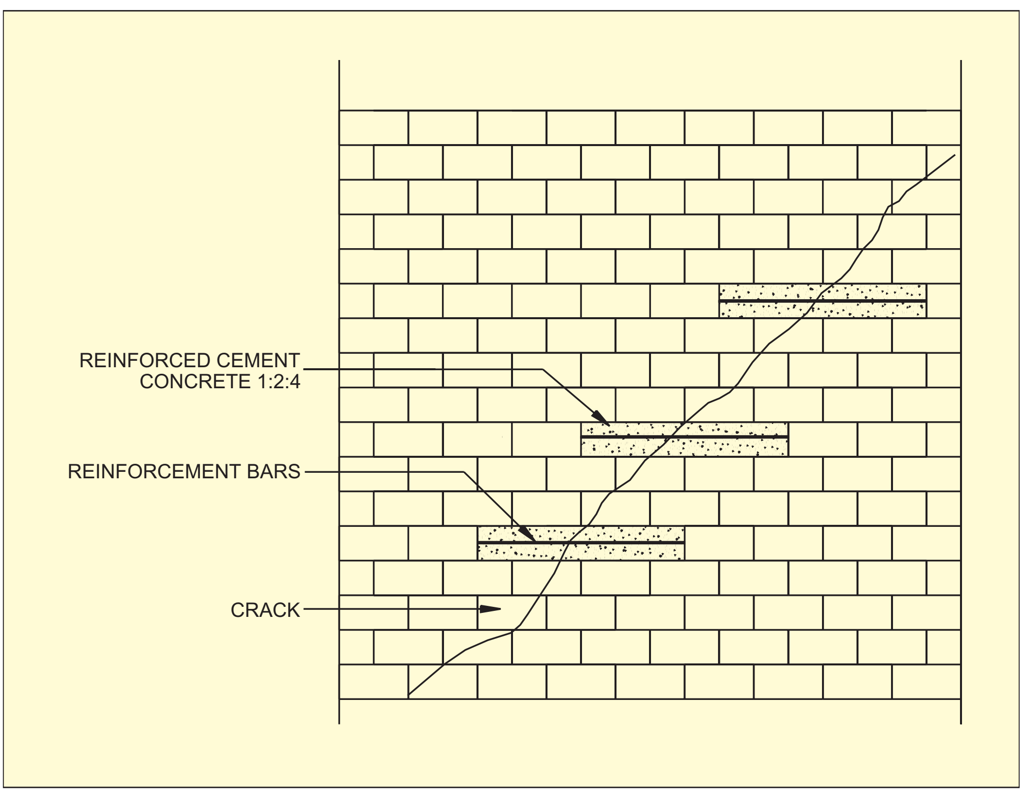

Fig. 6.14(b) Elevation of Brick Masonry Wall Showing Typical Cracks (Vertical or Diagonal)

6.7.6 Protection: Protective measures for preservation and extending the service life of the structure. They are given below.

- Water Proofing
- Depressed Floor Treatment (The step by step sequence of stages for one of the alternatives of treatments have been given in Annexure-6.2)
- Terrace Treatment(The step by step sequence of stages for treatment of Khurrahs at terrace have been given in Annexure-6.3)
- Sun Shade
- Surface Treatment
- Creation of Barrier

6.7.7 Foundation: The methods are explained in section 6.5.19

6.7.8 Base Isolation: Seismic forces are transmitted to the structure due to ground motion caused by the seismic activity. In this method, structure is isolated from ground motion by inserting elastomeric isolators. Most of the energy input from the earth due to seismic activity is absorbed due to isolators movement and thus the building is protected from damage. This method is of significance where it is not possible to make structural/ architectural alterations in the superstructure heritage value. The essential requirement of this method is availability of sufficient space all-round the building for movement of the superstructure and high cost.

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Suggested further reading Material and References

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Appendix 6.1

Structural Repairs to RCC Columns, Beams and Slabs

CASE-I: Crack Repair and Protective Coating for less damaged structural members like minor/hair cracks or spalling from beams and columns, where carbonation depth in cover concrete has not reached reinforcement level.

Caution: *It may be stated that recommended measures are cosmetic measures. The distress may continue to take place even after repairs, if the protective coating, provided as per step no. 7 below, is damaged or ineffective.*

Step-1: Measures shall be taken to ensure that no seepage/leakage etc. affects the RCC columns/beams.

Step-2: The plaster/finishes over the RCC columns/beams shall be removed as per relevant item in sub head 2 of Chapter 8 and relevant specifications in Chapter 9. The concrete surface exposed, spalled and loose cover concrete removed, cracks marked after close examination on the surface of concrete. Whereas the good surface of concrete shall be hacked and roughened for receiving the repair as per relevant item in sub heads 4 & 5 of Chapter 8 and relevant specifications in Chapter 9.

6

Step-3: Wherever loose/spalled cover concrete is removed, it shall be repaired with polymer modified cement mortar, done up in layers as per nomenclature of items in sub-heads 4 & 5 of Chapter 8 and relevant specifications in Chapter 9.

Step-4: All cracks in RCC columns/beams wherever noticed shall be sealed by injection grouting through nipples fixed along the crack line as per nomenclature of items in sub head 3 of Chapter 8 and relevant specifications in Chapter 9.

Step-5: Over the prepared surface of RCC columns/beams, 6 mm thick 1:3 cement sand plaster shall be applied with polymer modified cement

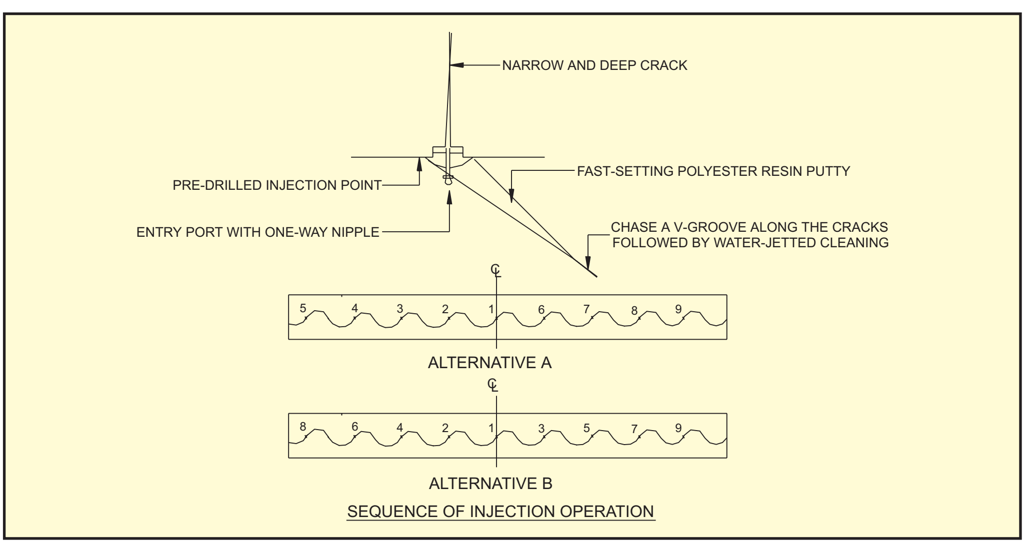

Fig. 6.15 Crack Sealing with Resin Injection Technique

slurry bond coat (item no. 3.2) within 24 hours of injection grouting as per preceding para.

Step-6: Cement plaster shall be cured strictly as per the nomenclature and of items in subhead 6 of Chapter 8 and relevant specifications in Chapter 9.

Step-7: After RCC columns/beams are cured and completely dried, a protective coating shall be applied over it for protecting the reinforcement and concrete against environmental aggressive chemicals in accordance with items of sub-head 8 in Chapter 8 and relevant specifications in Chapter 9

CASE-II: Repair to Damaged Columns/Beams/Slabs where carbonation depth of concrete has reached reinforcement level:

(i) Shotcreting

Stepwise sequence of methodology to be adopted is given hereunder

Step-1: Prop and support the structure in order to relieve the RCC column of stresses due to load coming over it as per the nomenclature of items in subhead 1 of Chapter 8 and relevant specifications in Chapter 9.

Step-2: Remove plaster and finishes all around the distressed RCC columns. Thereafter remove loose, cracked and spalled concrete to expose the rusted reinforcement as per the nomenclature and of items in subhead 2 of Chapter 8 and relevant specifications in Chapter 9.

Step-3 Remove concrete all around the reinforcement in order to get average 25 mm air gap all around i/c behind the reinforcement & clean the reinforcement of concrete and rust by appropriate methods as per nomenclature of items in subhead 2 of Chapter 8 and relevant specifications in Chapter 9.

Step-4 Put additional reinforcement wherever the reinforcement diameter has been reduced by more than 15% with the necessary overlap or welding with the existing reinforcement as per the nomenclature and of items in subhead 5 of Chapter 8 and relevant specifications in Chapter 9.

Step-5: Fix shear key bars of appropriate diameter at specified spacings in both directions over the surface to be covered with repair materials as per the nomenclature of items in subhead 2 of Chapter 8 and relevant specifications in Chapter 9.

Step-6 Apply appropriate passivating and bond coat over the reinforcement and prepared RCC surface as per the nomenclature of items in subhead 4 of Chapter 8 and relevant specifications in Chapter 9. Shotcrete the RCC column within the time limit specified as pot life of the epoxy or tacking period of slurry as per the nomenclature and of items in subhead 4 of Chapter 8 and relevant specifications in Chapter 9. The necessary shuttering as specified in specifications of shotcreting shall be used for ensuing the desired thickness and shape of the columns.

Step-7: 6 mm thick finishing coat with cement sand plaster 1:3(1cement:3fine sand) (of least possible thickness) if felt necessary, shall be applied within 48 hours of application of shotcreted repair.

Step-8 Wet curing shall be done over the finished surface of the shotcrete for a minimum period of 7 days as per the nomenclature and of items in subhead 6 of Chapter 8 and relevant specifications in Chapter 9.

Step-9: After RCC columns/beams are cured and completely dried, a protective coating shall be applied over it for protecting the reinforcement and concrete as per the nomenclature and of items in subhead 8 of Chapter 8 and relevant specifications in Chapter 9.

(ii) RCC Jacketting

Step no.1 to 5, same as in (i) above

Step-6: Appropriate passivating and bond coat shall be applied over the prepared surface as per the nomenclature and of items in subhead 4 of Chapter 8 and relevant specifications in Chapter 9.

Step-7: Within the tacky period of bond coat, shuttering and concreting shall be done with specified grade of concrete with minimum cement content as specified and water cement ratio not more than 0.45**.** The consistency of this concrete shall be flowing and self-compacting which shall be achieved by using super plasticiser. The thickness of RCC jacket shall be as specified.

Step-8: Follow steps no. 6 to 8 as in (i) above.

Case-III: Stages for repairs to RCC Slabs, where carbonation depth has reached reinforcement level.

(i) **Repair with polymer modified cement mortar** (For patch repairs or repairs over smaller magnitude)

Stepwise sequence of methodology to be adopted is given hereunder

Step-1: Propping and supporting of RCC slab under distress shall be as per the nomenclature of items in subhead 1 of Chapter 8 and relevant specifications in Chapter 9.

Step-2: All loose and spalled cover concrete shall be removed including finishing plaster wherever found loose by tapping as per the nomenclature and of items in subhead 2 of Chapter 8 and relevant specifications in Chapter 9.

Step-3: The rusted reinforcement shall be cleaned of concrete preferably by using sand blasting to give a minimum 15 mm clear air gap all around including behind the reinforcement as per the nomenclature of items in subhead 2 of Chapter 8 and relevant specifications in Chapter 9.

Step-4: Additional reinforcement wherever necessary shall be added and tied to the RCC slab with necessary binding wires and nails.

Step-5: Fix shear key bars of appropriate diameter at specified spacings in both directions over the surface to be covered with repair materials as per the nomenclature of items in subhead 2 of Chapter 8 and relevant specifications in Chapter 9.

Step-6: The rusted reinforcement shall be cleaned of rust and passivated and applied bond coating as per the nomenclature and of items in subhead 4 of Chapter 8 and relevant specifications in Chapter 9.

Step-7: The prepared concrete surface shall be covered with appropriate mix of polymer modified cement sand mortar in layers including behind reinforcement over a bond coat with polymer modified cement slurry as per the nomenclature of items in subhead 4 & 5 of Chapter 8 and relevant specifications in Chapter 9. The mortar cover thickness shall be not less than 15 mm over the reinforcement. The maximum thickness shall be not more than 30 mm with each layer not exceeding 10 mm.

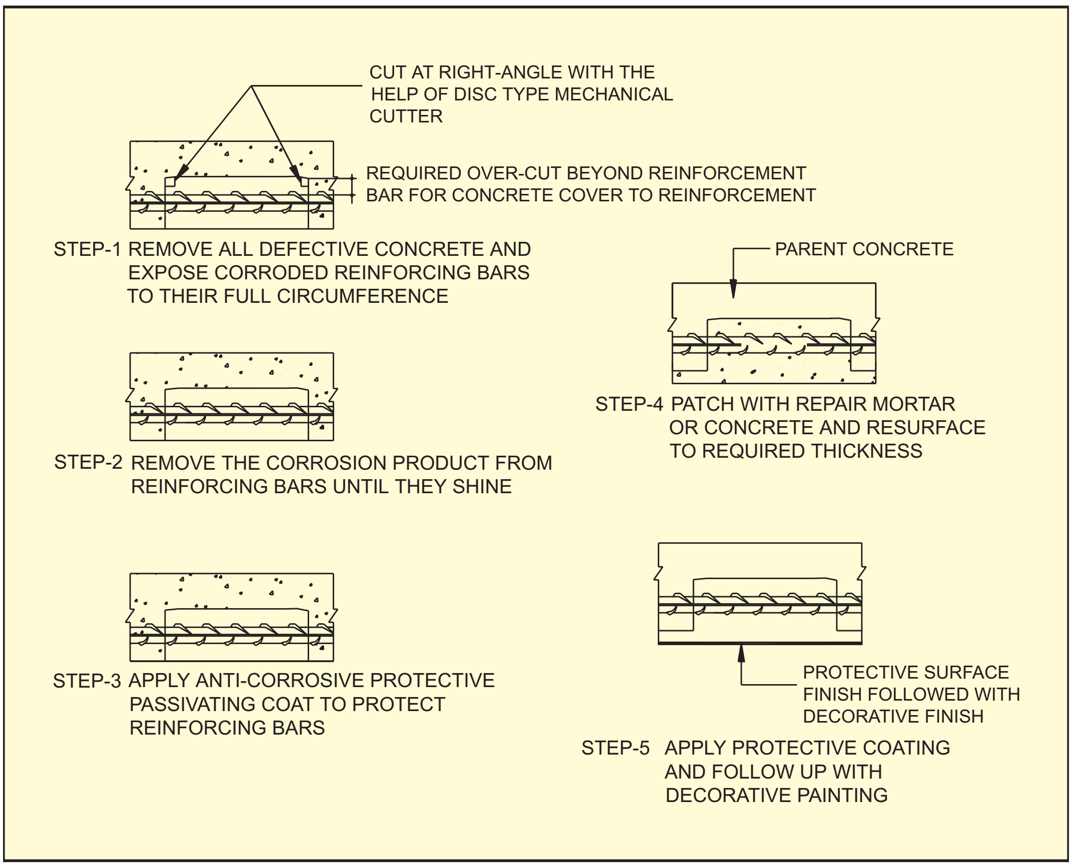

Fig. 6.16 Typical repair procedure for patch repair and corrosion damaged concrete

Step-8: Water curing shall be carried out for a minimum period of 7 days as per the nomenclature and of items in subhead 6 of Chapter 8 and relevant specifications in Chapter 9.

Step-9: Necessary white washing /painting of the surface may be carried out after the curing period is over and the surface gets dried up.

(ii) **Shotcreting:** (For repair jobs covering large areas and/ or large magnitude)

Stepwise sequence of methodology to be adopted is given hereunder

Step-1: Step no. 1 to 6 shall be same as in case of no. (i) above.

Step-7: Shotcreting with average thickness of 50 mm shall be done within the tacking period of epoxy bond coat to be applied over the prepared surface of concrete.

Step-8: Finishing plaster if necessary, may be provided within 48 hours of shotcreting without allowing the RCC slab to become dry during the intervening period.

Step-9: Water curing shall be carried out for a minimum period of 7 days as per the nomenclature and of items in subhead 6 of Chapter 8 and relevant specifications in Chapter 9.

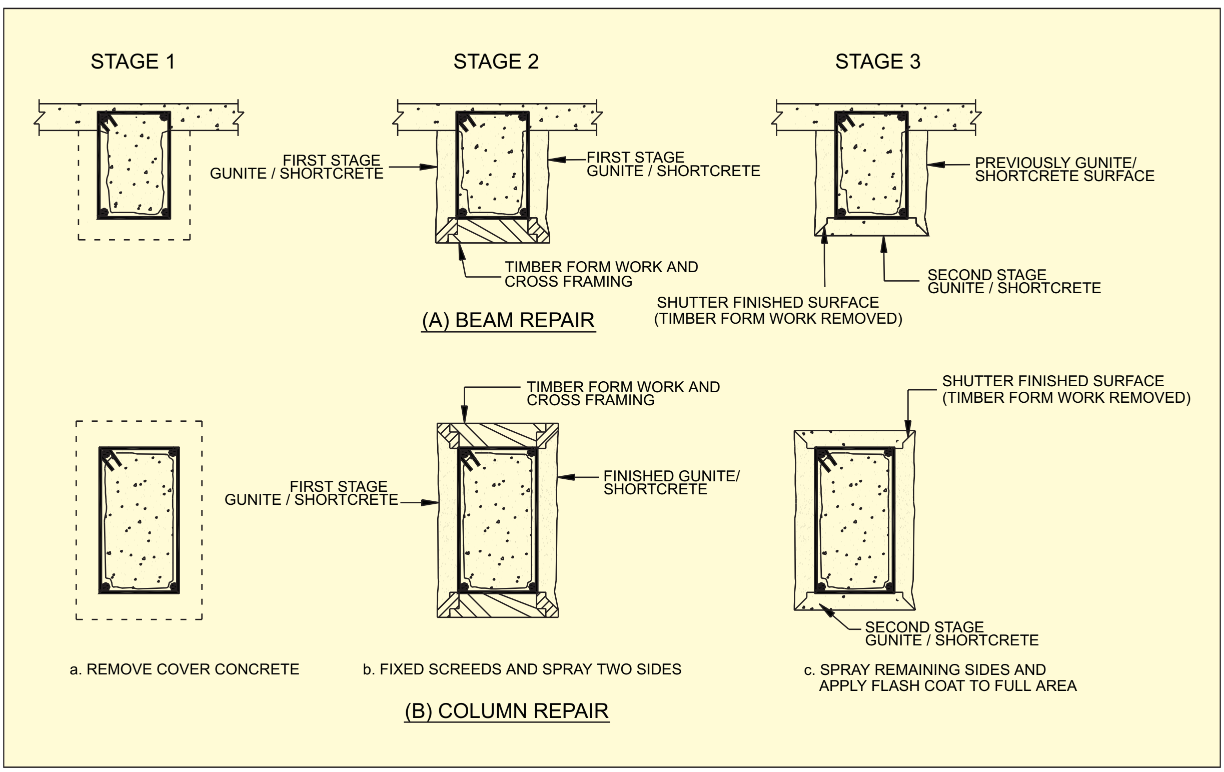

Fig. 6.17 Typical Column repair by Guniting

Appendix 6.2

TREATMENT OF DEPRESSED FLOOR IN TOILETS/KITCHEN

Stepwise sequence of methodology to be adopted is given hereunder

Step-1 Remove all materials /flooring from the sunken floors and expose the drainage pipes/G.I. water supply lines.

Step-2 Test the G.I. water supply lines less than 6 kg per sq.cm. Water pressure using the pressure-testing machine with pressure guage, which is readily available in the market.

Step-3 Test the drainage pipes and other joints for leakages if any, by plugging of horizontal pipe at tee junction with vertical stack and filling with water upto the finished floor level for 48 hours. Leakages noticed, if any, shall be attended to.

Step-4 Provide 40 mm dia G.I.pipe spout and CC flooring with water proofing compound laid in slope(1:48 minimum) for draining out leaking water, if any, from the sunken portion in the shaft.

Step-5 Provide 12mm thick cement plaster 1:3(1cement:3 fine sand) mixed with water proofing compound on the vertical walls of the sunken portion including providing necessary repair around the drainage spout provided.

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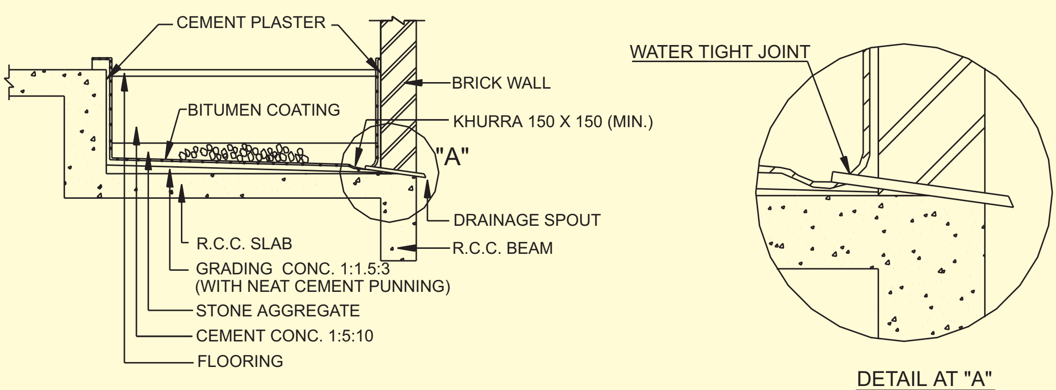

STEP 1 - PROVIDE DRAINAGE SPOUT

STEP 2 - GRADING CONCRETE 1:1.5:3 LAID TO SLOPE TOWARDS DRAINING SPOUT WITH FLOATING COAT OF NEAT CEMENT

STEP 3 - PROVIDE AND LAY WATER SUPPLY & DRAINING PIPES & TEST FOR LEAKAGE THE DRAINAGE /SANITARY PIPES SHALL BE LAID TO SLOPE AND A CLEAR GAP UNDERNEATH THE PIPES SHALL BE MADE AVAILABLE BY PROVIDING SUITABLE C.C. BLOCKS AT APPROPRIATE LOCATION FOR FREE FLOW (OF LEAKED WATER ,IF ANY) TOWARDS DRAINAGE SPOUT.

STEP 4 - 18 MM TH. CEMENT PLASTER 1:3 ON VERTICAL FACES MIXED WITH POLYMER MODIFIED WITH WATER PROOFING COMPOUND AND FLOATING COAT OF POLYMER MODIFIED NEAT CEMENT SLURRY & COATED WITH BITUMEN (2 COATS)

STEP 5 - 150 MM TH. 20 MM SINGLE SIZED STONE AGGRAGATE TO PROVIDE A FILTER MEDIA FOR ANY LEAKING WATER TO TRAVEL TO DRAIN SPOUT BELOW C.C. 1:5:10 (1-CEMENT : 5-COARSE SAND : 10-40 MM & DOWN GRADED STONE AGGREGATE)

NOTE :- 1. WATER PROOFING TREATMENT SHALL BE UNDERTAKEN ONLY WHEN ALL DRAINAGE PIPES / SANITARY PIPES / DRAINAGE SPOUT ETC. HAVE ALL BEEN LAID AND TESTED.

Fig. 6.18 Typical arrangement for treatment of Depressed Floor of Toilets etc.

Step-6 Provide two coats of bitumen (85/25 grade) coating in the sunken portion to ensure that the entire surface is properly covered and drainage pipes are also painted with bitumen.

Step-7 Provide a 100 mm thick dry stone aggregate in the sunken portion. The mouth of the drainage spout provided earlier shall have graded filter so as not to get choked.

Step-8 Rest of the depth of sunken portion shall be filled with lean concrete 1:5:10(1cement:5coarse sand:10aggregate) with stone aggregate and flooring laid to slope.

Step-9 The rusted/leaking G.I. pipes wherever noticed during carrying out the repairs shall be replaced or otherwise be cleaned of rust and coated with polymer modified cement slurry and two coats of bitumen painting.

Appendix 6.3

LEAKAGES FROM TERRACES

The source of leakage from terraces is invariably from

1. Khurrah locations
2. Through tile joints
3. Improper slope of tile terracing
4. Improperly done Gola
5. Depressions to cause stagnation of water

   Stepwise sequence of methodology to be adopted is given hereunder, which has also been explained in Refer Fig

Stepwise Sequence of operations:

Step-1: Dismantle the terrace tiling, mud phuska, gola, khurrahs etc and remove the earth and tiles from the roof slabs .

Step-2: Remove the brickwork of parapet so as to expose RCC slab in a width of 1.5 metre at the location of khurrahs.

Step-3: Clean the RCC surface of roof slab of all dust etc by suitable method including washing with clean water etc.

Step-3: Apply a coat of kerosene oil primer on the whole surface including the portion of RCC slab below the removed parapet at the location of khurrahs.

Step-4: Before the kerosene primer evaporates, apply the bitumen painting over whole terrace including the portion of RCC slab below the removed parapet at the location of khurrah.

Step-5: Provide 400 micron thick poly-ethylene sheet of appropriate size with hot bitumen under-laid at the location of khurrahs with one side of sheet taken up to the outer edge of parapet wall/RCC slab.

Step-6: Provide 50 mm thick cement concrete khurrah over the aforesaid poly-ethylene sheet as per CPWD specifications with one of the four sides (two adjacent sides in case of corner location) of the khurrah concrete taken out up to outer edge of the parapet wall.

Step-7: Re-fix the rain water pipe spout

Step-8: Redo the masonry of parapet at Khurrah location.

Step-9: Provide mud-phuska or the specified terrace treatment strictly as per CPWD specifications taking extra care while redoing mud-phuska in regard to following:

- Terrace tiling shall be laid to a minimum slope of 1: 48 with valleys pointing towards the khurrahs
- Terrace tiles shall be supported over the cement concrete of Khurrah overlapped by a minimum of 50 mm.

Step-10: The terrace tiles shall be saturated with water.

Step-11: The joints of terrace tiles shall be grouted with dry cement sand mortar 1:3 mixed with water proofing compound. Grouting shall be done using coconut broom and appropriate tools to ensure dry compaction of the mortar in the joints. This sand mortar should be allowed to set by absorbing moisture from saturated brick tiles.

Step-12: Wet curing shall be taken up after a minimum of 8 hours of mortar grouting for at least 7-days duration.

Step-13: Cement concrete gola shall be provided with grooved joints at a spacing of 3 metre centre to centre ensuring the concrete of Gola is provided after .

CHAPTER 7

GUIDELINES FOR FRAMING TERMS AND CONDITIONS FOR REPAIR & REHABILITATION WORKS CONTRACTS

7

GUIDELINES FOR FRAMING TERMS AND CONDITIONS FOR REPAIR & REHABILITATION WORKS CONTRACTS

Writen words are better than the best memory.

..A Chinese Proverb.

7.1 General:

The structural repairs to RCC are specialised works. These can be satisfactorily carried out only as per the expert advice of an experienced engineering consultant under strict engineering supervision through a well-equipped experienced contractor.

The provision relating to safety features, quality assurance and environmental protection are important aspects concerning structural repairs of RCC works. These are required to be included as separate individual items of work of measurable performance specifications to form part of the contract. The omnibus mention like 'work shall be carried as per the relevant IS: codes' etc. are avoided as far as possible.

Another aspect is assessment of bill of quantities, as it is very difficult to prejudge the quantities accurately. It should be ensured that all possible items are included in the bill of quantities with reasonably assessed quantity. It is desirable to have item rate contract for structural repairs.

There are three stages in the process of carrying out sound structural repair, which can be classified as under:

- Field investigation and determination of causes & their extent.
- Identification of repair system, framing of specifications and acceptance criteria.
- Execution of repairs.

The first two stages require higher level of intellectual inputs from experienced technical personnel (consultants) equipped with instruments for field inspections, sampling and testing. The third stage requires implementation through competent and experienced contractor equipped with adequate construction equipments and manpower.

At present in India, there are number of consultancy firms and contractors dealing with structural rehabilitation works. As such there is no necessity to approach a single firm of one's choice for the assignment of such jobs. Simultaneously, in view of the specialised nature of work, open competitive bidding without screening (based on credentials of such bidding firms) and awarding the job to the lowest open bid is not likely to yield the desired results.

In this chapter, broad guidelines have been given for short-listing consultants and contractors, for taking up major structural rehabilitation jobs. These will help in suitably formulating and incorporating specific contract conditions related to structural repair works in agreements of consultants and the contractor. However, before communicating with the consultants/contractor, it is necessary for the Employer to identify the job, its scope and work out its size.

7.2 Identification of problem and estimated quantum of job:

7.2.1 It is necessary for the Employer to be able to communicate with the prospective consultants/contractors and convey the nature of job and its size in very clear terms for enabling them to make up their intentions and submit applications for short-listing in the first instance. Therefore preparation of Terms of Reference and projecting the size of the project are the first task on the part of the Employer:

- **Terms of Reference (TOR):** The TOR is the initial statement in regard to the specific rehabilitation project as a means of communication of the Employer to the consultant/ contractor. With eventual modifications, this forms an integral part of the contract, which governs the project that the consultancy/contractor firm is to perform. Therefore the TOR should be as clear and precise as the nature of assignment. Normally the TOR should contain the following in regard to the consultant's/contractor's job of a particular rehabilitation project:

  i. Objective(s)
  ii. Scope and time
  iii. Inputs, if any, to be provided by the Employer
  iv. Details of the services required from the consultant/contractor

- **Size of Project/Cost Estimate:** Size of the structural rehabilitation project gives a reasonable idea to the applicant firms beforehand. For this, one should specify the nature of building & its distress, type of remodeling and its plinth area to be investigated/ rehabilitated/ remodeled. In addition, it is also desirable to give the reasonably assessed cost of execution of the structural rehabilitation/remodeling project.

These could be worked out through engineering establishment of the Employer or an engineering consultant. This estimated cost could be based on plinth area rates worked out on actual completion cost of the identically executed projects.

7.3 Engagement of Consultants:

The objective of engaging a consultant is to define the problem, determine its solution and scope of repair & rehabilitation work. This shall be based on the preliminary inspection of the work and discussions with Employer. The scope of work shall be clearly defined.

The competence, experience and dependability of the firm and its personnel, are far more important parameters for assessing the capability of a consultancy firm for structural rehabilitation/strengthening jobs.

Thus the engagement of a consultancy firm for a particular structural rehabilitation job shall be mainly in two principal stages. In the first stage we have to prepare a short-list of competent, experienced and dependable firms having generally two competent Key Personnel experienced in structural rehabilitation jobs in addition to other technical staff and other attributes. Such list of firms shall be prepared from amongst applications received based on an advertisement published in the press. The second stage of engagement involves receiving the price bids from short-listed consultancy firms after formulating general and specific contract conditions related to the particular rehabilitation project. The components of these two stages are as follows:

I Preparing a short-list of firms
   a. Determining the selection Procedure
   b. Preparing a short-list

II Entering into contract with consultancy Firm
   a. Invitation of price-bid from short-listed consultancy firms
   b. Evaluation of the price-bids
   c. Negotiating a contract with the selected consultancy firm

7.3.1 Short-listing of Consultancy Firms:

- **Associate Consultant(s):**

  It is quite possible that one consultancy firm may not have full capability of undertaking a consultancy assignment on its own capability. Therefore, it is generally an accepted practice to allow the main consultant to submit their applications along with their associate consultant(s) duly supported with explicit irrevocable consent. Identically, it should also be made a condition that the main consultant shall not be allowed to change the associate consultant(s) at a later date. Thus, the combined resources of such main and associate(s) consultants should be considered in evaluating experience and competence.

- **Determining the Procedure for Short-listing:** It is essential to prepare and freeze in advance the procedure before receiving the applications from the intending consultants for short-listing. For arriving at a rational procedure, **a**ll possible attributes of a good consultancy firm are required to be identified, listed out and assigned appropriate weightage.

  - **Key Personnel:** The qualification and experience of the 'Key Personnel' made responsible for the project, is of prime importance besides strength of other technical personnel in the employment. It is necessary that the consultancy firms in their applications submitted for short-list identify the Key Personnel for the rehabilitation project. It is desirable to have an alternate of Key Personnel of equivalent or slightly relaxed capability in consultancy assignments for ensuring that the alternate Key Personnel is exclusively available on full time basis for the consultancy project. However, the Key Personnel shall sign all the proposals/reports on behalf of the consultancy firm. The qualification, experience, age and length of employment of Key Personnel should be considered as important pre-requisites in determining suitability of the consultancy firm. If necessary, it would be desirable to supplement this by interviews. It shall be an essential condition for a consultancy firm to have the services of the identified Key Personnel for the work duration of the consultancy job.

  - **Other Attributes of the Consultancy Firm:** The structure and organisation, experience and adequacy for undertaking a consultancy job are considered other important attributes for a short-listed consultancy firm. These could be on the basis of the financial turnover, technical manpower, geographical location, period of existence of the firm, testing & analytical capabilities, related experience in rehabilitation, analysis & design, field execution of projects etc.

Appendix-7.1 gives an illustrative procedure of short-listing the Consultancy Firms.

- **Preparing a Short-List:** It is quite reasonable to have a list of three to six qualified and experienced short-listed firms through the above stated selection procedure. In cases, where the short-list is either too short or too long, it may be desirable to suitably modify the weightage of various attributes so as to bring the list well within this range. In such a case, it would be essential to go in for fresh invitation of applications from the intending consultants. The Price bids should be received only from such short-listed consultancy firms.

7.3.2 Entering into contract with consultancy Firm:

- **Invitation of price-bid from short-listed consultancy firms:**

A letter for invitation of Price-Bid involves preparation of a document containing all conditions agreement envisaged pertaining to the consultancy job. It will necessitate defining clearly the objective & scope of consultancy work (TOR), various phases of providing consultancy job, time frame for each phase, responsibilities of the Employer and the consultant, responsibility for accuracy of project proposals, indemnity for loss due to acts/omissions of consultant, copyrights and any other special conditions considered necessary to be incorporated in the agreement with the consultant, etc. These are briefly described as under:

➢ *OBJECTIVE:*

The objective of engaging a consultant is to define the problem, determine its solution and scope of repair & rehabilitation work. This shall be based on the preliminary inspection of the work and discussions with Employer. The scope of work shall be clearly defined.

➢ *SCOPE OF WORK:*

The consultant shall inspect work and conduct in-situ & laboratory tests necessary to establish the cause - effect relation. He shall design repair, rehabilitation and retrofitting scheme for the designated design life and performance standards. The consultant shall be responsible for preparation of detailed estimate within specified degree of accuracy, quality assurance procedure, contract document for call of tender, inspection of work during the execution of work and periodic inspection of work after completion. The specifications, nomenclature of items of works, analysis of rates and standards applicable shall be detailed out. He shall make presentation of his report to the group of specified number of engineers identified by the Engineer in Charge. The salient features shall be brought out in the presentation and supporting literature shall be made available. He shall also be present at the pre-bid conference to offer clarifications to the prospective tenderers. If necessary, consultant shall modify the proposal, if necessary, after the pre-bid conference

➢ *PHASES OF THE WORK:*

The consultancy job can be distinctly divided in to three phases of job.

A) *Phase-I:* The details should be given therein and should cover:

1. Collecting of information from the site.
2. Studying the structure in detail to determine the cause & extent of deterioration of structure, its source, leakage, cracking pattern etc.
3. Recording distortions/deflections of structural members if any.
4. Visual inspection for surface damages, cracks, flaking, colouration, local weaknesses etc and their damage classification.
5. Testing by tapping elements to test the surface hardness of concrete, breaking small portions of concrete to assess the homogeneity of concrete and condition of reinforcing steel with particular reference to steel corrosion.
6. Conducting further N.D.E. techniques like Schmidt, U.P.V., core tests etc. or combination of tests as required.
7. Collection & documentation of data in the form of grid drawings, worksheets etc.
8. Arranging all necessary scaffolding, platforms, necessary T & P, stationary, etc required for carrying out the field/ laboratory/ other investigations and preparation of report.
9. Assessment of residual strength.
10. Analysis of structural repairs
11. Submission of preliminary report covering the above aspects including the preliminary estimated cost of repairs/rehabilitation.
12. Identified key personnel shall make required number of visits as per contract conditions.
13. The report shall be examined by the Employer and in case found to be deficient or changes are required, modified report shall be submitted by consultant after additional investigations, if necessary & discussions with the Employer.

B) *Phase-II:* On acceptance of the phase-I report by the Employer, consultant shall prepare & submit a detailed rehabilitation plan, which shall include the following:

1. Details regarding selection of materials, equipment and methods of rehabilitation. If any new materials/techniques are proposed, they shall be supported with necessary technical/documentation/ data.
2. Detailed nomenclature of items to be executed.
3. Detailed specifications including acceptance criteria /standards for work to be executed & materials used.
4. Identification of critical items of work requiring execution of sample items of work under specialist supervision of consultant.

5. Step by step procedure for execution of work at different locations/ for different elements including surface preparation, method of construction & techniques to be adopted.
6. Design of suitable concrete mixes, identification of critical items of repairs requiring consultants supervision.
7. Detailed cost analysis along with bill of quantities for call of tenders.
8. Time Schedule for execution of work.
9. All drawings for execution shall be submitted in minimum of two sets along with a set in a reproducible format.
10. Safety plan before and during repair/rehabilitation including details of shuttering, centering & scaffolding required for repairs at different locations, keeping in view intricacies involved like large spans, extra heights, etc. Details for planned demolition of structurally sensitive portions shall also be prepared.
11. All design calculations regarding residual strength, redesigning of structure including appropriate strengthening with structural drawings for approval by the Employer.
12. Methods of fixing fixtures/fittings etc for the reinstallation/ installation of services, false ceiling, interior decoration, etc shall also be detailed out.
13. Detailed Quality Assurance System during execution.
14. Acceptance criteria of materials and the items of work to be executed
15. Arranging all necessary T & P, stationary, etc required for carrying out the field/ laboratory/ other investigations and preparation of report

The proposal will be examined and approved by the Employer. If modification of same the proposal is required, the consultant shall carry out the same.

a) *Phase -III***:** The consultant shall participate in the pre bid conference to clarify doubts raised by the prospective bidders. He shall render advice to department in tender evaluation, if required. He shall also assist in supervision and quality assurance of work during execution, conducting corrective supervision, acceptance of work executed and issuing stability and rehabilitation certificate. The consultant shall prepare guidelines for further maintenance and post repair periodic inspection. The details of phase-III should provide for:

   1) The consultant will be closely associated in the supervision of execution of samples of critical items as may be identified by the consultant or the Employer at the time of execution in order to ensure that the same is being carried out as per their concept and approval. While routine supervision will be carried out by the Engineer-in-charge, the consultant will render advice at different stages of execution. The consultant shall send a team of identified engineers having relevant experience for supervision as and when required by the Employer.

2) It will also include revision of designs and drawings, due to shortcomings, if any, which might surface at the time of execution. Consultant shall claim nothing extra in this regard.

3) Carrying out quality assurance tests during progress of work. During the actual testing the consultant shall be actively involved with the testing.

4) A detailed plan for maintenance manual.

5) Issue completion certificate based on acceptance tests carried out on rehabilitated structure.

6) Recasting of as built drawings.

7) Arranging all necessary T & P, stationary, etc required for carrying out the field/ laboratory/ other investigations.

8) Preparation of documentation using photographs, slides, videos, floppies, written text etc.

- **Time Frame**

The time frame for each phase of work is shall be clearly defined in the letter of Invitation of Price-bids as follows:

1. Phase-I PHASE-I (a) ________ weeks from the date of start of work.
2. phasePhase-II (a) _______ weeks from the date of approval of preliminary project report by the Engineer-in-charge.
3. Phase-III (a) _______ weeks from start of work.

   i. The work shall commence from 10th day after the date of written orders to commence the work.

   ii. The progress of the work shall be reviewed in weekly meetings between representative of consultantand Engineer, Employer and the contractor, if any. The record of such meetings shall be maintained.

   iii In case consultant is unavoidably hindered in carrying out the investigation, design/drawings on account of delayed decisions or approval by the Employer, which are necessary to carry out further work, he shall apply for be allowed suitable extension of time to the on occurrence of such hindrance. The decision of the Employer shall be final and bindings on the consultant.

   iv. In case of delays attributable to the Employer after the start of work, the Employer shall be made liable to pay compensation to the consultant at a rate as may be specified in the agreement towards the fixed charges of establishment including the remuneration of the key personnel, only if exclusively employed for the work in question.

   v. For the delays attributable to the consultant, the consultant shall be made liable to pay compensation to the Employer at a rate as may be specified in the agreement

- **Responsibility for Accuracy of Project Proposal**

  The consultant shall be responsible for-

  i. Accuracy of the data collected at all stages of work,
  ii. Procedure followed ,
  iii. Safety & soundness of designs as per the design standards followed,
  iv. Drawings prepared and their validation,
  v. Quantity and rates taken in the estimates,
  vi. Quality assurance procedure followed

- **Indemnity for Loss**

  The consultant shall indemnify the Employer against any direct or indirect loss due to inaccuracies in his proposal, which might surface at the time of implementation of the project or after the stipulated period after the completion of the work due to error in the analysis & design

- **Copyright**

  All plans, design and data collected by the consultant for this project shall remain the property of the Employer. The consultant shall have no right to deal with it in any way, other than the purpose for which these were supplied, without the explicit written consent of the Employer. All such plans, design and data or the process of inspection shall be kept strictly confidential & not passed on to any unauthorised person.

The proposals submitted by the consultant shall remain his property and shall not be utilised by the Employer, without the explicit permission, for any other purpose other than the purpose for which these are meant.

- **Special Conditions*:***

  i. The curriculum vitae and composition of the key personnel engaged in the study & the job assigned to each one of them shall be submitted before hand & got approved from the Employer.
  ii. The key personnel once approved, shall not be changed without the prior permission.
  iii. Members of team should have requisite experience in the filed assigned to them.
  iv. In case of any specialised investigation agency is to be engaged, the details of such agency shall be submitted & got approved from the Employer prior to their engagement.
  vi) The cost of engaging such an agency shall be borne by the consultants themselves including cost of any unfrastructural infrastructure support necessary to carry out the investigation.

- **Reports:**

  The format for the report shall generally be in line with the outline as per the details given in the Appendix-7.1.4.7. The consultant shall furnish two hard copies of the final report and one in reproducible format.

- **Evaluation of the price-bids**:

  The financial implications of any condition(s) given in the price bids by the bidders have to be carefully evaluated and loaded on the prices quoted to bring them at the equitable level of comparison for determining the lowest price-bid. As the price-bids have been received out of short-listed consultancy firms of requisite experience and competence, it would be desirable to select the evaluated lowest price-bid for negotiating a contract

- **Negotiating a contract with the selected consultancy firm:**

  Following the decision of the winning consultancy firm, the selected firm is invited to negotiate the contract with the Employer. The work plan, staffing, Employer's inputs, and the final form of the agreement are completed before the financial negotiations. The staff substitution by a consultancy firm is undesirable at any time and particularly between the receipt of the proposal and the start of fieldwork. However, if the validity of the price-bid has lapsed, staff substitution may be discussed during the negotiations. During an assignment, if the staff substitution is necessary due to ill health or otherwise, the consultant should propose some other appropriate staff for approval of the Employer during such negotiations.

Conduct of negotiations on price is customary because the selection process has already been made on technical basis before the receipt of price-bid. In cases where the best consultancy firm is not the lowest priced, asking them to do the work at the lowest price, is not appropriate. Another practice, which does not encourage deliverance of the quality is to negotiate with more than one firm at the same time.

Promptly after the completion of negotiations with the selected firm, the Employer should notify all other firms on the short-list that they were unsuccessful.

A sample form of Agreement with the consultancy firm is available at Appendix 7.2.

7.4 Engagement of Contractors:

The execution of structural repair and rehabilitation works require special skills, knowledge of new materials and processes. The quality assurance has to be of high standard. The civil contractors registered for new construction or for routine periodical repairs cannot be considered competent for repairs and rehabilitation works. Only such short-listed contractors, who qualify a minimum laid down standard, shall be made eligible for issue of tender documents. The detailed departmental instructions of CPWD for pre-qualification of contractors are available at Appendix-7.3.

It has generally been observed that the repairs and rehabilitation works are always accompanied with the renovation, up-gradation and addition & alterations, which are new construction works. Hence, it is desirable that single contractor is fixed for both repairs and rehabilitation works as well as such works involving new constructions, provided the quantum of such new works is not substantial.

7.4.1 Conditions of Contract

The repairs and rehabilitation contract be drawn up using standard CPWD contract form PWD-8. However, the issues relating to specific requirement shall have to be included as special conditions. The main issues to be addressed in such conditions of contract are as follows:

- **General Information:**

  The general information like content of the tender document, name of the project, location, engineer-in-charge, the estimated cost, stipulated time, name/s of the external agencies designated for quality assurance, general specifications, particular specification, referred standards, minimum tools and plants requirement, technical manpower requirement, list of mandatory tests & recommended tests, performance standard, documentation requirement, tender drawings etc. are to be provided stated in the contract.

- **Facilities**

  a. Electricity

  The electricity connection shall generally be made available by the department at one point marked in the drawing. The sub meter shall be arranged and sealed by the department. The distribution lines shall be laid by the contractor at its own cost. The electricity charges at fixed rates shall be deducted from the running bills from time to time according to actual consumption.

  When the department cannot provide electricity, the contractor shall be required to make his own arrangements.

  b. Water

  The water connection shall generally be made available by the department at one point marked in the drawing. The distribution lines shall be laid by the contractor at its own cost. The water charges at fixed rates shall be deducted from the running bills from time to time according to the actual consumption.

  When the department cannot arrange the connection, the contractor shall be asked to make his own arrangements.

  c. Tools & Plant

  Tools or plants available with the department, which can be issued to the contractor are required to be specified in the tender with hiring charges, conditions etc.

- **Constraints**
- **Sequence and Programme of Work**

  The contractor shall be required to submit detailed programme in identified computer software for project monitoring giving details of activities, their sequence, resources to be employed and time schedule etc for approval by the Employer. In case the contractor feels that the time schedule mentioned in the contract is required to be modified, he shall put forward detailed reasons for such a proposal. Such modifications and other issues should be sorted out during the Pre-bid conference.

- **Co-Ordination with other agencies:**

  Condition has to be inserted to ensure that the contractor extends all necessary co-operation to the other agencies involved in the work by way of making necessary adjustment in his work schedule including making site available to the other agencies.

- **Protective Measures:**

The contractor shall take all suitable measures to protect the structures, environment and workforce employed including passersby with necessary barricading, protective screens, helmets, goggles, gloves etc.

- **Temporary Works and Safety Arrangements**

  The contractor shall carry out temporary works to ensure that required dead loads, imposed loads shared by the structural members under repair are safely transferred to the foundation. The rates quoted for all items of work, unless otherwise specifically provided, shall include the cost of providing all temporary works.

- **Signage:**

  The entry to work area may be restricted to workmen and inspecting staff only. Notice boards of specified sizes shall be provided at appropriate locations for wide information.

- **Required Skill of workmen:**

  Certain items of repairs and rehabilitation e.g. jacketing, shotcreting, epoxy/ polymer based items, micro-concreting, pre-placed aggregate concrete, etc require qualified/experienced & skilled workmen for execution. Wherever feasible, suitable provision can be incorporated accordingly.

7.4.2 Pre-bid conference:

As the type of job to be contracted is of specialised nature, it could involve certain innovation with scope of further improvement by way of modification and/or rectification in the specifications contained in the tender documents. Also, some conditions in the tenders might be difficult to achieve in field. These are required to be discussed openly and mutually agreed in a Pre-bid conference with all tenderers, Employer and the consultant. This shall be done at least one week after the date of issue of tender documents and one week before the date of receipt of tenders. The proceedings of the Pre-bid Conference and decisions taken shall be made available to all the tenderers at least 2 days before the date of receipt of the tenders and shall form part of the tender documents. Provision shall be made in the tender documents accordingly.

7.5 Execution of Work

The aspects such as material storage, deployment of T & P, quality assurance, execution of sample of critical items, Tools & plant, etc given in para 9.0 shall also be considered and included in the tender documents.

7.5.1 Materials: Materials proposed to be deployed at work site, their storage arrangements, etc shall be submitted by the contractor before the commencement of the work. Suitable provisions are required to be incorporated for the materials brought to site, which shall be reported in the prescribed proforma in triplicate (Appendix-7.4) giving clearly the name of manufacturer, local source (i.e. dealer), batch no, manufacturer's test certificate etc. Materials shall be kept under recommended conditions storage to avoid damage to the materials. The materials shall be kept in the joint custody under double lock and key system and their receipt & issue recorded in a register by the representative of the Employer.

- **Single Source:** It is always recommended to procure all materials for repairs and protection systems (e.g reinforcement protective system, bonding aid or primer, repair mortar, surface filler, finishing coat and protection systems) from single manufacturer. Otherwise there could be divided responsibility in owning up the non-performance of a material, if such problem arises. If use of product from multiple manufacturers is unavoidable then the combination should be checked for compatibility. The evidence of previous successful use of materials in combination would also be useful.

- **Supply:** It is desirable to enforce the receipt of total assessed quantity of repair materials (e.g. reinforcement protective system, bonding aid or primer, repair mortar, surface filler, finishing coat, protection systems, etc) at site required in one lot at the appropriate stage. In case total requirement of materials cannot be brought at a time due to project period being too long or shelf life of the materials being short, the quantity of material to be brought shall accordingly be received in minimum number of lots.
- **Storage:** The storage facilities are required to be stated by the contractor in his tender. It shall be commensurate with the quantity likely to be stored at the start and during the execution of work.
- **Testing of Materials:** The contractor shall supply manufacturer's test certificate of each material brought to site of its batch of manufacture. The claims of manufacturers in regard to performance of materials may vary substantially for specific climatic conditions. Therefore it is essential that the ambient conditions for carrying out performance tests be specified in tender documents.

In addition, each lot of supply shall be tested for ensuring the desired quality standards. The sampling of materials shall be done in the presence of representatives of contractor and the Employer. The sampling and testing shall be done at specified frequency. The record of test results shall be maintained in the prescribed format for future reference.

7.5.2 Testing of Completed items of Work:

The specific post repair evaluation tests must be specified. The frequency of tests shall also be incorporated as specified by the consultant.

- **Costs of Field/Laboratory tests**:
  The cost of sample and test charges may be borne by the Employer. However, if the sample fails in the performance test, the cost of samples and the testing charges shall be borne by the contractor.

7.5.3 Tools & Plants: The minimum identified Tools & Plant for the all the processes and testing shall be clearly specified in the tender documents. Also the contractor, while tendering, should be required to inform the details of Tools & plants proposed to be deployed by him on the work. The tools and plants shall be kept in good working condition. Periodic preventive maintenance shall be carried out in order to avoid sudden break down and loss of working time.

7.5.4 Supervision and Inspection of works

- **Critical Repair Items :**
  Execution of sample of all critical repair items, identified by the consultant, shall be done in the presence of consultant and the Employer**.** It shall be pre requisite for taking up execution of subsequent stage of work. The record of observations made by the consultant during supervising execution of all such samples of critical items, shall be maintained in a proforma prescribed by the consultant for each of the critical repair items.

- **Record of Supervision and inspection of Surface preparation:**
  A record of day-today supervision and inspection of surface preparation shall be maintained by the contractor in a proforma prescribed by the consultant under the close supervision of the Employer or their authorised representative.
- **Supervision by the Consultant:** The consultant shall carry out inspection and testing at the specified interval for testing integrity of repairs with the substrate and its soundness, including impermeability and corrosion resistance tests for repairs. The consultant shall inspect to ensure that the work is carried out as per his recommendations. The frequency and stages of inspection shall be specified in the contract. The consultant shall give his written report with his observations and also make recommendations for any deviation/remedial measures. These shall be binding on the contractor.

7.5.5 Record of Testing, Supervision and Inspection:

The record of Inspection, supervision and testing of all materials, surface preparation etc shall all be taken over and preserved by the Employer for a specified period (preferably 5 years)

7.6 Post Repair Inspection

The consultant along with the Employer and the contractor shall carry out periodical inspection after completion of works at specified frequency (preferably every year) for a post repair period of five years. This is to ensure that the post repair defects are identified and effective remedial measures are taken. Also, the post repair maintenance is ensured to be carried out as per recommendation. This is necessary to ensure that completed work meets the intended durability and other performance requirements. Suitable provisions in the contract documents of the contractor and the consultant shall be made accordingly.

7.7 Performance Guarantee

The consultant shall guarantee the performance of the works as per designs and specifications prepared by him. In the event of failure to achieve the guaranteed performance laid down in the agreement due to reasons directly attributed to the consultant, he shall be liable for such failure and liability shall be limited to a maximum amount specified in the agreement.

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Suggested further reading Material and References

1. The Concrete Society Technical Report no. 26, Repair of concrete Damaged by Reinforcement Corrosion
2. German Committee on Reinforced Concrete, Guidelines for Protection and Repair of Concrete Components, part 3 Quality Assurance in the Execution of Works
3. Guidelines-Use of Consultants by World Bank Borrowers and by the World Bank as Executing Agency, August 1981 (ISBN 0-8213-9000-7)
4. National Highways Authority of India methodology including Criteria for Selection of Consultants
5. Employer-Consultant Model Services Agreement-1999 by Consulting Engineers Association of India and Consultancy Development Centre
6. Pre-Qualification Document for CPWD Works as amended by Office Memorandum No. DGW/MAN/65 dated 4 April, 2001 and No. DGW/MAN/81 dated 28-12-2001.

Appendix 7.1

AN ILLUSTRATIVE
PRE-QUALIFICATION DOCUMENT

For

SHORT-LISTING OF CONSULTANTS

For Undertaking

FIELD INVESTIGATIONS & SUBMITTING PROPOSALS

For

REPAIRS, REHABILITATION AND RETROFITTING OF RCC BUILDINGS

Appendix 7.1*(Contd..)*

I N D E X

Appendix 7.1.1

PRESS NOTICE
CENTRAL PUBLIC WORKS DEPARTMENT
INVITATION TO PRE-QUALITY

1. The Executive Engineer <*Specific particulars of the Employer to be filled*> , on behalf of the President of India invites pre-qualification applications from Consultants/ Consultancy Firms of repute for the following work(s): -

Sl.No.	Name of work	Nature of	Approx. Cost / Plinth Area of Building	Period of Completion
	<Write Name of Work as per TOR (Refer para 7.2.1 of the Handbook)>		*<Size of the project/ Cost Estimate (Refer para 7.2.1 of the Handbook)>*	*<Duration for completion of Consultancy job up to Phase-II as per para 7.3.2 of the Handbook>*

2. Applicant Consultants/ Consultancy Firms, who fulfill the following requirements shall be eligible to apply *(The applicants are allowed to pool the resources of maximum one associate consultant/associate consultancy firm)*.

   a. Applicants should have satisfactorily completed consultancy jobs of investigating more than 90% of the plinth area of work in question for of the identically distressed building projects during the last five years ending the last day of the month with each job having plinth area not less than 30% of that of the work in question (at least one project out of them shall be of Central Government/Central Autonomous Body/Central PSU).

   b. Should not have incurred any loss in more than two years during the last five years ending <*Write the last date & month of preceding Financial Year*>.

   c. Should have been in business of providing consultancy in civil Engineering for a minimum period of five years as on <*Write the last day of preceding calendar month of the date of receipt of letter of transmittal*>.

   d. Should have had average annual financial turnover not be less than Rs. <*As a guide, 1.5 times the average equivalent technical personnel (ETP) establishment cost envisaged in Proforma X*> lakhs during the last three years in consultancy jobs of Investigation of distressed RCC structures, submitting proposals for rehabilitation, preparation of structural designs and drawings of new buildings. Year in which no turnover is shown would also be considered for working out the average.

3. Desirous Consultants or Consultancy Firms may obtain prescribed blank 'Pre-Qualification Document' from the Executive Engineer <*Specific particulars of the Employer to be filled*> on payment of Rs. <*to be filled in*> in cash, upto 3.30 PM on <*Date, month and Year to be filled in*> on making a written request.

4. ‘Pre-Qualification Document’ duly completed and supported with prescribed Appendixs and supporting documents shall be received up to 03.00 P.M. on <*Date, month and Year to be filled in*> in sealed envelope with name of work and due date of opening super scribed legibly in bold letters on envelope. These will be opened by the Executive Engineer or his authorised representative in his office on the same day at 03.30 P.M in presence of the applicant consultants/authorised representatives of the applicant firms.
5. If any information furnished by the applicant is found to be incorrect at a later stage, the applicant shall be liable to be debarred from the tendering/taking up works in CPWD. The department reserves the right to verify the particulars furnished by the applicants independently.
6. The department reserves the right to reject any application without assigning any reason and to restrict the list of prequalified consultants to any number deemed suitable by it, if too many applications are received satisfying the basic pre-qualification criteria.

EXECUTIVE ENGINEER

Appendix 7.1.2

SECTION – 1

BRIEF PARTICULARS OF THE WORK

1. Salient details of the work for which pre-qualification applications are invited are as under :

Sl.No.	Name of work	Nature of	Approx. Cost / Plinth Area of Building	Period of Completion
	<Write Name of Work as per TOR (Refer para 7.2.1 of the Handbook)>		*<Size of the project/ Cost Estimate (Refer para 7.2.1 of the Handbook)>*	*<Duration for completion of Consultancy job up to Phase-II as per para 7.3.2 of the Handbook>*

2. The work is located at < <u>*Address of the work*</u>> .

3. General features and major components of the work are as under:

<Briefly Describe

- the Nature of distress,
- structural rehabilitation/strengthening, remodeling details,
- renovation and other addition/alteration, etc. as may be envisaged>

4. Consultancy services shall be rendered in <<u>*Fill number of phases-Refer para 7.3.2*</u> > phases as under:

a.Stage-I: *(Refer para 7.3.2)*

b.Stage-II: *(Refer para 7.3.2)*

c.Stage-III: *(Refer para 7.3.2)*

Appendix 7.1.3

SECTION II

INFORMATION AND INSTRUCTIONS TO APPLICANTS

1.0 GENERAL:

1.1 Letter of transmittal & Proformas for pre-qualification are given in Section III

1.2 All information called for in the enclosed Proformas should be furnished against the respective columns in the forms. If information is furnished in a separate document, reference to the same should be given against respective columns in the forms. If information is 'nil' it should also be mentioned as 'nil' or 'no such case'. If any particulars/query is not applicable in case of the applicant, it should be stated as 'not applicable'. However, the applicants are cautioned that not giving complete information called for in the application forms required, not giving it in clear terms or making any change in the prescribed forms or deliberately suppressing the information may result in the applicant being summarily disqualified. Applications made by telegram or telex and those received late will not be entertained.

1.3 The application should be typewritten. The applicant's name should appear on each page of the application.

1.4 Overwriting should be avoided. Correction, if any, shall be made by neatly crossing out, initialing, dating and rewriting.

1.5 All pages of the pre-qualification document shall be numbered and submitted as a package with signed letter of transmittal.

1.6 References, information and certificates from the respective past/ present employers certifying the applicant's experience, suitability, technical know-how or capability should be signed by an officer not below the rank of Executive Engineer/Project Manager or equivalent.

1.7 The applicant may furnish any additional information, which he thinks is necessary to establish his capabilities to successfully complete the envisaged work. He is, however, advised not to attach superfluous information.

1.8 No further information shall be entertained after submission of Pre-Qualification Document, unless it is called for by the Employer.

1.9 The Pre-Qualification Document in prescribed form duly completed and signed shall be submitted in a sealed cover. The sealed cover superscribed "Pre-Qualification Document for <*Name of Work*>"shall be received by the Executive Engineer, or his authorised representative upto 3.00 P.M. on <*Date, month and Year to be filled in*>. Documents submitted in connection with pre-qualification will be treated confidential and will not be returned.

1.10 The employer reserves the right to verify the particulars furnished by the applicants independently.

1.11 Any information furnished by the applicant found to be incorrect either immediately or at a later date, would render him liable to be debarred from taking up work in CPWD.

1.12 Prospective applicants may request clarification of the project requirement and pre-qualification document. Any clarification given by the Employer will be forwarded to all those who have purchased the pre-qualification document. No request for clarification will be considered after <*Date, month and Year to be filled in*>.

1.13 The department reserves the right to reject any application without assigning any reason and to restrict the list of pre-qualified consultants to any number deemed suitable by it, if too many applications are received satisfying the basic pre-qualification criteria. The department reserves the right to reject

2 DEFINITIONS:

2.1 In this document the following words and expressions have the meaning hereby assigned to them.

- "APPLICANT**"** means the individual, proprietary firm, firm in partnership, limited company private or public corporation engaged in the business of rendering consultancy services for civil engineering projects and had applied for pre-qualification as consultant for the project.
- "ASSOCIATE" means an associate consultant/associate consultancy firm of the Consultant to complement or supplement its resources for performing the consultancy services for the Project.
- "EMPLOYER" Means the President of India, acting through the Executive Engineer <*Specific particulars of the Employer to be filled*>.
- "KEY PERSONAL" and "ALTERNATE KEY PERSONAL" means agreed technical personnel representing the Consultant, who are overall responsible for supervising/overseeing all field & laboratory investigations & testing of collected samples, recommendations and signing all reports, drawings, technical specifications, contract conditions, quality assurance procedure, execution of identified critical repair items, etc and their accuracy.
- "PROJECT" means the works for which the consultancy services are to be provided.
- "SERVICES" means the services to be performed by the Consultant in accordance with the Agreement and comprise Normal Services, Additional Services and Exceptional Services.
- "WORKS" means the permanent works to be executed (including the goods and equipment to be supplied to the Employer) for the execution of the Project.

3 METHOD OF APPLICATION:

3.1 If an individual makes the application, the individual above his full typewritten name and current address shall sign it.

3.2 If a proprietary firm makes the application, it shall be signed by the proprietor above his full typewritten name and the full name of his firm with its current address.

3.3 If the application is made by a firm in partnership, it shall be signed by all the partners of the firm above their full typewritten names and current address or alternatively by a partner holding power of attorney for the firm, in which case a certified copy of the power of attorney shall accompany the application. A certified copy of the partnership deed and current address of all the partners of the firm shall also accompany the application.

3.4 If a limited company or a corporation makes the application, it shall be signed by a duly authorised person holding power of attorney for signing the application accompanied by a copy of the power of attorney. The applicant should also furnish a copy of Memorandum of Articles of Association duly attested by a Public Notary.

3.5 If the applicant has an associate, the applicant shall obtain and submit with the application an explicit irrevocable written consent from such associate to provide consultancy service clearly defining scope of services to be provided by the Associate.

3.6 The applicant and the associate consultant(s) shall also give joint undertaking that the applicant shall not be allowed to change the associate consultant(s) at a later date.

3.6 In case of associates associated with the applicant, the Part I and Part II of the application form shall be separately filled up & signed by the applicant and the Associate. The applicant shall necessarily sign the proforma pertaining to the associate.

3.7 The Applicant shall sign each page of the application form and all the Appendixs submitted therewith.

4.0 FINAL DECISION MAKING AUTHORITY

The employer reserves the right to accept or reject any application and to annul the pre-qualification process and reject all applications at any time, without thereby incurring any liability to the affected applicants or specifying the grounds for the Employer's action.

4.0 PARTICULARS PROVISIONAL

The particulars of the work given in Section-I are provisional and must be considered only as relevant information to assist the applicant.

6.0 SITE VISIT

The applicant is advised to visit and examine the site of work and its surroundings and obtain for himself on his own responsibility, all information that may be necessary for preparing the pre-qualification application. The cost of visiting the site and/or obtaining any additional information shall be at applicant's own expense.

7.0 INITIAL CRITERIA FOR ELIBILIGY FOR PRE-QUALIFICATION

7.1 The applicant should be in business of providing consultancy in Civil Engineering for a minimum period of five years as on <*Write the last day of preceding calendar month of the date of receipt of letter of transmittal*>.

7.2 The applicant should have satisfactorily completed works of similar class of magnitude as specified below during the last five years. For this purpose total plinth area of the work investigated by the consultant shall be considered, which an officer not below the rank of Executive Engineer/ Project Manager or equivalent should certify.

"Applicant should have satisfactorily completed consultancy jobs of investigating more than 90% of the plinth area of work in question of the identically distressed building projects during the last five years ending the last day of the month with each job having plinth area not less than 30% of that of the work in question (at least one project out of them shall be of Central Government/Central Autonomous Body/Central PSU)."

7.3 The applicant's average annual financial turn-over (gross) should not be less than Rs. <*As a guide, 1.5 times the average equivalent technical personnel (ETP) establishment cost envisaged in Proforma X*> lakhs during the last three years duly audited by Chartered Accountant in consultancy jobs of Investigation of distressed RCC structures, submitting proposals for rehabilitation, preparation of structural designs and drawings of new buildings. Year in which no turnover is shown would also be considered for working out the average.

7.4 The applicant or his associate should own adequate Investigative Non Destructive Evaluation equipment and laboratory facilities required for the proper and timely investigation. The applicant should furnish a list of these equipment.

7.5 The applicant should have sufficient number of Technical and Administrative employees for the proper execution of the consultancy job. The applicant should submit a list of these employees stating clearly how these would be involved in this Consultancy job.

7.6 The applicant's performance for each work completed in the last 5 years and in hand should be certified by an officer not below the rank of Executive Engineer/Project Manager or equivalent.

8.0 EVALUATION CRITERIA FOR PRE-QUALIFICATION

8.1 For the purpose of pre-qualification, applicants will be evaluated in the following manner:-

8.2 The initial criteria prescribed in para 7.2 & 7.3 above in respect of experience of similar class of works completed and financial turn over will first be scrutinised and the applicant's eligibility for pre-qualification for the work be determined.

8.3 Those firms qualifying the initial criteria as set out in para 7.2 & 7.3 above will then be evaluated for following criteria.

(a) Key Personal and the Alternate Key Personal
(b) Technical Personnel Establishment
(c) Experience in similar class of work.
(d) Performance on these works.
(e) Non-Destructive Evaluation instruments, analytical & design tools, Technical Library.

The details given by the applicants in the pre-qualification document will be evaluated by scoring method. To pre-qualify, the applicant must secure at least fifty percent in each of the above criteria and fifty percent in total as under:

S.No	Description	Weightage Marks Obtained	Minimum Marks for Eligibility
Part-I	**KEY PERSONAL / Alternate KEY PERSONAL**		
I.Key Personal		**100**	**60**
II.	**Alternate Key Personal**	**100**	**50**
Part-II	**GENERAL**		
X	**Structure & Organisation (XX)**	**30**	**15**
	i. Existence of the Firm	5 (Refer Proforma (X)	
	ii. Financial Turnover	5	
	iii Equivalent Technical Personnel (ETP)	15	
	iv. Geographical Location	5	
Y	**Particular Experience (YY)**	**50**	**25**
	i. Experience in Investigation of Deteriorated Structures and recommending Remedial Measures	20(Refer Proforma (Y)	
	ii. Field Supervision of Repairs & Rehabilitation Jobs	10	

7

S.No	Description	Weightage Marks Obtained	Minimum Marks for Eligibility
iii.	Structural Analysis and Design	20	
Z	**Adequecy for Assignment (ZZ)**	**20**	**10**
I.	Field/Laboratory Testing Facility 10	(Refer Proforma Z)	
ii.	Computer Hardware & Software 5		
iii.	Technical Library 5		
	Total (XX+YY+ZZ)	**100**	**50**

8.4 Even though applicants may satisfy the above requirements, they could be disqualified if they have:

(a) Made misleading or false representation or deliberately suppressed the information in the forms, statements and enclosures required in the pre-qualification document.

(b) Records of poor performance such as abandoning work, not properly completing the Consultancy job or financial failures/ weaknesses.

9.0 FINANCIAL INFORMATION

Annual financial statement for the last five years to be given in Part-II-Proforma 'X'. These should be supported by audited balance sheets and profit and loss accounts duly certified by a Chartered Accountant, as submitted by the applicant to the Income Tax Department.

10.0 EXPERIENCE, IN CIVIL CONSULTANCY WORKS HIGHLIGHTING EXPERIENCE IN SIMILAR WORKS

10.1 Applicant should furnish the following :-

(a) List of all works of Nondestructive Evaluation (NDE), Preparation of Reports, Implementation of Structural Repairs awarded during the last five years: [In Proforma Y(A) of Part-II].

(b) List of the projects of work supervision of Structural Repairs awarded in last five years [In Proforma Y(B) of Part-II]

(c) Structural Analysis & Design of New Projects of all Consultancy Jobs awarded in last five years [In Proforma Y (C) of Part-II]

10.2 The performance on completed works, that determine eligibility of applicant shall be authenticated/ certified by an officer not below the rank of Executive Engineer/ Project Manager or equivalent and separately for each work.

11.0 ORGANISATION INFORMATION

APPLICANT IS REQUIRED TO SUBMIT THE FOLLOWING IN RESPECT OF HIS ORGANISATION (In Part-II-Proforma X)

(a) Name and postal address, **website, email address** i/c telephone & telex number etc.

(b) Copies of original documents defining the legal status, place of Registration and principal places of business.

(c) Names and title of Directors and officers to be concerned with the work, with designation of individuals authorised to act for the organisation.

(d) Authorisation for employer to seek detailed references.

(e) Number of Technical employees with consultant/consultancy firm, associate consultant/consultancy firm and how these would be involved in this work (In Part-II-Proforma X).

12.0 Non-Destructive Evaluation Instruments and other Investigative, Analytical & Design Tools, Technical Library

Applicant should furnish the list of Non-Destructive Evaluation Instruments and other Investigative, Analytical & Design Tools e. computers, structural analysis and design software to be used in carrying out the work together with the Technical books and Joutrnals (In Part-II Proforma Z). Details of any other important investigative instrument required for the work (not included in Proforma Z) and available with the consultant may also be indicated.

13.0 LETTER OF TRANSMITTAL

The applicant should submit the letter of transmittal attached with pre-qualification document.

14.0 Price-Bid Submission

After evaluation of pre-qualification applications, a list of qualified consultants/ consultancy firms will be prepared. Thereafter, only those agencies pre-qualified for the work will be invited to submit price bids for the work.

15.0 SELECTION CRITERIA

15.1 The employer reserves the right to :-

(a) Amend the scope and plinth area of the building for submission of Price-bids.

(b) Reject any or all the Price-Bids without assigning any reason.

15.2 For any of the above actions, the Employer shall neither be liable for any damages, nor be under any obligation to inform the Applicants of the grounds for the same.

15.3 Effort on the part of the bidder or his agent to exercise influence or to pressurise the employer for his price bid shall result in rejection of such bid. Canvassing of any kind is prohibited.

Appendix 7.1.4

SECTION III

PRE-QUALIFICATION INFORMATION

Appendix 7.1.4.1

LETTER OF TRANSMITTAL

From :-

____

____

____

To

The Executive Engineer,

____

____

Sub.: **Submission of pre-qualification application for the work of <*Name of work*>.**

Sir,

Having examined the details given in pre-qualification Press Notice and Pre-Qualification Document for the above work, we hereby submit the pre-qualification and relevant documents.

1. We hereby certify that all the statements made and information supplied in the enclosed form Part-I and Part-II (Proforma X, Y and Z) including that of the associate consultant/associate consultancy firm and accompanying documents/statements are true and correct.
2. We have furnished all information and details necessary for pre-qualification and have no further pertinent information to supply.
3. We submit the following certificates in support of our eligibility to be determined in accordance with the Press Notice for having successfully completed the following works:-

Particulars of the Works :

Sl.No.	Name of work	Plinth Area	Completion Cost, if known	Month & year of completion
1				
2				
3				

7

4. Following are the details of our Associate for the specific scope of work mentioned as under:-

Sl No.	Name of the associate consultant/associate consultancy firm for the <*Name of Work*>	Full Address of the associate consultant/associate consultancy firm	Specific scope of work of the associate consultant/associate consultancy firm

The explicit irrevocable written consent obtained from the above said Associate to provide consultancy service, with his scope of work as above, is enclosed. Also, a joint undertaking that we shall not be allowed to change the associate at a later date signed by us and the associate is enclosed.

5. The Part-I and II of the Application form with the proformas duly complete & signed by the Associate and by us are also enclosed:-

Enclosures :
Seal of applicant
Date of submission **SIGNATURE OF APPLICANT**

7

Appendix 7.1.4.2

PART-I: CURRICULUM VITAE OF 'KEY PERSONAL' AND 'ALTERNATE KEY PERSONAL'

Important: 1. *The applicants must fill information in each column without fail.*

2. *In case of nil information, NIL should be filled in.*

3. *Additional sheets could be attached; wherever space provided is not enough.*

4. *Separate Proforma shall be used in respect of Main Applicant Consultancy Firm and each of its Associate Consultancy Firm*

PART-I	Key Personal	Alternate Key Personal
1.	Name	
2.	Date of birth	
3.	Qualifications B. Tech/M.Tech./ Other	Subject, year of acquisition
4.	Specialisation	
5.	Length of General Professional Experience	Details of companies served, Names of Projects designed/ executed/investigated, duration and nature of experience to be given in Chronological Sequence starting from latest to the oldest assignment
6.	Length of specialised Experience in Investigation of Deteriorated Structures and recommending Remedial Measures	Details of companies served, Names of Projects investigated, duration and nature of experience to be given in Chronological Sequence starting from latest to the oldest assignment
7.	Experience in Civil Engineering Projects in Developed countries Developing countries	Details of companies served, Names of Projects designed/ executed/investigated, duration and nature of experience to be given in Chronological Sequence starting from latest to the oldest assignment
8.	Experience in Civil Engineering Projects in other Developing countries Developing countries	Details of companies served, Names of Projects designed/ executed/investigated, duration and nature of experience to be given in Chronological Sequence starting from latest to the oldest assignment
9.	Period of continuous Employment with Applicant Consultancy Firm	

Certificate:

The Information furnished above is true to my knowledge and belief. I am aware that any mis-information or its concealment, which forms the basis of pre-qualification, is liable for any action against the firm, which could include termination of the agreement and/or blacklisting.

(Name and Signature of the Key Personal or Alternate Key Personal)

(Name & Signature of authorised Signatory of the Consultancy Firm with seal)

Appendix 7.1.4.3

PART-II Proforma X: GENERAL INFORMATION:

Important:
1. The applicants must fill information in each column without fail.
2. In case of nil information, NIL should be filled in.
3. Additional sheets could be attached; wherever space provided is not enough.
4. Separate Proforma shall be used in respect of Main Applicant Consultancy Firm and each of its Associate Consultancy Firm

1. Name of Consultant Firm :

2. Legal Status of the Firm (Individual/Proprietary Firm/ Firm in Partnership/Limited Company/Corporation) Attach signed copies original documents *defining the status* :

3. Particulars of Registration with various Govt Bodies *(Attach attested Photocopies)* :

Sl No	Name of the Govt Department	Registration No	Validity Period

4. Postal Addresses of headquarter & Branches, if any :

5. E-mail Address :

6. Website :

7. Audited Financial Turnover for Last Five Years :

S.No.	Year	Turnover (Rs in lakhs)	Profit /loss
1.			
2.			
3.			
4.			
5.			

(Enclose Copy of audited Reports and Income Tax Clearance Certificates)

8. Technical Staff employed with the firm :

Sl No.	Name of the Employee	Designation	Date of Birth	Technical Qualification and year of acquisition (Diploma/ Degree/Ph.D in Engineering/ MBA be clearly mentioned)	General Professional experience in Civil Engineering practice	Proposed utilisation of the person for the job

Certificate:

The Information furnished above is true to my knowledge and belief. I am aware that any mis-information or its concealment, which forms the basis of pre-qualification, is liable for any action against the firm, which could include termination of the agreement and/or blacklisting.

(Name &Signature of authorised Signatory with seal)

Witness with address:

Appendix 7.1.4.4

PART-II Proforma Y: PARTICULAR EXPERIENCE

Important:
1. The applicants must fill information in each column without fail.
2. In case of nil information, NIL should be filled in.
3. Additional sheets could be attached; wherever space provided is not enough.
4. Separate Proforma shall be used in respect of Main Applicant Consultancy Firm and each of its Associate Consultancy Firm

1. **Name of Consultant Firm :**

A. Nondestructive Evaluation (NDE), Preparation of Reports, Implementation of Structural Repairs (Chronological list of all Consultancy Jobs awarded in last five years) ***(Attach attested photocopies of documentary proof)***

S.No	Project	Employer	Estimated Cost	Plinth Area involved	Date of award of consul-tancy job	Whether comple-ted ? (Yes/No)	If not comple-ted, state reasons
1							
2							

B. Works supervision of Structural Repairs (Chronological list of all Consultancy Jobs awarded in last five years) ***(Attach attested photocopies of documentary proof)***

S.No	Project	Employer	Estimated Cost	Plinth Area involved	Date of award of consul-tancy job	Whether comple-ted ? (Yes/No)	If not comple-ted, state reasons
1							
2							

C. Structural Analysis & Design of New Projects (Chronological list of all Consultancy Jobs awarded in last five years) ***(Attach attested photocopies of documentary proof)***

S.No	Project	Employer	Estimated Cost	Plinth Area involved	Date of award of consul-tancy job	Whether comple-ted ? (Yes/No)	If not comple-ted, state reasons

D. Whether applicant firm or any of its partners ever debarred or blacklisted by any organisation at any time? If so, details

Name of the debarring/ blacklisting Department/ Organisation	Name of the Applicant Firm or any of its partner in individual capacity, debarred/blacklisted	Brief Particulars of blacklisting/debarring from tendering

E.

F. Any Other Information related to Experience

Certificate:

The Information furnished above is true to my knowledge and belief. I am aware that any mis-information or its concealment, which forms the basis of pre-qualification, is liable for any action against the firm, which could include termination of the agreement and/or blacklisting.

(Name &Signature of Authorized Signatory with seal)

Witness with Address

1.

2.

Appendix 7.1.4.5

PART-II Proforma Z: ADEQUACY FOR THE ASSIGNMENT

Important:
1. The applicants must fill information in each column without fail.
2. In case of nil information, NIL should be filled in.
3. Additional sheets could be attached; wherever space provided is not enough.
4. Separate Proforma shall be used in respect of Main Applicant Consultancy Firm and each of its Associate Consultancy Firm

1. Name of Consultant Firm :

A. Non Destructive Evaluation (NDE) Instruments available with the Consultancy Firm:

S.No	Instrument Model	Make & acquisition	Year of utilization in testing of structure	Field of working Condition? (Yes/No)	Whether in
1.					
2.					

B.1 Analytical Computer Hardware:

S.No	Machine	No	Brand & Model	Year of acquisi-tion	Specifications	Whether in working Condition? (Yes/No)
1.						
2.						

B.2 Structural Analysis and other Softwares

S.No	Software (Commercial Name, if procured)	Developed by	year	Purpose
1.				

C. Technical Library :

S.No.	Standard / Books	Numbers
1	Technical Books	
2	Technical Journals	
3	Indian Standards/Codes of Practice	
4	Foreign Standards/Codes of Practice	
	Total	

Certificate:

The Information furnished above is true to my knowledge and belief. I am aware that any mis-information or its concealment, which forms the basis of pre-qualification, is liable for any action against the firm, which could include termination of the agreement and/or blacklisting.

(Name & Signature of authorised Signatory with seal)

Appendix 7.1.4.6

EVALUATION ABSTRACT FOR SHORT-LISTING OF CONSULTANTS

(for use in Employer's Office)

Summery

S.No	Description	Weightage	Marks Obtained	Minimum Marks for Eligibility
Part-I	**KEY PERSONAL / Dy KEY PERSONAL**			
	A Key Personal	**100**		**60**
	B Dy Key Personal	**100**		**50**
Part-II	**GENERAL**			
	A Structure & Organisation	**30**	**XX**	**15**
	i. Existence of the Firm	5	(Refer Sheet X)	
	ii. Financial Turnover	5		
	iii Equivalent Technical Personnel (ETP)	15		
	iv. Geographical Location	5		
	B Particular Experience	**50**	**YY**	**25**
	i. Experience in Investigation of Deteriorated Structures and recommending Remedial Measures	20	(Refer Sheet Y)	
	ii. Field Supervision of Repairs & Rehabilitation Jobs	10		
	iii. Structural Analysis and Design	20		
	C Adequecy for Assignment	**20**	**ZZ**	**10**
	i. Field/Laboratory Testing Facility	15	(Refer Sheet Z)	
	ii. Computrer Hardware & Software	5		
	Total	**100**	**XX+YY+ZZ**	**50**

Appendix 7.1.4.6 *(..Contd)*

EVALUATION ABSTRACT OF PART-I FOR SHORT-LISTING OF CONSULTANTS

(For use in Employer's Office)

Part I Proforma for Key and Alt. Key Personal

S. No.	Item			Marks Scored
A	**Educational Qualification (Maxi Marks 20)**	**Y/N**	**Marks (A)**	
	(I) Graduate in Civil Engineering (Weightage=75%)			
	(II) Post Graduate in Civil Engineering (Weightage=90%)			
	(II) Ph.D in Civil Engineering (Weightage=100%)			
			Total(A)	AA
B	**Age : Max Marks 5**	**(Y/N**	**Marks (B)**	
	(I) 40 to less than 50 yrs (Weightage=50%)			
	(II) 50 to less than 60 yrs (Weightage=100%)			
	(III) 60 to 65 yrs (Weightage=50 %)			
			Total Marks(B)	BB
C	**General Professional Experience (Max Marks=15)**	**(Y/N)**	**Marks (C)**	
	(I) 25 yrs and above (Weightage=100%)			
	(II) 20 yrs and above (Weightage=80%)			
	(III) Less than 20 yrs (Weightage=50%)			
			Total Marks(C)	CC
D	**Experience in Investigation of Deteriorated Structures and recommending Remedial Measures (Max Marks=40)**	**(Y/N)**	**Marks (D)**	

7

(I) More than seven Projects Completed (Weightage=100 %)

(II) Four to Six Projects Completed (Weightage=80%)

(III) One to three Projects Completed (Weightage=50%)

Total Marks(D) DD

E Experience in Civil Engineering Projects executed in Developed Countries (Max Marks=10) **(Y/N** **Marks (E)**

(I) Three Projects and above (Weightage=100%)

(II) Two Projects (Weightage=80%)

(III) One Project (Weightage=50%)

Total Marks(E) EE

F Experience in Other Developing Countries (Max Marks=5) **(Y/N)** **Marks (F)**

(I) 5 Yrs and above (Weightage=100%)

(II) 3-5 yrs (Weightage=80%)

(III) 1 to 3 yrs (Weightage=50%)

Total Marks(F) FF

G Employment with the Firm (Max Marks=5) **(Y/N** **Marks (G)**

(I) One to three years (Weightage=20%)

(II) Three to Five yrs (Weightage=60%)

(III) More than five yrs (Weightage=100%)

Total Marks(A) GG

Grand Total: (AA+BB+CC+DD+EE+FF+GG)

Appendix 7.1.4.6 *(..Contd)*

Part-II Proforma X Evaluation Abstract Part-I Proforma-X Structure & organisation of firm

(For use in Employer's Office)

Maximum Marks(30)

S. No.	Item		Marks Scored
A	**Existence of Firm (Max Marks=5)**	**Y/N**	**Marks (A)**
	(I) Less than five years (Weightage=50%)		
	(II) Five years & less than ten years (Weightage=75%)		
	(II) Ten years & above (Weightage=100%)		
		Total(A)	AA
B	**Financial Turnover (Max Marks=5)**	**(Y/N)**	**Marks(B)**
	(I) Up to 50 Lacs (Weightage=50%)		
	(II) More than 50 Lacs & upto 100 Lacs (Weightage=75%)		
	(II) More than 100 Lacs (Weightage=100%)		
		Total(B)	BB

C Equivalent Technical Personnel (ETP) Strength

Method of Calculation of ETP

Education (Ed)	Experience (Ex)	No of Personnel in Position (No)	ETP (Ed*Ex*No)
Diploma in Civil Engineering (Weightage=0.5)	Upto five years (Weightage=1)		A
	More than five & upto ten years (Weightage=1.5)		B
	More than ten & upto fifteen years (Weightage=2.0)		C
	More than fifteen years (Weightage=2.5)		D

7

Education (Ed)	Experience (Ex)	No of Personnel in Position (No)	ETP (Ed*Ex*No)
Graduate in Civil Engineering (Weightage=1.0)	Upto five years (Weightage=1)		E
	More than five & upto ten years (Weightage=1.5)		F
	More than ten & upto fifteen years (Weightage=2.0)		G
	More than fifteen years (Weightage=2.5)		H
Post Graduate in Civil Engineering Subjects (Weightage=1.5)	Upto five years (Weightage=1)		I
	More than five & upto ten years (Weightage=1.5)		J
	More than ten & upto fifteen years (Weightage=2.0)		K
	More than fifteen years (Weightage=2.5)		L
Ph.D in Civil Engineering (Weightage=2.0)	Upto five years (Weightage=1)		M
	More than five & upto ten years (Weightage=1.5)		N
	More than ten & upto fifteen years (Weightage=2.0)		O
	More than fifteen years (Weightage=2.5)		P
	Total number of ETP	(A+B+C+D+E+F+G+H+I+J+K+L+M+N+O+P)	

(I) Less than five (Weightage=25%)

(II) Five & upto twenty (Weightage=50%)

(II) More than twenty (Weightage=100%)

Total (C) CC

7

		(Y/N)	Marks(C)
	ETP Strength (Max Marks=15)		
D	**Geographiocal Location (Max Marks=5)**	**(Y/N)**	**Marks(D)**
	(I) 201 Km to 500 Km (Weightage=50%)		
	(II) 101 to 200 Km (Weightage=75%)		
	(III) Less than 100 Km (Weightage=100%)		

Total (D) DD

Grand Total (AA+BB+CC+DD)

Appendix 7.1.4.6 *(..Contd)*

Part-II: Proforma Y Evaluation Abstract Part-II: Proforma Y Particular Experience

(For use in Employer's Office)

Particular Experience of Consultant Firm (Max. Marks 50)

S. No	Item	Marks Scored	
A	**Experience in Investigation of Deteriorated Structures and recommending Remedial Measures undertaken in the last five years (Max Marks=20)**	**(Marks (A)**	
	(I) One Project Completed (Weightage=50%)		
	(II) Two Projects Completed (Weightage=75%)		
	(III) More than Two Projects Completed (Weightage=100%)		
		Total Marks(A)	AA
B	**Works supervision of structural repairs undertaken in the last five years (Max Marks=10)**	**Marks (B)**	
	One Project completed (Weightage=50%)		
	Two Projects completed (Weightage=75%)		
	More than two Projects completed (Weightage=100%)		
		Total Marks(B)	BB
C	**Structural Analysis and Design undertaken in the last five years (Max Marks=20)**	**Marks (B)**	
	Two Projects completed (Weightage=50%)		
	Three Projects & upto five Projects completed (Weightage=75%)		
	More than five Projects completed (Weightage=100%)		
		Total Marks(C)	CC
		Grand Total (AA+BB+CC)	YY

7

Appendix 7.1.4.6 *(..Contd)*

Part-II: Proforma Z: Evaluation Abstract Part-II: Proforma Z Adequacy for Assignment

Adequacy for the Assignment, Max Marks(20)

S. No	Item	Marks Scored	
A	**Field/Laboratory Testing Facility (Max Marks=10)**	**Marks(A)**	
	(I) Bar locator & cover meter (Weightage=20%)		
	(II) Core cutting Machine with Core Cutting bits (Weightage=20%)		
	(III) Ultrasonic Pulse Velocity (UPV), (Weightage=20%)		
	(IV) Half Cell Potential Measuring Instrument or Resistivity Meter (Weightage=10%)		
	(V) Rebound hammer (Weightage=10%)		
	(VI) Laboratory for Geo Technical Examination (Weightage=20%)		
		Total Marks(A)	AA
B	**Computer Hardware & Software: Max. Marks (5)**	**Marks(A)**	
	(I) Two computer with an acceptable Structural Analysis Package (Weightage=40%)		
	(II) More than two & upto five computers with an acceptable Structural Analysis Package (Weightage=60%)		
	(III) More than five computers with an acceptable Structural Analysis Package (Weightage=100%)		
		Total Marks(B)	BB
C	**Technical Library: Max Marks (5)**	**Marks(A)**	
	(I) 100 to less than 500 Books/ Journals (Weightage=50%)		

7

(II) 500 to less than 1000 Books/ Journals (Weightage=75%)

(III) 1000 Books/Journals and above (Weightage=100%)

Total Marks(C)	CC
Grand Total (AA+BB+CC)	ZZ

Appendix 7.1.4.7

Suggested Format of Report

Phase-I: Preliminary Report

1. Introduction and Background History
2. Scope and methodology
3. Results
4. Immediate remedial measures for safety of structure and its users.
5. Information required for further investigations

Note: The report shall indicate the name of technical team members involved with the inspection and testing separately.

Phase-II: Detailed Investigation Report

1. Introduction
2. Description of the building and brief background history *(including information and data gathered from site during preliminary and detailed inspection)*
3. Data furnished by the client
4. Scope of the Report
5. Investigations carried out
   a. Visual Inspection
   b. Analysis and Design
   c. Field Testing
   d. Laboratory Testing
6. Main observations forming the basis for conclusions
7. Conclusions *(specifically covering the causes of deterioration, their source(s), rehabilitability of the structure)*
8. Recommendations (*remedial measures given in easy to understand step by step procedure to be followed with alternatives, cost estimate including nomenclature of items and related specifications, suggested special conditions of contract, list of critical repair items, Quality Assurance Procedure and its certification formats, time required for execution, post repair maintenance procedure and expected life gain)*

Note:

1 Photographs, Worksheets, Record of Field/Laboratory/ visual observations in statistical format, which form the basis of conclusions, shall also form part of the report.

2. The report shall indicate the name of technical team members involved with the inspection and testing separately.

Appendix 7.2

SAMPLE FORM

of

AGSEEMENT

with

CONSULTANCY FIRM

7

Appendix 7.2 *(..Contd.)*

INDEX

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Appendix 7.2.1

AGREEMENT

This Agreement made on today, the < *Date*> day of <*Month and Year*> between the Executive Engineer, <*Specific particulars of the Employer to be filled*>, on behalf of the President of India (hereinafter called "the Employer") of the one part and <*Full Name of the Consultant/ Consultancy Firm with its address*>(hereinafter called "the Consultant") of the other part.

Whereas the Employer desires that the Consultant should perform certain consultancy services namely <________________________________*Name____of Work*________________________________>

and has accepted a proposal of the Consultant for performance of such Services.

Now this Agreement witnesseths as follows:

1. In this Agreement, words and expressions shall have the same meaning as are respectively assigned to them in the Conditions of the Employer/Consultant Agreement hereinafter referred to.

2. The following documents attached hereto shall be deemed to form (and be read and construed as) part of this Agreement, namely :

   a. The Letter of Acceptance;
   b. The Conditions of the Employer/Consultant Services Agreement (General Conditions);
   c. The Appendices, namely:

      Appendix A - Objectives & Description of the Project
      Appendix B - Commencement & Completion of Services
      Appendix C - Remuneration and Payment
      Appendix D - Scope of Services
      Appendix E - Prints, Drawings & Specifications
      Appendix F - Assigned Specialists, Personnel, Equipment, Facilities and Services of others to be provided by the Employer.

3. In consideration of the payment to be made by the Employer to the Consultant as hereinafter mentioned, the Consultant hereby agrees with the Employer to perform the Services in conformity with the provisions of the Agreement.

4. The Employer hereby agrees to pay the Consultant in consideration of the performance of the Services such amounts as may become payable under the provisions of the Agreement at the time and in the manner prescribed by the Agreement.

In Witness whereof the Parties hereto have caused this Agreement to be executed the day and year first above written.

B. Binding Signature(s) of Employer	**Binding Signature(s) of Consultant**
(Seal, if any)	(Seal, if any)
In the presence of	**In the presence of**
(1) Witness	(2) Witness
Name ______________________	Name ___________________
Signature ___________________	Signature _________________
Address _____________________	Address __________________
_____________________	______________________
____________________	______________________

Appendix 7.2.2

CONDITIONS OF EMPLOYER/CONSULTANT SERVICES AGREEMENT

GENERAL CONDITIONS

1.0 DEFINITIONS AND INTERPRETATIONS

1.1 Definitions

The following words and expressions shall have the meanings assigned to them except where the context otherwise requires:

- "AGREEMENT" means the Employer/Consultant Services Agreement.
- "ASSOCIATE" means a consultant/consultancy firm associated by the Consultant to complement or supplement its resources for performing the consultancy services for the Project.
- "CONSULTANT" means the party named in the Agreement, who is employed as an independent firm by the Employer to perform the Services, and legal successors to the Consultant and permitted assignees.
- "CRITICAL REPAIR ITEM" means the item of repair work, which is critical and important for the durability and successful execution of the rehabilitation project.
- "DAY" means the period of twenty-four hours commencing with the midnight of any day.
- "EMPLOYER" means the party named in the Agreement, who employs the Consultant, and legal successors to the Employer and permitted assignees.
- "FEES" means the amount of money to be paid to the Consultant by the Employer for services rendered by the Consultant to the Employer.
- "KEY PERSONAL" and "ALTERNATE KEY PERSONAL" means agreed technical personnel representing the Consultant, who are overall responsible for supervising/overseeing all field & laboratory investigations & testing of collected samples, recommendations and signing all reports, drawings, technical specifications, contract conditions, quality assurance procedure, execution of identified critical repair items, etc and their accuracy.
- "MONTH" means the period of one month according to the Gregorian calendar commencing with any day of the month.
- "PARTY" and "PARTIES" means the Employer and the Consultant and "Third Party" means any other person or entity, as the context requires.
- "PROJECT" means the works for which the consultancy services are to be provided.
- "SERVICES" means the services to be performed by the Consultant in accordance with the Agreement and comprise Normal Services, Additional Services and Exceptional Services.
- "WORKS" means the permanent works to be executed (including the goods and equipment to be supplied to the Employer) for the execution of the Project.

1.2 Interpretations

1.2.1 The headings in the Agreement shall not be used in its interpretation.

1.2.2 The singular includes the plural, the masculine includes the feminine, and vice-versa, where the context so requires.

1.2.3 If there is conflict between provisions of the Agreement, the written last chronologically shall prevail.

2.0 PERSONNEL

2.1 Authorised Representative of the Consultant

For administration of the Agreement, the Consultant shall authorise a mutually agreed Key Personal (and Alternate Key Personal, if the situation so arises), to represent the Consultant, who shall be available for liasoning with the Employer or its nominee for communication during the normal working hours. Key Personnel once approved shall not be changed without the written approval of the Employer.

2.2 Other Technical Personnel

Other members of the team employed by the consultant shall have the requisite experience in the fields assigned to them.

2.3 Changes in Personnel

If it is necessary to replace any person employed by the consultant on the project, for which the Employer shall make request in writing stating the reasons for the replacement, the consultant shall immediately arrange for replacement by another person of comparable competence. The cost of such replacement shall be borne by the consultant.

3.0 COMMENCEMENT, COMPLETION, ALTERATION AND TERMINATION OF THE AGREEMENT

3.1 Agreement Effective

The Agreement is effective from the 10th day of signing by the Employer of Letter of Acceptance of the Consultant's proposal for providing consultancy for the Project. The appending of signature by the parties is necessary to complete the formal Agreement.

3.2 Commencement and Completion

The Services shall be commenced and completed by or within the times or periods stated in Appendix B subject to extensions in accordance with the Agreement.

3.3 Modification to Agreement

Should circumstances arise which call for modification of the Agreement, these may be made by mutual consent in writing. (Proposal in this respect from one party shall be given due consideration by the other party)

3.4 Delays

If the Services are impended or delayed by, or because of, the Employer or his contractors so as to increase the duration of the Consultancy services, the Consultant shall inform the Employer of the circumstances and the adverse impact, if any, in writing. Accordingly, the time for completion of the Services shall be suitably increased by the Employer.

3.5 Changed Circumstances

a) If circumstances arise for which the Consultant is not responsible and which make it impossible for him to perform in whole or in part the Services in accordance with the Agreement he shall promptly notify the Employer in writing.

b) In these circumstances, if certain Services have been suspended or have to be suspended, the time for their completion shall be extended until the circumstances no longer apply plus a reasonable period not exceeding 10 days for resumption of these services.

c) If the speed of performing certain Services has to be reduced, the time for their completion shall be extended as may be made necessary by the circumstances.

3.6 Abandonment, Suspension or Termination

a) By Notice of the Employer

i) The Employer may suspend all or part of the Services or terminate the Agreement by giving notice, in writing, of at least 15 days to the Consultant who shall immediately make arrangements to stop the Services and minimize expenditure.

ii) If the Employer considers that the Consultant is, without good reason, not discharging his obligations, he shall notify in writing to the Consultant stating the grounds for the notice, terminate the Agreement provided that such further termination notice is given without 45 days of the Employer's earlier notice.

b) Force- Majeure

Neither the Employer nor the Consultant shall be considered in default in performance of the obligations under this Agreement if such performance is prevented or delayed by events such as, but not limited to, war, hostilities, revolutions, riots, civil commotion, strikes, lock-outs, conflagrations, epidemics, accident, fire, wind, flood, drought, earthquake, or ordinance of any Government or of any sub-division thereof, or because of any act of God, or for any other cause beyond the reasonable control of the party affected, provided notice in writing of any such cause with necessary evidence that the obligation under the Agreement is thereby affected or prevented or delayed is given within 10 (Ten) days from the happening of the event and in case it is not possible to serve the notice within the said ten days period, then within the reasonable shortest possible period without delay. As soon as the cause of force Majeure has been removed, the party whose ability to perform its obligation has been affected shall notify the other of such cessation and of the actual delay incurred in such affected activity adducing necessary evidence in support thereof. From the date of the occurrence of a case of force Majeure, the obligations of the party affected shall be suspended during the continuance of any inability so caused until the case itself and the inability resulting therefrom have been removed and the agreed time of completion of the respective obligations under the Agreement shall stand extended by a period equal to the period of delay occasioned by such events.

c) Default by the Employer

The Consultant may, by written notice to the Employer, terminate this Agreement

i) If he has not received payment of that part of any invoice which is not contested within sixty (60) days of submission thereof;

ii) If the Services have been postponed as provided for in Clause 3.6 and the period of postponement has exceeded six (6) months.

d) Entitlement of Consultant upon Postponement or Termination

Upon postponement of the Services or termination of this Agreement under Clause 3.6 (a), (b) or (c) and subject to the obligation of the Consultant to reduce expenditure to a minimum as stated in Clause 3.6(a) the Consultant shall be entitled to receive the remuneration due up to the effective date of postponement or termination and reimbursement in full for such of the costs specified in Appendix –C as shall have been incurred prior to the effective date of such postponement or termination and for all costs incidental to the orderly termination of the Services, including return travel of the Consultant's personnel.

(e) Claims for Default

Any claim for damages arising out of default and termination shall be agreed between the Employer and the Consultant or, failing agreement, shall be referred to arbitration in accordance with Clause 3.6(f) of this Agreement.

f) Arbitration

Any dispute or difference arising out of this Agreement including those considered as such by any one of the parties, shall be finally settled under the provisions of The Arbitration and Conciliation Act, 1996 as amended from time to time. The Chief Engineer, CPWD shall upon receipt of a request from the party(s) shall appoint an Arbitrator for adjudication of the disputes. The appointment of Arbitrator, so made, shall be binding on the parties.

3.7 Exceptional Services

a) Upon the occurrence of circumstances described in Clause 3.6 or abandonment or suspension or resumption of Services or upon termination of the Agreement otherwise than under the provisions of Clause 3.6 (a) any necessary work or any other essential activity involving expense by the Consultant extra to the Normal and Additional Services shall be regarded as Exceptional Services.

b) The performance of Exceptional Services shall entitle the Consultant to extra time necessary for their performance and to payment for performing them.

3.8 Rights and Liabilities of Parties

Termination of the Agreement shall not prejudice or affect the rights or claims of the parties, accruing otherwise.

3.9 Assignment

a) The Consultant shall not, without the written consent of the Employer, assign the benefits, other than the assignment of any monies due, or to become due, under this Agreement.

b) The Consultant shall not, without the written consent of the Employer, in any way assign or transfer his obligations under this Agreement or any part thereof, to anyone, except its associate(s), which formed the basis for selection of the Consultant, only for such work, which falls within the scope of work originally envisaged during the process of pre-qualification.

4.0 FEE & TERMS OF PAYMENT

4.1 The Employer shall pay the Consultant for Normal Services in accordance with the conditions and details stated in Appendix-C and in accordance with Clause 4.3.

4.3 Terms of Payment

a) Employer shall pay amounts due within 15 days of the submission of bill/claim by the Consultant.

b) The Employer shall pay the Consultant Service Tax and/or any other levies by Central/State Governments or any other statutory authority, over and above the fee specified.

5.0 GENERAL PROVISIONS

5.1 Copyright

All plans, design and data collected by the consultant for this project shall remain the property of the Employer. The consultant shall have no right to deal with it in any way, other than the purpose for which these were supplied, without the explicit written consent of the Employer. All such plans, design and data or the process of inspection shall be kept strictly confidential & not passed on to any unauthorised person.

The proposals submitted by the consultant shall remain his property and shall not be utilised by the Employer, without the explicit permission, for any other purpose other than the purpose for which these are meant.

5.2 Conflict of Interest

a) Unless otherwise agreed in writing by the Employer, the Consultant and his personnel shall have no interest in nor receive remuneration in connection with the Project except as provided for in the Agreement.

b) The Consultant shall not engage in any activity, which might conflict with the interests of the Employer under the Agreement.

5.3 Notices:

Notices under the Agreement shall be in writing and will take effect from the date of receipt at the address of the party. Delivery can be by hand or facsimile message, against written confirmation of receipt or by registered letter or by telex subsequently confirmed by letter.

5.4 Publication:

Unless otherwise permitted by the Employer in writing, the Consultant, either alone or jointly with other, cannot publish material relating to the Works and Services.

5.5 Patent:

If the terms of purchase of patented or patent pending articles, methods or devices involve or require the payment of any license fee or royalty in addition to the purchase price, and do not contain patent indemnification in a form satisfactory to the Employer, no such article, method or device shall be used or supplied in connection with the work or incorporated in the Work without the prior written approval of the Employer.

5.6 Secrecy

The Consultant shall use all the document, drawings and other date and information of a proprietary nature received from the Employer, solely for the purpose of performing and carrying out the obligations on his part under the Agreement and shall not disclose the same to any other person except to the extent required, in the performance of the Works for the Project and shall maintain the utmost secrecy. The Consultant shall bind his employees, who are involved in engineering of the Project, by a suitable secrecy agreement. The Consultant shall not use the documents, drawings and other data and information received from the Employer for any other purpose.

5.7 Controlling Laws

The laws of the land will govern the rights and obligations of the Employer and the Consultant under this Agreement.

6.0 OBLIGATIONS OF THE CONSULTANT

6.1 Scope of Services

6.1.1 The Consultant shall exercise reasonable skill, care and diligence in the performance of his obligations under the Agreement and shall be responsible for:

vii. Accuracy of the data collected at all stages of work,
viii. Procedure followed for investigations and framing recommendations
ix. Accuracy in arriving at conclusions
x. Safety & soundness of designs as per the design standards followed,
xi. Drawings prepared and their validation,
xii. Quantity and rates taken in the estimates,
xiii. Correctness of technical Specifications, contract conditions and Quality assurance procedure recommended for execution of the project

The Consultant shall perform Services relating to the Project. The scope of the Services is stated in Appendix – D.

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6.2 Report

6.2.1 The format for the report shall generally be in line with the outline as per the details given in the Annexure-**7.1.2**. The consultant shall furnish two hard copies of the final report and one in reproducible format.

6.3 Normal, Additional & Exceptional Services

6.3.1 Normal Services are those described as such in Appendix- D.

6.3.2 Additional Services are those described as such in Appendix –D or which by written agreement of the parties are otherwise additional to Normal Services**.**

6.3.3 Exceptional Services are those which are not Normal or Additional Services but which are necessarily performed by the Consultant consequent to such changed circumstances for which Consultant is not responsible and in accordance with the Agreement or arising out of abandonment or suspension or resumption of Services.

6.4 Care and Exercise of Authority

6.4.1 The Consultant shall exercise reasonable skill, care and diligence in the performance of his obligations under the Agreement

6.4.2 Where the Services include the exercise of powers or performance of duties authorized or required by the terms of the contract between the Employer and any third party, the Consultant shall:

a) act in accordance with the contract provided that the details of such powers and duties are acceptable to him where they are not described in Appendix- D.

b) if so authorized, certify, decide or exercise his discretion fairly between the Employer and third party not as an arbitrator but as an independent professional by his skill and judgment.

c) If so authorized, vary the obligations of any third party, subject to obtaining the prior approval of the Employer to any variation which can have an important effect on costs or quality or time (except in any emergency when the Consultant shall inform the Employer of the action taken by him as soon as practicable)

6.5 Performance Guarantee

6.5.1 The Consultant shall carry out the Services in conformity with generally accepted norms and sound standards of engineering and be responsible for the technical soundness of the Services rendered. In the event of any deficiency in these Services, the Consultant shall promptly redo such design and engineering at no additional fees to the Employer.

6.5.2 The Consultant shall guarantee the performance of the Works as per designs and specifications prepared by him. In the event of the failure to achieve the guaranteed performance as laid down in the Agreement due to inaccuracy in its investigations/ testing, recommendations, identification of Critical Repair Items, inappropriate execution of project, etc for which the responsibility directly attributed to the Consultant, he shall be liable for such failure and the liability shall be limited to a maximum on all accounts, upto 10% of the fees received/receivable by the Consultant. However, such liability shall be limited for a period of five years from the date of actual completion of executed project.

6.5.3 The Consultant shall not be liable for any hardware cost of rectification, consequential loss, direct or remote or loss of profit suffered by the Employer in connection with or arising from the Agreement.

6.6 Alterations and Variations

The Consultant shall have authority to make minor alternations to design but he shall obtain prior approval of the Employer to any substantial modification of the design and costs of the said Works and to any instruction to a Contractor which constitutes a major variation, omission or addition to the latter's contract.

In any emergency requiring immediate action in the Employer's interest, the Consultant shall have authority to issue orders as required on behalf of and at the expense of the Employer.

The Consultant must inform the Employer immediately of any orders issued without the latter's prior consent which will result in additional cost to the Employer and follow up such advice as soon as possible with an estimate of the probable cost.

6.7 Certificate of Completion of Works

6.7.1 When the Works have been completed except for minor items which do not affect its use or safety in use or operations, the Consultant may submit to the Employer a Certificate of Completion of Works, which the Employer shall within thirty days of the receipt thereof, sign and return to the Consultant. The Certificate of Completion of works shall list such minor items as remain to be completed and such minor items shall be completed within specified period thereafter.

6.7.2 If the Employer has reasonable grounds for withholding the Certificate of Completion of Works it shall, not later than thirty days after receipt of the Certificate of Completion of Works, issue to the Consultant a list of items of Works which remain to be done for the want of which the plant cannot be used or cannot be operated safely. After the said items of works have been completed, the Consultant may re-submit the Certificate of Completion of Works, which the Employer shall then immediately sign and return to the Consultant.

6.8 Prints, Drawings & Specifications

The Consultant will furnish to the Employer three copies and a suitable reproducible format of prints of all drawings, specifications, schedules etc. as specified in Appendix–E.

7.0 OBLIGATIONS OF THE EMPLOYER

7.1 Information

The Employer shall, so as not to delay the Services and within a reasonable time, give to the Consultant free of cost all information which is in his power to obtain and which may pertain to the Services.

7.2 Decisions

On all matters properly referred to him in writing by the Consultant, the Employer shall give his decision in writing within a reasonable time so as not to delay the Consultant's Services.

7.3 Equipment and Facilities

7.3.1 The Employer shall make available, free of cost, to the Consultant for the purpose of the Services, the equipment and facilities described in Appendix- F

7.3.2 Delays in receiving the equipment and/or facilities set forth in Appendix –C shall entitle the Consultant to appropriate time extension for completion of the Services.

7.3.3 If the anticipated equipment and/or facilities are not forthcoming, the Employer and the Consultant shall agree on how the affected part of the Services shall be carried out and fix the revised remuneration therefor.

7.4 Services of Others

The Employer shall at his cost arrange for the provision of services from others as described in Appendix – F, and the Consultant shall co-operate with the suppliers of such services but shall not be responsible for them or their performance.

Appendix 7.2.3

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APPENDIX-A OF AGREEMENT

OBJECTIVES AND DESCRIPTION OF PROJECT

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Appendix 7.2.4

APPENDIX-B OF AGREEMENT3

OBJECTIVES AND DESCRIPTION OF PROJECT

Appendix 7.2.5

APPENDIX-C OF AGREEMENT

COMMENCEMENT AND COMPLETION OF SERVICES

Appendix 7.2.6

APPENDIX-D OF AGREEMENT

SCOPE OF SERVICES

Appendix 7.2.7

APPENDIX-E OF AGREEMENT

PRINTS, DRAWINGS AND SPECIFICATINS

Appendix 7.2.8

APPENDIX-F OF AGREEMENT

ASSIGNED SPECIALIST, PERSONNEL, EQUIPMENT, FACILITIES AND SERVICES OF OTHERS TO BE PROVIDED BY THE EMPLOYER

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Appendix 7.3

CENTRAL PUBLIC WORKS DEPARTMENT

STANDARD PRE-QUALIFICATION DOCUMENT

FOR

RESTRICTED CALL OF TENDERS

Standard & Specifications Unit

Central Public Works Department,

Nirman Bhawan, New Delhi – 110 011.

CRITERIA FOR EVALUATION OF THE PERFORMANCE OF CONTRACTORS FOR PRE-QUALIFICATION

	ATTRIBUTES		EVALUATION
(A)	Financial Strength (25 Marks)	(i)	60% marks for minimum eligibility criteria.
		(ii)	100% marks for twice the min. eligibility criteria or more. In between (i) & (ii) - on pro-rata basis.
(B)	Experience in Similar Class of works (30 Marks)	(i)	60% marks for minimum eligibility criteria.
		(iii)	100% marks for twice the min. eligibility criteria. In between (i) & (ii) - on pro-rata basis.

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(C) Performance on works (25 Marks)

Parameter		Calculation for points	Score	Max.
1. Time Over Run- 'TOR'	(a)	TOR = AT/ST Where ST = Stipulated Time AT = Actual Time	15 if TOR = 1.00 12 if TOR = 2.00 6 if TOR = 3.00 0 if TOR > 3.50	18
	(b)	Compensation levied for delay in completion = C Estimated cost put to tender = E (Cx100/E)=B(No points awarded if compensation is not decided).	Bonus/Penalty Points awarded (+) 3 if B = 0 (+) 0 if B = 1 (-) 2 if b = 5 (-) 3 if B = 10	

Note : Marks for values in between the stages indicated in a & b above is to be determined by straight line variation basis.

Parameter		Calculation for points	Score	Max.
2. Quality	(i)	Very Good	7	7
	(ii)	Good	5	
	(iii)	Fair	2	
	(iv)	Poor	0	

Parameter	Calculation for points	Score	Max.
(D) Personnel and Establishment (10 Marks)	(i) Graduate Engineer 3 marks for each.		
	(ii) Diploma holder Engineer 2 marks for each upto Max. 4 marks.		
	(iii) Supervisor/Foreman 1 mark for each upto Max. 5 marks. (Total Max. marks limited to 10)		
(E) Plant & equipment (10 marks)	(i) Mixer – 1 mark for each upto Max. 2 marks.		
	(ii) Vibrator 1 mark for each upto Max. 2 marks.		
	(iii) Trucks/Tippers 2 marks for each upto Max. 4 marks.		
	(iv) Steel Shuttering 2 marks for each 800 sqm upto Max. 4 marks.		
	(v) Pumps Maximum 1 mark.		
	(vi) Special Equipment (Marks to be fixed as per requirement) (Total Max. marks limited to 10)		

2.1 Criterion for pre qualification

B. Technical personnel

The contractor shall be required to submit the details of skill, technical qualification, work experience and number of the personnel available, which are to be deployed on the works.

C. Financial Capability

The financial soundness is essential for the timely execution of the work. The financial statements for the past three years as submitted to the income tax authorities shall be examined viz. a viz. the works in hand. The works in hand with progress of works shall be ascertained to check the balance capacity available to take up the work under consideration.

D. Tools and Plants

After the structural repairs have been carried out, these have to be evaluated for their adequacy in regard to performance requirement and subsequent monitoring. The availability of such equipments is essential for proper execution of work. The list of such equipments required should necessarily form part of such pre-qualification document. The contractors shall be required to submit the list of equipment for actual execution.

E. Experience of similar works

Experience shall be based on the nature of work, the materials and techniques used in the execution of works. The contractor shall be asked to furnish the details of such works carried out.

(i)

Prequalification Document

for

Name of Work: -

This Document consists of pages i & ii and pages 1 to __________ total ________ pages.

Prepared by : -

Checked by :-

A.S.W. S.W. S.S.W.

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APPROVED

Chief Engineer

(ii)

I N D E X

PRESS NOTICE

CENTRAL PUBLIC WORKS DEPARTMENT

INVITATION TO PRE-QUALITY

1. The Executive Engineer ____ on behalf of the President of India invites pre-qualification applications from firms/ contractors of repute for the following works: -

Sl.No.	Name of work	Approx. Cost	Period of Completion

2. Contractors who fulfill the following requirements shall be eligible to apply. Joint ventures are not accepted.

   a. Experience of having successfully completed works of similar class during the last five years.

   b. Average annual financial turn over on civil construction works of Rs. _____________ Cross during the last three years.

3. Eligible applicants may obtain pre-qualification document on request in writing from the Executive Engineer ____ on payment of Rs. 250/- in cash, upto 3.30 PM on __________________.

4. Application for pre-qualification duly supported by prescribed annexure, which should be placed in sealed envelope, with the name of work and due date written on envelope, will be received upto 03.00 P.M. on ______________ and will be opened by the Executive Engineer or his authorised representative in his office on the same day at 03.30 P.M.

EXECUTIVE ENGINEER

SECTION – 1

BRIEF PARTICULARS OF THE WORK

1.0 Salient details of the work for which pre-qualification applications are invited are as under :

Sl.No.	Name of work	Approx. Cost	Period ofCompletion

2.0 All drawings (Architectural/Structural/Services) for the work shall be made available by the employer.

3.0 The work is situated at ________________________.

4.0 General features and major components of the work are as under.

(i)

(ii)

(iii)

(iv)

5.0 Work shall be executed as per General Conditions of contract for Central P.W.D. works.

SECTION II

INFORMATION AND INSTRUCTIONS TO APPLICANTS

1.0 GENERAL:

i Letter of transmittal & forms for pre-qualification are attached. (Section III)

ii All information called for in the enclosed forms should be furnished against the respective columns in the forms, if information is furnished in a separate document, reference to the same should be given against respective columns. If information is 'nil' it should also be mentioned as 'nil' or 'no such case'. If any particulars/ query is not applicable in case of the applicant, it should be stated as 'not applicable'. However, the applicants are cautioned that not giving complete information called for in the application forms required, not giving it in clear terms or making any change in the prescribed forms or deliberately suppressing the information may result in the applicant being summarily disqualified. Applications made by telegram or telex and those received late will not be entertained.

iii The application should be typewritten. The applicant's name should appear on each page of the application.

iv Overwriting should be avoided. Correction, if any, shall be made by neatly crossing out, initialing, dating and rewriting. All pages of the pre-qualification document shall be numbered and submitted as a package with signed letter of transmittal.

v References, information and certificates from the respective Employers certifying suitability, technical know-how or capability of the applicant should be signed by an officer not below the rank of Superintending Engineer/Chief Project Manager or equivalent. 7

vi The applicant is advised to attach any additional information, which he thinks is necessary in regard to his capabilities to establish that the applicant is capable in all respects to successfully complete the envisaged work. He is, however, advised not to attach superfluous information. No further information will be entertained after pre-qualification document is submitted, unless it is called for the Employer.

vii The pre-qualification document in prescribed form duly completed and signed shall be submitted in a sealed cover. The sealed cover super scribed "pre-qualification document for ______________________ ______________- shall be received by the Executive Engineer, or his authorised representative upto 3.00 P.M. on ____________. Documents submitted in connection with pre-qualification will be treated confidential and will not be returned.

viii Prospective applicants may request clarification of the project requirement and pre-qualification document. Any clarification given by the Employer will be forwarded to all those who have purchased the pre-qualification document. No request for clarification will be considered after ______________.

2.0 DEFINITIONS:

i In this document the following words and expressions have the meaning hereby assigned to them.

ii **EMPLOYER :** Means the President of India, acting through the Executive Engineer ______________________________.

iii **APPLICANT :** Means the individual, proprietary firm, firm in partnership, limited company private or public corporation.

iv 'Year' mean 'Financial Year'.

3.0 METHOD OF APPLICATION:

i If the application is made by an individual, it shall be signed by the individual above his full typewritten name and current address.

ii If the application is made by a proprietary firm, it shall be signed by the proprietor above his full typewritten name and the full name of his firm with its current address.

iii If the application is made by a firm in partnership, it shall be signed by all the partners of the firm above their full typewritten names and current address or alternatively by a partner holding power of attorney for the firm, in which case a certified copy of the power of attorney shall accompany the application. A certified copy of the partnership deed and current address of all the partners of the firm shall also accompany the application.

iv If the application is made by a limited company or a corporation, it shall be signed by a duly authorised person holding power of attorney for signing the application, ink which case a certified

4.0 FINAL DECISION MAKING AUTHORITY

The employer reserves the right to accept or reject any application and to annual the pre-qualification process and reject all applications at any time, without thereby incurring any liability to the affected applicants or specifying the grounds for the Employer's action.

i PARTICULARS PROVISIONAL

The particulars of the work given in Section I are provisional and must be considered only as advance information to assist the applicant.

15.0 SITE VISIT

The applicant is advised to visit and examine the site of work and its surroundings and obtain for himself on his own responsibility, all information that may be necessary for preparing the pre-qualification application. The cost of visiting the site shall be at applicant's own expense.

16.0 INITIAL CRITERIA FOR ELIBILIGY FOR PRE-QUALIFICATION

16.1 The applicant should be in Civil Engineering business for a minimum period of five years as on _______________.

16.2 The applicant should have satisfactorily completed works of similar class of magnitude as specified below during the last five years. For this purpose gross value of the completed work including the cost of materials supplied by the Govt./Employer shall be considered, which should be certified by an officer not below the rank of Superintending Engineer/ Chief Project Manager or equivalent.

____

____

____

16.3 The applicant's average annual financial turn-over (gross) in Civil construction works during the last three years duly audited by Chartered Accountant should not be less than Rs. ______________ Crores. Year in which no turnover is shown would also be considered for working out the average.

16.4 The applicant should own adequate construction equipment required for the proper and timely execution of the work. The applicant should furnish a list of these equipment.

16.5 The applicant should have sufficient number of Technical and Administrative employees for the proper execution of the contract. The applicant should submit a list of these employees stating clearly how these would be involved in this work.

16.6 The applicant's performance for each work completed in the last 5 years and in hand should be certified by an officer not below the rank of Superintending Engineer/ Chief Project Manager or equivalent.

17.0 EVALUATION CRITERIA FOR PRE-QUALIFICATION

17.1 For the purpose of pre-qualification, applicants will be evaluated in the following manner:-

17.2 The initial criteria prescribed in para – 7.2 & 7.3 above in respect of experience of similar class of works completed and financial turn over will first be scrutinised and the applicant's eligibility for pre-qualification for the work be determined.

17.3 Those firms qualifying the initial criteria as set out in para 7.2 & 7.3 above will then be evaluated for following criteria.

(f) Financial Strength

(g) Experience in similar class of work.

(h) Performance on these works.

(i) Personnel/Establishment

(j) Plant and Equipment

The details given by the applicants in the pre-qualification document will be evaluated by scoring method. To pre-qualify, the applicant must secure at least fifty percent in each of the above criteria and seventy percent in total.

(a)	Financial strength (Form 'A')	:	Maximum 25 marks.
(b)	Experience in similar class of (work during last five years (Form 'B')	:	Maximum 30 marks.
(c)	Performance on works(Form 'D')	:	Maximum 25 marks.
(d)	Personnel and establishment (Form 'E' & E-1)	:	Maximum 10 marks.
(k)	Plant & equipment (Form 'F')	:	Maximum 10 marks.
	Total	**:**	**100 marks.**

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17.4 Even though applicants may satisfy the above requirements, they are subject to be disqualified if they have:

(c) Made misleading or false representation or deliberately suppressed the information in the forms, statements and enclosures required in the pre-qualification document.

(d) Records of poor performance such as abandoning work, not properly completing the contract, or financial failures/ weaknesses.

18.0 FINANCIAL INFORMATION

(a) Annual financial statement for the last three years (In Form 'A'). These should be supported by audited balance sheets and profit and loss accounts duly certified by a Chartered Accountant, as submitted by the applicant to the Income Tax Department.

(b) Name and address of the banker's, identification of individuals familiar with the applicant's financial standing and a banker's statement on availability of credit.

19.0 EXPERIENCE, IN CIVIL WORKS HIGHLIGHTING EXPERIENCE IN SIMILAR WORKS

19.1 Applicant should furnish the following :-

(d) List of all works of similar class successfully completed during the last five years: (In Form 'B').

(e) List of the projects under execution or awarded (In Form 'C').

19.2 Particulars of completed works and performance of the applicant duly authenticated/ certified by an officer not below the rank of Superintending Engineer/ Chief Project Manager or equivalent should be furnished separately for each work completed or in progress. (In Form 'D').

20.0 ORGANISATION INFORMATION

APPLICANT IS REQUIRED TO SUBMIT THE FOLLOWING IN RESPECT OF HIS ORGANISATION (In Form 'E' and 'E-1')

(f) Name and postal address, **website, email address** i/c telephone & telex number etc.

(g) Copies of original documents defining the legal status, place of Registration and principal places of business.

(h) Names and title of Directors and officers to be concerned with the work, with designation of individuals authorised to act for the organisation.

(i) Information on any litigation / **arbitration** in which the applicant was involved during the last five years, including any current litigation.

(j) Authorisation for employer to seek detailed references.

(k) Number of Technical and Administrative employees in parent company, subsidiary company and how these would be involved in this work (In Form 'E-1').

21.0 CONSTRUCTION PLANT AND EQUIPMENT

Applicant should furnish the list of construction plant and equipment including steel shuttering, centering and scaffolding likely to be used in carrying out the work. (In Form 'F'). Details of any other plant and equipment required for the work (not included in Form 'F') and available with the contractor may also be indicated.

22.0 LETTER OF TRANSMITTAL

The applicant should submit the letter of transmittal attached with pre-qualification document.

23.0 TENDER SUBMISSION

After evaluation of pre-qualification applications, a list of qualified agencies will be prepared. Thereafter, only those agencies prequalified for the work will be invited to submit tenders for the work.

16. AWARD CRITERIA

16.1 The employer reserves the right to :-

(c) Amend the scope and value of contract to the bidder.

(d) Reject any or all the bids without assigning any reason.

16.2 For any of the above actions, the Employer shall neither be liable for any damages, nor be under any obligation to inform the Applicants of the grounds for the same.

16.3 Effort on the part of the bidder or his agent to exercise influence or to pressurise the employer for his bid shall result in rejection of such bid. Canvassing of any kind is prohibited.

SECTION III
PRE-QUALIFICATION INFORMATION
LETTER OF TRANSMITTAL

From :-

To

The Executive Engineer,

____

____

Sub.: **Submission of pre-qualification application for the work of ____.**

Sir,

Having examined the details given in pre-qualification press. Notice and pre-qualification document for the above work, we hereby submit the pre-qualification and relevant documents.

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6. We hereby certify that all the statements made and information supplied in the enclosed form A to F and accompanying statement are true and correct.

7. We have furnished all information and details necessary for pre-qualification and have no further pertinent information to supply.

8. We submit the requisite certified solvency certificate and authorise the Executive Engineer __________________ to approach the Bank issuing the solvency certificate to confirm the correctness thereof. We also authorise Executive Engineer ____ to approach individuals, employers, firms and corporation to verify our competence and general reputation.

9. We submit the following certificates in support of our suitability, technical know-how and capability for having successfully completed the following works:-

Name of Work :	Certificate form
1.	1.
2.	2.
3.	3.

Enclosures :

Seal of applicant

Date of submission **SIGNATURE OF APPLICANT**

FORM 'A'

FINANCIAL INFORMATION

1. Financial Analysis – Details to be furnished duly supported by figures in Balance Sheet / Profit and Loss Account for the last three years duly certified by the Chartered Accountant, as submitted by the applicant to the Income -–Tax Department (Copies to be attached).

	YEARS		
(i) Gross Annual turn-over In construction works.			
(ii) Profit/Loss			
(iii) Financial Position :			
(a) Cash			
(b) Current assets			
(c) Current liabilities.			
(d) Working capital. (b-c)			
(e) Current Ratio: Current Assets/Current Liabilities. (b/c)			
(f) Acid Test Ratio Quick Assets / Current Liabilities (a/c)			

II. Income Tax clearance Certificate.

III. Certificate of Financial Soundness from Bankers of Applicant.

IV. Financial arrangements for carrying out the proposed work.

(SIGNATURE OF APPLICANT)

FORM 'B'

DETAILS OF ALL WORKS OF SIMILAR – CLASS COMPLETED DURING THE LAST FIVE YEARS

S.No.	Name of work/ Proj. & location	Owner of sponsoring organisation	Cost of work in crores	Date of commen-cement	S!tipulated date of completion	Actual date of completion as per contract	Litigation / Arbitration pending/ in progress with details	Name and address/ telephone of officer to whom reference may be made.	Remarks
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.

(SIGNATURE OF APPLICANT)

FORM 'C'

DETAILS OF ALL WORKS OF SIMILAR – CLASS COMPLETED DURING THE LAST FIVE YEARS

S.No.	Name of work/ Proj. & location	Owner of sponsoring organisation	Cost of work in crores	Date of commen-cement as per contract	Stipulated date of completion	Up-date percentage progress of work	Slow Progress if any, and reasons thereof	Name and address/ telephone of officer to whom reference may be made	Remarks (indicate whether any show cause notice issue or arbitration initiated during the progress of work)
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.

(SIGNATURE OF APPLICANT)

FORM 'D'

PERFORMANCE REPORT OF WORKS REFERRED IN FORM 'B' & 'C'

1. Name of work/
   Project & Location
2. Agreement No.
3. Estimated Cost
4. Tendered Cost
5. Date of start
6. Date of Completion
   (a) Stipulated date of completion
   (b) Actual date of completion
7. Amount of compensation levied for delayed completion if any.
8. Performance report
   i) Quality of work — Very Good / Good / Fair / Poor
   ii) Resourcefulness — Very Good / Good / Fair / Poor

Date :

SUPERINTENDING ENGINEER/
CHIEF PROJECT MANAGER
OR EQUIVALENT

FORM 'E'

STRUCTURE AND ORGANISATION

1. Name and address of the applicant.

   Website and email Address:
2. Telephone No./Telex No./ Fax No.
3. Legal status [Attached copies of original document defining the legal status]

   The applicant is :
   (a) An Individual
   (b) A proprietary Firm
   (c) A Firm in Partnership
   (d) A limited Company or Corporation
4. Particulars of registration with various Government bodies

   (Attached attested photocopy)
   (a) Registration Number.
   (b) Organisation/Place of registration.
5. Names and Title of Directors and Officers with designation to be concerned with this work with designation of individuals authorised to act for the organisation.
6. Were you ever required to suspend construction for a period of more than six months continuously after you commenced the construction? If so, give the name of the project and give reasons there of.
7. Have you or your constituent partner ever left the work awarded to you incomplete? (If so, give name of the project and reasons for not completing the work).
8. Have you or your constituent partner been debarred/black listed for tendering in any organisation at any time? If so, give details.
9. In which field of Civil Engineering construction, you claim specialisation and interest?
10. Any other information considered necessary but not included above.

(SIGNATURE OF APPLICANT)

FORM 'E-1'

DETAILS OF TECHNICAL AND ADMINISTRATIVE PERSONNEL TO BE EMPLOYED FOR THE WORK

S.No.	Designation	Total Number available for this work carried out	Number	Name	Qualifications	Professional experience and details of work	How these would be involved in this work	Remark
1.	2.	3.	4.	5.	6.	7.	8.	9.

(SIGNATURE OF APPLICANT)

FORM 'F'

DETAILS OF CONSTRUCTION PLANT & EQUIPMENT LIKELY TO BE USED IN CARRYING OUT THE WORK

S. No.	Name of equipment	Nos.	Capacity or Type	Age	Condi- tion	OWNERSHIP STATUS Pre sently owned	Leased	To be Pur- chased	How these would be involved in this work	Remarks
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
	EARTH MOVING EQUIPMENT									
1.	EXCAVATORS (VARIOUS SIZES)									
	EQUIPMENT FOR HOISTINKG & LIFTING									
1.	TOWER CRANE									
2.	BUILDING									
	EQUIPMENT FOR CONCRETE WORK									
1.	CONCRETE BATCHING PLANT									
2.	CONCRETE PUMP									
3.	CONCRETE TRANSIT MIXER									
4.	CONCRETE MIXER (DIESEL)									
5.	CONCRETE MIXER (ELECTRICAL)									
6.	NEEDLE VIBRATOR (ELECTRICAL)									
7.	NEEDLE VIBRATOR (PETROL)									
8.	TABLE VIBRATOR (ELECT./PETROL)									

Contd...

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
	EQUIPMENT FOR BUILDING WORK									
1.	BLOCK MAKING MACHINE									
2.	BAR BENDING MACHINE									
3.	BAR CUTTING MACHINE									
4.	WOOD THICKNESS PLANER									
5.	DRILLING MACHINE									
6.	CIRCULAR SAW MACHINE									
7.	WELDING GENERATORS									
8.	WELDING TRANSFORMERS									
9.	CUBE TESTING MACHINES									
10.	M.S. PIPES									
11.	STEEL SHUTTERING									
12.	STEEL SCAFFOLDING									
13.	GRINDING/POLISHING MACHINES									
	EQUIPMENT FOR ROAD WORK									
1.	ROAD ROLLERS									
2.	BITUMEN PAVER FINISHERS									
3.	HOT MIX PLANT									
4.	SPREADERS									
5.	EARTH RAMMERS									
6.	VIBRATORY ROAD ROLELRS									

Contd...

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
	EQUIPMENT FOR TRANSPORTATION									
1.	TIPPERS									
2.	TRUCKS									
	PNEUMATIC EQUIPMENTS									
1.	AIR COMPRESSOR DIESEL									
	DEWATERING EQUIPMENT									
1.	PUMP DEWATERING (DIESEL)									
2.	PUMP DEWATERING (ELECTRIC)									
	POWER EQUIPMENT									
1.	DIESEL GENERATORS									
	ANY OTHER PLANT/EQUIPMENT									

(SIGNATURE OF APPLICANT)

APPENDIX 7.4

REPAIR MATERIAL

1.	Name of the work	:
2.	Agreement no.	:
3.	Contractor	:
4.	Name of Material	:
5.	Manufacturer	:
6.	Dealer/Soruce	:
7.	Bill No. & date	:
8.	Batch No. & date	:
9.	Expiry date	:
10.	Pot life	:
11.	Systems for erpair	:
12.	Storage Recommendation	:
13.	Manufacturers test Certificate	:

(Name of Contractors Representative)
Enclosure:

For Office use:

1. Manufactures test certificate: attached/not attached
2. Samples taken/not taken for testing:
3. Samples sent to:Laboratory name and address
4. Entry made in the register: Page———date——

Date:
Place:

(Name of Representative of Engineer in Charge)

CHAPTER 8

SCHEDULE OF SPECIAL ITEMS FOR STRUCTURAL REPAIR WORK

8

SCHEDULE OF SPECIAL ITEMS FOR STRUCTURAL REPAIR WORK

What we have to learn to do, we learn by doing.

..Aristotle

Item No.	Description of item	Unit of Measurement
	SUB-HEAD I GENERAL	
8.1.1	**Propping and supporting the structural members** and its adjoining areas with steel props (adjustable or as required), bracings, steel/timber runners etc to relieve the structural member of the required load coming over it as per the pattern given by the contractor & approved by Engineer-in-charge complete.	
	A (a) Steel Prop of up to 5 MT Capacity and up to 3.2 m height	Each
	(b) Extra for every additional height of 0.3 M or part thereof	Each per 0.3 M extra height
	B (a) Extra for steel prop (adjustable or as required) for having additional capacity of 2 MT or part thereof beyond 5 MT and up to 3.2 M height	Each
	(b) Extra for every additional height of 0.3 M or part thereof	Each per 0.3 M extra height
8.1.2	**Providing and fixing special water tight centering and shuttering** including bolting, strutting, propping etc so as to withstand a pressure of 0.1 Mpa including removal of forms for all locations including beams, columns, slabs, walls, foundations, footings, landings, stairs, balconies etc.	sqm
8.1.3	**Providing and fixing temporary engineered steel tubular standard double scaffolding system** on the exterior side, maintaining it in a serviceable condition for the required duration as approved and removing it thereafter. The scaffolding system shall be stiffened with bracings, runners, connection with the building etc with suitable working platforms at required locations with essential safety features for the workmen etc complete as per directions and approval of Engineer-in-charge. The elevational area of the scaffolding shall be measured for payment purpose.	sqm

Item No.	Description of item	Unit of Measurement
8.1.4	**Providing and fixing plywood covering panels** as per the directions of Engineer-in-charge with necessary backing framework to shield windows etc. from falling debris and removing and taking away the material after completion of work including making good any incidental damage(s) to the existing building or its finishes etc complete. (The measurements for payment shall be made in terms of the area protected by such covering).	sqm
8.1.5	**Providing, erecting, maintaining and removing temporary protective barricading/screens** of 1.8 m in height made in panels with each panel having minimum 40x40x6 mm size MS angle frame with minimum 24 g thick G.I corrugated sheet or suitably stiffened plane G I sheet fixed on one side of the frame. Such panels shall be interconnected to each other with nuts and bolts, fixed to ground firmly, at about 2 m spacing for the work duration as required by the Engineer in charge. (The rate shall cover applying at least one coat of paint over existing paint or red-oxide zinc chromate primer).	sqm
8.1.6	**Providing, erecting, maintaining and removing temporary protective barricading/screens** of 1.8 m. in height, made out of minimum 100 mm dia ballis or wooden verticals of minimum size 50 mm x 100 mm, fixed to ground firmly at a spacing of about 2 m and with at least two horizontals of 50 mm x 100 mm with minimum 24 g. thick G.I corrugated sheet fixed on one side for work duration as required by Engineer in charge. (The rate shall cover applying at least one coat of paint over existing paint or primer).	metre
8.1.7	**Providing, erecting, maintaining and removing temporary protective barricading/screens** of 1.8 m height, made out of bamboo or other locally available panels with verticals and atleast two horizontals of required sizes, made out of acceptable local wood, fixed on one side of the panels and secured to the ground at required spacing for the work duration as per directions and approval of Engineer-in-charge.	metre
8.1.8	**Providing, erecting, maintaining and removing temporary protective screens** made out of specified fabric with all necessary fixing arrangement to ensure that it remains in position for the work duration as required by Engineer in charge.	
	A Jute Cloth	sqm
	B Woven PVC Cloth	sqm
	C Geotextile	sqm
	D Wire Mesh	sqm

Item No.	Description of item	Unit of Measurement
8.1.9	**Providing and fixing the G.I. corrugated sheet door shutter,** maintaining in serviceable condition for the work duration and removing it thereafter. The door shutter shall be made of G.I. corrugated sheet (24 gauge) fixed on accepta ble local wooden frame with verticals, horizontals of required size and middle horizontal member at centre including at least one aldrop with locking arrangement, required number of hinges etc complete as per the Engineer in charge. (The rate shall cover applying at least one coat of paint over existing paint or primer).	sqm
8.1.10	**Providing & erecting covered shelters complete with side coverings,** door/window frame and its openings, raised pacca platform for storage of materials, maintaining them in serviceable condition for the work duration and removing thereafter. The covered shelters shall be made of steel/ timber/bamboo verticals and steel/timber/ bamboo horizontals covered with AC/GIsheets, tarpaulin etc. to remain in serviceable condition during work duration as directed by Engineer- in –charge (Plan area shall be measured for payment)	sqm
	SUB-HEAD II : SURFACE PREPARATION	
8.2.1	**Chipping of existing plaster manually** from masonry or concrete surface using chisel and hammer and disposal of debris within a lead of 50 m complete as per directions of Engineer-in-Charge	
8.2.2	**Chipping of unsound/weak concrete material** from slabs, beams, columns etc. with standard power driven percussion type or pneumatic chisel of standard make as directed by Engineer-in-charge including tapering all edges, making square shoulders of cavities etc complete and disposal of debris up to 50 metres and all lifts.	
	A 25 mm average thickness for slabs	sqm
	B 50 mm average thickness for Beams	sqm
	C 75 mm average thickness for Columns	sqm
	D Deduct/Add for every less/extra 10 mm thickness.	sqm
	E Extra for disposal of debris beyond 50 meters and up to 1 kilometer [Area for payment under this item shall be sum total of area measured and debris disposed under A,B,C and D as (A+2B+3C±0.4D)]	sqm
	F Extra for disposal of debris beyond 1 kilometer and up to 5 kilometers [Area for payment under this item shall be sum total of area measured and debris disposed under A,B,C and D as (A+2B+3C±0.4D)]	sqm

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Item No.	Description of item	Unit of Measurement
8.2.3	**Dismantling & removing existing treatment over RCC slabs** at all heights including stacking of serviceable material for reuse as per direction of Engineer-in-Charge & disposal of balance unserviceable material within a lead of 50 metre	cum
	A. Extra for disposal of unserviceable material beyond 50 metres and up to 1 kilometer	cum
	B. Extra for disposal of unserviceable material beyond 1 kilometer and up to 5 Kilometers	cum
8.2.4	**Dismantling existing RCC work but excluding cutting of reinforcement bars** at all heights including disposal of unserviceable material within a lead of 50 metre.	
	A. Manually using chisel and hammer	cum
	B. Mechanically using power driver/pneumatic percussion chisels/hammers	cum
	C. Extra for disposal of unserviceable material beyond 50 metres and up to 1 kilometer	cum
	D. Extra for disposal of unserviceable material beyond 1 kilometer and up to 5 Kilometers	cum
8.2.5	**Cutting reinforcement bars** in RCC or reinforced brickwork. carefully without damaging the existing structure and its finishes	
	A Bars of dia 12mm or less	Each
	B Bars of dia more than 12 mm but not exceeding 20 mm	Each
	C All bars of dia more than 20 mm	Each
8.2.6	**Removing concrete all around reinforcement including from behind** the reinforcing bars to give an average 25mm (but not less than 15mm clear air gap). Length of reinforcement bars cleared of concrete all around shall be measured for payment	
	A By manual methods (hammering the rebar, using wire brushes, chiseling etc.)	
	(a) Bars up to and including 12mm diameter	metre
	(b) Bars above 12mm diameter	metre
	B Extra for using standard power driven or pneumatic abrading tools/chisel of standard make.	
	(a) Bars up to and including 12mm diameter	metre
	(b) Bars above 12 mm diameter	metre
8.2.7	**Cleaning reinforcement of total rust including from behind** the reinforcing bars to give it a totally rust free finished steel surface. Length of reinforcement bars cleaned of rust all around shall be measured for payment	

8

Item No.	Description of item	Unit of Measurement
	A By manual methods (hammering the rebar, using wirebrushes, chiseling etc.)	
	(a) Bars up to and including 12mm diameter	metre
	(b) Bars above 12mm diameter	metre
	B Extra for using sand blasting	
	C Extra for using alkaline chemical rust remover with paint brush and removing loose particles after 24 hours of its application with wire brush and thoroughly washing with water and allowing it to dry.	metre
	(a) Bars upto 12 mm diameter	metre
	(b) Bars above 12 mm diameter	metre
8.2.8	**Introducing new reinforcement bars for structural connections** in RCC beams, lintels, columns and slabs including power drilling holes of appropriate diameters in reinforced or plain cement concrete to a minimum depth of 150mm and upto 200 mm, fixing the reinforcement in position using epoxy. (Rate shall include cost of labour, T&P for power drilling in concrete, epoxy cartridges, plastic nozzle etc complete including cleaning the drilled holes of loose dust by blowing air. The cost of reinforcement shall be payable separately	
	A Upto and including for 12 mm dia reinforcing bar	each
	B Bars of dia more than 12 mm but not exceeding 20 mm	each
	C All bars of dia more than 20 mm	each
8.2.9	**Providing and inserting mild steel shear key bars/ leveling gauges** (for shotcreting) of required length and diameter in reinforced/plain concrete as per drawing and directions of Engineer-in-charge including power drilling holes of appropriate diameters to a minimum depth of equal to 12 times the diameter of shear key bar/levelling gauge, cleaning the drilled holes of loose dust by blowing, insertion of epoxy from cartridge, placing the shear key bar in position and allowing it to stay undisturbed for 24 hours. (Rate shall include cost of labour, all materials, T&P for power drilling in concrete, epoxy cartridges, plastic nozzle etc complete including cleaning the drilled holes of loose dust by blowing air.	
	A 12mm dia. 300 mm long@ M.S. shear key	each
	B 16mm dia. 400 mm long@ M.S. shear key	each
8.2.10	**Cleaning exposed concrete surface of lightly sticking materials** including foreign materials, loose concrete/aggregates, etc. The rates shall include cost of movable scaffolding & working platform	

@ The projected length of shear key shall be more than 10 times its diameter plus half the thickness of cover concrete plus bend length.

8

Item No.	Description of item	Unit of Measurement
	(cost of working platform shall not be paid under other item) disposing of all debris up to a lead of 50 metres and complete in all respects.	
	A With wire brush, chisel etc for all heights	sqm
	B By sand blasting with coarse sand followed by and including cleaning with oil free air blast	
	i) Up to a height of 15metre above plinth level	sqm
	ii) Extra for every additional height of 3 metre or part thereof beyond 15 metre height above plinth level.	sqm
8.2.11	**Providing and fixing anchor fastener system,** mechanical/epoxy based of standard make for connections in concrete as per design and drawings and/or as directed by Engineer-in-charge. (Rate shall include cost of bolts, labour, all materials including epoxy cartridges (wherever required), T&P for power drilling, cleaning the drilled holes of loose dust by blowing air, insertion of epoxy from cartridge with plastic nozzles as may be required, placing internally threaded sleeve, driving of bolts, 2 nos-4mm thick (hot dip galvanized/epoxy coated) washers, fastening screw and tightening with nuts and check nuts etc. as may be required	
	A. Mechanical Anchor fastener:	
	a) 8mm dia anchor fasteners	each
	a) 10 mm dia anchor fasteners	each
	b) 12 mm dia anchor fasteners	each
	c) 16 mm dia anchor fasteners	each
	B Extra for epoxy in mechanical anchor fasteners, if used	
	a) 8 mm dia anchor fasteners	each
	b) 10 mm dia anchor fasteners	each
	c) 12 mm dia anchor fasteners	each
	d) 16 mm dia anchor fasteners	each
	SUB HEAD III: CRACK/HONEYCOMB AREA REPAIR	
8.3.1	**Providing and inserting 12mm dia Aluminium/ galvanized iron injection nipples** along crack lines or honey-comb area, including	
	i) drilling holes of required diameter up to depths from 40mm to 80mm or half the thickness of member (whichever is less), at required spacing but not exceeding the thickness of member or 300 mm	
	ii) Making grooves of size 12mm x 12mm along the crack line.	
	iii) Making the crack dust free by blowing compressed air and then washing with water.	

Item No.	Description of item	Unit of Measurement
	iv) Sealing the distance between the injection nipples with approved putty *(Polymer modified cement mortar /polyester putty/epoxy putty)* etc and allow it to cure.	
	v) If cementitious grout material proposed to be used, washing and saturating the cracked surface with water by pumping from top most nipple and down wards	
	complete as per the direction of Engineer-in-charge.(The rate shall include all material, labour and all operations above. The cost of grout material shall be paid separately on the basis of actual quantity consumed.	
	A In concrete work	each
	B In masonry work.	each
8.3.1a	**Supply** of approved crack/honeycombed area sealing material/ Admixture.	
	A Approved Emulsified acrylic Polymer (Rates shall be in terms of solid contents of polymer)	kg
	B Approved Emulsified SBR Polymer (Rates shall be in terms of solid contents of polymer)	kg
	C Approved epoxy (Total weight of Resin & hardener in proportion specified by manufacturer)	kg
	D Shrinkage compensating cement	kg
8.3.2	**Injecting approved grout** in appropriate proportion excluding cost of such grout material covered under item No. 8.3.2a into cracks/ honey-comb area of concrete/masary by suitable gun/pump at required pressure including cutting of nipples after curing etc. complete as per directions of Engineer-in-charge. (The payment shall be made on the basis of actual weight of approved grout injected).	
	A Epoxy grout in	
	a) Concrete/ RCC work	Kg
	b) Masonry Work	Kg
	B Stirrer mixed acrylic Polymer modified cement slurry made with shrinkage compensating cement in	
	a) Concrete/RCC work	Kg
	b) Masonry Work	Kg
	C Stirrer mixed SBR Polymer modified cement slurry made with shrinkage compensating cement in	
	a) Concrete/RCC work	Kg
	b) Masonry Work	Kg

8

Item No.	Description of item	Unit of Measurement
	D Stirrer mixed shrinkage compensating plain cement slurry in	
	a) Concrete/RCC work	Kg
	b) Masonry work	Kg
	E Stirrer mixed shrinkage compensating cement sand slurry in RCC/PCC/Masonry in proportion	
	a) 1:0.5 (1- cement and : 0.5-specified grade of sand by weight)	Kg
	b) 1:1 (1- cement and : 1-specified grade of sand by weight)	Kg
	c) 1:1.5 (1- cement and : 1.5-specified grade of sand by weight)	Kg
	d) 1:2 (1- cement and : 2-specified grade of sand by weight)	Kg
8.3.2a	**Supply** of approved grout material/admixture	
	A Approved Emulsified acrylic Polymer (Rates shall be in terms of solid contents of polymer)	Kg
	B Approved Emulsified SBR Polymer (Rates shall be in terms of solid contents of polymer)	Kg
	C Approved epoxy (Total weight of Resin & hardener in proportion specified by manufacturer)	Kg
	D Approved shrinkage compensating cement	Kg
	E Approved Ordinary Portland Cement of Grade 43	Kg
	F Approved Ordinary Portland Cement of Grade 53	Kg
	SUB-HEAD IV BONDING COATS	
8.4.1.	**Mixing and applying bonding coat**, excluding cost of material, on prepared non-metallic surface of parent material as per specifications and direction of Engineer-in-Charge complete.	
	A. Acrylic polymer modified cementitious bond coat @ 2.2 Kg cement per sqm. of surface area with specified proportion of polymer admixed (Rate shall include cost of cement)	sqm
	B. SBR polymer modified cementitious bond coat @ 2.2 kg cement per sqm of surface area with its proportion as specified	sqm
	C. Approved epoxy adhesive.	sqm
8.4.1a	**Supply** of approved bonding material for prepared non-metallic surface	
	A Approved Emulsified acrylic Polymer (Rates shall be in terms of solid contents of polymer)	Kg
	B Approved Emulsified SBR Polymer (Rates shall be in terms of solid contents of polymer)	Kg
	C Approved epoxy (Total weight of Resin & hardener in proportion specified by manufacturer)	Kg
	D Ordinary Portland Cement 43 Grade	Kg

Item No.	Description of item	Unit of Measurement
8.4.2	**Applying alkaline passivating & bonding coat** of approved adhesive excluding the cost of material over reinforcement duly approved by Engineer-in-Charge with.	
	A Approved CPCC material, a two coat patented system of CECRI on	
	a) Steel reinforcement bars up to 12 mm diameter metre	metre
	b) Steel reinforcement bars above 12 mm diameter	metre
	B Two coats of approved acrylic polymer and cement in the ratio of 1:5 (1-solid contents of acrylic polymer and 5-cement) by weight at an interval not less than 4 hours	
	a) Steel reinforcement bars up to 12 mm diameter	metre
	b) Steel reinforcement bars above 12 mm diameter	metre
	C Epoxy phenolic IPN-RB, an epoxy based, CBRI patented coating system, including sprinkling silica sand (no 10) for:	
	a) Bars upto 12 mm diameter	metre
	b) Bars above 12 mm diameter	metre
	D Approved epoxy bonding coat as per manufacturer's specifications including sprinkling silica sand (no 10) for;	
	a) Bars upto 12 mm diameter	metre
	b) Bars above 12 mm diameter	metre
8.4.2a	**Supply** of approved bonding / passivating adhesive for reinforcement	
	A Emulsified acrylic Polymer (payment shall be made for the weight of solid contents of polymer)	litre
	B CPCC coating material (excluding the weight of cement)	Kg
	i) Primer coat	
	ii) Sealer Coat	litre
	C Epoxy phenolic IPN-RB, a CBRI licensed product (Payment shall be for quantity of Resin plus hardener in manufacturer specified proportion)	Litre
	D Approved epoxy (payment shall be for total weight of Resin plus hardener in manufacturer specified proportion)	Kg
	E Ordinary Portland Cement 43 Grade	Kg
		Kg
	SUB-HEAD V STRUCTURAL REPAIR ITEMS	
8.5.1	**Providing and placing in position Micro-concrete,** which shall be cement based prepacked single component, chloride free, non-shrink, free flow, self compacting, ready to use after mixing water in specified proportion obtained from approved manufacturer as per specification and directions of Engineer in charge (Payment under this item shall be	

Item No.	Description of item	Unit of Measurement
	made only after proper wet curing has been done and surface has been satisfactorily evaluated by sounding/tapping with a blunt metal instrument)	
	A Grade M25	cum
	B Grade M30	cum
	C Grade M40	cum
	D Grade M50	cum
	E Grade M60	cum
8.5.2	**Shotcreting R.C.C. columns, beams and slabs etc.** in layers with approved design mix concrete having the specified minimum characteristic compressive strength [with ordinary portland cement, coarse sand and graded stone aggregate of 10 mm maximum size in proportion as per design criteria] including the cost of centering and shuttering at edges and corners etc. as directed by Engineer-in-Charge The rates shall include the providing necessary ground wires etc. The levelling gauges, if used, shall be paid separately. (Payment under this item shall be made only after proper wet curing has been done and surface has been satisfactorily evaluated by sounding/tapping with a blunt metal instrument)	
	A Upto a height of 15m above plinth level.	
	a) 25 mm thick in Grade M 20 with cement content not less than 320 Kg per Cu M	sqm
	b) 50 mm thick in Grade M 20 with cement content not less than 320 Kg per Cu M	sqm
	c) 75 mm thick in Grade M 20 with cement content not less than 320 Kg per Cu M	sqm
	d) 25 mm thick in Grade M 25 with cement content not less than 350 Kg per Cu M	sqm
	e) 50 mm thick in Grade M 25 with cement content not less than 350 Kg per Cu M	sqm
	f) 75 mm thick in Grade M 25 with cement content not less than 350 Kg per Cu M	sqm
	g) 25 mm thick in Grade M 30 with cement content not less than 400 Kg per Cu M	sqm
	h) 50 mm thick in Grade M 30 with cement content not less than 400 Kg per Cu M	sqm
	i) 75 mm thick in Grade M 30 with cement content not less than 400 Kg per Cu M	sqm
	B Deduct for every 10 mm thickness provided less than the specified	

Item No.	Description of item	Unit of Measurement
	thickness of shotcrete.	
	a) in Grade M 20 with cement content not less than 320 Kg per Cu M	sqm
	b) in Grade M 25 with cement content not less than 350 Kg per Cu M	sqm
	c) in Grade M 30 with cement content not less than 400 Kg per Cu M	sqm
	C Extra for every additional height of 3 metre or part thereof beyond 15 metre height for every 25 mm thick layer or part thereof	sqm
8.5.3	**Providing and laying plain/reinforced concrete** jacket for the structural members e.g. columns, pillars, piers, beams etc with concrete having the specified minimum characteristic compressive strength [with ordinary portland cement, coarse sand and graded stone aggregate of 10 mm maximum size in proportion as per design criteria] with specified average thickness all-round existing core of RCC member. Rates shall be for finished surface area of concrete and shall include the cost of making holes in existing RCC slab, if required, for pouring concrete in shuttering mould of jacket and appropriate approved super-plasticiser for rendering concrete as flowable, self compacting but shall exclude cost of reinforcement, bond coat, shear keys, centering and shuttering, strutting, propping etc (Payment under this item shall be made only after proper wet curing has been done and surface has been satisfactorily evaluated by sounding/tapping with a blunt metal instrument)	
	A a) 150 mm thick in Grade M 20 with cement content not less than 320 Kg per Cu M	sqm
	b) 100 mm thick in Grade M 20 with cement content not less than 320 Kg per Cu M	sqm
	c) 75 mm thick in Grade M 20 with cement content not less than 320 Kg per Cu M	sqm
	d) 50 mm thick in Grade M 20 with cement content not less than 320 Kg per Cu M	sqm
	e) 150 mm thick in Grade M 25 with cement content not less than 350 Kg per Cu M	sqm
	f) 100 mm thick in Grade M 25 with cement content not less than 350 Kg per Cu M	sqm
	g) 75 mm thick in Grade M 25 with cement content not less than 350 Kg per Cu M	sqm
	h) 50 mm thick in Grade M 25 with cement content not less	sqm

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Item No.	Description of item	Unit of Measurement
	than 350 Kg per Cu M	
	i) 150 mm thick in Grade M 30 with cement content not less than 400 Kg per Cu M	sqm
	j) 100 mm thick in Grade M 30 with cement content not less than 400 Kg per Cu M	sqm
	k) 75 mm thick in Grade M 30 with cement content not less than 400 Kg per Cu M	sqm
	l) 50 mm thick in Grade M 30 with cement content not less than 400 Kg per Cu M	sqm
	B Extra for every 10 mm thickness of jacket over the specified thickness	sqm
	a) Grade M 20 with cement content not less than 320 Kg per Cu M	
	b) Grade M 25 with cement content not less than 350 Kg per Cu M	sqm
	c) Grade M 30 with cement content not less than 400 Kg per Cu M	sqm
8.5.4	**Providing and laying an overlay of plain/reinforced concrete** over prepared surface of existing concrete slab with concrete *[as per design mix criteria]* of *[specified]* average thickness as per the direction of Engineer-in-Charge. Rates shall be for finished surface area of concrete and shall include the providing necessary ground wires etc. the cost of appropriate approved super-plasticiser for rendering concrete as flowable self compacting but shall exclude cost of reinforcement, bond coat, shear keys, centering and shuttering, strutting, propping, levelling gauges (if used),.etc (Payment under this item shall be made only after proper wet curing has been done and surface has been satisfactorily evaluated by sounding/tapping with a blunt metal instrument)	sqm
8.5.5	**Reinforcement for R.C.C.** work including Cutting bending, binding, straightening and placing in position &/or welding with the existing bars wherever necessary complete.	sqm
	A MS bars	
	B Cold twisted CTD bars	kg
	C TMT bars	kg
	D Hard drawn hot dipped galvanized steel wire fabric	kg
	E Hot dipped galvanized Wire	kg
8.5.6	**Providing structural connections** including necessary formwork for concreting, wherever required, as directed by Engineer-in-charge by :	kg
	i) Chipping of concrete and exposing the reinforcement to the required extent.	
	ii) Welding necessary dowels to the existing exposed main	

Item No.	Description of item	Unit of Measurement
	reinforcement.	
	iii) Providing shear keys/ mechanical anchors	
	iv) Applying a bonding coat of approved epoxy resin on the substrate as per manufacturer's specifications	
	v) Concreting the joint along with new structural member within the pot life of epoxy bonding coat.	
	Costs of concrete, reinforcement, welding, shear key/mechanical anchors and formwork shall be paid under the relevant items separately. Under this item, finished surface area at interface of the connection shall be measured for payment. Rates shall include cost of all the operations mentioned above. (Payment under this item shall be made only after proper wet curing has been done and surface has been satisfactorily evaluated by sounding/tapping with a blunt metal instrument)	
8.5.7	**Providing, mixing and applying polymer modified cement mortar in layers,** each layer not exceeding 10mm thick, including trowelling with wooden tools etc. complete as per specifications and directions of Engineer-in-charge (cost of polymer shall be paid separately) For payment purposes, pre-measurement of thickness shall be done just after the surface preparation is completed. (Payment under this item shall be made only after proper wet curing has been done and surface has been satisfactorily evaluated by sounding/tapping with a blunt metal instrument)	sqm
	A Cement Sand mortar in proportion of 1:2 (1-cement: 2-graded coarse sand) with polymer admixed in proportions approved by Engineer-in-charge. (75mm size cube crushing strength at the end of 28-day to be not less than 30 N/sqmm)	
	a) 25 mm average thickness for slabs	sqm
	b) 50 mm average thickness for Beams	sqm
	c) Deduct/Add for every less/extra 10 mm thickness	sqm
	B. Cement Sand mortar in proportion of 1:2.5 (1-cement: 2.5 graded coarse sand) with polymer admixed in proportions approved by Engineer-in-charge. (75mm size cube crushing strength at the end of 28-day to be not less than 25 N/sqmm)	
	a) 25 mm average thickness for slabs	sqm
	b) 50 mm average thickness for Beams	sqm
	c) Deduct/Add for every less/extra 10 mm thickness	sqm
	C. Cement Sand mortar in proportion of 1:3(1-cement: 3- graded coarse sand) with polymer admixed in proportions approved by Engineer-in-charge. (75mm size cube crushing strength at the end of 28-day to be not less than 20 N/sqmm)	
	a) 25 mm average thickness for slabs	

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Item No.	Description of item	Unit of Measurement
	b) 50 mm average thickness for Beams	sqm
	c) Deduct/Add for every less/extra 10 mm thickness	sqm
8.5.7a	**Supply** of Polymer for polymer modified mortar	sqm
	A Emulsified Acrylic Polymer (Rates shall be in terms of solid contents of polymer)	
	B Emulsified SBR Polymer (Rates shall be in terms of solid contents of polymer)	kg
8.5.8	**Mixing and applying epoxy mortar** using approved epoxy resin, hardener and silica sand in proportions as per manufacturer's recommendation complete. (The rate shall include the cost of silica sand. The epoxy shall be paid separately on the basis of actual consumption of the resin and hardener by weight and nothing extra shall be paid for silica sand.	kg
	(priming/ bonding coat of epoxy to be paid separately as per the relevant item in the schedule)	sqm
	A 25 mm average thickness for slabs	
	B 50 mm average thickness for Beams	sqm
	C Deduct/Add for every less/extra 10 mm thickness	sqm
8.5.8a	**Supplying** approved epoxy for epoxy mortar(payment shall be for total weight of Resin plus hardener in manufacturer specified proportion)	sqm
8.5.9	**Providing, mixing and applying dry pack mortar** 1:2.5 (1-cement: 2.5- graded sand passing 1.18 mm size sieve) by weight. Priming/ bonding coat required to be applied shall be paid separately as per the relevant item in the schedule. For payment purposes, pre-measurement of volume shall be done just after the surface preparation is completed. (Payment under this item shall be made only after proper wet curing has been done and surface has been satisfactorily evaluated by sounding/tapping with a blunt metal instrument)	Kg
8.5.10	**Providing Pre-placed Aggregate Concrete (PAC)** with well compacted or hand packed aggregates of size not less than 20 mm with self flowing grout of cement sand mortar, to be injected *as per specified proportions [neither leaner than 1:2 (1-cement: 2 clean sand passing 1.18 mm size sieve) nor richer than 1:1(1-cement : 1 clean sand passing 1.18 mm size sieve)]*. The water cement ratio shall be not more than [*to be specified but not exceeding 0.5)* but with approved super plasticisers admixed to achieve required flowability etc complete. For payment purposes, pre-measurement of volume shall be done just after the surface preparation is completed. The rates shall include all necessary labour, materials, T&P including grout pumps etc for executing the job	cum

Item No.	Description of item	Unit of Measurement
	as per specifications. Shuttering and priming/ bonding coat, if applied, shall be paid separately as per the relevant item in the schedule. (Payment under this item shall be made only after proper wet curing has been done and surface has been satisfactorily evaluated by sounding/tapping with a blunt metal instrument)	
8.5.11	**Strengthening RCC structural member (Beam/Column/Slab/etc) with hybrid fabric system** of a reputed firm comprising of E-glass and Kevlar fibres woven in the two orthogonal directions soaked in epoxy complete. Rate shall include cleaning surface, patching up surface irregularities, rounding of the corners to min. radius of 20 mm, pre-cutting the fabric according to dimensions required, mixing the epoxy with high speed mixer for 5 minutes, saturating the fabric with epoxy manually or using the mechanical saturator, wrapping the member with the saturated the fabric material after priming the surface with epoxy and curing for 24 hours at ambient temperatures including applying cement plaster finish over the outermost layer etc complete. Removing plaster from the parent surface, if involved, shall be paid for separately under the relevant item. (The rates shall be for finished surface area and shall cover the cost of a minimum of 100 mm over laps).	sqm per layer
8.5.12	**Strengthening RCC structural member (Beam/Column/Slab/etc) with unidirectional high strength fibres** comprising of E-glass fibres wrapped over prime coated surface with special epoxy, saturated after wrapping with saturant epoxy complete. Rate shall include cost of cleaning surface, patching up surface irregularities, rounding of the corners to min. radius of 20 mm, pre-cutting the fibres according to dimensions required, mixing the epoxy with high speed mixer for 5 minutes, saturating the fibres with epoxy manually or using the mechanical saturator, wrapping the member with the high strength fibres after priming the surface with epoxy and curing for 24 hours at ambient temperatures including applying cement plaster finish over the outermost layer etc complete. Removing plaster from the parent surface, if involved, shall be paid for separately under the relevant item. (The rates shall be for finished surface area and shall cover the cost of over laps, if any).	sqm per layer
	SUB HEAD VI: CURING	
8.6.1	**Wet curing** of shotcreted or plastered surface or RCC work as per specifications by keeping it continuously wet for a minimum period of seven days	sqm per layer
	A With regular sprinkling of water by keeping the surface continuously wet.	
	B Using pre-tested and approved water based concrete curing compound	
	a) Using non-pigmented wet curing compound	sqm

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Item No.	Description of item	Unit of Measurement
	b) Using pigmented wet curing compound	
8.6.1a	**Supplying** pretested and approved water based concrete curing compound	sqm
	A Non-pigmented wet curing compound	sqm
	B Pigmented wet curing compound	
	SUB-HEAD VII CHHAJJA/SUN SHADES	Litres
8.7.1	**Providing and fixing [*40 mm or to be specified*] thick *[red sandstone or to be specified*]** chajja over door/window/ventilator in MS angle iron *[40x40x6mm or to be specified]* frame pre-painted with a coat of zinc rich epoxy primer and two coats of tar-epoxy paint. The stone slab shall be supported on three sides of the frame, the fourth side of the stone slab to be supported on brick wall as shown in the drawing (*Fig 8.1, which could be modified as per site specific requirements*). The angle iron are to be embedded in brick wall as shown in drawing in cement concrete block of specified size including providing gola as per CPWD specification along the wall face. Measurements shall be done for the funished projected chhajja in sqm correct to second place of decimal. Rates shall include cost of all labour and materials. *(The size of angle iron frame could be modified as per structural requirement depending upon the size of chhajja)*	Litres
8.7.2	**Providing and constructing average 25mm thick Ferro-cement Chhajja/ weather shade,** reinforced with 2 layers of 21 gauge galvanised Iron orthogonally woven wire mesh of 12x12mm size, sandwiching a layer of 3.15 mm dia M.S. weld mesh of 100x100mm size, grouted to full depth with cement mortar 1:2.5 (1-cement: 2.5 graded sand, conforming to zome-II of IS:383, admixed with polymer admixture @ 2 Kg per 50 Kg of cement) and a cover of 4 mm of same mortar at top and bottom and with necessary fixing on beam/drop pardi etc. complete with water drip course (cost of polymer admixture, shuttering, and structural steel supports to be paid separately). Ferro-cement units must be vibrated during casting using modified vibrator or orbital vibrators.	sqm
8.7.2a	**Supply** of Polymer admixture for Ferro-cement Chhajja/weather shade	
	A Emulsified Acrylic Polymer (Rates shall be in terms of solid contents of polymer)	sqm
	B Emulsified SBR Polymer (Rates shall be in terms of solid contents of polymer)	
	SUB HEAD VIII WATER PROOFING & PROTECTIVE COATINGS	Kg
		Kg

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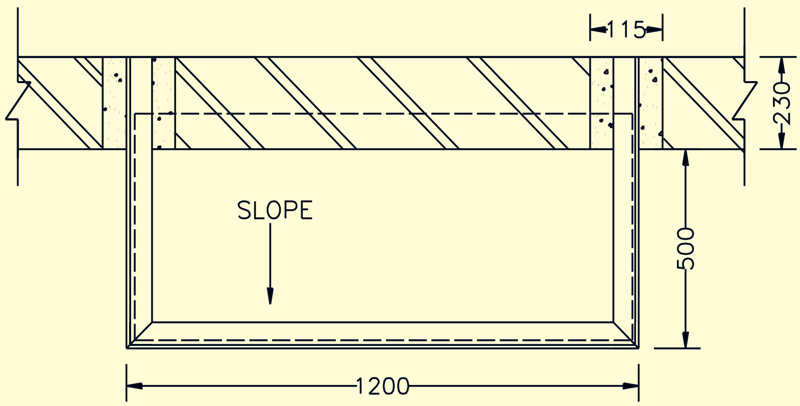
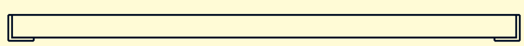
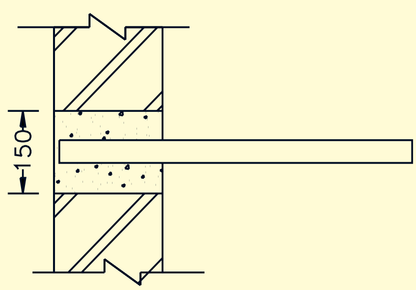


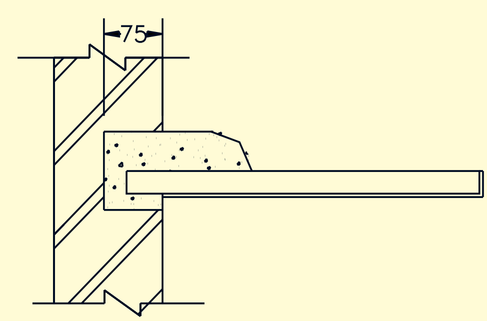
SECTIONAL PLAN OF PROPOSED CHAJJA



SECTIONAT X–X



SECTIONAL PLAN OF PROPOSED CHAJJA



SECTIONAL PLAN OF PROPOSED CHAJJA

Fig 8.1: Details of Sand stone Chhajja in MS Angle Iron frame

Item No.	Description of item	Unit of Measurement
	Note: Also Refer Section on Water Proofing of 'CPWD-Delhi Schedule of Rates'. All items covered under this subhead 'Water Proofing & protective coatingsd' shall carry 10 year guarantee for water tightness and dry surface on opposite side of treatments on non-judicial stamp paper. The work shall be carried out by specialised agency having excellent track record.	
8.8.1	**Providing, mixing and applying two coats of polymer based protective, waterproofing and anticarbonation coating** with manufacturer's recommended admixed dose in cement mixed with minimum quantity of additional water to make mix workable over exposed surface at all heights as per specifications. Mixing to be done by a vertical stirrer type grout mixer. (The cost of polymer shall be paid separately as per the actual consumption)	
8.8.1a	**Supply** of Polymer admixture for waterproofing and anti carbonation coating	sqm
	A Emulsified Acrylic Polymer (Rates shall be in terms of solid contents of polymer)	
	B Emulsified SBR Polymer (Rates shall be in terms of solid contents of polymer)	kg
8.8.2	A **Applying an appropriate priming coat of standard primer compatible to the substrate (bituminous or cementitious)** surface including injection grouting the cracks, filling the voids, undulations etc. complete using quantity not less than theoretical consumption as per manufacturer's specifications and directions of Engineer-in-Charge. The rates shall include the cost of carrying out repairs to concrete surface, if required but shall not cover the injection grouting, which shall be payable separately under the relevant item.	kg
	B **Applying two or more coats of ready mixed UV resistant acrylic polymer based water proof coatings** with broad brush or roller over prepared and primer applied surface using not less than theoretical consumption as per the manufacturer's specifications and directions of Engineer-in-Charge (time gap between two coats of coatings shall be not less than 8 hours).	sqm
8.8.2a	**Supplying** appropriate primer for bituminous/cementitious substrate for water proof coating with UV resistant acrylic polymer manufactured by reputed manufacturer as approved by the Engineer in charge in sealed containers.	sqm
8.8.2b	**Supplying** ready mixed UV resistant acrylic polymer based water proof coating manufactured by reputed manufacturer as approved by the Engineer in charge in sealed containers.	kg
8.8.3	**Providing and laying ferrocement water proofing treatment** comprising of layers of hot dip galvanised 22 gauge orthogonal	kg

Item No.	Description of item	Unit of Measurement
	woven wire mesh with 12 mm size mesh openings stretched and fixed to substrate with 100 mm overlaps in both directions at a clear spacing of 4 mm and also maintaining a clear bottom cover of 4 mm complete with plasticiser and polymeric pore sealant admixed in appropriate approved proportions to 1:2 cement mortar (1-Cement : 2-graded coarse sand) applied over a bond coat of polymer modified cement sand slurry, finished with mechanical vibratory orbital trowel. The bottom cover and the gap between the layers shall be maintained with 4mm dia GI wire with one layer of wire mesh stretched in the one direction & fixed with GI wire nails/clamps at 450 mm c/c and another set of 4 mm GI wires stretched in the other direction and second layer of mesh stretched over and fixed with GI wire nails/clamps at a spacing of 450 mm c/c. The fixing with G.I. wire nail/clamps shall be done with epoxy in drilled holes complete as per standard specifications and directions of Engineer-in-Charge. The rates shall include cost of all materials, labour, T&P involved, but shall not cover the cost of woven wire mesh, polymer admixed as pore sealant and bond coat which shall be paid for separately.	
	A 15 mm thick with two layers of woven wire mesh	
	B 20 mm thick with three layers of woven wire mesh	
	C 25 mm thick with three layers of woven wire mesh	
8.8.3a	**Supplying** hot dip galvanised 22 g orthogonal woven wire mesh with 12 mm size mesh openings in rolls with widths 750 mm to 1200 mm as may be approved by Engineer-in charge	sqm sqm sqm
8.8.3b	**Supply** of Polymeric pore-sealant for ferrocement water proofing traetment	
	A Emulsified Acrylic Polymer (Rates shall be in terms of solid contents of polymer)	sqm
	B Emulsified SBR Polymer (Rates shall be in terms of solid contents of polymer)	
8.8.4	**Providing and laying polymeric water proofing compound admixed cement plaster** 1:4 (1-cement : 4-graded coarse sand conforming to zone-II of IS : 383) *(specify thickness 12 mm to 18 mm thick)* mm thick in layers with the water proofing compound mixed in proportions as per manufacturer's recommendations including preparation of surface and application of bond coat etc. complete over all vertical and inclined surfaces of RCC work/ Brick Masonry/ block masonry including necessary scaffolding, clearing the site complete as per. directions of Engineer-in-Charge. The rates shall include cost all materials, labour and operations but shall exclude the cost of bond coat, which shall be paid separately.	kg kg
8.8.5	**Providing injection type post construction water proofing to concrete structures** such as under ground tanks, swimming pools etc by installing minimum 12/15 mm dia aluminium or GI nozzles	Sqm

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sqm
sqm
sqm

Item No.	Description of item	Unit of Measurement
	at specified intervals and mechanically injecting machine mixed water proofing polymer modified cement slurry at the minimum pressure of 3 kg/sqcm. Water proofing polymeric compound and shrinkage compensating admixtures shall be added in proportion as per manufacturer's recommendations. The rate shall include all materials, labour and operations and finishing etc complete but shall exclude the cost of providing, fixing and cutting off nozzle projections grouting holes, which shall be paid separately. (Only treated surface area measurement to be measured).	
	SECTION IX: MASONRY REPAIR	
8.9.1	**Cutting, removing, and rebuilding the decayed/damaged masonry with**	Sqm
	A Brickwork of class designation 75 in	
	a) Cement Sand Mortar 1 : 4 (1-Cement : 4-Coarse Sand	
	b) Cement Sand Mortar 1 : 5 (1-Cement : 5 Coarse Sand)	
	c) Cement Sand Mortar 1 : 6 (1-Cement : 6 Coarse Sand)	
	B In situ concrete 1:2: 4 (1-cement: 2-coarse sand : 4-12 mm and downsized graded stone aggregate) in part section of a brick or part there of.	cum cum cum
	C Build up by guniting in thickness	Per brick or part thereof
	a) up to 25 mm	
	b) Above 25 mm but not exceeding 50 mm	
	D Applying bonding coat, providing & fixing GI wire mesh and building up the masonry section to required thickness by providing polymer mortar 1:3 (1-Cement : 3-Sand Conforming to zone-III as per IS : 383) in layers not more than 12mm in thickness or part there of. Polymer shall be paid separately.	sqm sqm
8.9.1a	**Supply** of polymer for polymeric bond coat and/or polymer mortar	
	A Emmulsified Acrylic Polymer (rates shall be in terms of solid contents of polymer)	sqm layer
	B Emulsified SBR polymer (Rates shall be in terms of solid contents of polymer	kg
8.9.2	**Repair of cracks in 115 mm/230 mm thick masonry wall** by cutting the masonry, and providing and fixing precast RCC runners in M20 concrete and packing with stiff cement mortar 1:4	kg
	A 600mm x 115mm x 75mm with 2 nos.6mm MS bar	
	B 600mm x 230mm x 75mm with 2 nos. 6mm MS bar	
8.9.3	**Repair of cracks in 115/230 mm thick masonry wall** by cutting the masonry, and providing cast in-situ RCC runners in M20 concerte	each each

Item No.	Description of item	Unit of Measurement
	A 600mmx115mmx70mm with 2 nos. 6mm MS bar B 600mmx230mmx70mm with 2 nos. 6mm MS bar C 1200mmx230mmx70mm with 2 nos. 10mm CTD/TMT	
8.9.4	**Dismantling removing and cleaning damaged masonry and Providing cast in-situ RCC Bed Blocks** in M20 concrete including shuttering complete excluding reinforcement, if any	each each each
8.9.5	**Raking of joints , washing and applying salt peter antidote and replastering** with cement plaster 1:4 (1 cement :4 coarse sand).	
8.9.6	Chipping off the area and removing the plaster ,cleaning wetting and applying a layer of polymer mixed bonding coat covering the joint with one layer of 20 gauge hot dipped galvanised wire mesh strip in plaster area extending it 75 mm on both sides of the joint and replastering in cement mortar 1:4. Polymer shall be paid separately.	cum sqm
8.9.6a	**Supply** of polymer for polymeric bond coat and/or polymer mortar	
	A Emmulsified Acrylic Polymer (rates shall be in terms of solid contents of polymer)	sqm
	B Emulsified SBR polymer (Rates shall be in terms of solid contents of polymer	
	SECTION X: TESTING OF MATERIALS AND PRE / POST REPAIR TESTING OF STRUCTURE	kg kg
8.10.1	**Ultrasonic Pulse Velocity (UPV) measurement** in accordance with IS: 13311 Part-1-1992 by measuring the time taken for travel of a known distance through concrete medium being tested. The rate shall include the necessary surface preparation including its smoothening and making it flat, application of petroleum jelly, etc necessary for intimate contact of the transmitter & receiver with the concrete surface, recording the minimum & stable reading, necessary scaffolding and platform, presentation of results in an acceptable format etc all complete.	
8.10.2	**Measurement of Rebound Index** in accordance with IS: 13311 Part-2-1992 for a location on concrete surface with calibrated rebound hammer placed perpendicular to the surface and taking required number of rebound readings. The rate shall include surface preparation, which shall cover removal of surface plaster, if any, with chisel etc, removal of cement slurry layer from concrete surface with grinding stone, making surface even & smooth, necessary scaffolding and platform, presentation of results in an acceptable format etc all complete.	Each
8.10.3	**Measuring the Half Cell Potential readings** at the nodes of pre-marked grid on concrete surface for determining the probability	Each location

Item No.	Description of item	Unit of Measurement
	of corrosion activity of embedded steel reinforcement in concrete with specified half cell electrode in accordance with ASTM C876-1980 after moistening the concrete surface with water. The rate shall include surface preparation, moistening concrete surface, all the operations and materials enumerated above, necessary scaffolding and platform, presentation of each location results in an acceptable format etc all complete.	
	A i) With Copper-Copper Sulphate Half Cell Electrode	Each set of 10 readings
	ii) With Silver-silver chloride Half Cell Electrode	Each set of 10 readings
	iii) With Calomel Electrode	Each set of 10 readings
	B Plotting the half cell potential readings in graphical presentation with potential contours plotted in acceptable format	Each set of 10 readings
8.10.4	**Measuring the Half Cell Potential readings** with wheel electrode at the nodes of pre-marked grid points on concrete surface in a suitable grid for determining the probability of corrosion activity of embedded steel reinforcement in concrete with specified half cell electrode in accordance with ASTM C876-1980 after moistening the concrete surface with water. The rate shall include surface preparation, moistening concrete surface, all the operations and materials enumerated above, necessary scaffolding and platform, presentation of results in an acceptable format etc all complete.	
	A. i) With Copper-Copper Sulphate Half Cell Electrode	Each set of 10 readings
	ii) With Silver-silver chloride Half Cell Electrode	Each set of 10 readings
	iii) With Calomel Electrode	Each set of 10 readings
	B. Plotting the half cell potential readings in graphical presentation with potential contours plotted in acceptable format	Each set of 10 readings
8.10.5	**Cutting and extracting undisturbed concrete core** of specified diameters preferably with its length finished after end preparation equal to twice the diameter but in any case not less than the diameter of the core, without encountering any steel reinforcement from the RCC members at specified locations with portable power driven core cutting equipment. After the core has been extracted, the hole shall be made good by plugging with dry pack concrete and finished as per the existing finish. The rate shall include necessary scaffolding and	

Item No.	Description of item	Unit of Measurement
	platform and cost of all the operations, scanning T& P and materials etc complete.	
	A (i) 50 mm diameter	Each
	(ii) 75mm diameter	Each
	(iii) 100 mm diameter	Each
	B Testing the extracted concrete cores of any diameter for	
	i) Evaluating compressive strength	Each
	ii) Determining density of concrete	Each
	iii) Determining depth of carbonation with phenolphthalein indicator	Each
	iv) Determining the total acid soluble chloride contents in concrete as per BS 1881:Part 124	Each
	v) Determining the total sulphate contents in concrete expressed as sulphate buy mass of concrete as per BS 1881:Part 124	Each
8.10.6	**Determining depth of carbonated cover concrete** by spraying phenolphthalein pH indicator with physician's injection syringe (or other fine spraying equipment) over freshly broken/drilled concrete surface (after blowing away dust, if any, due to drilling operation). The rate shall include cost of all the operations, T&P and materials including making good the surface damaged with dry pack concrete, etc as approved by Engineer-in-charge.	Each
8.10.7	**Scanning the concrete surface** with standard non-destructive embedded metal detecting instrument and plotting the reinforcement scan, determining its diameter and concrete cover thickness	
	A Plot of reinforcement	sqm
	B Cover Thickness	Each
	C Bar diameter	Each
8.10.8	**Determination of relative density** of samples of fluid, Pyknometer or relative density bottle for polyester resins, etc according to Annex-F of IS:6746:1994	Each
8.10.9	**Determination of relative density samples** of liquid admixtures using hydrometer and according to Annex-E of IS:9103:1999	Each
8.10.10	**Determination of solid content of samples of polymer** according to IS 13435 (Part 1) 1992	Each
8.10.11	**Determination of pH value** of sample using pH meter electrode conforming to IS:2711:1979 and testing done according to IS13435	Each

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Item No.	Description of item	Unit of Measurement
	(Part 4) 1992.	
8.10.12	**Determination of viscosity of samples of polyester** resin by Brookfield viscometer, expressed in centipoises according to Annex-A of IS 6746:1994	Each
8.10.13	**Determination of percentage of air entrained in hardened concrete/mortar** due to an admixture with reference to standard concrete/mortar without admixture considered as reference by casting standard 75 mm size concrete cubes, three nos. each of admixed and standard mortar samples respectively prepared and weighing them after 28 days of standard curing procedure.	Each
8.10.14	**Determination of water soluble chloride content** in samples of admixtures according to IS:6925-1973	Each
8.10.15	**Determination of total acid soluble chloride content** of concrete /mortar, expressed as percent of mass, according to BS 1881: Part 124	Each
8.10.16	**Determination of total acid soluble sulphate content** of concrete /mortar, expressed as percent of mass, according to BS 1881:Part 124	Each
8.10.17	**Determination of gel time** expressed in minutes, of polyester resins, according to Annex-D of IS 6746:1994	Each
8.10.18	**Determination of air content of freshly prepared concrete / mortar,** expressed as percent of mass, according to IS:1199-1959	Each
8.10.19	**Conducting tests for uniformity tests** (dry material content, ash content, relative density, chloride ion content &pH) on admixtures according to Annex E of IS:9103-1999.	Each
8.10.20	**Determination of resistance of concrete against freezing and thawing** according to Annex B of IS:9103-1999.	Each
8.10.21	**Determination of flow of concrete of high workability concrete** according to Annex C of IS:9103-1999.	No.
8.10.22	**Determination of bleeding of concrete** according to Annex D of IS:9103-1999.	No.
	@ the projected length of shear key shall be more than 10 times its diameter plus half the thickness of cover concrete plus bend length	No.

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CHAPTER 9

SPECIFICATIONS FOR STRUCTURAL REPAIR WORK

PAGE NO.

PAGE NO.

9

SPECIFICATIONS FOR STRUCTURAL REPAIR WORK

Science is a self-correcting system. No fraus (or honest mistake) is going to stay undetected for long.

..C.P. Snow

9.0 GENERAL

9.0.1 Quality Assurance

9.0.1.1 Submittals:

The contractor shall submit manufacturer's certification that the firm has manufactured the supplied materials.

9.0.1.2 Labelling:

All containers shall be clearly marked with following information.

(a) Name of Manufacturer
(b) Manufacturer's product identification
(c) Manufacturer's instruction for mixing.
(d) Warning for handling and toxicity.
(e) Date of manufacturing & its shelf life.

9.0.1.3 Manufacturer's Test Certificate:

The contractor shall submit manufacturer's certification verifying conformance to material specification as specified.

9.0.1.4 Application control:

The contractor shall submit mixing application procedure for each of the manufactured repair material for the approval of Engineer-in-Charge prior to their use.

9.0.1.5 Measurements Control: Measurements for payment of the item of repair shall be done only after completion of all steps of execution listed in the particular specification.

9.0.2 Product Delivery, Storage and Handling:

Storage: The contractor shall get approved from the Engineer-in-Charge the storage space for epoxy/polymer/patented/other manufacture of materials to ensure that the storage temperature is maintained between 5^0 C and 38^0 C unless recommended otherwise by the manufacturer.

Delivery: Contractor shall deliver all materials in sealed containers in packing as approved by Engineer-in-Charge with labels legible and intact.

Handling: All materials shall be handled in a safe manner and in a way to avoid breaking container seals.

9.0.3 Environmental Requirements:

Contractor shall comply with manufacturer recommendations so as to comply with environmental conditions under which the repair materials may be applied.

9.0.4 Personnel:

9.0.4.1 General Requirements

(1) Production, processing, testing and supervision require the employment of an Engineer-in-Charge by the Employer and Site Contract Manager & skilled site workers by the contractors who shall have adequate qualifications and experience for the proper execution of such works and already performed works of this kind with success.

9.0.4.2 Engineer-in-Charge:

(1) The Engineer-in-Charge shall represent the Employer and should have adequate knowledge and experience in protection and repair measures for the work.

(2) The Engineer-in-Charge is in charge of and responsible for work on the construction site and where relevant, for the management of the Materials Field Testing Laboratory. He may perform the tasks of the competent planning engineer

(3) So far as they have not been dealt with at the planning stage, the tasks of the Engineer-in-Charge include:

- Recording and evaluating the states of structures, for example in terms of statics, design, concrete technology, materials technology, fire protection technology and physics relating to construction (determination of the actual state and of the causes of damage).
- Deciding whether additional experts should be consulted in respect to safety, relevant work and other specialized tasks.
- Assessing protection and repair plans especially in respect of the choice of the repair systems to be employed.
- Planning and assessing application oriented suitability tests.
- Setting out and, where relevant, assessing performance specifications and assessing the feasibility, effectiveness and durability of the protection and repair measures, taking structural stability aspects into account.
- Devising working plans.
- Assessing the specialist qualifications of the skilled site personnel and test laboratory personnel
- Evaluating internal supervision measures.

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9.0.4.3 Site Contract Manager

(1) The site contract manager or a qualified deputy of the site contract manager is the engineer representing the contractor, whose credentials were submitted and approved by the employer before issue of tender forms. He must be present on the construction site at all times during construction works.

(2) The site contract manager ensures safe execution of the works according to the plans and, in particular, discharges the following tasks over and above his tasks.

a) Notifying the works to the employer and the consultant
b) Arranging for and carrying out supervision
c) Using the envisaged, (quality) assured construction materials.
d) Where relevant, ensuring adequate treatment of the concrete substrate and intermediate layers.
e) Ensuring compliance with the technical conditions for the works and with proper production, processing, after-treatment, and formwork removal as stipulated by the Engineer-in-Charge or the consultant.
f) Communicating the most important results of internal supervision measures to the external supervising authority.
g) Supervision measures in respect to preventive safety engineering and occupational medicine.

9.0.4.4 Skilled Site Personnel

(1) Skilled workers shall be employed by the Contractor. They shall be equipped with special training in manual crafts and possessing knowledge, skills and practical experience in respect of concrete technology and other materials appropriate to the scope, type and difficulty of the repair measures. They must be present on each construction site at all times. His qualification for works according to these guidelines must be demonstrated to the external supervision agency by means of an appropriate certificate.

(2) The Contractor must ensure that the skilled workers employed at site, are informed of and instructed in protection and repair measures at maximum intervals of 3 years so as to enable them to take all measures for the proper execution of the construction measure, including tests and internal supervision as per the latest prevalent technology.

(3) The tasks of the skilled site personnel include

- practical execution of the protection and repair measures according to the prescribed planning / execution documents (directions for execution).
- specifying and supervision any work delegated to other skilled site personnel, insofar as it affects the success of the measure.
- directing the other skilled site workers to whom execution of the construction measures has been entrusted and checking their manual craft skills.
- carrying out the tests required as part of internal supervision and recording and interpreting the results.

(4) If the Contractor has a Materials Field Testing Laboratory (see Section 9.0.7) with appropriately qualified personnel the requirements contained in Paragraphs (1) and (2) in respect to the skilled site personnel are deemed to be satisfied if

- responsibility for the tasks is assumed by the Materials Field Testing Laboratory and
- a person delegated by the Materials Field Testing Laboratory is present on the construction site at all times and
- This delegated persons has been instructed and trained in the relevant protection and repair measure and the results of the training have been documented to the external supervising authority.

9.0.5 Safety:

Workers: Contractor shall advise all workers working with epoxies to avoid contact with eyes and skin, inhalation of vapours, and ingestion. Necessary protective and safety equipments in the form of hand gloves, welders' goggles, shall be provided by the contractor and used on site.

Structural Safety: Care shall be taken to ensure that vibrations are well within acceptable limits for structural safety and users of the building.

9.0.6 Tools & Plants (T&P):

(1) For the execution of protection and repair works, properly maintained plant and equipment permitting adequate treatment of the concrete substrate, proper execution of the work and determination of the required properties of the construction materials and construction measures must be present on the construction site.

In particular, these are plant and equipment for

a) Treatment of the concrete substrate
b) Dosing of the base materials.
c) Mixing of the base materials
d) Processing and after-treatment
e) Measurement and testing.

(2) To ensure efficient and effective functioning, all plant and equipment must be checked on-site and at field material testing laboratory prior to first use and at appropriate intervals thereafter.

9.0.7 Materials Field Testing Laboratory:

(1) The Materials Field Testing Laboratory must be equipped and staffed to carry out all pre and post repair tests (*Refer Appendix 9.1-Test Methods for* Execution of Works) to ensure required quality of repair jobs and also to monitor the satisfactory performance of plant and equipment during execution. The testing laboratory and the site must cooperate closely with one another.

(2) The materials testing laboratory carries out the following specific tasks:

a) Suitability testing for concrete and shotcrete; assessment and choice of premixed construction materials.

b) Assessing and, where necessary, testing the concrete substrate and intermediate layers.

c) Checking and supervision of the required technical conditions.

d) Testing quality and setting, in so far as such tests are not performed by the skilled site personnel.

e) Checking the equipment of the construction sites according to Section 9.0.6 above prior to commencement of the works.

f) Continuous checking and advice in respect to the production, processing and after-treatment of the construction materials. The results of checks according to e) and f) are to be recorded.

g) Interpreting and assessing the results of site tests on all work sites advised by the materials testing laboratory and communicating the results to the Contractor and its site contract manager.
h) Training / refreshing the know-how of the skilled site personnel.

(3) The Contractor may not entrust internal supervision to a field materials testing laboratory also responsible for supervising one of its suppliers.

(4) The Materials Field Testing Laboratory may also cause the sites to be equipped with test devices.

This applies particularly to

i) testing of base materials
ii) testing of the concrete substrate
iii) testing processing conditions
iv) testing the construction materials in the green state and after setting.
v) Where necessary, checking layer adhesion.
vi) Making up and storing test specimens and retained specimens.

(5) Where necessary, the Materials Field Testing Laboratory must ensure that the site is equipped with the necessary plant and equipment for supervision measures and tests during the required period. Functioning of all plant and equipment at the Materials Field Testing Laboratory and on the construction site must be checked prior to first use and at appropriate intervals thereafter.

9.0.8 SUPERVISION OF WORKS

9.0.8.1 General

(1) Supervision consisting of internal and external supervision must be conducted for construction measures according to these guidelines.

(2) Internal supervision must be carried out by the site contract manager in conjunction with the specialized staff of the Contractor and possibly in conjunction with the field materials testing laboratory.

(3) External supervision must be carried out by a supervisory association or on the basis of a specified contract with an official testing institute.

(4) For construction measures according to these guidelines, the Contractor or the site contract manager must notify the following information to the external supervising authority at latest 48 hours before commencement of the relevant works.

a) designation of the construction site, qualified executive manager, site contract manager, skilled site personnel.
b) The existence of written directions for the site in respect to the production, processing, after-treatment and supervision of all tasks required.
c) The intended time of commencement and probable time of completion of the works.
d) The internal supervision laboratory.
e) If work is interrupted for a lengthy period – especially following lengthy periods of frost or, where relevant, rain – recommencement of the works must be notified.

9.0.8.2 Internal Supervision

Documentation during Execution of the Works

(1) Depending on the type and scope of the works, continuous verifiable records of all data significant for the quality and durability of the structure and its parts are to be made in a certifiable form, e.g. on forms (site log)., by the site contract manager, his deputy or the skilled site personnel for construction measures according to these guidelines. They must contain at least the following information

a) commencement and completion of the individual works.

b) Whether conditions, air temperature, atmospheric humidity (where relevant), temperature of the materials at the time of execution of the individual construction phases or components up to adequate hardening. A special note must be made of days on which the processing conditions were not fulfilled (e.g. due to frost, rain).

c) The materials processed

d) Supplier and delivery note, batch number where relevant

e) Records of the work procedures and checks according to the directions for work and execution.

f) Proper functioning of the equipment employed

g) Specimens made up, with their designations, date of making up and details of the individual components or phases of construction for which the associated construction material was used, test date and results and required properties.

h) Testing of the concrete substrate and, where relevant, of intermediate layers, with results specified for each component

i) Where necessary, temperatures and moisture of the components.

j) Measures taken when requirements were not met

k) Names of the skilled site personnel executing and supervision the work.

(2) The records must be available on the site during the construction period and must be shown on demand to the person responsible for supervision.

(3) Following completion of the construction works, the results of important tests stipulated by the external supervision agency must be handed over to that agency.

Type, Scope and Frequency of Supervisory Measures

(1) The type, scope and frequency of the supervision measures are specified in Tables 9.1 to 9.7; if the construction measure is interrupted, the test time spans are prolonged accordingly.

(2) In case of doubt, tests which are not normally required, for example on properties of the base materials, their composition, suitability of methods of execution and testing, must also be performed. The qualified executive manager is responsible for ordering such tests.

(3) If test results are inadequate, the Contractor must eliminate the causes and any defects – where necessary including defects on the structure – without delay.

Table 9.1: Concrete according to IS: 456 (continued)

Sl. No.	Object of test	Type of test, test on, test variable	Requirements	Frequency, time
	Base materials			
1.	Cement	Delivery note and packaging stamp or silo certificate (possibly lead-sealing)	Labelling (type, strength class and proof of monitoring) according to IS269 IS:3466	Each delivery
2.	Aggregate	Delivery note	Designation, proof of monitoring according to IS 383	Each delivery
3.		Visual inspection for aggregate type, granulometric composition absence of rock defects, harmful constituents (e.g. clay, chalk, coal) and particle shape	Compliance with specifications according to IS 383: 1952	Each delivery
4.		Granulometric composition Through sieve analysis according to IS 383	Compliance with granulometric composition and reproducibility	At first delivery, at appropriate intervals, on change of a manufacturing works
5.	Concrete agents, fibres, colorants	Delivery note and possibly sack labeling or silo lettering	Designation, mark of conformity or approval and proof of monitoring	Each delivery
6.	Concrete agents	Delivery note and packaging or drum labels or silo lettering labeling	Designation, mark of conformity and proof of monitoring	Each delivery
7.	Admixed water	Constituents interfering with initial setting and hardening	No constituents interfering with initial setting and hardening	Only if potable water is not used and if interfering constituents are suspected
	Prefabricated materials			
8.	Handover of ready mixed concrete and fresh mortar	Delivery note	Complete specification data according to IS 4926	Each delivery
9.	Handover of plant-mixed dry products	Delivery note and packaging stamp, labeling	Designation, proof of monitoring	Each delivery
10.		Visual inspection	No obvious changes	Continuously
11.	Storage	Storage conditions	According to manufacturer's directions for use	On storage, in case of doubt
12.	Working plan	Directions for treatment of the substrate	**Mean Tensile Strength** $\geq$ 1.5 N/sq mm; Min. & Max Temp as per Step-9 in 9.4.1.2	Prior to commencement of works

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Sl. No.	Object of test	Type of test, test on, test variable	Requirements	Frequency, time
13.	Concrete substrate	Visual inspection	Suitability of concrete substrate for the planned measure	Prior to commencement of works
14.		Surface tensile strength	Suitability of the concrete substrate in terms of surface tensile strength according 3.2.1.4	> 20m² 3 single tests > 200m² 3 single tests per started 200m²
	Concrete			
15.	Composition of materials	Suitability tests based on IS: 456 attained reliably	The properties required in each case must be materials or site onditions	Prior to commencement works and if the base change significantly.
16.	Mixed materials	Composition of the mixture	Compliance with mixing directions	First use of each type; at appropriate intervals; during production of test specimens for strength tests
17.	Green concrete	Consistency (appearance)	Compliance with speci- fied consistency range	Each mix or delivery vehicle
18.		Consistency factor according IS 1199: or as determined	Compliance with the consistency factor specified in the suitability test for	First use of each type; appropriate intervals; production of test specimens for strength tests
19.		Water content	Compliance with the specification	According to IS:456:2000
20.		Air content according to IS 1199	Proof of air content for concrete or mortar with high frost/salt resistance according to IS 456	First use of each type; at appropriate intervals (each mix)
21.	Hardened concrete	Compressive strength according to IS 516	Proof of compressive strength of concrete according to IS 456	Every 7 days during use of concrete/mortar, a series of six test specimens
22.		Impermeability to water according to IS 3085	Compliance with specification	By agreement, but at least three test specimens
23.	Working plan	Directions for making up (mixing directions), transportation, working and after treatment	Compliance with specifications	Prior to commencement of works
24.	Weather	Air temperature, maximum and minimum values	Compliance with specifications	Every working day, prior to commencement of works, in case of doubt
25.		Relative atmospheric humidity	Compliance with specifications	Every working day, prior to commencement of works, in case of doubt

Sl. No.	Object of test	Type of test, test on, test variable	Requirements	Frequency, time
26.	Concrete	Moisture	Compliance with substratespecifications	Prior to commencement of subsequent works, in case of doubt
27.		Temperature	Compliance withIn Specifications	In case of doubt
28.	Construction Material	Temperature Specifications	Compliance with	Every working day, in case of doubt
29.	Finished Component	Adhesive strength	Compliance with Specifications	By agreement with the client if not agreed, then at least half the tests for surface tensile strength
30.		Concrete cover	Compliance with specifications according to IS 456	As specified
	Technical equipment			
31.	Dosing equipment for cement	Visual inspection	Unexceptionable functioning	Weekly
32.	Aggregate, colouring agents, fibres, admixed water, plant-mixed materials.	Function check	Compliance with projected quantity to an accuracy of 3%	At commencement of works, thereafter monthly
33.	Dosing equipment for concrete additives	Function check	Compliance with projected quantity to an accuracy of 3%	At least once per working day
34.	Mixing machines transportation, charging and compacting machines	Function check	Unexceptionable functi-oning, in the case of mixing in ready-mixed concrete transporters adequate screw height	At commencement of works, thereafter at least monthly
35	Measuring testing and laboratory equipment	Function check accuracy	Adequate measuring intervals	On first use, at appropriate
36.	Own or hired vehicles with IS 456 agitating equip -ment or mixer vehicles for transporting concrete and mortar	Adequate instruction of driver by Test Station E	Compliance with specification per	On first use, then at appropriate intervals

Table 9.2: Shotcrete

Sl. No.	Object of test	Type of test, test on, test variable	Requirements	Frequency, time
	Base materials			
1.	Cement	Delivery note and packaging label or silo certificate (possibly lead-sealing)	Labelling (type, strength class and proof of monitoring) according to IS 269	Each delivery
2.	Concrete aggregate	Delivery note	Designation, proof of monitoring according to IS 383	Each delivery
3.	Concrete additives	Visual check of type of aggregate granulometric composition stone quality and harmful constituents (e.g. clay, chalk, lime, coal)	Compliance with specifications in IS 383	Each delivery
4.		Granulometric composition by sieve analysis according to IS 383	Compliance with granulometric composition and reproducibility	At first delivery, once each week of concreting
5.	Concrete agents	Delivery note and possibly packaging or drum label or silo lettering	Designation mark of conformity to IS:9103 or approval & proof of monitoring	Each delivery
6.		Delivery note and packaging or drum label or silo lettering and proof of monitoring	Designation, mark of conformity to IS:9103	Each delivery
7.		Visual inspection	No obvious changes	Continuously
8.	Storage of base materials	Storage conditions	According to manufacturer's directions	At storage, in case of doubt
9.	Admixed water	Constituents interfering with setting and hardening	No constituents interfering with setting and hardening	Only if potable water is not used and interfering contamination is suspected
	Pre-mixed materials			
11.	Ready-mixed concrete or fresh mortar	Delivery note	Completeness of specified data	Each delivery
	Plant-mixed dry Products	Delivery note and packaging stamp, labelling	Designation, proof of monitoring	Each delivery
12.	Plant-mixed dry products	Visual inspection	No obvious changes	Continuously
13		Shortage conditions	According to manufacturer's instructions (directions for use)	At storage, in case of doubt
	Ready-mixed material, Test level 1			
14.	Concrete	Suitability tests	The properties required in each case must be attained	Prior to commencement of works and if the base materials or site conditions change significantly.

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Sl. No.	Object of test	Type of test, test on, test variable	Requirements	Frequency, time
15.	Job-mixed concrete	Composition of the mix	Compliance with mixing instructions	At the beginning of each day of concreting, during production of test specimens for Strength tests
16.	Ready-mixed material, dry spray method	Inherent moisture	Compliance with agreed inherent moisture	<100m³ or 500m² = 1 series, 100m³/500m² to 300m³/1500m² = 1 series per 100m³/500m², >300m³/1500m² = 1 series per 250m³/1250m²+ 1 series at commencement of concreting
17.	Ready-mixed material, wet method dry method with admixed water	Consistency	Compliance with consistency factor specified on the basis of the suitability test	
18.		Green concrete apparent specific density	Compliance with the green concrete apparent specific density specified on the basis of the suitability test	
19.	Compressive strength		Compliance with the compressive strength specified on the basis of the suitability test.	
Shotcrete, test level 2				
20.	Green concrete	Green concrete apparent specific density	Compliance with the green concrete apparent specific density specified on the bases of the suitability test.	<100m³ or 500m² = 1 series,100m³/500m² to 300m³/1500m=1series per 100m³/500m² >300m³/1500m² = 1 series /1250m² + 1 series at commencement of concreting
21.	Green concrete	Water content	Compliance with the water content specified on the basis of the suitability test.	
22		Granulometric composition < 0.25 mm	Compliance with the granulometric composition specified on the basis of the suitability test.	In case of doubt
23.	Hardened concrete	Apparent specific density (air dry at storage 20°C, 65% relative atmospheric humidity)	Compliance with the apparent specific density specified on the basis of the suitability test.	<100m³ or 500m² =1 series, 100m³/500m² to 300m³/1500m²= 1 series per 100m³/500m²,>300m³/1500m² = 1 series per 250m³/1250m² at commencement of concrete.
24.		Compressive strength	Compliance with the strength class specified on the basis of the suitability test	

Sl. No.	Object of test	Type of test, test on, test variable	Requirements	Frequency, time
25.		Impermeability to water	Compliance with the impermeability to water specified on the basis of the suitability test	Half the tests for compressive strength, at least three specimens
	Concrete substrate			
26	Surface for coating	Directions for the treatment of the concrete substrate and, where relevant, placing of re-inforcement	Compliance with specifications	Prior to commencement of works
27		Visual inspection measure	Suitability for the planned	Prior to commencement of subsequent works
28.		Moisture	Suitability in terms of moisture for the planned measure	Prior to commencement of subsequent of works, in case of doubt.
29.		Temperature	Compliance with specifications	In case of doubt
30.		Surface tensile strength	Suitability for the planned measure	By agreement with the client; in the absence of an agreement: >20m² 3 single tests> 200 m² 3 single tests per started 200m². The single tests must be distributed uniformly throughout the area.
Processing				
31	Working instructions	Directions for making up (mixing instructions) transportations, working and after treatment	Compliance with specifications	Prior to commencement of works
32.	Weather	Air temperature, maximum and minimum value; weather condition	Compliance with specificatons	Every working day
33.	Construction	Temperature	Compliance with specificatons	Every working day in case of doubt
34.	Surface of shotcrete	After-treatment	Compliance with specificatons	Each stage of work
35.	Finished component	Layer thickness	Compliance with agreed layer cover	Each stage of work
36.		Percussion	No cavities	Each layer
37.		Adhesive strength	Compliance with specifications or according to repair concept	By agreement with client; in the absence of an agreement 5 values per started 250m²; at least 5 values per structure
38		Concrete cover	Compliance with specifications	In case of doubt

Sl. No.	Object of test	Type of test, test on, test variable	Requirements	Frequency, time
	Technical equipment			
39.	Dosing equipment for base materials	Visual inspection	Unexceptionable functioning	Weekly
40	Prefabricated materials	Function check	Compliance with projected quantities	At commencement of works, thereafter monthly.
41.	Mixer, shotcreting equipment	Function check		
42.			Unexceptionable functioning	At commencement of works, thereafter at least monthly
43.	Measuring and testing devices	Function Check	Adequate measuring accuracy	On first use, at appropriate intervals
	Where relevant, own or hired transport vehicles with agitation equipment or readymixed concrete and mortar transporters	Adequate instruction of drivers by Test Station	Compliance with requirements	On first use, then at appropriate intervals

Table 9.3: Polymer-modified cement mortar and concrete, cement mortar

Sl. No.	Object of test	Type of test, test on, test variable	Requirements	Frequency, time
Pre-fabricated materials				
1.	Handover of plant-mixed products	Delivery note and packaging stamp	Designation, proof of monitoring	Each delivery
2.		Visual inspection	No obvious changes	Continuously
3.	Storage	Storage conditions	According to directions for use	On storage, in case of doubt
	Concrete substrate			
4.	Working plan	Directions for treatment of the concrete substrate	Compliance with specifications	Prior to commencement of works
5.	Concrete substrate	Visual inspection	Suitability of the concrete substrate for planned measure	Prior to commencement of subsequent works
6.		Surface tensile strength	Suitability of the concrete substrate in terms of surface tensile strength	> 20m² single tests; >200 m² 3 single tests per started 200m²
	Mortar/concrete			
7.	Composition of construction materials	Basic test	The properties required in each case must be attained reliably	Prior to commencement of works
8.	Mixed materials	Compositions of the mix	Compliance with mixing instructions	At first use of each type; at appropriate intervals; when specimens are made up for strength tests
9.	Green mortar/ concrete	Consistency (appearance)	Compliance with specified consistency range	Each mix
10.		Air content	Proof of required air content	At first use of each type, at appropriate intervals
11.	Hardened mortar / concrete	Flexural tensile and compressive strength	Proof of strength	Every 6 days during working of concrete / mortar, a series of 3 specimens; at least one series of 3 specimens.
12.	Processing	Directions for making up (mixing instructions), transportation, working and after-treatment	Compliance with directions for use	Prior to commencement of works
13.	Weather	Air temperature, maximum and minimum values	Compliance with specifications	Every working day, prior to commencement of works in case of doubt.
14.		Relative atmospheric humidity/weather conditions	Compliance with specifications	Every working day , prior to commencement of work, incase of doubt.

Sl. No.	Object of test	Type of test, test on, test variable	Requirements	Frequency, time
15.	Concrete	Moisture	Compliance with specifications	Prior to substrate commence ment of subsequent works, in case of doubt.
16.		Temperature	Compliance with specifications	In case of doubt.
17.	Construction material	Temperature	Compliance with specifications	In case of doubt.
18.	Finished component	Adhesive strength	Compliance with specifications	By agreement with the client, in the absence of an agreement, at least half the tests for surface tensile strength
19.		Concrete cover	Compliance with specifications	By aggrement
	Technical equipment			
20.	Dosing equipment for additives and water.	Visual inspections	Unexceptionable functioning	Weekly
21.		Function Check	Compliance with projectedquantity to an accuracy of 3%	At commencement of works, thereafter monthly
22.	Mixing equipment, transportation, charging and compacting equipment	Function check	Unexceptionable functioning	At commencement of works, thereafter at least monthly.

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Table 9.4: Epoxy mortar and concrete

Sl. No.	Object of test	Type of test, test on, test variable	Requirements	Frequency, time
Prefabricated materials				
1.	Handover of plant mixed products	Delivery note and packaging stamp	Designation, proof of monitoring	Each delivery
2.		Visual inspection	No obvious changes	Continuously
3.	Storage	Storage conditions	According to directions for use	On storage, in case of doubt
	Concrete substrate			
4.	Working plan	Directions for treatment of the concrete substrate	Compliance with specifications	Prior to commencement of works
5.	Concrete substrate	Visual inspection	Suitability of the concrete substrate for the planned measure	Prior to commencement of subsequent works
6.		Surface tensile strength	Suitability of the concrete substrate in terms of surface tensile strength	>20 m2 tests;>200 m2 3 single tests per s.
	Epoxy mortar/concrete			
7.	Composition	Basic test of construction materials	The properties specified in each case must be attained reliably	Prior to commencement of works.
8.	Mixed construction materials	Composition of mix	Compliance with mixing Instructions	On first use of each type; at appropriate intervals; when specimens are made up for strength tests.
9.	Green mortar/ concrete	Consistency (appearance)	Compliance with specified consistency range	Each mix
10.	Hardened mortar/ concrete	Flexural tensile and compressive strength according to Table 5.8	Proof of strengths according to specifications	Every 6 days during working of concrete / mortar, a series of 3 specimens; at least one series of 3 specimens.
	Processing			
11.	Working plan	Directions for making up (mixing instructions) transportation, working and after treatment.	Compliance with directions for use.	Prior to commencement of works.
12.	Weather	Air temperature, maximum and minimum value.	Compliance with specifications.	Each working day, before beginning work, in case of doubt.
13.	Weather	Relative atmospheric humidity, weather conditions	Compliance with specifications	Every working day, prior to commencement of works, in case of doubt.

Sl. No.	Object of test	Type of test, test on, test variable	Requirements	Frequency, time
14.	Concrete substrate	Moisture	Compliance with limits specified by material manufacturer	Prior to commencement of subsequent works, in case of doubt.
15.		Temperature	Temperature 3^{O}C higher than dew-point temperature	Prior to commencement of execution of the works and following changes in the weather.
16.	Construction material	Temperature	Compliance with specifications	Prior to commencement of execution of the works and following changes in the weather.
17.	Finished component	Adhesive Strength	Compliance with specifications	By agreement with the client; in the absence of an agreement, at least half the test for surface tensile strength.
	Technical Equipment			
18.	Dosing equipment	Visual inspection	Unexceptionable functioning	Weekly
19.		Function check	Compliance with projected quantity to an accuracy of 3%	At commencement of works, thereafter at least monthly.
20.	Mixing equipment, transportation, charging and compacting equipment	Function check	Unexceptionable functioning	At commencement of works, thereafter at least monthly.
21.	Measuring, testing and laboratory equipment	Function check	Adequate measuring accuracy	On first use, at appropriate intervals.

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Table 9.5: Surface protection systems

Sl. No.	Object of test	Type of test, test on, test variable	Requirements	Frequency, time
	Base materials/ system			
1.	Surface protection System	Delivery note, packaging stamp	Designation proof of monitoring.	Each delivery.
2.		Visual inspection	No obvious changes	Continuously.
3.	Storage	Storage conditions	According to manufacturer's regulations	On storage, in case of doubt.
4.	Composition of materials, system	Basic test	Compliance with directions for use	Prior to commencement of works, at each change in materials, systems.
	Concrete Substrate			
5.	Working plan	Directions for treatment of the concrete substrate	Compliance with directions for use	Prior to commencement of works.
6.	Concrete substrate	Visual inspection	Suitability of concrete substrate for the planned measure	Prior to commencement of subsequent works.,
7.		Surface tensile strength	Suitability of concrete substrate	>20 m^2 3 single tests; > 200 m^2 3 single tests per started 200 m^2
	Processing			
8.	Working plan	Directions for making up and working	Compliance with directions for use	Prior to commencement of works
9.	Weather	Air temperature	Compliance with directions for use	3 x per working day.
10.		Relative atmospheric humidity	Compliance with directions for use.	3x per working day.
11.	Concrete substrate	Temperature	Compliance with directions for use	Prior to commencement of execution of works and following changes in weather.
12	.	Moisture	Compliance with directions for use	Prior to commencement of execution of works and following changes in weather.
13.		.Dew-point temperature	Temperature 3^{O} C higher than dew-point temperature.	Prior to commencement of execution of works and following changes in weather
	Surface protection system			
14.	Protective measure	Quantities of materials	Comparison of quantities	As specified
15		.Layer thickness	Compliance with directions for use	As specified.

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Sl. No.	Object of test	Type of test, test on, test variable	Requirements	Frequency, time
16.	Protective measurements	Visual inspection, pores, blisters	Compliance with require	As specified.
17		Adhesive strength	Compliance with Specifications.	By agreement with the lient; in the absence of an agree ment at least half the tests for surface tensile strength.
18.		Water absorption, test method not yet specified	Compliance with directions for use.	As specified.
19.		Grid test	Compliance with directions for use	As specified.
20.		Roughness (peak – to – valley height)	Compliance with directions for use.	As specified
21.		Electrical leakage resistance	Compliance with directions for use	As specified
22.		Voids content, test method currently being validated	Compliance with directions for use	As specified
	Technical equipment			
23.	Dosing equipment	Visual inspection	Unexceptionable functioning	Weekly
24.		Function check	Compliance with projected quantity to an accuracy of 3%	On first use, thereafter at least monthly
25.	Mixing equipment	Function check	Unexceptionable functioning	On first use, thereafter at least monthly.
26.	Processing equipment	Function check	Unexceptionable functioning	On first use, thereafter at least monthly
27.	Measuring and test equipment	Function check	Adequate measuring accuracy	On first use, at appropriate intervals.

Table 9.6: Crack-Sealing

Sl. No.	Object of test	Type of test, test on, test variable	Requirements time	Frequency,
	Base material			
1.	Filler, cement, damming material, fitting nozzles	Delivery note and packaging stamp	Designation, proof of monitoring.	Each delivery
2.		Visual inspection	No obvious changes	Continuously
3.	Storage	Storage conditions	According to directions for use	On storage, in case of doubt.
4.	Composition	Basic test	Compliance with required properties	Prior to commencement of works
	Concrete substrate			
5.	Working plan	Directions for treatment of the concrete substrate and the cracks	Compliance with specifications according to directions for use.	Prior to commencement of works.
6.	Concrete substrate	Visual inspection	Suitability for the planned measure.	Prior to commencement of works.
7.		(Component) temperature	Compliance with directions for use	Prior to commencement of works.
8.		Crack-width / change in crack width	As specified	Prior to commencement of works.
9.		Moisture state of the cracks	As per specifications	Prior to commencement of works.
	Processing (damming materials, filler)			
10.	Working plan	Directions for making up and working	Compliance with directions for use	Prior to commencement of works.
11.	Weather conditions	Air temperature	Compliance with directions for use	Prior to commencement of works.
12.	Filling nozzles	Function check	Through-feed	Each crack
13.	Damming	Function check	Sealing	Each Crack
14.	Cement paste, constant viscosity	Marsh funnel Discharge time	As in basic test and directions for use	Each mix.
15.	Cement paste and injection equipment.	Sand column filling	No plunger, < 10 min to emergence of cement paste	Daily before beginning work and in case of doubt.
16.	Crack-filling	Visual inspection	Emergence of cement paste from next filling nozzle	Each crack
17.	Filling	Degree of filling	Completeness of filling	By agreement with the employer, in case of doubt.

Sl. No.	Object of test	Type of test, test on, test variable	Requirements	Frequency, time
	Technical equipment			
18.	Dosing equipment	Visual inspection	Unexceptionable functioning	Weekly
19.		Function check	Projected quantities to an accuracy of 3%	On first use, at appropriate intervals.
20.	Mixing equipment for damming material for filling compound	Function check appropriate intervals.	Unexceptionable functioning	On first use, at
21.	Filling device	Function check	Unexceptionable functioning	On first use at appropriate intervals.

Table : 9.7 Corrosion protection materials for reinforcement

Sl. No.	Object of test	Type of test, test on, test variable	Requirements	Frequency, time
	Base materials			
1.	Corrosion protective material	Delivery note and packaging stamp.	Designation, proof of monitoring	Each delivery
2.		Visual inspection	No obvious changes	Continuously
3.	Storage	Storage conditions doubt	According to directions for use	On storage, in case of
4.	Composition of the system	Basic test	Compliance with required properties	Prior to commencement of works.
	Reinforcement			
5.	Concrete substrate, reinforcement	Visual inspection	Suitability of the substrate	Prior to commencement of works.
6.		Temperature	Compliance with directions for use	3 x per working day
7.		Moisture	Compliance with directions for use	Prior to commencement of works.
8.		Dew-point temperature	Compliance with directions for use	In case of doubt.
	Processing			
9.	Working plan	Directions for making up and working.	Compliance with directions for use.	Prior to commencement of works.
10.	Weather	Air Temperature	Compliance with the specifications	Each working day.
11.		Relative atmospheric humidity	Compliance with specifications (e.g. < 70%)	Each working day.
12.	Finished corrosion protection	Layer density	Compliance with directions for use.,	As specified.
	Technical equipment			
13.	Dosing equipment	Visual inspection	Accuracy 3%	Weekly
14.	Mixing equipment	Function check	Unexceptionable functioning	At commencement of works, thereafter at least monthly.

(4) After the defect has been remedied, the relevant tests are to be repeated insofar as they are technically possible and are necessary in order to verify elimination of the defect.

(5) Materials which fail to comply with the requirements must be separated and marked as unsuitable.

(6) Working equipment which fails to comply with the requirements must not be used and must be marked as unsuitable.

9.0.8.3 External Supervision

External Supervision by Consultant/Employer

a. Commencement of External Supervision

(1) Prior to commencement of external supervision of works, being carried out by Contractor, the external supervising authority must establish whether the personnel and equipment are such that proper execution of the works may be anticipated (initial test).

(2) The Contractor must communicate to the external supervision agency in writing.

a) the name of the Engineer-in-Charge and any change in this post.
b) Where relevant, the internal Materials Field Testing Laboratory the name of the Engineer responsible and any change in this post.
c) Commencement of work on each construction site at which works according to these guidelines are carried out.
d) The name of the site contract manager and any change in this post.
e) The names of the skilled site personnel according to Section 9.0.4.4 and any changes in these posts.
f) The nature of the work to be carried out.
g) The construction materials intended for use in each construction measure.

b. Execution of External Supervision

(1) Each notified construction measure must normally be inspected at least once without advance notice. Construction measures of longer duration must be re-inspected at appropriate intervals. The frequency of the inspections is to be decided by the external supervising authority, with due regard to its responsibilities, and is to be in line with its conclusions and with the results of internal and external supervision. The reliability of internal supervision measures, the conclusions arrived at in the course of external supervision and the special requirements imposed on execution of the works and on the materials / material – systems are to be taken into account.

(2) No objection is to be made in the case of defects, including any defects on the structure, which are detected in the course of internal supervision measures but which are eliminated without delay.

(3) In the case of significant objections, a repeat inspection is to be made.

(4) The person responsible for carrying out the tests must examine the records of internal supervision measures according to Section 9.0.8.2. including.

a) the site log
b) the test records (test frequency and results) and the internal supervision documentation
c) the documentation relating to execution of the works and where relevant the performance specifications and the directions for work.
d) The proofs of suitability and supervision and the directions for use issued by the manufacturer of the material
e) The delivery notes
f) The mixing instructions in cases where materials are produced on site.
g) The records of function checks carried out on the plant and machinery employed

(5) The person responsible for carrying out the tests must as far as possible inspect the execution of the construction measures; during such inspections he may carry out the tests specified in these guidelines or cause them to be carried out.

The following items must normally be inspected:

a) the nature and storage of the construction materials
b) the nature of the machines and equipment employed and their functionality.
c) The execution of the works according to the specified working plans and directions for execution.
d) The suitability and level of instruction of the skilled site personnel.

(6) In case of doubt, the person responsible for carrying out the tests must perform additional checks; he is also entitled to take specimens and to cause them to be tested or to test existing retained specimens or to cause them to be checked.

Sampling

(1) The specimen is normally to be taken on the construction site by the person responsible for carrying out the tests, in accordance with statistical principles.

(2) A construction material identified as defective or a material identified as unsuitable by internal supervision measures is to be excluded from sampling only if such material has been separated and has been clearly marked as defective or unsuitable.

(3) The specimen is to be marked uniquely. The person responsible for making the tests must prepare a report on the taking of the specimen, must sign the report and must have it countersigned by the person supervising the construction site. The report must contain at least the following items:

a) Contractor and site
b) description of the material
c) number or amount of the specimens and their markings.
d) Time and date
e) signatures

Supervision Report

(1) The conclusions arrived at by the external supervising authority and its evaluation must be recorded in a supervision report. The report must contain at least the following items:

a) Contractor, site and internal supervision laboratory.
b) Brief description of the construction measure
c) Engineer-in-Charge, site contact manager and skilled site personnel.
d) Details of the materials and requirements.
e) Conclusions on the equipment employed
f) Conclusions on the type and execution of the construction measures performed.
g) Conclusions on internal supervision.
h) Appraisal of internal supervision
i) Where relevant, details of specimens taken
j) Results of tests carried out in the course of external supervision
k) Date of the inspection, signature and stamp of the person responsible for carrying out the tests.

(2) The supervision reports must be kept by the Contractor and by the external supervising authority for at least 5 years.

Site Markings

Construction sites supervised are to be marked at a clearly visible point, citing the designation and the external supervising authority according to Section 9.0.4.

9.0.9 Records

The results of the tests must be recorded and must be subjected to an appropriate degree of statistical analysis. The records must be kept for at least five years after completion of the tests or of the construction project.

9.1 SITE REQUIREMENTS

9.1.1 PROPPING & SUPPORTING STRUCTURAL MEMBERS SCHEDULE ITEM No. 8.1.1

PURPOSE: *To provide relief in stress and strains of structural members, which are deteriorated, overstressed, required to be repaired or strengthened, by transfer of dead and live loads safely through an alternate system to the founding medium.*

9.1.1.1 General

a) In repairs and rehabilitation works, design of false work is essential for avoiding damage to the distressed structure.

b) This is one of the most important operations in carrying out rehabilitation of a distressed structure. The success of structural repair depends mostly on ensuring that the parent material and the repair material of the structure participate jointly in resisting the applied loads due to self-weight and superimposed loads. Therefore, the quantum of relief given to distressed structural member determines success of the repair in the structural member.

c) It is necessary that the self-load and imposed loads over the structural members being repaired are transferred to the false work and the adjoining existing structural members safely, taking in to account the capacity of such adjoining members and the false work. And thus, the structural member is relieved of strains and stresses before it actually receives the structural repairs.

d) Particular attention is to be given to the shear capacity of the existing beams receiving load through false work, as it may lead to sudden and permanent damage to the structure being repaired.

e) Standardised false work systems are preferred option. The design of false work is to follow the general principles for the design of a permanent structure and relevant codal provisions.

f) Design brief covering all important operating instructions to the field engineers has to be prepared meticulously describing all issues crucial for the successful repair process.

g) The specifications of formwork (Centering and shuttering) contained in Para 5.2 of CPWD specifications 1996 (Vol-II) shall otherwise generally apply except otherwise mentioned herein these specifications.

9.1.1.2 Design Brief

Following are the important points to be included in the design brief of false work.

a) The plan of the structure.
b) Design considerations clearly giving material properties of the false work.
c) Dead and Imposed loads (including horizontal loads) on the false work.
d) Type of foundation for false work and its capacity, including flooding possibility, if any.
e) Reserve strength of supporting parent members.
f) Drawing & Specifications of falsework complete with required instructions.
g) Adjustment arrangement at the time of repairs.
h) Sequence of fixing and removal of false work including safe load transfer
i) Sequence of repair and strengthening

9.1.1.3 Requirements of good false work

a) It shall be strong enough to withstand all the dead and live loads and forces caused by dismantling, chipping, ramming, vibration of concrete and other incidental loads imposed over it including that of working platform and personnel during and after repair work.

b) It shall be made sufficiently rigid by using adequate number of ties and braces, screw jacks or hard wood wedges wherever required to ensure actual relieving of the load from member and its transfer through props, supports and structurally sound structural members of the existing structure.

c) Sole plates are secured and fixed against movement, forming level, camber as specified, if any.

d) Necessary plates, screw jacks, hard wood wedges shall be provided wherever required to make up any settlement in the props/supports.

e) Ladders, platforms, guardrails for providing access to the workmen are secured with the other members.

f) De-shuttering shall be done after the elapse of specified time and re-propping done if specified. The manner of de-shuttering shall avoid instability during removal of false work.

9.1.1.4 Inspection of False Work

Following are the checkpoints before allowing the next stage of false work to proceed:

a) The compliance of notes given in the false work drawing and the specification of materials to be used in the work.
b) Setting out of the work, founding medium for support and sole plates of the props.
c) Sequence of erection keeping the stability of the false work in mind at every stage by ensuring proper connection of joints. It must be ensured that ties and /or bracing (longitudinal, lateral and inclined) have been joined near the nodes simultaneously to ensure stability of the false work.
d) The plumb of vertical members to be ensured within specified limit.
e) The false work executed shall conform to the approved design.
f) Centering and shuttering is properly serviced after removal and before its next use.

9.1.1.5 Execution Procedure:

Step-1 **Design the prop and support system** using steel tubular sections with extension pieces or with built-up sections to ensure required relief to structural members from stresses due to loads coming over it, including the self-load of the member itself. No timber ballies etc. shall be used as props. However, timber runners/beams/planks of adequate section could be used for supporting structural beams, slabs as load distribution mechanism.

Step-2 **Prepare the design brief** covering all-important operating instructions and shall be got approved from the Engineer-in-charge beforehand.

Step-3 **Arrange all propping and supporting elements** as per approved design.

Steps-4&5 Refer these steps separately **for columns, beams and slabs** as given subsequently.

Step-6 **Work shall be inspected before taking up structural repairs** for safe load transfer to the founding medium by implementation of approved drawings/design of prop & support system.

a) Steps 4 & 5 for Columns:

Step-4 **Identify and mark the RCC columns** under structural distress, which are unable to sustain service load conditions and/or which are required to be ripped open for undertaking structural repairs or retrofitting.

Step-5 **Prop and support the column for the full height** of building, to relieve its axial loads through its adjoining intersecting beams and/or slabs at all floor levels of the building using designed steel props adjustable with extension pieces, screw jacks etc with sole plates. This shall be done, even if only one storey length (intermediate, lowest or the uppermost storey) out of many storey lengths of the same column, had been identified for structural repairs.

The loads relieved are required to be transferred directly through props and supports on to the building foundation system or to soil as per approved design of foundations.

Under no circumstances, the column loads above the storey should be transferred by transfer through adjoining upper or lower intersecting beams alone.

b) Steps 4 & 5 for Beams:

Step-4 **Identify and mark the RCC beams** under structural distress, which are unable to sustain the service load conditions and/or are required to be ripped open for undertaking structural repairs or retrofitting.

Step-5 **Prop and support the identified beams** to provide relief in stresses & strains to the distressed beam by suitably supporting such RCC slabs, which are contributing load to the beam itself. The load relieving shall be done using designed steel props adjustable with extension pieces, screw jacks, hard wood wedges etc with sole plates at suitable intervals but shall generally not exceed 1.5 metre centre to centre as per design approved by Engineer-in-Charge.

To avoid any overstressing of any existing flexural members receiving the transferred load of the distressed beam, the steel prop and supports shall be taken and continued to the firm ground. For upper storeys, the steel props shall be taken at least two storeys below or as per the design approved by Engineer-in-Charge.

c) Steps 4 & 5 for Slabs:

Step-4 **Identify and mark the points for propping and supporting** on soffit of RCC slab requiring structural repairs, for transfer of loads to relieve it from stresses and simultaneously avoiding its collapse during the repair process. However, such points shall preferably be not be farther than 1.2m x 1.2m.

Step-5 **Prop and support slabs** at identified locations with steel props to provide relief in stresses & strains suitably as per approved design with bearing plates adjustable with extension pieces, screw jacks etc.

To avoid any overstressing of existing flexural members receiving the load of the distressed RCC slab, the steel props and supports shall be provided just below the aforesaid identified points and shall be taken and continued to the firm ground or at least two slabs below as per the design approved by Engineer-in-Charge.

9.1.1.6 Measurements:

Number of props of specified capacity shall be measured for the purpose of payment.

9.1.1.7 Rates:

The rates shall cover cost of all materials, labour and T&P involved in all the operations described above including its removal after the work duration. The removed material shall remain the property of the contractor.

9.1.2 SPECIAL WATERTIGHT SHUTTERING/FORMWORK (Schedule Item No. 8.1.2):

PURPOSE: *To provide shuttering or formwork and its joints to be able to resist a* *hydraulic pressure at least equivalent to a 10 metres water head without causing any leakage.*

9.1.2.1 General

Special watertight shuttering/formwork shall be provided for special applications involving concrete or mortar, which are more fluid than normal concrete. e.g. Preplaced Aggregate Concrete, Self compacting & self levelling concrete (pumpable concrete, Micro concrete, etc making use of plasticisers/ super plasticisers), etc. This shall necessarily require structural stability, retention of form shape and resistance to leakage under hydraulic pressures of water/cement slurry/ concrete/mortar not less than 10 metre water head. The hydraulic pressures could either be externally applied or due to static pressure of poured concrete or mortar.

9.1.2.2 Materials:

The basic material for shuttering /formwork shall be MS sheet and MS structural sections, fasteners and the joint sealants

9.1.2.3 Design:

The shuttering/formwork shall be suitably designed to be able to resist the assessed hydraulic pressures likely to be exerted.

Minimum Configuration of the shuttering plates shall however be as under:

a. Steel plate shuttering materials using a minimum 3 mm thick MS sheets welded over a frame of MS Angle iron or T-iron of minimum size 40 X 40 X 5 mm thick with shorter span not exceeding 600 mm.

b. 10 mm dia MS nuts, bolts and washers at a spacing of 300 mm c/c for connecting and tightening joints with suitable resilient packing material to ensure retention of required shape and water tightness for the required pressure.

9.1.2.4 Testing:

The sample of shuttering shall be tested for retention of its shape and water tightness before proceeding with the work

9.1.2.5 Fabrication and Erection:

The CPWD specifications for formwork, propping, centering and shuttering shall generally apply to fabrication and erection.

9.1.2.6 Measurement:

Wherever, water tight shuttering specified and stipulated to be paid for separately, measurement shall be taken of the area of shuttering in contact with the finished concrete/ mortar surface. Dimensions of the formwork shall be measured correct to a centimeter and area worked out in square metres correct to second place of decimal.

9.1.2.7 Rates:

The rates shall cover cost of all materials, labour and T&P involved in all the operations described above including its removal after the work duration. The removed material shall remain the property of the contractor.

9.1.3 ENGINEERED STEEL TUBULAR DOUBLE SCAFFOLDING SYSTEM (Schedule Item No. 8.1.3)

PURPOSE: *To prov ide a scaffolding system with adjustable working platforms on the exterior of the building for the workmen to work upon any part of the area to be accessed safely and with ease for surface preparation, application of repairs and construction activity.*

9.1.3.1 Materials:

The standard proprietary tubular double scaffolding system of repute with all accessories, working platforms etc

9.1.3.2 Design:

It shall be designed for all the incidental dead, live and wind loads as per IS: 875 in steel tubular sections as per general design considerations governed by IS:800. The design of the scaffolding system shall cater to the safety features for the workmen.

9.1.3.3 Fabrication and Erection:

Fabrication and erection shall be done as per the design brief and installation instructions of the proprietary firm. It shall be maintained in functional condition for the work duration.

9.1.3.4 Measurements:

For the purpose of payments, length and height of double scaffolding on the exterior of building shall be measured correct to a centimeter and area worked out in square metres correct up to second place of decimal. For internal work, suitable fixed or mobile platform, self supporting scaffolding with working platforms shall be erected for which no payment shall be made.

9.1.3.5 Rates:

The rates shall cover cost of all materials, labour and T&P involved in all the operations described above including its removal after the work duration. The removed material shall remain the property of the contractor.

9.1.4 PLYWOOD COVERING PANELS TO COVER WINDOWS ETC. DURING REPAIRS (Schedule Item No. 8.1.4):

PURPOSE: *To protect the finished items against their spoiling/damage to finishes during the process of carrying out repairs in a building. The items could include finished windows, doors, glass curtain wall or other such items.*

9.1.4.1 Materials:

a) Wooden Battens of size 50mm X 50mm (approximately) or as approved by Engineer-in-charge, free from warping, cracks etc. made from locally available timber.

b) Plywood of suitable thickness, preferably 6 mm thick, as approved by Engineer-in-Charge.

c) Nails, screws etc. as per requirement.

9.1.4.2 Fabrication

a) Size of covering panels shall be more than the size of windows etc. to be shielded/ protected, enough to be fixed to the walls without damaging the windows etc.

b) Wooden battens shall be cut approximately to the size of panels of windows etc. to be protected. The joints of the wooden framework shall be lap joint or as approved by Engineer-in-Charge.

c) Where the panel size is more than 2 square metres or as specified by the Engineer-in-Charge, the stiffening shall be done with batten backing to impart stiffness enough to provide rigidity against undue deflection due to impact of falling debris, self load, etc.

d) Plywood shall be fixed with nails/screws over the batten frames. The spacing of nails/screws shall be about 300mm c/c or as may be required at site.

9.1.4.3 Fixing

The plywood covering panel shall be suitably fixed without damaging the windows etc. being protected by such panels with nails/screws fixed in walls strong enough to resist the forces likely to be imparted during repair work. It shall be done in such a manner that it can be removed with ease without damaging the covered windows etc. after completion of repairs.

9.1.4.4 Removal

After completion of work, the covering panels shall be removed carefully, so as not to cause any damage to windows etc. covered. The damages, if any, shall be made good.

9.1.4.5 Measurements

The measurements shall be done correct to a centimeter for the dimensions of window etc. shielded /protected and area shall be worked out in square metre correct to second place of decimal.

9.1.4.6 Rates

The rates shall cover cost of all materials, labour and T&P involved in all the operations described above including its removal after the work duration and making good the damage, if any, caused to windows etc. so protected. The removed material shall remain the property of the contractor.

9.1.5 TEMPORARY BARRICADING USING ANGLE IRON VERTICALS AND CGI SHEETS PANELS (Schedule Item No. 8.1.5):

PURPOSE: *To provide a barricading on ground to physically define the boundaries of the site of construction/repair activity for restricted entry of only those involved with the construction work.*

9.1.5.1 Materials:

Available Corrugated G.I. Sheet minimum 24 G thick, Framing structural material

(at least MS Angle iron of size 40x40x5mm or equivalent)

9.1.5.2 Fabrication & Erection:

a) Size of framing panel shall be decided depending upon site conditions and these could be approximately 2.0 metres long with height as 1.8 metre.

b) It shall be made up at least of two verticals, each with additional length of about 600 mm for fixing in to ground firmly and two horizontals equal to the length of panel.

c) It shall be made up by cutting the structural sections to size, shear punching holes in verticals and horizontals for nuts and bolts or making other suitable provision for receiving CGI sheet or other specified panelling material and connection of panel with adjoining panels.

d) Fabrication of frame of an individual panel shall be by welding at corners, welding MS plate at base of verticals or any other acceptable practice approved by Engineer-in-charge.

e) G. I sheet or other specified panelling material shall be suitably fixed. It shall preferably be done by means of nuts and bolts at its ends spaced at about 300 mm c/c transversely and at about 600 c/c longitudinally along corrugations. The corrugations of CGI sheet shall run along the shorter span of the panel.

f) In case of newly fabricated panels, these shall be painted with red oxide zinc chromate primer on steel work and approved primer on other material and at least one coat of paint of approved shade. In case of used panels, one coat of paint of approved shade shall be applied over the existing paint. The portion of verticals to be embedded in ground shall be suitably protected against rusting by painting it with bitumen or other suitable paint.

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g) The fabricated panels shall be suitably fixed vertically and firmly in to the ground to the satisfaction of Engineer-in charge by maintaining a uniform height of about 1.8 metres above GL and connecting each panel with the adjoining panels with nut and bolts or other suitable means.

h) Suitable provision of frame/posts in the openings provided in barricading shall be made for receiving door shutter (payable separately) at locations as approved by Engineer-in-Charge.

9.1.5.3 Measurements:

Length of barricading shall be measured in running metres correct to a centimeter. No deduction shall be done for such openings made in the barricading, where door frame or posts have been separately provided to receive door shutter.

9.1.5.4 Rates:

The rates shall cover cost of all materials, labour and T&P involved in all the operations described above including its removal after the work duration. The removed material shall remain the property of the contractor.

9.1.6 PROTECTIVE BARRICADING USING BALLIS OR WOODEN VERTICALS AND CGI SHEET PANELS (Schedule Item No. 8.1.6):

PURPOSE: *To provide a barricading on ground to physically define the boundaries* *of the site of construction/repair activity for restricted entry of only those involved with the construction work*

9.1.6.1 Materials:

Available Corrugated G.I. Sheet minimum 24 G thick, Framing structural material comprising of minimum 100 mm dia ballis, nails, Galvanised J-hooks and other related accessories

9.1.6.2 Fabrication& Erection:

Work shall be carried out according to Para 9.1.5.2

9.1.6.3 Measurements:

As per Para 9.1.5.3

9.1.6.4 Rates:

The rates shall cover cost of all materials, labour and T&P involved in all the operations described above including its removal after the work duration. The removed material shall remain the property of the contractor.

9.1.7 PROTECTIVE BARRICADING USING BAMBOO AND LOCALLY AVAILABLE PANELS (Schedule Item No. 8.1.7):

PURPOSE: *To provide a barricading on ground to physically define the boundaries of the site of construction/repair activity for restricted entry of only those involved with the construction work*

9.1.7.1 Materials:

Locally available bamboo panelling material or equivalent,

Framing structural material comprising of minimum 100 mm and 75 mm dia ballis/ bamboos, nails, Galvanised J-hooks and other related accessories and fixtures

9.1.7.2 Fabrication& Erection:

Work shall be carried out according to Para 9.1.5.2

9.1.7.3 Measurements:

As per Para 9.1.5.3

9.1.7.4 Rates:

The rates shall cover cost of all materials, labour and T&P involved in all the operations described above including its removal after the work duration. The removed material shall remain the property of the contractor.

9.1.8 TEMPORARY PROTECTIVE FABRIC SCREENS (Schedule Item No. 8.1.8):

PURPOSE : *To protect passersby from falling debris and also to protect the workmen and structure being repaired against direct exposure to sun.*

9.1.8.1 Materials

For screening purpose jute cloth, woven PVC cloth, geo-textile or wire-mesh as specified and approved by Engineer-in-Charge shall be used, which shall conform to their relevant

BIS Code. Screen materials shall be fixed by suitable means comprising of M.S.Flats/ J-bolts /nails/clamps, etc with washer or any other suitable means on frames of existing scaffolding etc.

9.1.8.2 Procedure

- Scaffolding, if required, comprising of verticals, horizontals and diagonal bracings of steel tubes shall be fixed over ground as per Para 9.1.3 which is payable separately.
- One end of the screening material, brought to site in looms/rolls, shall be properly fixed over top horizontal member with suitable means and suspended so as to cover the required area.
- The vertical fall of screen shall be suitably fixed/firmed up at intermediate levels so as to keep it in position during the work duration.
- Next strip of the screening material shall be fixed with its sides stitched or suitably jointed or lapped with the previous ones as approved by Engineer-in-charge.
- Spacing of frame member of scaffolding shall be so selected that the sagging of screen shall not hinder the repair process.
- The contractor shall maintain the protective screens in acceptable conditions for the entire work duration as required by the Engineer-in-Charge.

9.1.8.3 Measurement

Length and height of screen shall be measured correct to a centimeter and area shall be worked out in square metres, correct up to second place of decimal.

9.1.8.4 Rate

The rates shall cover cost of all materials, labour and T&P involved in all the operations described above including its removal after the work duration. The removed material shall remain the property of the contractor.

9.1.9 PROVIDING AND FIXING DOOR OF CORRUGATED OR STIFFENED PLAIN GI SHEET OVER FRAME OF LOCAL WOOD ETC. (Schedule Item No. 8.1.9):

PURPOSE: *To provide door shutter to temporary covered shelters, stores, yard, openings of temporary barricading etc.*

9.1.9.1 Material

a) Door frame shall be local acceptable wood or structural steel of section & size as approved by Engineer-in-charge and shall be free from warp, bend and shall have smooth surface.

b) Corrugated GI sheet conforming to IS-277 with thickness not less than 24 gauge or plain GI sheet stiffened by cold pressing

c) Hinges, aldrops, nails/screws etc.

9.1.9.2 Fabrication:

a) Wooden/structural steel frame shall be made of at least three horizontal members as bottom, middle and top rail and two vertical members as styles suitably jointed with diagonal members, if necessary.

b) Corrugated GI sheet or plain GI sheet shall be aligned such that its corrugation are vertical and fixed suitably with the help of nails /screws, nuts, bolts, washers, etc and fixed to door opening.

c) One coat of red oxide zinc chromate primer and one coat of paint shall be applied over GI sheet/steelwork and approved wooden primer and paint shall be applied over woodwork.

9.1.9.3 Fixing:

a) Door shutter shall be fixed to the existing frame with the help of approved hinges and screws of size, numbers and shape suitable for the size of door.

b) Approved aldrop shall be fixed to door shutters to make safe locking arrangements

c) If required by Engineer-in-Charge additional aldrops/tower bolts /other suitable device shall be fixed to the door shutters for ensuring safety.

d) If the GI sheet and /or horizontal rails are already painted, these shall be provided at least one finishing coat of paint to give it a uniform shade. On new work, one coat of primer and paint shall be applied.

9.1.9.4 Measurements

Finished dimensions of door shutter shall be measured correct to a centimeter and area worked out in square metres correct to second place of decimal.

9.1.9.5 Rate

The rates shall cover cost of all materials, labour and T&P involved in all the operations described above including its removal after the work duration. The removed material shall remain the property of the contractor.

9.1.10 PROVIDING AND ERECTING COVERED SHELTERS (Schedule Item No. 8.1.10):

PURPOSE: *Erection of temporary shelters for storage of materials, T&P, etc incidental to carrying out the structural repairs, which require their protection during storage against extreme weather conditions.*

9.1.10.1 Materials

- Corrugated GI Sheets or wooden panels/boards
- Steel /timber/bamboo frame work as may be specified and approved by
- Engineer-in-Charge.
- Bricks
- Ordinary Portland Cement, Sand, any other construction material as may be required for construction of temporary shelters as per approved design.
- Necessary electrical connection, wiring & fittings essential for lighting, ventilation. Arrangements for cooling, heating etc to maintain humidity and temperature as per special material storage requirements.

9.1.10.2 Procedure:-

- The location, size and specifications of temporary covered shelters shall be got approved from the Engineer-in-Charge with justification of their use for storage of manufactured repair chemicals during carrying out of repairs. These shall be constructed to serve the purpose intended and in accordance with Para 9.0.2.

- The shelters shall be made according to the approved plan, size, plinth level and a desirable average ceiling height of 3.3 metres or as may be approved by Engineer-in charge and with approved materials.
- Floor shall be pucca and kept sufficiently high to protect materials against weather, inundation etc.
- Necessary door, window and ventilator openings with frames to receive door shutters shall be kept in the side walls.
- If necessary, the required grills, window and ventilator shutters, with necessary fittings shall also be provided for ensuring the safety of stored materials.
- The electrical connection, wiring, fittings, etc as may be required and approved by the Engineer-in-charge for lighting, ventilation, temperature and humidity control shall be provided and fixed therein.
- At least one coat of approved primer and paint shall be applied on the inside and outside to give it a finishing touch and redoing it periodically, if necessary, to keep it in neat and tidy condition for the work duration

9.1.10.3 Measurements:

The overall plan dimensions of the covered shelters shall be measured correct to a centimeter and the area of the covered shelters shall be worked out in square metres correct to second place of decimal.

9.1.10.4 Rates:

The rates shall cover cost of all materials, labour and T&P involved in all the operations described above including its removal after the work duration. The removed material shall remain the property of the contractor.

9.2 SURFACE PREPARATION

9.2.1 REMOVAL OF PLASTER MANUALLY FROM MASONRY OR CONCRETE SURFACE USING CHISEL AND HAMMER AND DISPOSAL OF DEBRIS ETC. (Schedule Item No. 8.2.1):

PURPOSE: *For removal of all type of loose /delaminated /damaged/weak cement plaster from surface of masonry or concrete.*

9.2.1.1 Procedure

Step-1 **Safety shall be ensured in accordance with Para 9.0.5**

Step-2 **Provide double scaffolding,** if necessary for heights above 3.0 metres Refer Para 9.1.3) .

Step-3 **Provide protective screens,** if necessary (Refer Para No 9.1.8).

Step-4 **Existing plaster to be to be identified for removal** by tapping all areas and its boundary shall be marked with a colour marking (Refer Fig 6.1a), which shall be approved by Engineer-in-Charge.

Step-5 **Make a cut normal to the surface** all along the boundaries with power driven cutters. The depth of cut shall not exceed the thickness of plaster.

Step-6 **Remove the plaster manually** with the help of chisel and hammers to completely expose the parent masonry or concrete surface, so as not to have any traces of such plaster left behind.

9.2.1.2 Measurement

The dimensions of removed plaster patch shall be measured correct to a centimeter and area shall be worked out in square metres correct to second place of decimal. The lead of disposal shall be measured in metres and rounded off to nearest multiple of 50 metres.

9.2.1.3 Rate

The rates shall cover cost of all materials, labour and T&P involved in all the operations described above except those involved in steps 2 and 3.

9.2.2 CHIPPING OF UNSOUND/WEAK CONCRETE MATERIAL (Schedule Item No. 8.2.2):

PURPOSE: *To remove weak, loose or carbonated concrete over an area from its surface with pneumatically operated or power driven tools by chiselling, chipping etc.*

9.2.2.1 Materials and T&P:

Power or pneumatically driven chisel, chipping tools complete with accessories, hand-tools like chisels, hammer, pH indicator (0.2% phenolphthalein solution) with pH range at least up to 10.5, clinical injection syringe.

9.2.2.2 Safety: Safety shall be ensured in accordance with Para 9.0.5

9.2.2.3 Procedure:

Step-1 **Prop and support** (Refer Para 9.1.1) to relieve the structural member of stress and strains.

Step-2 **Scaffolding** (Refer Para no 9.1.3), if necessary for the exterior members, shall be done for working upon the area.

Step-3 **Working Platforms** for interior members, if necessary, shall be erected suitably or provided as mobile.

Step-4 **Provide Protective Screen, if necessary** (Refer Para 9.1.8).

Step-5 **Mark off the area** to be repaired using straight lines between corners. The marked area shall have 90^{o} corners with the sides parallel or normal to the direction of the reinforcement. The marked boundaries for the repair area should be a minimum of 50 mm outside the perimeter of the spall. For a single spall, the repair area should have a minimum width of 100mm in any direction. If a number of spalls are closely located to each other, these spalls should be included in a single area marked for repair (Refer Fig 6.1a).

Step-6 **Cut shall be made along the marked boundary,** normal-to-the surface. It should be made with a diamond cutter blade. However, when diamond cutting is not practical, the normal cut can be made with a power driven chisel. Minimum depth of cut shall be 10 mm. In situations where the diamond saw could cut into the reinforcing steel due to inadequate concrete cover, the boundary edge should be formed manually by means of chisel and impact hammers. A cover meter could be used to estimate the depth of cover.

Step-7 **Chipping to remove all the unsound and weak concrete** material shall be done carefully from the damaged portions of structural members by adopting mechanical or manual means up to the required depth to produce sound concrete surface to a near uniform depth for the repair area.

Tolerance: The chipping tolerances shall be ± 5mm

9

Chiselling Hand Tools are typically applicable for concrete removal for smaller, moderate and areas of limited access. Removal should begin at the interior of the repair area and progress toward the boundaries, using suitable hammer.

Power Driven Chisels/Hammers are normally applicable for chiselling smaller thicknesses up to about 50 mm.

Pneumatic Hammers are normally applicable for chiselling larger thicknesses in excess of 50 mm

Mechanical Milling (single drum, rotary cutter head with Tungsten–carbide bits) is applicable for large areas where the concrete cover is to be removed. Care must be taken to avoid contact with the reinforcing steel as both the reinforcement and the cutter drum could be damaged.

Rounded And Feathered Edges should be hand cut to form normal-to-the-surface boundaries. All the edges and cavities shall be square shouldered.

Step-8 **Test for carbonation** shall be carried out at embedded or exposed reinforcement locations, by spraying phenolphthalein indicator on concrete in contact and in the immediate vicinity of reinforcement ***soon after its chipping.*** As otherwise, chipped concrete surface in contact with air is likely to get carbonated soon after its coming in contact with atmospheric carbon dioxide.

Step-9 **A full-depth chiselling and removal of concrete** all round reinforcement shall be carried out, in case the concrete in contact and in immediate vicinity of the reinforcement is carbonated (Refer Para no 9.2.6).

Step-10 **Inspection and soundness testing,** after concrete removal & cleaning, for weaknesses and delamination of exposed surfaces shall be visually carried out. If required, additional removal will be done.

Step-11 **Cleaning of debris and dust** shall be carried out from within the chiselled/ chipped area and its disposal as per direction of the Engineer-in-Charge.

9.2.2.4 Measurements:

The dimensions of the area chipped off for RCC slabs, beams and columns shall be measured separately. The average thickness shall be determined by taking an average of five thickness readings recorded with one reading each at corner and at the point of intersection of wires stretched diagonally from corner points of the rectangular area chipped. The extra/less thickness than specified for slabs, beams and columns shall be recorded in millimeters. Corresponding areas of slab, beam and columns shall be separately worked out in square meters correct to second place of decimal. The lead of disposal shall be measured in metres and rounded off to nearest 50 metres.

9.2.2.5 Rates:

The rates shall cover cost of all materials, labour and T&P involved in all the operations described above except those involved in steps 1, 2, 4, 8 and 9.

9.2.3 DISMANTLING & REMOVING EXISTING TREATMENT OVER RCC SLABS AT ALL HEIGHTS (Schedule Item No. 8.2.3):

PURPOSE: *Removal of any type of existing surface treatment e.g roofing, water proofing treatment, flooring, etc over RCC slabs at all heights*

9.2.3.1 Materials and T&P:

Power or pneumatically driven chiselling, chipping tools complete with accessories, hand-tools like chisels, hammer.

9.2.3.2 Procedure:

Step-1 **Carefully remove** the identified portion of the existing surface treatment over the RCC slab with required chipping, chiselling tools without causing excessive vibrations or damaging the structure. Para 9.2.2.3 generally applies.

Step-2 **Stack the serviceable material** for reuse as directed by the Engineer-in-charge.

Step-3 **Dispose off the balance material** as per the direction of Engineer-in-charge.

9.2.3.4 Measurements:

The surface area of RCC slab exposed shall be measured correct to a centimeter and area worked out in square metres correct to second place of decimal. The lead of disposal shall be measured in metres and rounded off to nearest multiple of 50 metres.

9.2.3.5 Rates:

Rates cover all labour, materials and T&P involved in the operations involved as above.

9.2.4 DISMANTLING EXISTING RCC WORK BUT EXCLUDING CUTTING REINFORCEMENT BARS (Schedule Item No 8.2.4):

PURPOSE: *Dismantling of RCC structural members using hand tools as may be required for rehabilitation/repair.*

9.2.4.1 Materials and T&P:

Concrete breaking hand tools like Chisels, Hammers and related tools complete with incidental accessories.

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9.2.4.2 Safety: Safety shall be ensured in accordance with Para 9.0.5

9.2.4.3 Procedure:

Step-1 **Identify the RCC portion** to be dismantled as approved by Engineer-in-charge.

Step-2 **Prop and support** (Refer Para 9.1.1)**,** if not done already, to relieve the structural member of stress and strains.

Step-3 **Scaffolding & working platforms** for the exterior members (Refer Para 9.1.3), if not already done and if necessary, shall be erected for working upon the area.

Step-4 **Working Platforms** for interior members, if not already done and if necessary, shall be erected suitably or provided as mobile.

Step-5 **Provide Protective Screens** (Refer Para 9.1.8), if not already done and if necessary.

Step-6 **Carefully remove only the RCC** i.e. concrete portion with the hand tools/ mechanically without causing excessive vibrations or damaging the structure.

Do not cut the embedded reinforcement, if any, but shall be cleaned of concrete. However, the loose reinforcement shall be recovered for use.

Step-7 **Dismantling to remove all the unsound and weak concrete** material shall be done carefully from the damaged portions of structural members by adopting mechanical or manual means up to the required depth to produce sound concrete surface to a near uniform depth for the repair area.

Chiselling Hand Tools are typically applicable for concrete removal for smaller, moderate and areas of limited access. Removal should begin at the interior of the repair area and progress toward the boundaries, using suitable hammer.

Power Driven Chisels/Hammers are normally applicable for chiselling smaller thicknesses up to about 50 mm.

Pneumatic Hammers are normally applicable for chiselling larger thicknesses in excess of 50 mm

Step-8 **Stack the reinforcement, if recovered** for reuse in step-6 and balance material disposed off as per the direction of Engineer-in-charge.

9.2.4.4 Measurements:

Pre-measurements of the dimensions of RCC to be dismantled shall be recorded before taking up the dismantling operations and shall be measured correct to a centimeter and volume worked out in cubic metres correct to second place of decimal. The lead of disposal shall be measured in metres and rounded off to nearest multiple of 50 metres.

9.2.4.5 Rates:

Rates cover all labour, materials, T&P involved in the operations involved as above except those involved in steps 2, 3 and 5.

9.2.5 CUTTING REINFORCING BARS IN RCC OR REINFORCED BRICKWORK (Schedule Item No. 8.2.5):

PURPOSE: *To cut visible portion of embedded reinforcing bars in RCC or Reinforced Brickwork using hand tools.*

9.2.5.1 Materials and T&P:

Reinforcing cutting/shearing hand tools like hacksaw, chisels, hammer and related tools complete with incidental accessories.

9.2.5.2 Safety: Safety shall be ensured in accordance with Para 9.0.5

9.2.5.3 Procedure:

Step-1 **Identify the visible reinforcing bars** required to be cut, which shall be approved by Engineer-in-charge.

Step-2 **Carefully cut/shear** the reinforcing bars with the hand tools without causing excessive vibrations or damaging the structure.

Step-3 **Stack the reinforcement recovered** for reuse as per the direction of Engineer-in-charge

9.2.5.4 Measurements:

Pre-measurements of the number of reinforcing bars to be cut shall be recorded in three categories of diameters e.g. upto 12 mm, above 12 mm and not exceeding 20 mm and those exceeding 20 mm.

9.2.5.5 Rates:

Rates cover all labour, materials, T&P involved in the operations involved as above and stacking the reusable material within a lead of 50 metres.

9.2.6 REMOVING CONCRETE ALL AROUND REINFORCEMENT INCLUDING FROM ITS BEHIND (Schedule Item No. 2.6):

PURPOSE: *To create an average clear air gap equal to nominal size of coarse aggregate plus 5 mm all around embedded reinforcement, in contact with carbonated concrete for rust removal & passivating its surface with fresh alkaline passivating coat and concrete/ mortar.*

9.2.6.1 Materials and T&P:

Power or pneumatically driven chiselling, abrading, chipping tools complete with accessories, hand-tools like chisels, hammer, pH indicator i.e. 0.2% solution of phenolphthalein indicator for pH range preferably up to 11.5 or at least up to 10.5, clinical injection syringe.

9.2.6.2 Safety:

Safety shall be ensured in accordance with Para 9.0.5.

9.2.6.3 Procedure:

Step-1 **Prop and support** (Refer Para 9.1.1)**,** if not done already, to relieve the structural member of stress and strains.

Step-2 **Scaffolding & working platforms** for the exterior members (Refer Para 9.1.3), if not already done and if necessary, shall be erected for working upon the area.

Step-3 **Working Platforms** for interior members, if not already done and if necessary, shall be erected suitably or provided as mobile.

Step-4 **Provide Protective Screen** (Refer Para 9.1.8), if not already done and if necessary.

Step-5 **Test for carbonation** shall be carried out at embedded or exposed reinforcement locations, by spraying phenolphthalein indicator on *freshly chipped* concrete in contact and in the immediate vicinity of reinforcement.

Step-6 **A full-depth chiselling and removal of concrete** all round reinforcement shall be carried out, if the concrete in contact and in immediate vicinity of the reinforcement is carbonated.

The concrete around reinforcement shall be removed so as to have a near uniform air gap of about 5 mm plus the nominal size of coarse aggregate to be used in repair concrete/mortar. However, the air gap shall not be less than 15 mm in any case.

Power/pneumatic driven tools/chisels shall be used for such portions of carbonated concrete around reinforcement, which could not be removed manually, to achieve a near uniform required air gap all around including behind the reinforcement.

Power Driven Chisels/Hammers are normally applicable for chiselling smaller depths up to about 50 mm.

Pneumatic Hammers are normally applicable for chiselling larger depth in excess of 50 mm

Step-7 **Cleaning of debris and dust** shall be carried out from within the chiselled /chipped area and its disposal as per direction of the Engineer-in-Charge.

9.2.6.4 Measurements:

The reinforcing bars cleaned of concrete shall be grouped in two diawise categories, i.e. upto and including 12 mm and the other in excess of 12 mm. For each of such categories of bars, length cleaned of concrete all around, shall be separately measured for cleaning manually and using standard power/pneumatically driven abrading/chiselling tools. The length shall be measured in metres correct up to second place of decimal.

9.2.6.5 Rates:

The rates shall cover cost of all materials, labour and T&P involved in all the operations described above except those involved in steps 1, 2 and 4.

9.2.7 CLEANING REINFORCEMENT OF TOTAL RUST INCLUDING FROM BEHIND REINFORCEMENT (Schedule Item No. 8.2.7):

9.2.7.1 Materials and T&P:

Chiselling, abrading, chipping, hammering, wire brushes, paint brush, abrading cloth, etc hand tools complete with accessories, tested and approved alkaline chemical rust remover.

9.2.7.2 Testing:

Chemical rust remover shall be tested to ensure that it is an alkaline material with its pH more than 11.5 and for its efficacy by a sample of rust removal.

Sand to be used for sand blasting shall conform to Zone-I or II of IS:383

9.2.7.3 Safety:

Safety shall be ensured in accordance with Para 9.0.5

9.2.7.4 Procedure:

Step-1 **Remove the rust manually** from all round the surface along the length of reinforcement, using hand tools like chisels, hammers, wire brushes, abrading cloth/paper, etc. This shall be continued manually along the length of the rusted reinforcement till such time that the steel surface is cleared of all rust that could be removed manually.

Step-2 **Remove the Rust by sand blasting and/or using tested chemicals,** if directed by Engineer-in-Charge, due to unsatisfactory results of manual rust removal.

A. By sand blasting:

Coarse sand shall be sprayed under pressure over the exposed reinforcement so as to cause an intense abrading of the reinforcement surface and removal of rust from its entire surface to achieve shining bright metal.

B. **Using tested chemicals:**
Chemical rust remover shall be brush applied over the reinforcement surface thoroughly all around the circumference and along the full length of rusted reinforcement. After 24 hours of its application, the surface shall be cleaned with wire brush and all loose particles removed. It shall be washed with water thoroughly and allowed to dry.

9.2.7.5 Measurements:

The reinforcing bars cleaned of concrete shall be grouped in two diawise categories, i.e. upto and including 12 mm and above of 12 mm. For each of such categories of bars, length cleaned of rust all around, shall be separately measured for cleaning manually, using sand blasting and using alkaline chemical rust remover. The length shall be measured in metres correct up to second place of decimal

9.2.7.6 Rates:

The rates shall cover cost of all materials, labour and T&P involved in all the operations described above.

9.2.8 INTRODUCING NEW REINFORCEMENT BARS FOR STRUCTURAL CONNECTION IN RCC STRUCTURAL MEMBER (Schedule Item No. 8.2.8):

PURPOSE: *For introducing additional reinforcing bars for new structural connection or supplementing additional steel area to existing RCC beams, lintels, columns for cantilevers, chajjas, etc or alike.*

9

9.2.8.1 Material and T&P:

1. Epoxy cartridges and specified steel reinforcement.
2. Standard Power driven drilling/hammering equipment
3. Hand operated blow out pump, brushes, epoxy dispenser, epoxy cartridge holder, disposable PVC mixing nozzle for epoxy, and any other incidental accessories and T&P items.

9.2.8.2 Testing:

The epoxy in the cartridges shall be subjected to testing for its conformity to the manufacturer's specifications.
The power drilling/hammering equipment, drill bits, etc shall be tested for their effective functioning.

9.2.8.3 Procedure

Step 1 **Design** additional cross-sectional area required and get them approved from the Engineer-in-Charge.

Step-2 **Cross sectional area of steel reinforcement** provided for new structural connection or for supplementing the existing cross-sectional area shall be as per approved design/drawings.

Step 3 **Provide the depth of embedment of the reinforcing bar** in concrete as specified in the approved design/drawings. Based on assessed strength of concrete, Tables 9.8 to 9.10 could be used as a guide for assessment of the depth of embedment of steel reinforcing bar. The strength of concrete shall be determined quantitatively by core test or capo test for ensuring reliability, which shall be paid for separately.

Step 4 **Prepare the surface** of the existing RCC member to receive the structural connection as per Para 9.2 and its sub paras.

Step 5 **Mark the new reinforcing bar locations** on prepared surface for fixing.

Step 6 **Drill holes of specified diameter and depth** in concrete at locations marked as per approved design calculations. Tables 9.8 to 9.10 are rough guide corresponding to the grade of existing concrete and diameter of the steel reinforcement.

Step 7 **Clean the drilled hole** in dry state with round brushes and by blowing air through a tube inserted in the hole and connected to hand operated blow out pump (Fig. 9.1).

Step 8 **Inject epoxy from the foil pack** with the help of epoxy dispenser, epoxy cartridge holder and disposable PVC mixing nozzle inserted inside the drilled hole to fill it from bottom of the hole and upwards. The approximate consumption of the epoxy in cubic cm. is given in Table 9.11 as a general guide.

Step 9 **Insert the reinforcing bar** and allow the epoxy adhesive to cure.

9.2.8.4 Measurements:

9

Number of reinforcing bars introduced/inserted shall be measured in three separate groups for bars upto and including 12 mm dia, more than 12 mm but not exceeding 20 mm dia and all bars with dia more than 20 mm.

9.2.8.5 Rates:

The rates shall cover cost of all materials, labour and T&P involved in all the operations

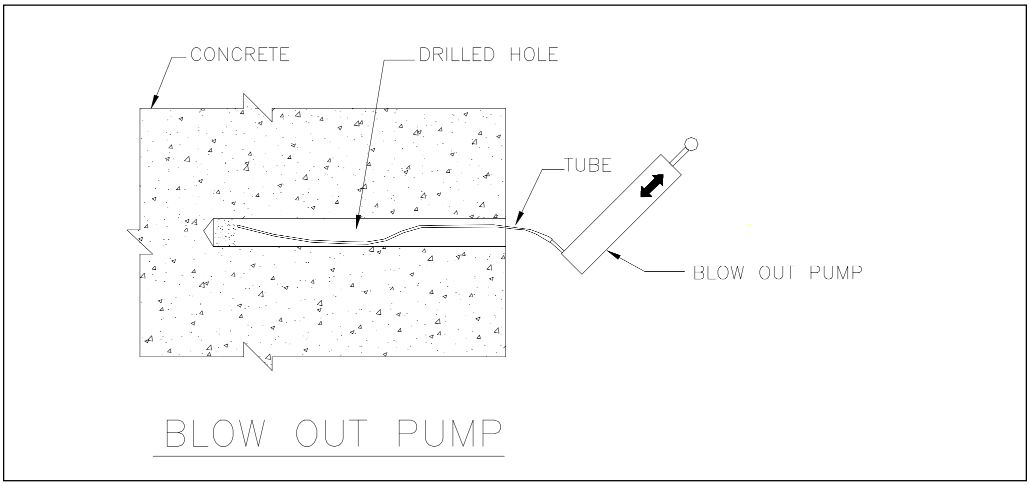

Fig 9.1: Hand Operated Blowout Pump

Table 9.8

Concrete Grade M 20; Yield Strength of Steel 415 N/mm^2

(Source: Literature of Hilti India Ltd.)

Rebar Dia	**Hole Dia**	**Depth of Hole**	**Recommended Tensile Load of Rebar Frec (Kn)**																
(in mm)	(in mm)		100	120	140	160	180	200	220	240	270	300	330	370	400	450	500	600	850
8	12		9.73	11.6	12.09	12.09	12.09	12.09	12.09	12.09	12.09	12.09	12.09	12.09	12.09	12.09	12.09	12.09	12.09
10	14		10.51	12.62	14.72	16.82	18.90	18.90	18.90	18.90	18.90	18.90	18.90	18.90	18.90	18.90	18.90	18.90	18.90
12	16			13.49	15.74	17.98	20.23	22.48	24.73	26.98	27.21	27.21	27.21	27.21	27.21	27.21	27.21	27.21	27.21
14	18				16.69	19.07	21.46	23.84	26.23	28.61	32.19	35.76	37.09	37.03	37.03	37.03	37.03	37.03	37.03
16	22					21.09	23.72	26.36	29.00	31.63	35.59	39.54	43.49	48.37	48.37	48.37	48.37	48.37	48.37
20	28							29.74	32.71	35.68	40.15	44.61	49.07	55.01	59.47	66.91	74.34	75.58	75.58
25	32										42.92	47.69	52.45	58.81	63.58	71.53	79.48	95.37	118.09

Partial Safety Factor for Steel = 1.15, for Variable actions = 1.5

Table 9.9

Concrete Grade M25; Yield Strength of Steel 415 N/mm^2

(Source: Literature of Hilti India Ltd.)

Rebar Dia	Hole Dia	Depth of Hole	Recommended Tensile Load of Rebar Frec (Kn)																
(in mm)	(in mm)		100	120	140	160	180	200	220	240	270	300	330	370	400	450	500	600	850
8	12		9.87	11.85	12.09	12.09	12.09	12.09	12.09	12.09	12.09	12.09	12.09	12.09	12.09	12.09	12.09	12.09	12.09
10	14		11.04	13.25	15.45	17.66	18.90	18.90	13.90	18.90	18.90	18.90	18.90	18.90	18.90	18.90	18.90	18.90	18.90
12	16			14.51	16.93	19.35	21.77	24.18	26.60	27.21	27.21	27.21	27.21	27.21	27.21	27.21	27.21	27.21	27.21
14	18				18.29	20.90	23.51	26.12	28.73	31.35	35.26	37.03	37.03	37.03	37.03	37.03	37.03	37.03	37.03
16	22					22.34	25.13	27.93	30.72	33.51	37.70	41.89	46.08	48.37	48.37	48.37	48.37	48.37	48.37
20	28							31.22	34.34	37.47	42.15	46.83	51.52	57.76	62.44	70.25	75.58	75.58	75.58
25	32										47.12	52.36	57.60	64.58	69.81	78.54	87.27	104.72	118.09

Partial Safety Factor for Steel = 1.15 for Variable actions = 1.5
Values for the above table remain same for all subsequent higher grade of concrete.

Table 9.10

Concrete Grade M30; Yield Strength of Steel 415 N/mm^2

(Source: Literature of Hilti India Ltd.)

Rebar Dia	Hole Dia	Depth of Hole	Recommended Tensile Load of Rebar Frec (Kn)																
(in mm)	(in mm)		100	120	140	160	180	200	220	240	270	300	330	370	400	450	500	600	850
8	12		9.87	11.85	12.09	12.09	12.09	12.09	12.09	12.09	12.09	12.09	12.09	12.09	12.09	12.09	12.09	12.09	12.09
10	14		11.04	13.25	15.45	17.66	18.90	18.90	18.90	18.90	18.90	18.90	18.90	18.90	18.90	18.90	18.90	18.90	18.90
12	16			14.51	16.93	19.35	21.77	24.18	26.60	27.21	27.21	27.21	27.21	27.21	27.21	27.21	27.21	27.21	27.21
14	18				18.29	20.90	23.51	26.12	28.73	31.35	35.26	37.03	37.03	37.03	37.03	37.03	37.03	37.03	37.03
16	22					22.34	25.13	27.93	30.72	33.51	37.70	41.89	46.08	48.37	48.37	48.37	48.37	48.37	48.37
20	28							31.22	34.34	37.47	42.15	46.83	51.52	57.76	62.44	70.25	75.58	75.58	75.58
25	32										47.12	52.36	57.60	64.58	69.81	78.54	87.27	104.72	118.09

Partial Safety Factor for Steel = 1.15 for variable actions -= 1.5

Table 9.11

Epoxy Requirement for Rebar Embedment

Rebar Dia	Hole Dia	Depth of Hole						REBAR APPLICATION Consumption in cm^3 (ml)										
(in mm)	(in mm)	100	120	140	160	180	200	220	240	270	300	330	370	400	450	500	600	850
8	12	9	10	12	14	16	17	19	21	23	26	29	32	36	39	43	52	74
10	14	10	12	14	16	18	20	22	24	27	30	33	37	40	45	51	61	86
12	16	12	14	16	18	21	23	25	28	31	35	38	43	46	52	58	69	98
14	18	13	16	18	21	23	26	29	31	35	39	43	48	52	58	65	78	110
16	22	24	29	33	38	43	48	52	57	64	71	79	88	95	107	119	143	203
20	28	40	49	57	65	73	81	89	97	109	121	133	150	162	182	202	243	344
25	32	40	49	57	65	73	81	89	97	109	121	133	150	162	182	202	243	344

described above.

9.2.9 SPECIFICATION FOR PROVIDING AND INSERTING SHEAR KEY BARS (Schedule Item No. 8.2.9):

PURPOSE: *Shear key bars are used for providing a structural connection of the applied repair material with the substrate/parent surface for transfer of forces occurring at the interface.*

9.2.9.1 Materials and T&P:

1. Epoxy cartridges and specified lengths and diameter of steel reinforcement.
2. Standard Power driven drilling/hammering equipment

Hand operated blow out pump, brushes, epoxy dispenser, epoxy cartridge holder, disposable PVC mixing nozzle for epoxy, and any other incidental accessories and T&P items.

9.2.9.2 Procedure

Step 1: **Mark the locations of shear keys and get the same approved** for structural connection from the Engineer-in-charge.

Step 2: **Drill holes to specified depth and diameter in concrete** at marked locations for the specified dia of shear key bars.

Step 3: **The drilled hole in dry state shall be cleaned** with round brushes and by blowing air through a tube inserted in the hole and connected to hand operated blow out pump (Fig. 9.1).

Step 4: **Inject epoxy from the foil pack** with the help of epoxy dispenser, epoxy cartridge holder and disposable PVC mixing nozzle inserted inside the drilled hole to fill it from bottom of the hole and upwards. The approximate consumption of the epoxy in cubic cm. is given in Table 9.11 as a general guide.

Step 5: Insert the reinforcing bar and allow the epoxy adhesive to cure.

9.2.9.3 Measurements:

Measurements shall be done in number of specified bars introduced in two separate groups for shear key bars of 12 mm dia and 16mm dia bars.

9.2.9.4 Rates:

The rates shall cover cost of all materials, labour and T&P involved in all the operations described above.

9.2.10 SPECIFICATION FOR CLEANING EXPOSED CONCRETE SURFACE OF LOOSE AND FOREIGN MATERIALS BY MEANS OF SAND BLASTING (Schedule Item No. 8.2.10):

PURPOSE: *To clean the prepared concrete surface of all-loose, lightly sticking materials, including the foreign materials, loose concrete, aggregates etc so as to provide a good bond with the applied repair material.*

9.2.10.1 Materials and T&P:

Coarse sand conforming to Zone I or II as per IS: 383, Air compressor of a minimum 35 Kilowatt capacity, spray gun for sand, all related accessories for sand blasting, hand tools like wire brushes, chisels, etc

9.2.10.2 Testing of Materials and T&P:

The sand shall be tested to conform to the specification.

The air compressor shall be tested to perform to the required standards as laid down in Para 9.5.2.1.2 subsequently.

9.2.10.3 Safety:

Safety shall be ensured in accordance with Para 9.0.5.

9.2.10.4 Procedure:

Step-1: **Specified tested coarse sand shall be collected at site** in required quantity for sand blasting.

Step-2: **Make available mechanical power driven air compressor** in working condition at site with all required accessories for carrying out sand blasting as well as air blasting operations.

Step-3: **Clean the final chipped off concrete** surface and exposed reinforcement, if any, of all loose and foreign materials to be subsequently followed with oil free air blast.

9.2.10.5 Measurements:

Length and breadth of the area cleaned by sand blasting shall be recorded correct to a centimeter and area worked out in square metres correct to second place of decimal.

9.2.10.6 Rates:

The rates shall cover cost of all materials, labour and T&P involved in all the operations described above.

9.2.11 PROVIDING AND FIXING ANCHOR FASTNER SYSTEM MECHANICAL/ EPOXY BASED (Schedule Item No. 8.2.11):

PURPOSE: *To provide an anchor fastner to be able to resist a known pull out force. The anchor fastner system shall be standard system with minimum guaranteed load carrying capacities for a given substrate.*

9.2.11.1 Materials and T&P:

As per the proprietary firm and as specified.

9.2.11.2 Testing:

The designated capacity of the mechanical/epoxy based anchor fastener shall be tested by appropriate pull out strength measurement device.

9.2.11.3 Procedure:

As per the proprietary firm and as specified.

9.2.11.4 Measurement:

Measurements shall be done in number of fastners complete for each category, diameter wise of the anchor fastner system separately for mechanical and epoxy based system.

9.2.11.5 Rates:

The rates shall cover cost of all materials, labour and T&P involved in all the operations described above.

9.3 CRACK/HONEYCOMB AREA REPAIR

9.3.1 SPECIFICATION FOR PROVIDING DRILLING AND INSERTING NIPPLES ALONG CRACK LINES (Schedule Item No. 8.3.1):

PURPOSE: *To fix injection nipples and seal the remaining portion of honey combed or cracked concrete /masonry for grout injection.*

9.3.1.1 Materials and T&P:

12 mm diameter approved aluminium /Galvanised Iron nipples, Chisel, hammer, power driven tool for chase cutting & drilling, hand operated blow out pump, sealing putty of polyester/epoxy/polymer modified mortar etc. and all related accessories and materials.

9.3.1.2 Testing:

The sealing putty and the nipples shall be tested to conform to the manufacturers specifications.

The power driven tools shall be test driven and their drill/cutting bits shall be tested for effectiveness before taking up the repair operation.

9.3.1.3 Procedure:

Step-1: **Follow the guidelines** for Safety, Quality Assurance, Environmental Protection, Personnel, Supervision, Product delivery, Storage and Handling etc given in Para 9.0.

Step-2: **Identify the Cracks and mark the area** for injection grouting.

Step-3: **Prop & support** the structural member, if required, to relieve it of stress and strains (Refer Para 9.1.1)

Step-4: **Open up cracked surface** by making ‘V’ notch or groove of size 12 mm x 12mm.

Step-5: Remove plaster, if required, to identify and mark the honey combed area (Refer 9.2.1).

Step-6: **Drill holes** at least 25 mm diameter and 40mm deep

- along crack lines at spacing of 300 mm or thickness of the structural member, whichever is less.
- In honey combed area @ 9 nos per sqm. as directed by Engineer-in-Charge and upto 30 mm to 40 mm depth.

Step-7: **Remove coarse debris and dust** in opened up cracks and drilled holes by blowing oil free compressed air, if available with air compressor, otherwise with hand operated blow out pump. Concrete surfaces required to be grouted shall be free from all loose and unsound materials by means of mechanical abrasion using stiff wire brushes, after removing all loose areas with chissel

and hammer. Area shall be made free from any deleterious materials, such as oil dust dirt etc. by means of oil free jet of compressed air.
All prepared concrete surfaces shall be thoroughly inspected and got approved by the contractor.

Step-8: **Insert 12mm dia specified injection nipples** in holes drilled along crack lines and fix them by sealing only its sides with epoxy or polymer modified mortar.

Step-9: **Seal the crack or the honey combed surface** between the nipples by means of epoxy mortar after applying epoxy primer or polymer modified mortar as may be approved by Engineer-in charge. The epoxy/polymer used shall be of approved grade and applied as per specifications mentioned separately elsewhere. The epoxy mortar shall be air cured for 24 hours, whereas the polymer-modified mortar shall be moist cured for 1-3 days and allowed to gain strength before actual grouting commences.

9.3.1.4 Measurements:

For payment purposes, number of nipples fixed shall be separately measured for concrete and masonry work.

9.3.1.5 Rates:

The rates shall cover cost of all materials, labour and T&P involved in all the operations described above except those involved in above mentioned steps 3 and 5.

9.3.2 SEALING OF CRACKS BY INJECTION OF APPROVED GROUT (Schedule Item No. No. 8.3.2):

PURPOSE: *To inject the specified grout into honeycombed or cracked concrete/ masonry*

9.3.2.1 Materials and T&P:

a. Specified grout

i. Cementitious Grout shall have following components:

Cement: The cement used shall be ordinary Portland cement of the specified grade and conforming the relevant BIS code of Practice.

Sand: The sand shall be sharp washed well graded generally falling in Zone IV of IS 383

Water: Water used for grout shall conform to the requirements of IS 456.

Admixture: If required, admixture shall be used only after the approval of Engineer-in-Charge, who shall be furnished with all the required literature pertaining to its efficacy. The mixture shall meet the requirement of IS 456 and IS 9103. Payment for admixture shall be made separately.

Polymer: It shall be as specified and shall conform to ASTM-C-1059 The physical and mechanical properties of polymers shall conform to Tables 5.4 and 5.5.

ii. **Epoxy Grout** shall conform to ASTM C-882 and have following properties:

Viscosity at 25°C maximum	- 2 Pas
Minimum Gel time	- 30 minutes
14 days bond strength at 25°C min.	- 3.5 MPa
Min. compressive strength	- 60 MPA at 7 days.
Tensile strength 7 days min.	- 45 MPa

b. **Hand/power operated grouting pressure pump/gun** with pressure gauge. The grouting equipment shall be capable of supplying, mixing, stirring and pumping grout to the satisfaction of the Engineer-in-Charge. The equipment shall have the capacity to inject grout at a pressure upto 7 kg per square centimeter measured at the grout connections. It shall be capable of mixing and pumping of cement sand grout 1:2 with water cement ratio ranging from 0.5 to 1.

c. **Air compressor** with all related accessories for carrying compressed air to the required location. Hand operated blow out pump may be allowed by Engineer-in-Charge for small crack depths/areas.

d. **Calibrated Spring Balance** (for accurately weighing different components of materials in required proportions),

e. **Mechanical blender** for mixing

f. **Spray equipment/brush** for application of epoxy/ polymer modified/ bonding cement slurry

9.3.2.2 Execution:

Step-1 **Follow the guidelines** for Safety, Quality Assurance, Environmental Protection, Product delivery, Personnel, Supervision, Storage and Handling, etc given in Para 9.0.

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Step-2 **Full quantity of manufactured material (e.g. specified resin, hardener, polymer, cement, etc as may be required) shall be received** at site in factory sealed containers with labels legible and intact provided that the shelf life so permits. Otherwise substantial quantity as could be consumed within the storage period shall be received as per quantity approved by Engineer-in-Charge. Full quantity shall be worked out as theoretically required for consumption in the whole work.

Step-3 **Collect random samples of materials for test** and send to approved laboratories so as to ensure that they satisfy the physical and mechanical properties.

The grout pump and the pressure gauge shall be tested before taking up the repair operation.

Step-4 **Identify the Cracks and mark the area** for injection grouting.

Step-5 **Surface Preparation:** The appropriate propping/supporting, surface preparation and crack sealing as per site requirements shall be completed, which may sequentially cover one or more of the following items of work:

a) **Prop & support** the structural member to relieve it of stress and strains (Refer Para 9.1.1)

b) Provide grouting nipples (Refer Para 9.3.1).

Step-6 **Blow the compressed air followed by washing with water** through nipples located at the highest level and downwards to ensure removal of even fine dust particles from the cracked surface, which could obstruct the free flow of grout material and impede its bonding with cracked surface (and drying with air blast wherever epoxy injection grout is to be used).

Step-7 **Saturate the cracked surface** in the vicinity of crack/honeycombed concrete/ masonry with water (but without excess water), only if the cementitious grout is to be injected. Otherwise, this step may be skipped.

Step-8 **Prepare the injection grout** as under:

A EPOXY GROUT

Epoxy component shall be mixed in a clean container free from harmful residue or foreign particles. Epoxy component shall be thoroughly blended in a mechanical mixer to a uniform and homogeneous mixture. Small batches (upto 1 litre) however may be allowed for manual mixing using spatulas, pallattes, knives, etc.

B. CEMENT SLURRY

Mixes consisting of cement, water, sand and admixture like fluidifiers (of approved type) in the proportions directed by the Engineer-in-Charge who will, from time to time make changes to suit the conditions encountered in the particular grout work. The water cement ratio shall be varied to meet the characteristics of each hole as revealed by the grouting operations and will range between 0.5 and 1.0.

Shrinkage compensating cement slurry mixed to a lump free creamy consistency shall be made by thoroughly blending in a mechanical mixer and shall be continuously stirred mechanically to keep the cement particles in suspension to retain uniform consistency till the grout is injected. Only small batches (upto 1 litre) be allowed by manual mixing with spatulas, pallattes, knives, etc.

C. SBR/ACRYLIC POLYMER CEMENT SLURRY

Shrinkage compensating cement mixed with polymer and water, in specified proportion in conformity with Table 5.4. For other details it would be similar to preparation of cement slurry as given in preceding paragraph above.

Step-9 **Inject the approved & specified grout** into the cracks by means of suitable gun or pump at a pressure of 1- 2 kg./cm^2 for epoxy grout and 4-7 kg./cm^2 for cementitious grout.

In case of vertical cracks injection shall be started at the lowest nipple and continued until the injected grout begins to flow out at the next higher nipple. Whereas in other cases of horizontal locations, the injection shall be started from one nipple and continued until the injected grout begins to flow out at the other nipple.

The first nipple shall then be closed off and injection continued at the second until the grout flows out at the third. The process shall be repeated until the whole of the crack has been sealed. As soon as the system is cured, the nipples shall be cut.

In case of Honeycombed Area, each grout hole shall be grouted individually. Grouting pressures to be used in the work will vary with the conditions encountered and different areas and the pressure used shall be between 1 to 4 kg/cm^2. The sequence of injection shall be as per the direction of Engineer-in-Charge

Step-10 **Pre and Post Repair Evaluation**

As per directions of the Engineer-in-Charge, the contractor shall carry out Ultrasonic Pulse Velocity Test (UPV) and core test in an approved manner prior to injection grouting and after injection and cure of the grout to ascertain the quality and efficacy of the grouting work. Cores from the post-repaired area shall be extracted only when UPV test results are reported satisfactory. For UPV test and Core test. Nomenclature of relevant items given in Sub Head- X of Chapter 8. Such tests carried out at one location prior to and after the grouting shall be considered as one test only and shall be carried out with at least one test for every 100 square metre of injection grouted surface area. The UPV and core tests shall be carried out only by experienced personnel/ agency.

Step-11 **Re-grout, based on test results**, if in the opinion of Engineer-in-Charge the condition of concrete along the path of grouting is not satisfactory, the contractor shall drill more holes at the locations as required by Engineer-in-Charge and re-grout the member according to the procedure laid down as above. The grouting operation shall be followed till the results of ultrasonic pulse velocity test and core test are satisfactory.

9.3.2.3 Measurements:

(a) **Material supplied:** The quantities of specified resin and hardener, polymers, cements etc supplied shall be recorded after satisfying acceptability criteria. The solid contents of Acrylic/SBR polymer shall be determined in field laboratory or designated laboratory for each batch of supply of latex received and recorded separately batch wise for determining the solid contents for the purpose of payment.

The measurements of weight of the grouting materials supplied shall be weight of resin plus hardener for epoxy; solid contents of polymer, cement for each batch of supplies received:

(b) **Grout Material Consumed:** The weight of the grout material shall include the gross weight of injected material for:

(i) Epoxy grout - weight of resin, hardener & silica sand

(ii) Polymer modified or plain cement sand slurry- weight of cement, sand, and solid contents of polymer & plasticiser, if any, but excluding the weight of mixed water.

(iii) Cement slurry- excluding the weight of mixed water.

The weight of grout shall exclude the quantity of water added directly or through the polymer emulsion.

Pre-measurements of the quantities of such grouting materials available or brought at site and the balance quantities remaining at the end of grouting application shall be recorded separately, which will determine the quantity of grout materials actually injected in to the crack/honeycomb area.

The quantities of grout material wasted, discarded, hardened shall not count for payment and shall be recorded for deduction at the end of each operation.

The measurements shall be separately recorded for concrete and masonry work.

9.3.2.4 Rates:

The rates shall cover cost of all materials, labour and T&P involved in all the operations described above except those covered by step-5. Cost of admixture shall be paid separately.

Note : In respect of materials supplies, two stage payment shall be made. In the first stage 75 % of the rates quoted be released after the materials are brought to site of work and tested satisfactorily. Balance 25 % of the rates quoted shall be released in the second stage, which will be after their consumption in the work.

9.4 BONDING COATS

9.4.1 BONDING COAT FOR HARDENED CONCRETE WITH REPAIR CONCRETE/ SHOTCRETE/ CEMENT MORTAR (Schedule Item No. 8.4.1):

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PURPOSE: *To provide adequately strong adhesion of parent concrete with applied repair concrete or mortar.*

9.4.1.1 Materials and T&P:

Specified bonding materials e.g. epoxy or polymer and cement, mixing water, necessary T&P for mixing and applying bond coat e.g. brush, spray gun, mixer, mechanical stirrer, etc

Product:

A) **Epoxy Adhesives** shall conform to ASTM C-882.

B) **Polymer Latex** shall conform to ASTM C-1059

C) **Cement** shall be ordinary Portland cement conforming to IS: 269

9.4.1.2 Execution:

Step-1 **Follow the guidelines** for Safety, Quality Assurance, Environmental Protection, Product delivery, Personnel, Supervision, Storage and Handling, etc given in Para 9.0.

Step-2 **Full quantity of manufactured repair materials shall be received** at site in factory sealed containers with labels legible and intact, if the shelf life so permits. Otherwise substantial quantity as could be consumed within the shelf life shall be received as per quantity approved by Engineer-in-Charge. Full quantity shall be worked out as theoretically required for consumption in the whole work.

Step-3 **Prepare the surface** for treatment (Refer Para 9.2.1, 9.2.2, 9.2.6 and 9.2.7 as may be applicable).

Step-4 **Saturate the surface with water** but shall be free of excess surface water, debris and dust, where cementitious bond coat is to be applied. Otherwise, surface to remain dry and clean of debris and dust.

Step-5 **Thoroughly inspect all the concrete surfaces** prior to applications of adhesive and get approved from the Engineer-in-Charge.

Step-6 **Test the materials** by taking random samples and testing in approved laboratories so as to check whether they satisfy the physical and mechanical properties.

Step-7 **Make available at site** all necessary mechanical equipment as under :

a. Calibrated Spring Balance (for accurately weighing different components of materials in required proportions),

b. Mechanical blender for mixing

c. Spray equipment/brush for application of epoxy/ polymer modified/ bonding cement slurry

Step-8 **Bond Coat Mixing**: Components of the bonding coat mix shall be weigh batched and mixed in specified proportions in a clear container free from harmful residue or foreign particles. The components shall be thoroughly blended with a mechanical mixer to a uniform and homogeneous mixture. Small batches (upto 1 litre) may however be allowed by manual mixing using spatulas, palette, knives etc.

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Step-9 **Bond coat application** for jacket concrete/ shotcrete/ Mortar placement:

The specified adhesive shall be applied to concrete surface at atmospheric temperatures below 40°C for epoxy adhesive and below 30°C for polymer modified cement or cement-sand slurry adhesive. Bonding coat shall be applied by spray equipment or stiff nylon bristle brush as approved by Engineer-in-Charge. The bonding material shall be worked well into the surface of the parent body ensuring that no pinholes are visible.

Polymer modified bonding cement slurry shall be applied to a thickness not in excess of 2 mm.

If necessary, a second coat shall be applied at right angles to the first to ensure complete coverage and absence of pin holes.

All concrete surface shall be well protected beyond limits of surface receiving adhesive against spillage.

Step-10 **Repair Material Application**: Fresh plastic concrete/ shotcrete/ mortar shall be applied while adhesive is still tacky and well within the pot-life/ setting period. If adhesive cures to the extent of loosing its tack or has set before plastic concrete/shotcrete/mortar is placed, the same shall be removed or slightly abraded and second coat of adhesive applied.

Freshly placed plastic concrete shall be thoroughly consolidated to ensure full bonding of new concrete with the substrate.

Step-11 Bond of repair shall be tested in accordance with 9.4.1.3 given hereinafter.

9.4.1.3 Field Quality Performance Requirement:

Bond of repair with parent concrete

i) **Evaluate bonding** of fresh concrete/ shotcrete/ mortar to existing concrete after the fresh material has cured for not less than 7 days by sounding and tapping fresh concrete with a blunt metal instrument to the satisfaction of Engineer-in-charge. Suspect inadequate bonding, if a hollow sound is detected in any area. In case of conflicted location contractor shall extract one core from the repaired surface area at the end of 28 days.

ii) **Conduct one core test at random** for checking the bond, for every 100 square metre or part thereof. The contractor shall core each area after 28 days of application of concreting/ shortcreting/ repair mortar application for determination of bonding adequacy.

iii) **Core drilling shall be done through applied repair material** and into the existing concrete. Core diameter shall be not less than three times the nominal size of the coarse aggregate used in repair material or as required by the Engineer-in-Charge. Length of cylindrical cores shall preferably be twice the core diameter or twice the thickness of applied repair material or as instructed by Engineer-in-Charge but in any case not less than the dia of the core.

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iv) **Cores shall be visually inspected** by Engineer-in-Charge for evidence of poor workmanship.

v) **Cores shall be tested in tension** to evaluate the quality of bond between new concrete/shotcrete/mortar and the parent concrete. If the failure is in the parent concrete the bond of new repair material shall be deemed to be satisfactory.

vi) **Failure at the bond line or in the repair material** shall be concluded as lack of proper bond or inadequate strength of repair mortar

vii) **Dismantle such areas of work** failed in bond or repair material and re-prepare the surface after chipping off new concrete/mortar work and abrading the epoxy/ polymer/cement slurry interface. Nothing for testing concrete for bond between old and new concrete shall be paid separately.

9.4.1.4 Measurements:

a) **Materials supplied**: The quantities of specified resin and hardener, polymers etc supplied shall be recorded after satisfying acceptability criteria. The solid contents of Acrylic/SBR polymer shall be determined in field laboratory or designated laboratory for each batch of supply of latex received and recorded separately batch wise for determining the solid contents for the purpose of payment.

The measurements of weight of the bonding materials supplied shall be weight of resin plus hardener for epoxy; solid contents of polymer for each batch of supply received;

b) **Materials Consumed**: Pre-measurements of the quantities of bonding materials (e.g. epoxy, Acrylic/SBR polymer) available or brought at site and the balance quantities remaining at the end of bonding coat application shall be recorded separately, which will determine the quantity of bonding materials actually consumed.

c) **Materials wasted:** The quantities of bond material wasted, discarded, hardened shall not count for payment and shall be recorded for deduction at the end of each operation.

For proper control so that the wastage is separately accounted, a register shall be maintained to get the cumulative quantity of material received as supply, consumed in the work, net balance in the store.

Bond Coat Application: The concrete surface, over which bond coat has been applied, shall be measured correct to a centimeter and area of surface worked out in square meters correct to second place of decimal.

Measurements shall be separately recorded for the supplies of material received, material consumed and area over which bond coat applied from time to time.

9.4.1.5 Rates:

The rates shall cover cost of all materials, labour and T&P involved in all the operations described above but shall not cover those involved in step 3 & 10.

Note : In respect of materials supplies, two stage payment shall be made. In the first stage 75 % of the rates quoted be released after the materials are brought to site of work and test results found satisfactory. Balance 25 % of the rates quoted shall be released in the second stage, which will be after their consumption in the work..

9.4.2 ALKALINE PASSIVATING BOND COAT OVER REINFORCEMENT (Schedule Item No. 8.4.2):

PURPOSE: *To protect steel reinforcement with a passivating alkaline layer provided all around its circumference along the length with strong adhesive to bond with applied repair concrete or mortar.*

9.4.2.1 Materials and T&P:

Specified alkaline passivating & bonding materials e.g. CPCC material, epoxy, epoxy phenolic IPN-RB or specified polymer and cement, mixing water, necessary T&P for mixing and applying bond coat e.g. brush, mechanical mixer, mechanical stirrer, etc.

Product:

A) **Epoxy Adhesives** shall conform to ASTM C-882.

B) **Polymer Latex** shall conform to ASTM C-1059

C) **Cement** shall be ordinary Portland cement conforming to IS: 269

D) **Patented materials** e.g. CPCC or epoxy-phenolic IPN-RB as per licensee’s specifications

9.4.2.2 Execution:

Step-1 **Follow the guidelines** for Safety, Quality Assurance, Environmental Protection, Product delivery, Personnel, Supervision, Storage and Handling, etc given in Para 9.0.

Step-2 **Full quantity of manufactured repair materials shall be received** at site in factory sealed containers with labels legible and intact, if the shelf life so permits. Full quantity shall be worked out as theoretically required for consumption in the whole work .

Step-3 **Prepare the surface** for treatment (Refer Para 9.2.1, 9.2.2, 9.2.6 and 9.2.7 as may be applicable).

Step-4 **Thoroughly inspect all the concrete surfaces** prior to applications of passivating/bond coat and get approved from the Engineer-in-Charge.

Step-5 **Test the materials** by taking random samples and testing in approved laboratories so as to check whether they satisfy the physical and mechanical properties.

Step-6 **Make available at site** all necessary mechanical equipment as under :

a. Calibrated Spring Balance (for accurately weighing different components of materials in required proportions),
b. Mechanical blender for mixing
c. Brush for application of specified and approved passivating/bond coat.

Step-7 **Material Mixing**: Components of the passivating/ bond coat mix shall be weigh batched and mixed in specified proportions in a clear container free from harmful residue or foreign particles. The components shall be thoroughly blended with a mechanical mixer to a uniform and homogeneous mixture. Small batches (upto 1 litre) may however be allowed by manual mixing using spatulas, palette, knives etc.

Step-8 **Material Application**: The alkaline passivating & bonding material shall be applied to prepared reinforcement substrate after tying in new reinforcement wherever specified in the form of bars or welded wire fabric. It shall be applied to reinforcement surfaces by stiff nylon bristle brush. The coating material shall be worked well all round the periphery and along its exposed length using a stiff brush ensuring that no pinholes are remaining. The second coat, if required, the same shall be applied as per manufacturer's recommendation after the first coat is touch dry.

9.4.2.3 Measurements:

a) **Material supplied:** The quantities of specified resin and hardener, polymers, patented materials etc supplied shall be recorded after satisfying acceptability criteria. The solid contents of Acrylic/SBR polymer shall be determined in field laboratory or designated laboratory for each batch of supply of latex received and recorded separately batch wise for determining the solid contents for the purpose of payment.

The measurements of weight of the passivating and bonding materials supplied shall be weight of resin plus hardener for epoxy; solid contents of polymer for each batch of supply received;

b) **Material Consumed:** Pre-measurements of the quantities of passivating and bonding materials (e.g. epoxy, Acrylic/SBR polymer/patented material) available or brought at site and the balance quantities remaining at the end of passivating & bonding coat application shall be recorded separately, which will determine the quantity of bonding materials actually consumed.

c) **Materials wasted:** The quantities of bond material wasted, discarded, hardened shall not count for payment and shall be recorded for deduction at the end of each operation.

For proper control so that the wastage is separately accounted, a register shall be maintained to get the cumulative quantity of material received as supply, consumed in the work and net balance in the store.

Passivating Coat Application: For the purpose of payment, the reinforcing bars coated with passivating and bond coat shall be grouped in two diawise categories, with one being upto and including 12 mm and the other above 12 mm. For each of such categories, length of bars coated all around, shall be separately measured. The length shall be measured in metres correct to second place of decimal

Measurements shall be separately recorded for the supplies of material received, actual quantity of material consumed from time to time.

9.4.2.4 Rates:

The rates shall cover cost of all materials, labour and T&P involved in all the operations described above except those involved in step-3.

Note : In respect of materials supplies, two stage payment shall be made. In the first stage 75 % of the rates quoted be released after the materials are brought to site of work and test results found satisfactory. Balance 25 % of the rates quoted shall be released in the second stage, which will be after their consumption in the work.

9.5 REPAIR ITEMS

9.5.1 SPECIFICATION FOR MICRO-CONCRETE (Schedule Item No. 8.5.1):

PURPOSE: *A manufactured cementitious concrete mix for use in constricted locations, which is received in pre batched, prepackaged, single component dry mix of specified grade. When mixed with specified quantity of water, it is to have free flowing and self compacting characteristics in plastic state and on hardening it shall have non-shrink and impervious characteristics.*

9.5.1.1 Materials and T&P:

Specified grade of micro-concrete, mixing water, mechanical mixer, transportation and handling equipment, all necessary T&P for surface preparation, reinforcement bars, shear key bars, epoxy, power drilling equipment, props & supports, waterproof shuttering, specified passivating & bond coats for reinforcement and concrete, the ingredients as per design of concrete mix including super-plasticiser, micro-silica, other mineral admixtures to achieve concrete of specified grade and workability.

9.5.1.2 Procedure:

Step-1 **Follow the guidelines** for Safety, Quality Assurance, Environmental Protection, Product delivery, Personnel, Supervision, Storage and Handling, etc given in Para 9.0.

Step-2 **Full quantity of manufactured repair materials shall be received** at site in factory sealed containers with labels legible and intact provided that the shelf life so permits. Otherwise substantial quantity as could be consumed within the shelf life shall be received as per quantity approved by Engineer-in-Charge. Full quantity shall be worked out as theoretically required for consumption in the whole work.

Step-3 **Testing of Material:** The requisite number of test specimens of micro-concrete shall be cast from each batch of manufacture or supply received (whichever is less) for these to be tested for conformance to the specified requirements of 7 and 28-day cube crushing strength, surface absorption of water, permissible limits of shrinkage, etc before use on the work.

Step-4 **Surface Preparation:** The appropriate surface preparation and crack sealing as per site requirements shall be completed, which may sequentially cover one or more of the following items of work:

a) Prop & support the structural member to relieve it of stress and strains (Refer Para 9.1.1)

b) Removal of existing surface plaster shall be done according to Para 9.2.1.

c) Chipping unsound/weak concrete material shall be done according to Para 9.2.2.

d) Removing concrete all around embedded rusted reinforcement shall be done according to Para 9.2.6.

e) Removing and cleaning reinforcement of rust from its surface to give it a shining bright metal shall be done according to Para 9.2.7.

f) Sealing the cracked or honeycombed concrete with injection grouting shall be done according to Para 9.3.1 and 9.3.2

g) Providing and inserting mild steel shear keys shall be done according to Para 9.2.9.

h) Cleaning of lightly sticking materials and foreign matter from the exposed concrete surface and steel reinforcement by suitable means shall be done according to Para 9.2.10.

Step-5: **Additional reinforcement, if required,** shall be tied with required overlaps or welded. (Refer Para No 9.5.5).

Step-6 **Apply Passivating & bonding** coat over the cleaned reinforcement according to Para 9.4.2.

Step-7 **Apply bond coat** on the cleaned concrete substrate according to Para 9.4.1.

Step-8 **Erect pre-fabricated watertight shuttering**, if required, while the bond coat is still tacky according to Para 9.1.2 to receive the self compacting free flowing micro concrete

Step-9 **Prepare self compacting, free flowing micro-concrete** simultaneously along with step-8 so as to have a uniform consistency and texture in a mechanical concrete mixer by adding a specified proportion of water in the preweighed dry mix of pre-batched, prepackaged, single component micro concrete .

Step-10 **Pour the fresh micro-concrete** in the shuttering mould or over the surface prepared to receive it, while the bond coat is still tacky.

Step-11 **Wet cure the micro-concrete** according to Para 9.6.1

Step-12 **Field Quality Performance** shall be culculated as per Para 9.4.13

9.5.1.3 Measurements:

After surface preparation, if necessary for working out volume of applied repair material, pre-measurements of dimensions of the substrate shall be recorded. For the purpose of payment, measurements of the finished surface shall be recorded only after wet curing is done and surface evaluated satisfactorily. The dimensions shall be recorded correct to a centimeter and volume shall be worked out in cubic metres correct to second place of decimal.

9.5.1.4 Rates:

The rates shall cover cost of all materials, labour and T&P involved in all the operations described above except for those involved in steps 4, 5, 6, 7, 8 and 11.

Note : In respect of materials supplies, two stage payment shall be made. In the first stage 75 % of the rates quoted be released after the materials are brought to site of work and tested satisfactorily. Balance 25 % of the rates quoted shall be released in the second stage, which will be after their consumption in the work.

9.5.2 SPECIFICATION FOR SHOTCRETE (Schedule Item No.. 9.5.2):

PURPOSE: *Application of repair concrete of specified mix proportions by spraying it under pressure in layers over prepared substrate.*

9.5.2.1 Materials and T&P:

9.5.2.1.1 Materials:

Cement:

The cement shall be ordinary Portland cement of 43 grade conforming to relevant B.I.S. Code of Practice.

Aggregates:

Sand for shotcrete shall comply with the requirements given in IS 383 and graded evenly from fine to coarse as per Zone-II and Zone III grading. Sand failing to satisfy this grading may, however, be used only if pre-construction testing establishes that it gives good results.

Coarse aggregate when used shall comply with the requirements of IS 383. It shall, generally conform to the grading given below:

GRADING OF COARSE AGGREGATES

IS Sieve Designation, mm	Percentage Passing by mass for aggregate of nominal maximum size
10	100
4.75	10-30
2.36	0-10
1.18	0-5

All over sized pieces of aggregate shall be rejected by screening.

Gradation of the combined coarse and fine aggregate mixture used for shotcrete shall generally lie between the following limits.

I.s.sieve	Percent passing by Weight Gradation
10 mm	100 -100
4.75 mm	72- 85
2.36 mm	52-73
1.18 mm	36-55
600 microns	28-38
300 microns	7-20
150 microns	0-8

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Water

Water used for shotcrete shall conform to the requirement of I.S. 456-2000

Admixture

Admixture shall only be used if approved by the Engineer-in-Charge who shall be furnished with all required literature pertaining to its efficacy. Guniting admixtures & quick setting agents may be used to minimise the rebound loss and increase the bond & enable thicker layers per coat. The admixture shall meet the requirement of I.S. 456 and I.S. 9103 .

Reinforcement

Reinforcement bars if used shall conform to I.S. 432 (Part-I) or I.S. 1786. Welded wire fabric where used shall conform to I.S. 1566.

Concrete

The grade of concrete shall be as specified i.e. the characteristic compressive strength of 15 cm cube at 28 days should be as specified. The water cement ratio for shotcrete shall be within the range 0.45- 0.50 by mass.

9.5.2.1.2 Equipment

For Dry mix process:

Batching and mixing equipment- Batching shall be done by mass. The moisture content of the sand shall be such that the sand cement mixture will flow at a uniform rate through the delivery hose. The sand shall be moistened or dried as required to bring the moisture content to a satisfactory level. Fluctuations in moisture content shall be avoided.

The mixing equipment shall be capable of thoroughly mixing the sand and cement in sufficient quantity to maintain continuity of placing. The mixing time shall be not less than 1 minute in a drum type mixer, where other mixers are proposed, satisfactory evidence shall be presented to the Engineer-in-Charge that they are capable of thorough mixing. The mixer shall be self cleaning capable of discharging all mix material without any carry over from one batch to the next. It shall be inspected and thoroughly cleaned at least once in a day and more often if instructed by Engineer-in-Charge to prevent accumulations of batched material.

Delivery equipment or guniting equipment- The delivery equipment shall comply with requirements given in I.S. 6433.

Air Supply - The compressor shall be fitted with a moisture extractor to keep up a supply of clean, dry air adequate for maintaining a sufficient nozzle velocity for all parts of the work while simultaneously operating a blow pipe for clearing away re-bound material.

A gauge near the material outlet of the gun shall measure the operating pressure. The air pressure shall be uniformly steady (non pulsating).

For lengths of hose upto 30m, air pressure at the gun shall be 0.3 N/Sq.mm or more. Where length exceeds 30m the pressure shall be increased by 0.035 N/Sq.mm for each additional 15 m of hose required & by 0.035 N/sq.mm for each 7.5 M that the nozzle is raised above the gun.

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Water supply -The water pressure at the discharge nozzle shall be sufficiently greater than the operating air pressure to ensure that the water is intimately mixed with the other materials. If the line water pressure is inadequate, a water pump shall be introduced into the line. The water pressure shall be uniformly steady (non pulsating).

9.5.2.2 Procedure:

Step-1 **Follow the guidelines** for Safety, Quality Assurance, Environmental Protection, Product delivery, Personnel, Supervision, Storage and Handling, etc given in Para 9.0.

Step-2 **Full quantity of manufactured repair materials shall be received** at site in factory sealed containers with labels legible and intact provided that the shelf life so permits. Otherwise substantial quantity as could be consumed within the storage period shall be received as per quantity approved by Engineer-in-Charge. Full quantity shall be worked out as theoretically required for consumption in the whole work.

Step-3 **Mix Design**: The shotcrete mix design shall be developed by laboratory tests and field trials and got approved from Engineer-in-charge.

Step-4 **Pre-construction testing**- A laboratory trial and testing shall be carried out prior to the commencement of the work in order to check the operation of the equipment, the skill of the operating staff and also to verify that the specified quality of shotcrete would be expected in the structure. The procedure for pre-construction testing shall be as below;

A. The operating staff, using the equipment, materials and mix proportions proposed for the job, shall fabricate test panels simulating actual job conditions.

B. For the dry mix process, the amount of water added at the nozzle shall be adjusted so that in place shotcrete shall be adequately compacted and will neither sag nor show excessive rebound. At least, two mixes shall be tested before deciding on the final mix proportion.

C. The panels shall be fabricated by gunning on to a back form of plywood. A separate panel shall be fabricated for each gunning position to be encountered in the structure. At least part of the panel shall contain the same reinforcement as the structure to show whether sound shotcrete is obtained behind the reinforcing rods. The panel shall be large enough to obtain all the tests specimen needed, and also to indicate quality and uniformity that may be expected in the structure. Generally the size of panel shall be not less than 75cm x 75 cm. The thickness shall be the same as in the structure except that it shall be not less than 50mm.

D. Cores shall be taken from the panels for testing. The cores shall preferably have a diameter of 7.5 cm but not less than 50 mm and a length to diameter ratio of at least 1. The specimen shall be tested in compression at the age of 7 or 28 days or both as directed by Engineer-in-Charge. The result of the tests shall be compared with the cube strength taken earlier. Nothing extra shall be paid for core testing of concrete for pre construction testing.

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E. The cut surface of the specimen shall be carefully examined and additional surfaces shall be exposed by sawing or breaking the panel, if it is considered necessary by Engineer-in-Charge to check soundness and uniformity of the material. All cut and broken surfaces shall be dense and free from laminations and sand pockets.

Step-5 **Surface Preparation:** The appropriate surface preparation and crack sealing as per site requirements shall be completed, which may sequentially cover one or more of the following items of work:

a) Prop & support the structural member to relieve it of stress and strains (Refer Para 9.1.1)

b) Scaffolding & working platforms for the exterior members (Refer Para 9.1.3), if not already done and if necessary, shall be erected for working upon the area.

c) Working Platforms for interior members, if not already done and if necessary, shall be erected suitably or provided as mobile.

d) Provide Protective Screen (Refer Para 9.1.8), if not already done and if necessary.

e) Removal of existing surface plaster (Refer Para no 9.2.1)

f) Chipping unsound/weak concrete material (Refer Para no 9.2.2). However, no square shoulders shall be left at the perimeter of the cavity, all edges shall be tapered. The final cut surface shall be critically examined to make sure that it is sound and properly shaped.

g) Removing concrete all around embedded rusted reinforcement (Refer Para no 9.2.6).

h) Removing and cleaning reinforcement of rust from its surface to give it a shining bright metal (Refer Para no 9.2.7).

i) Sealing the cracked or honeycombed concrete with injection grouting (Refer Para no 9.3.1 and 9.3.2),

j) Providing and inserting mild steel shear keys, also to act as depth gauge for controlling thickness of gunite/shotcrete (Refer Para no 2.9)

k) Cleaning of lightly sticking materials and foreign matter from the exposed concrete surface and steel reinforcement by suitable means followed by an oil free dry air blast(Refer Para no 2.10)

Step-6 **Additional reinforcement, if required, and welded wire fabric** shall be tied with required overlaps or welded. (Refer Para No 9.5.5).

Step-7 **Adequate and safe working platform,** as approved as per Para 9.1.3, shall be provided so that the gunite/shotcrete operator can hold the nozzle at optimum angle and distance from the surface for all parts of work.

Step-8 **Suitable formwork** of plywood sheeting or other suitable material shall be fixed true to lines and dimension to get finished sides and edges of the gunited/ shotcreted surface. Refer Specifications of form work (centering and shuttering)' contained in Para 5.2 of CPWD Specifications 1996 (Vol-II).

They shall be adequately braced to protect against excessive vibration and shall be constructed so as to permit the escape of air and rebound during the gunning operation. Forms shall be oiled or dampened and they shall be cleaned just before gunning.

Formwork shall be necessarily required for first stage application of shotcrete/ gunite on two opposite faces of rectangular columns and beams, whereas in second stage of application of repair material on the remaining faces, gunited/ shotcreted surface at edges/corners shall serve the purpose without requiring further formwork.

The minimum clearance between the reinforcement and the formwork or other back up material shall be provided as per detailed drawing.

Step-9 **Alignment & thickness Control**- Adequate ground wires shall be installed to establish thickness and surface planes of the shotcrete build up. Both horizontal and vertical ground wires shall be installed at the corners and offsets not clearly fixed by the formwork, i.e. at exterior corners of columns and beams and other such locations. Ground wires shall be tight and true to line and placed in such a manner that they may be further tightened.

Step-10 **Passivating/bond coat** shall be applied to the reinforcement and the welded wire fabric (Refer Para no 4.2)

Step-11 **Bond coat** over the prepared concrete and reinforcement substrate as above shall be applied (Refer Para no 4.1)

Step-12 **Gunite/Shotcrete Application:** Fresh gunite/shotcrete shall be applied at the earliest possible, when bond coat, as applied in Step-11 above, is still tacky.

Maximum thickness to be applied in one pass will be, in general, limited to 25 mm for overhead application and 50 mm on sides. Where gunite is to be placed to a thickness of more than 50 mm on sides or 25 mm overhead, it is preferable for it to be built up in more than one application.

Each layer of shotcrete shall be built-up by making several passes or loops of the nozzle over the working area. This will be done by moving the nozzle rythmetically in series of loops from side to side and up and down. The shotcrete shall emerge from the nozzle in a steady, uninterrupted flow. If the flow becomes intermittent due to any cause, the Operator shall direct it away from the work until it again becomes constant. The distance of nozzle from work (usually between 0.5 and 1.5 m) shall be such as to give the best results for the working conditions. The nozzle shall be held perpendicular to the surface of application. However, when gunning through and encasing reinforcing bars the nozzle shall be held closer and at a slight angle to the perpendicular. Also the mix shall be little wetter than normal but not so wet as to cause sloughing behind the bars.

Application shall begin at the bottom for columns and beams and for slabs, the nozzle shall be held at a slight angle to the perpendicular so that the rebound is blown on to complete portion from where it shall be removed.

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Embed reinforcement atleast adjacent to the form in the first layer completely. The thickness of layers shall be adjusted so that shotcrete does not sag. Where thick layers are applied, top surface shall be maintained at a 45 degree slope.

Rebound material, ricocheting off the surface, shall not be worked back into the construction. If it does not fall clear of the work, it shall be removed. Rebound shall not be salvaged and included in later batches.

Theoretical consumption of cement - For working out the theoretical consumption of cement in shotcreting, following coefficients shall be added for accounting for the concrete wasted as loss due to rebound in various items.

1. Ceiling of RCC slab - 40%
2. Vertical faces of R.C.C. beams columns & R.C.C. walls
   a. with face width not exceeding 450 mm - 50%
   b. with face width exceeding 450 mm - 45%

Construction joints- Construction joints shall generally be tapered to a thin edge over a width of 300 mm. However, in case of joints, which in the opinion of the Engineer-in-Charge, are likely to be subjected to compressive stresses, square joints shall be provided by temporarily fixing the batten formwork of required thickness. In case of square joints, steps shall be taken by the Contractor to avoid or remove trapped rebound in the joint. The entire joint shall be thoroughly cleaned and the approved bonding coat applied prior to the application of additional shotcrete.

Preparation for succeeding layers- When a layer of shotcrete is to be covered by a succeeding layer, it shall first be allowed to take its initial set. Then all laitance, loose materials and rebound shall be removed by brooming. Any laitance that has attained final set shall be removed by sand blasting and the surface cleaned with an air jet. In addition the surface shall be thoroughly sounded with a hammer for drummy areas, sags or any other defects, which shall be carefully cut out and replaced with succeeding layer as instructed by Engineer-in-Charge. Succeeding layers shall be shot within 4 to 8 hours to attain the required thickness. In case application of succeeding layer is delayed beyond 24 hours, then the bond coat shall be applied at the interface for which no extra payment shall be made to the contractor.(Refer Para No 9.4.1).

Suspension of work: The application of shotcrete shall be suspended in condition of likely exposure to high winds, freezing or rain.

At the end of each day of work, or on stopping work for any other reason, the shotcrete shall be sloped off to a thin edge and then the work shall be resumed on next day after cleaning the surface of joint and applying a bond coat of approved formulation.

Inspection- The shotcreting shall be continuously inspected by a qualified supervisor, who shall check material, forms, reinforcement, ground wires, delivery equipment, application of material, curing, protection against high or low temperatures. Each layer of concrete shall be systematically sounded with a hammer to check for drummy areas.

Permissible Tolerances: The permissible tolerance on the thickness of work executed by shotcrete shall be (-) 3 mm to (+) 8 mm.

Quality control: Small un-reinforced test panels, at least 30 cm square and 75 mm thick shall be periodically gunned, and cores shall be extracted and compressive tests shall be performed periodically in the same manner as at step-4 above. The frequency of samples shall be one sample for every 10 cum of gunite/shotcrete.

In addition, concrete cubes prepared by directly gunning into 15 cm cube mould, shall also be used for day-to-day quality control tests. One sample comprising of three test specimens for testing at 28 days, shall be taken for every 5.0 cubic metre of concrete. Additional cubes if instructed by Engineer-in-Charge shall also be taken for each sample to determine the strength of gunite/ shotcrete at seven days.

All the specimen shall be tested as described in IS 516.

The gunite shall be deemed to comply with the strength requirements if the test results satisfies the acceptance criteria as per IS 456

Step-13 Wet cure the shotcreted/gunited surface (Refer 9.6.1).

Step-14 F**ield Quality Performance** shall be evaluated as per Para **9.4.1.3:**

9.5.2.3 Measurements

Shotcreting upto 50 mm thickness shall be measured in square metre of finished surface area.

9.5.2.4 Rates:

Rate includes cost of all T & P material, labour and T&P involved in all the operations described above except specifically mentioned and those involved in steps 5, 6, 8, 10, 11 and 13.

Note : In respect of materials supplies, two stage payment shall be made. In the first stage 75 % of the rates quoted be released after the materials are brought to site of work and tested satisfactorily. Balance 25 % of the rates quoted shall be released in the second stage, which will be after their consumption in the work.

9.5.3 PLAIN/REINFORCED CONCRETE JACKET FOR THE STRUCTURAL MEMBERS e.g. COLUMNS, PILLARS, PIERS, BEAMS ETC. (Schedule Item No. 8.5.3):

PURPOSE: *To provide a thin walled RCC element structurally bonded to the substrate of an existing stress-relieved structural member either to increase its structural size & strength or to restore the reduced structural size due to chipping.*

9.5.3.1 Materials and T&P:

All necessary T&P for surface preparation, mechanical mixer, transportation and handling equipment, reinforcement bars, shear key bars, epoxy, power drilling equipment, props & supports, waterproof shuttering, specified passivating & bond coats for reinforcement and concrete, mixing water, the ingredients as per design of concrete mix including super-plasticiser, micro-silica, other mineral admixtures to achieve concrete of specified grade and workability.

9.5.3.2 Procedure:

Step-1 **Follow the guidelines** for Safety, Quality Assurance, Environmental Protection, Product delivery, Personnel, Supervision, Storage and Handling, etc given in Para 9.0.

Step-2 **Full quantity of manufactured repair materials shall be received** at site in factory sealed containers with labels legible and intact provided that the shelf life so permits. Otherwise substantial quantity as could be consumed within the shelf life shall be received as per quantity approved by Engineer-in-Charge. Full quantity shall be worked out as theoretically required for consumption in the whole work.

Step-3 **Testing of Material:** The requisite number of test specimens of concrete shall be cast from each batch of manufactured or supplied materials received (whichever is less) for these to be tested for conformance to the specified requirements of 7 and 28-day cube crushing strength, surface absorption of water, permissible limits of shrinkage, etc before use on the work.

Step-4 **Surface Preparation:** The appropriate propping, surface preparation and crack sealing as per site requirements shall be completed, which may sequentially cover one or more of the following items of work:

a) Prop & support the structural member to relieve it of stress and strains (Refer Para 9.1.1)

b) Removal of existing surface plaster shall be done according to Para 9.2.1.

c) Chipping unsound/weak concrete material shall be done according to Para 9.2.2.

d) Removing concrete all around embedded rusted reinforcement shall be done according to Para 9.2.6.

e) Removing rust scales and cleaning reinforcement of rust from its surface to give it a shining bright metal shall be done according to Para 9.2.7.

f) Sealing the cracked or honeycombed concrete with injection grouting shall be done according to Para 9.3.1 and 9.3.2

g) Providing and inserting mild steel shear keys shall be done according to Para 9.2.9.

h) Additional reinforcement, if required, shall be tied with required overlaps or welded. (Refer Para No 9.5.5).

i) Cleaning of lightly sticking materials and foreign matter from the exposed concrete surface and steel reinforcement by suitable means shall be done according to Para 9.2.10.

Step-5 **Drill holes in RCC Slabs of appropriate** diameter at appropriate locations for pouring concrete in the jacket close to beam and slab soffits.

Step-6 **Apply Passivating & bonding** coat over the reinforcement according to Para 9.4.2.

Step-7 **Apply bond coat** on the cleaned concrete substrate according to Para 9.4.1.

Step-8 **Fabricate and erect watertight shuttering**, if required, while the bond coat is still tacky according to Para 9.1.2 to receive the self compacting free flow concrete

Step-9 **The specified concrete (self compacting and free flow) shall be prepared, poured and compacted** well within the tacky period of bond coat. The CPWD specifications for manufacture and placing of concrete shall generally be followed.

Step-10 **Wet cure the concrete** jacket according to Para 9.6.1

Step-11 **Test the Surface** of 7-day cured concrete for soundness.

Step-12 F**ield Quality Performance** shall be evaluated as per Para **9.4.1.3:**

9.5.3.3 Measurements:

Dimensions of area of finished surface shall measured correct to a centimeter and area worked out in square metres correct to second place of decimal for payment purposes.

9.5.3.4 Rates:

The rates shall cover cost of all materials, labour and T&P involved in all the operations described above except for those involved in steps 4, 5, 6, 7, 8 and 10.

Note : In respect of materials supplies, two stage payment shall be made. In the first stage 75 % of the rates quoted be released after the materials are brought to site of work and tested satisfactorily. Balance 25 % of the rates quoted shall be released in the second stage, which will be after their consumption in the work.

9.5.4 PROVIDING AND LAYING AN OVERLAY OF REINFORCED CONCRETE OVER PREPARED SURFACE OF EXISTING RCC SLAB/BEAM ETC. (Schedule Item No. 8.5.4):

PURPOSE: *To provide specified additional thickness of RCC over an existing stress-relieved RCC slab/beam, bonded structurally to the substrate either to increase the structural thickness and/or additional reinforcement to enhance the load carrying capacity or to restore the reduced thickness of RCC slab due to removed weak and/or carbonated concrete.*

9.5.4.1 Materials and T&P:

All necessary T&P for surface preparation, reinforcement bars, shear key bars, epoxy, power drilling equipment, props & supports, specified passivating & bond coats for reinforcement and concrete, mechanical mixer, transportation and handling equipment, the ingredients as per design of concrete mix including mixing water, super-plasticiser, micro-silica, other mineral admixtures to achieve concrete of specified grade and workability.

9.5.4.2 Procedure

Step-1 **Follow the guidelines** for Safety, Quality Assurance, Environmental Protection, Product delivery, Personnel, Supervision, Storage and Handling, etc given in Para 9.0.

Step-2 **Full quantity of manufactured repair materials shall be received** at site in factory sealed containers with labels legible and intact provided that the shelf life so permits. Otherwise substantial quantity as could be consumed within the self life shall be received as per quantity approved by Engineer-in-Charge. Full quantity shall be worked out as theoretically required for consumption in the whole work.

Step-3 **Testing of Material:** The requisite number of test specimens of concrete shall be cast from each batch of manufactured or supplied materials received (whichever is less) for these to be tested for conformance to the specified requirements of 7 and 28-day cube crushing strength, surface absorption of water, permissible limits of shrinkage, etc before use on the work.

Step-4 **Mark the area of overlay** over the RCC slab/beam.

Step-5 **Surface Preparation:** The appropriate propping/supporting, surface preparation and crack sealing as per site requirements shall be completed, which may sequentially cover one or more of the following items of work:

a) Prop & support the structural member to relieve it of stress and strains (Refer Para 9.1.1)
b) Removal of existing surface plaster/treatment shall be done according to Para 9.2.1 or 9.2.3 as the case may be.
c) Chipping unsound/weak concrete material shall be done according to Para 9.2.2.
d) Removing concrete all around embedded rusted reinforcement shall be done according to Para 9.2.6.
e) Removing and cleaning reinforcement of rust from its surface to give it a shining bright metal shall be done according to Para 9.2.7.
f) Sealing the cracked or honeycombed concrete with injection grouting shall be done according to Para 9.3.1 and 9.3.2
g) Providing and inserting mild steel shear key bars shall be done with minimum 3 nos per square meter of surface area of substrate according to Para 9.2.9, which may also be used as depth measuring gauge.
h) Additional reinforcement, if required, shall be tied with required overlaps or welded. (Refer Para No 9.5.5).
i) The rust, if any, persisting over the existing exposed reinforcement or the new reinforcement shall be removed mechanically or chemically, as per Para no 8.2.7 and Para 9.2.7
j) Cleaning of lightly sticking materials and foreign matter from the exposed concrete surface and steel reinforcement by suitable means shall be done according to Para 9.2.10
k) Provide shuttering along sides of overlay as per Para 5.2 of CPWD Specifications 1996Vol-II.

Step-6 **Clean the dust from the prepared surface** of concrete and reinforcement wth a clean oil free air blast.

Step-7 **Alignment & thickness Control**- Ground wires shall be fixed at reference points to measure and control the thickness of overlay. Shear keys fixed earlier could also function as depth gauges. Adequate ground wires shall be installed to establish thickness and surface planes of the overlay build up. Ground wires shall be tight and true to line and placed in such a manner that they may be further tightened.

Step-8 **Apply Passivating & bonding** coat over the existing and new reinforcement according to Para 9.4.2.

Step-9 **Apply bond coat** on the concrete substrate according to Para 9.4.1.

Step-10 **Prepare self compacting, free flowing concrete for overlay** as per design mix so as to have a uniform consistency and texture in a mechanical concrete mixer by adding a specified proportion of water to the weigh batched ingredients of the design mix including necessary super plasticisers.

Step-11 **Pour the fresh concrete** over the surface prepared to receive it, while the bond coat is still tacky.

Step-12 **Wet cure the concrete overlay** according to Para 9.6.1

Step-13 **Test the Surface** of 7-day cured concrete overlay for soundness by tapping or sounding with hard blunt surface.

9.5.4.3 Measurements:

Length and width of the specified thickness of overlay concrete shall be measured correct to a centimeter and area worked out in square metres correct to second place of decimal. This item shall be measured only after proper wet curing has been done and surface has been satisfactorily .

9.5.4.4 Rates:

The rates shall cover cost of all materials, labour and T&P involved in all the operations described above except for those involved in step nos 5, 8, 9 and 12.

Note : In respect of materials supplies, two stage payment shall be made. In the first stage 75 % of the rates quoted be released after the materials are brought to site of work and tested satisfactorily. Balance 25 % of the rates quoted shall be released in the second stage, which will be after their consumption in the work.

9.5.5 REINFORCEMENT FOR RCC WORK ETC. (Schedule Item No. 8.5.5):

PURPOSE: *To provide reinforcement in repair concrete for structural purposes, controlling effects of thermal variation or holding shotcrete/gunite material in position. The reinforcement material may comprise specified grade and quality with or without zinc coating.*

9.5.5.1 Material & T&P:

Specified reinforcing material, necessary hand or power driven tools for cutting, bending, binding, transportation, handling and placement, etc Reinforcement bars if used shall conform to I.S. 432 (Part-I) or I.S. 1786. Welded wire fabric where used shall conform to I.S. 1566.

9.5.5.2 Procedure:

The general requirements, placing in position, measurement etc. shall be generally followed as in Para 5.3 of CPWD specifications 1996 Vol-II excepting those specifications provided in the following clauses.

Step-1 **Follow the guidelines** for Safety, Quality Assurance, Environmental Protection, Product delivery, Personnel, Supervision, Storage and Handling, etc given in Para 9.0.

Step-2 **Testing of Material:** The requisite number of test specimens of specified reinforcing material shall be collected from each batch of manufacture or supply received (whichever is less) for these to be tested for conformance to the specified requirements before use on the work.

Step-3 **Execution**:

The required reinforcement as per detailed drawings in the form of round bars or welded wire fabric in such a way so as to cause the least interference with placement of repair material.

Overlaps: Lapped reinforcing bars shall not be tied together. They shall be separated by at least 50 mm wherever possible. Wire mesh shall be lapped by 1-1/2 squares in all direction. Minimum requirement of lap length of bars shall be as specified in I.S. 456.

Clearance around reinforcement: Sufficient clearance shall be provided around the existing exposed and additional reinforcement to permit complete encasement with sound repair material.

Cover: Minimum cover to reinforcement shall be as per I.S. 456. As far as possible the bars shall be arranged so as to permit shooting from opposite side.

Fixing: Reinforcement shall be fixed to existing shear key bars and depth gauges driven into the concrete with wires and secured rigidly so that the vibration resulting from the deposition of repair material shall not impair or displace them.

Where gunite /shotcrete to be done in more than one layer: In such cases, the additional reinforcement should be so fixed that it is encased in succeeding layer. No additional reinforcement is required to be fixed in first layer of gunite.

Mesh reinforcement shall be fixed in the manner so that it is firmly held at least 12 mm away from the parent concrete surface as well as from the final finished surface. It shall be ensured that it is stiffened enough and cannot belly out during the guniting / jacketing / concrete overlays with consequent lack of cover. It shall be done by tying with parent concrete surface through shear key bars or depth gauges. GI-wire mesh fabric will add sacrificial "Zinc" coating & shall reduce corrosion process in the reinforcement. The wire mesh spacing shall be as specified in the drawings.

9.5.5.3 Measurements:

For the purpose of measurement for payment, length of specified reinforcing bars/ wires shall be measured correct to a centimeter and that of wire fabric, length and width shall be measured correct to a centimeter to work out area in square metres correct to second place of decimal. Overlaps shall be accounted for in the length/area measurements.

For each batch of supply of steel reinforcement or the wire fabric, weight coefficients shall be worked out per meter length for bars and wires and per square meter for wire fabric. The weight coefficients shall be calculated correct to third place of decimal in each batch by weighing three randomly taken samples from the lot of supply and taking an arithmetical mean of the weights per unit length/area.The total weight shall be worked out in Kilograms correct to second place of decimal

9.5.5.4 Rates:

Rates shall cover the costs of all labour, material and T&P involved in all operations detailed above.

Note : In respect of materials supplies, two stage payment shall be made. In the first stage 75 % of the rates quoted be released after the materials are brought to site of work and tested satisfactorily. Balance 25 % of the rates quoted shall be released in the second stage, which will be after their consumption in the work.

9.5.6 PROVIDING STRUCTURAL CONNECTION (Schedule Item No. 8.5.6):

***PURPOSE**: To establish a structural connection for a new RCC member to be connected with the existing structural member for transfer of the end forces between the members.*

9.5.6.1 Specifications:

This item is a combination of various other items of work, specifications of which are distinctly given under relevant items. Hence no separate specification of materials, T&P, execution procedure is being given.

9.5.6.2 Measurements:

The Cross-sectional area at the interface of the structural connections shall be measured and area shall be worked out in square metres correct to second place of decimal.

9.5.6.3 Rates:

Rates shall cover all incidental cost of labour, material and T&P involved in all operations other than those items of work distinctly mentioned in the nomenclature payable separately.

9.5.7 CEMENT BASED POLYMER MODIFIED MORTAR (Schedule Item No. 8.5.7):

***PURPOSE:** To carry out structural repairs to prepared patches of spalled concrete with an alkaline impervious repair material comprised of polymer admixed cement-sand mortar.*

9.5.7.1 Materials and T&P:

Polymers in emulsion or powder forms as may be specified conforming to ASTM C-1059, Ordinary Portland Cement of 43 grade conforming to relevant BIS code, Sand conforming to Zone-II or Zone-III grade of IS: 383, Mixing water conforming to IS: 456-2000, mortar mixer with mechanical water dozer, spatulas, trowels, etc.

9.5.7.2 Procedure:

Step-1 **Follow the guidelines** for Safety, Quality Assurance, Environmental Protection, Product delivery, Personnel, Supervision, Storage and Handling, etc given in Para 9.0.

Step-2 **Full quantity of specified polymers shall be received** at site in factory sealed containers with labels legible and intact provided that the shelf life so permits. Otherwise substantial quantity as could be consumed within the shelf life shall be received as per quantity approved by Engineer-in-Charge. Full quantity shall be worked out as theoretically required for consumption in the whole work.

Step-3 **Testing of Material:** The requisite number of test specimens of mortar shall be cast from each batch of manufactured or supplied materials received (whichever is less). These are to be tested for conformance to the specified requirements contained in Table 5.5 before use on the work. Polymer modified cement mortar with cement: sand proportion by weight as (1:3) shall have the following properties

Minimum compressive strength - 20N/sq.mm after 28 days at 27°C
Minimum tensile strength - 6.5 N/sq.mm after 28 days at 27°C

Step-4 **Identify and mark the area** for Polymer modified mortar repair.

Step-5 **Surface Preparation:** The appropriate propping/supporting, surface preparation and crack sealing as per site requirements shall be completed, which may sequentially cover one or more of the following items of work:

a) Prop & support the structural member to relieve it of stress and strains (Refer Para 9.1.1)

b) Removal of existing surface plaster/treatment shall be done according to Para 9.2.1 or 9.2.3 as the case may be.

c) Chipping unsound/weak concrete material shall be done according to Para 9.2.2.

d) Removing concrete all around embedded rusted reinforcement shall be done according to Para 9.2.6.

e) Removing and cleaning reinforcement of rust from its surface to give it a shining bright metal shall be done according to Para 9.2.7.

f) Sealing the cracked or honeycombed concrete with injection grouting shall be done according to Para 9.3.1 and 9.3.2

g) Providing and inserting mild steel shear key bars shall be done with minimum 3 nos per square meter of surface area of substrate according to Para 9.2.9, which may also be used as depth measuring gauge.

h) Additional fresh reinforcement, if required, shall be tied with required overlaps or welded. (Refer Para No 5.5).

i) The rust, if any, persisting over the existing exposed reinforcement or the new reinforcement shall be removed mechanically or chemically, as per Para no 8.2.7 and Para 9.2.7

j) Cleaning of lightly sticking materials and foreign matter from the exposed concrete surface and steel reinforcement by suitable means shall be done according to Para 9.2.10

Step-6 **Clean the dust and saturate the prepared surface** of concrete and reinforcement with a clean oil free air blast and water fit for construction.

Step-7 **Inspection of concrete surface** prior to adhesive application shall be thoroughly inspected and got approved by the Engineer-in-Charge. Surfaces shall be ensured to be free from any deleterious materials such as oil, dust, dirt etc. using oil free air blast.

Step-8 **Alignment & thickness Control-** Ground wires shall be fixed at reference points to measure and control the thickness of overlay. Shear keys fixed earlier could also function as depth gauges. Adequate ground wires shall be installed to establish thickness and surface planes of the overlay build up. Ground wires shall be tight and true to line and placed in such a manner that they may be further tightened.

Step-9 **Apply Passivating & bonding** coat over the cleaned existing and new reinforcement according to Para 9.4.2.

Step-10 **Apply bond coat** on the cleaned concrete substrate according to Para 9.4.1.

Step-11 **Mix and Prepare Polymer Modified Mortar** to have a uniform consistency and texture by adding cement sand and polymer as weigh batched ingredients of the design mix, a specified proportion of water through water dozer.

Use of prepacked ready to use components supplied by manufacturers in containers may be allowed subject to approval of Engineer-in-Charge. In case where prepacked ready to use materials are to be used, the contractor shall submit the manufacturer's certificate verifying conformance to material specification as specified, manufacturer's mixing and application procedure for approval by Engineer-in-charge.

Plastering with cement based polymer modified mortar shall be done immediately after applying the bonding slurry to the prepared surfaces, preferably in coats of approximately 10mm thickness with thickness of trowelling not to exceed the range given in Table 5.6 as greater thickness may lead to delamination/collapse. However, coats shall be applied in fairly rapid successions within 15 to 30 minutes. After applications of mortar the surface shall be finished using a wooden float.

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The guidelines on mortar mix proportioning & application, available in Table 5.6, Para 5.3.2.8 and 5.3.2.9 are generally applicable

. Step-12 **Moist cure the polymer modified mortar** surface for 1-3 days followed by air curing at ambient temperature or as per manufacturer's specification, if specified otherwise. Use of flowing water or ponding of water shall not be done for curing. Steam curing shall not be permitted.

Step-13 **Test the Surface** of 7-day cured concrete overlay for soundness by tapping or sounding with hard blunt surface.

9.5.7.3 Inspection & Quality control:

The mortar application work shall be continuously inspected by a qualified supervisor who shall check materials, application of mortar, curing stoppage of work during low temperatures (minimum working temperature being 8^0C in most of the polymer modified mortar or as per manufacturer direction) and high winds etc. Each completed work of mortar shall be systematically sounded with a hammer to check for drummy areas after hardening.

In suspect areas or whenever directed by Engineer-in-Charge, the contractor shall drill the cores from the finished work and in to the host concrete after 28 days of mortar application. The cores shall be examined for evidence of poor workmanship by the Engineer-in-Charge, and if he is satisfied that either the bonding work or the subsequent layer of mortar are not of the required workmanship, the contractor at the instruction of Engineer-in-Charge shall dismantle such areas of work as required by the Engineer-in-Charge and re-do the same after re-preparing the surface by chipping off mortar work and abrading the bonding slurry interface.

9.5.7.4 Measurements:

Pre-measurement of dimensions of plaster patches shall be measured correct to a centimeter and area worked out in square metres correct to second place of decimal. The pre-measurement of the average thickness shall be done by taking an average of five thickness readings recorded with one reading each at corner and at the point of intersection of wires stretched diagonally from corner points of the rectangular area chipped.

9.5.7.5 Rates

The rates shall cover cost of all materials, labour and T&P involved in all the operations described above. The payment shall be made on the actual consumption of cement on kilograms basis.

Note : In respect of materials supplies, two stage payment shall be made. In the first stage 75 % of the rates quoted be released after the materials are brought to site of work and tested satisfactorily. Balance 25 % of the rates quoted shall be released in the second stage, which will be after their consumption in the work.

9.5.8 EPOXY MORTAR ((Schedule Item No. 8.5.8):

PURPOSE: *To carry out structural repairs to prepared patches of spalled c oncrete with an epoxy repair mortar comprised of resin, hardener and specified silica sand.*

9.5.8.1 Materials and T&P:

Epoxy comprising of resin and hardener in proportions as specified by manufacturer and shall conform to ASTM C-882, Silica sand falling in Zone-II as per IS:383, mechanical mortar mixer, spatulas, trowels, etc.

9.5.8.2 Procedure:

Step-1 **Follow the guidelines** for Safety, Quality Assurance, Environmental Protection, Product delivery, Personnel, Supervision, Storage and Handling, etc given in Para 9.0.

Step-2 **Full quantity of specified resin, hardener and silica sand shall be received** at site in factory sealed containers with labels legible and intact provided that the shelf life so permits. Otherwise substantial quantity as could be consumed within the storage period shall be received as per quantity approved by Engineer-in-Charge. Full quantity shall be worked out as theoretically required for consumption in the whole work.

Step-3 **Testing of Material:** The requisite number of test specimens of mortar shall be cast from each batch of manufactured or supplied materials received (whichever is less) for these to be tested for conformance to the specified requirements contained in Table 5.8 before use on the work in general. Epoxy Mortar of Resin: Silica sand proportion as 1:7 shall have the following properties

Specific gravity	1.87+ 0.05
Minimum gel time	30 minutes
Bond strength after 7 days curing at 25^0C	75-100 Kg/sqcm
Compressive strength at 7 days curing at 25^0C	800-1200 kg/sqcm
Split Tensile strength after 7 days curing at 25^0C	100 -130 kg./sqcm
Flexural Strength after 7 days curing at 25^0C	295 Kg/sqcm

Step-4 **Identify and mark the area** for epoxy mortar repair.

Step-5 **Surface Preparation:** The appropriate propping/supporting, surface preparation and crack sealing as per site requirements shall be completed, which may sequentially cover one or more of the following items of work:

a) Prop & support the structural member to relieve it of stress and strains (Refer Para 9.1.1)

b) Removal of existing surface plaster/treatment shall be done according to Para 9.2.1 or 9.2.3 as the case may be.

c) Chipping unsound/weak concrete material shall be done according to Para 9.2.2.

d) Removing concrete all around embedded rusted reinforcement shall be done according to Para 9.2.6.

e) Removing and cleaning reinforcement of rust from its surface to give it a shining bright metal shall be done according to Para 9.2.7.

f) Sealing the cracked or honeycombed concrete with injection grouting shall be done according to Para 9.3.1 and 9.3.2

g) Providing and inserting mild steel shear key bars shall be done with minimum 3 nos per square meter of surface area of substrate according to Para 9.2.9, which may also be used as depth measuring gauge.

h) Additional reinforcement, if required, shall be tied with required overlaps or welded. (Refer Para No 5.5).

i) The rust, if any, persisting over the existing exposed reinforcement or the new reinforcement shall be removed mechanically or chemically, as per Para no 8.2.7 and Para 9.2.7

j) Cleaning of lightly sticking materials and foreign matter from the exposed concrete surface and steel reinforcement by suitable means shall be done according to Para 9.2.10

Step-6 **Inspection of concrete surface** prior to adhesive application shall be thoroughly inspected and got approved by the Engineer-in-Charge. Surfaces shall be ensured to be free from any deleterious materials such as oil, dust, dirt etc. using oil free air blast.

Step-7 **Alignment & thickness Control-** Ground wires shall be fixed at reference points to measure and control the thickness of repair mortar. Shear keys fixed earlier could also function as depth gauges. Adequate ground wires shall be installed to establish thickness and surface planes before application of repair mortar. Ground wires shall be tight and true to line and placed in such a manner that they may be further tightened.

Step-8 **Apply Passivating & bonding** coat over the cleaned existing and new reinforcement according to Para 9.4.2.

Step-9 **Apply epoxy bond coat** on the cleaned concrete substrate according to Para 9.4.2. Work of application of primer coat shall not be allowed to be performed beyond 40^0C atmospheric temperature and/or pot life of epoxy.

Step-10 **Mix and Prepare Epoxy Mortar** to have a uniform consistency and texture in a mechanical mixer by adding resin, hardener and silica sand as weigh batched ingredients of the mix.

Use of pre-packed ready to use components supplied by manufacturers in containers may be allowed subject to approval of Engineer-in-Charge. In case where pre-packed ready to use materials are to be used, the contractor shall submit the manufacturer's certificate verifying conformance to material specification as specified, manufacturer's mixing and application procedure for approval by Engineer-in-charge.

Plastering with epoxy mortar immediately after applying the epoxy bonding coat (Refer 9.4.2) to the prepared surfaces shall be done by trowel, roller or spray equipment, at a thickness not less than, nor more than that recommended by manufacturer,

The mortar shall be worked into place and consolidated so that all contact surfaces are wet by the mortar and the surfaces shall be finished by wooden floats or steel trowels.

The guidelines on mortar mix proportioning & application, available in Table 5.8, Para 5.3.3.2-E and 5.3.3.3 are generally applicable

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All concrete surfaces shall be well protected beyond limits of surface receiving primer coat or mortar, against spillage.

. Step-11 **Air cure the epoxy mortar** surface for 24 hrs at ambient temperature or as per manufacturer's specification, if specified otherwise.

Step-12 **Test the Surface** after 24 hrs days cured epoxy mortar for soundness by tapping or sounding with hard blunt surface.

9.5.8.3 Inspection & Quality control:

The mortar application work shall be continuously inspected by a qualified supervisor who shall check materials, application of mortar, curing, stoppage of work during low temperatures and high winds etc. Each completed work of mortar shall be systematically sounded with a hammer to check for drummy areas after hardening.

In suspect areas or whenever directed by Engineer-in-Charge, the contractor shall drill the cores from the finished work and in to the host concrete after 24 hrs of mortar application. The cores shall be examined for evidence of poor workmanship by the Engineer-in-Charge, and if he is satisfied that either the bonding work or the subsequent layer of mortar are not of the required workmanship, the contractor at the instruction of Engineer-in-Charge shall dismantle such areas of work as required by the Engineer-in-

Charge and re-do the same after re-preparing the surface by chipping off mortar work and abrading the epoxy interface.

9.5.8.4 Measurements:

Pre-measurement of dimensions of plaster patches shall be measured correct to a centimeter and area worked out in square metres correct to second place of decimal. The pre-measurement of the average thickness shall be done by taking an average of five thickness readings recorded with one reading each at corner and at the point of intersection of wires stretched diagonally from corner points of the rectangular area chipped.

10.5.8.5 Rates

The rates shall cover cost of all materials, labour and T&P involved in all the operations described above. The payment shall be made on the actual consumption of resin plus hardener on kilograms basis.

9.5.9 DRY PACK AND EPOXY BONDED DRY PACK (Schedule Item No. 8.5.9):

PURPOSE: *To carry out structural repairs to prepared patches of spalled concrete with an epoxy repair mortar comprised of resin, hardener and specified silica sand.*

9.5.9.1 General: The work shall be carried out as per description of the item of work given in Para 8.5.9, general guidelines & description given Para 6.5.2 and directions of the Engineer-in-Charge

9.5.9.2 Measurements:

Pre-measurement of dimensions of patches shall be measured correct to a centimetre and volume worked out in Cubic metres correct to second place of decimal. The pre-measurement of the average thickness shall be done by taking an average of fibre thickness readings recorded with one reading each at corner and at the point of intersection of wires stretched diagonally from corner points of the rectangular area clipped.

9.5.9.3 Rates

The rates shall cover cost of all materials, labour and T&P involved in all the operations described above.

9.5.10 PREPLACED AGGREGATE CONCRETE (Schedule Item No 8.5.10):

PURPOSE: *To carry out structural strengthening of concrete.*

9.5.10.1 General: The work shall be carried out as per Para 6.5.3 in general and as per specification and directions of the Engineer-in-Charge

9.5.10.2 Measurements:

Pre-measurement of dimensions of surface shall be measured correct to a cm. and volume worked out in square metres per layer correct to second place of decimal.

9.5.10.3 Rates

The rates shall be cover cost of all materials, labour and T&P including grout pump etc. involved in all the operations describd above. Shuttering and priming/bonding coat, if applied, shall be paid separately as per the relevent item.

9.5.11 STRENGTHENING WITH HYBRID ORTHOGONAL WOVEN FABRIC SYSTEM SOAKED IN EPOXY (Schedule Item No. No 8.5.11):

PURPOSE: *To increase the load carrying capacity (shear, flexural, compressive) and ductility of reinforced concrete members through a non-intrusive structural strengthening technique comprised of the Composite Fiber System, without causing* any destruction or distress to the existing concrete.

9.5.11.1 General: The work shall be carried out as per Para 6.5.18 in general and as per specification and directions of the Engineer-in-Charge

9.5.12 STRENGTHENING WITH UNIDIRECTIONAL HIGH STRENGTH FIBRES OVER EPOXY COATED SURFACE (Schedule Item No. No 8.5.12)

PURPOSE: *To increase the load carrying capacity (shear, flexural, compressive) and ductility of reinforced concrete members through a non-intrusive structural strengthening technique comprising of unidirectional E-glass fiber and 0.4 mm effective thickness, complete*

9.5.12.1 General: The work shall be carried out as per Para 6.5.18 in general and as per specification and directions of the Engineer-in-Charge.

9.6 CURING

9.6.1 CURING OF SHOTCRETED, PLASTERED AND/OR RCC SURFACES ETC. (Schedule Item No 8.6.1):

PURPOSE: *To ensure satisfactory hydration of cement by retaining or replenishing the mixing water lost due to natural drying and evaporation process for a specified period through exposed cementitious surfaces of the freshly placed cement mortar/ concrete.*

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9.6.1.0 General:

Importance of wet curing to all items of work involving use of cement need not be over emphasised. It is important to note that the measurement and payment of all relevant items involving use of cement such as shotcrete, plaster, RCC etc. is subject to the precondition of successful execution of the item of curing.

Any surface experiencing discontinuity of dampness of surface with any patch having dried out during the specified period of curing, it shall be prominently marked with lime or other suitable prominent colour. Measurement and payment of such portion shall neither be made under the item of curing nor under the relevant items of shotcrete, plaster or RCC etc but rejected & redone.

9.6.1.1 Materials and T&P

Curing compound, brush or hand operated spraying gun and all other related accessories for application on Concrete/Plastered Surface.

9.6.1.2 Procedure:

Step-1 **Follow the guidelines** for Safety, Quality Assurance, Environmental Protection, Product delivery, Personnel, Supervision, Storage and Handling, etc given in Para 9.0.

Step-2 **Full quantity of specified manufactured material shall be received** at site in factory sealed containers with labels legible and intact provided that the shelf life so permits. Otherwise substantial quantity as could be consumed within the shelf life shall be received as per quantity approved by Engineer-in-Charge. Full quantity shall be worked out theoretically for consumption in the whole work.

Step-3 **(A) Moist Curing:**

Cover all exposed surface of concrete, when the concrete begins to harden i.e. two to three hours after compaction with moist gunny bags or any other material approved by the Engineer-in-Charge.

Keep the exposed surfaces continuously damp after its final setting (i.e. after a maximum of 8 hours of concreting) by ponding with a sheet of water or by covering with a layer of sacks, canvass, hessian or similar water absorbent materials constantly kept wet by water sprinkling for at least 7 days, where ordinary portland cement is used and 10 days, where portland pozzolana cement is used from the date of placing of concrete. For concrete work with other types of cement, curing period shall be as per manufacturer's recommendations or as directed by the Engineer-in-Charge.

(B) Using Curing compound:

Testing of Materials: It must be ensured that curing compound should neither affect the strength nor the surface of concrete. It shall not leave any undesirable stains on surface to affect the bond of plaster or other finishes to be applied later. It should be soluble in water, so that it can be removed by splashing or washing with water without scrubbing the surface.

Test for Efficacy: The testing of curing compounds shall be done from each lot of curing compound received at site by casting two sets of 15 cm cubes with each set having 6 cubes. One set shall be moist cured by covering with damp gunny bags and subsequently by immersing under water and the other set by applying curing compound on top after 2 to 3 hours of casting and subsequently on de-moulding apply on the remaining faces all around. The cubes shall be kept in an environment similar to which the actual structure is exposed for a period of 7 days after its casting. Three concrete cubes each from both sets shall be tested after 7 days for their crushing strength as per test procedure specified in clause 5.4.9.1 of CPWD specification 1996 Vol-II under identical condition. The average crushing strength of cubes cured with curing compound shall be not less than 95% of the crushing strength of cubes cured under damp or immersion curing.

Test for Staining: The set of three sample cubes applied with curing compound, remaining after 7-day cube crushing strength test, shall be washed with water with soft brush scrubbing with nylon bristles and allowed to dry for a period of seven days in an atmosphere with relative humidity not exceeding 40% at ambient temperature. The other set of three cubes cured for seven days under damp or immersion conditions shall also be kept for another seven days under identical humidity and temperature conditions. The surface of the two sets of such cubes shall be compared by closely observing for any visible stain and texture that may detrimentally affect its bond with subsequently applied plain plaster or aesthetic appearance. Such observations shall be recorded in three categories as no effect, slight effect and moderate effect. The curing compound shall be considered as acceptable in the 'no effect' category and unacceptable in the 'moderate' category. The decision of Engineer-in-Charge, which shall be final and binding, based on the likely use of finished surface of concrete/plaster shall determine the acceptability of the 'slight effect' category.

Concrete curing compounds, after testing satisfactorily for efficacy, may be used in lieu of moist curing with the permission of the Engineer-in-Charge. Such compounds shall be applied to all exposed surfaces of the concrete by spraying or brushing within two to three hours of casting and well within an hour of removal of formwork.

9.6.1.3 Measurements:

Dimensions of exposed surface of concrete wet cured shall be measured correct to a centimeter and areas worked out in square metres correct to second place of decimal.

9.6.1.4 Rate:

The rates shall cover cost of all materials, labour and T&P involved in all the operations described above**.**

Note : In respect of materials supplies, two stage payment shall be made. In the first stage 75 % of the rates quoted be released after the materials are brought to site of work and tested satisfactorily. Balance 25 % of the rates quoted shall be released in the second stage, which will be after their consumption in the work.

9.7 CHHAJJA/SUN SHADES

9.7.1. SPECIFIED SAND STONE CHHAJJA (Schedule Item No. 8.7.1):

PURPOSE: *To protect the windows/ doors, etc located on the exterior of the building from heat and water due to sun or rain etc.*

9.7.1.1 Materials and T&P

Specified angle iron, sand stone, zinc rich and tar-epoxy resins and hardeners, cement concrete, all applicable T & P complete with necessary accessories.

9.7.1.1 Procedure:

Angle iron frame for chhajja shall be fabricated correct to required size at ground & fixed in position in the wall as per the standard drawing.

Steel work in frame shall conform to the provisions of Para 10.4 of CPWD specifications 1996 Vol.-III. However, steel frame work shall be given priming coat Zinc rich epoxy coating followed with two coats of tar-epoxy paint.

The specified sand stone shall conform in general to the provisions of Para 7.8 of CPWD specifications 1996 Vol-II. Size of stone shall, however, be as specified.

Frame shall be tightly embedded into the masonry with cement concrete 1:3:6

(1 cement: 3 coarse sand : 6 graded stone aggregate 20 mm) blocks 150 mm x 115mm x 230 mm.

Junction of wall & the chajja shall be finished with cement concrete gola for proper drainage of rain water. Gola shall conform to the provisions in Para 12.15 of CPWD specification 1996-Vol-IV.

The exposed surfaces of the angle iron frame and chajja shall be finished with two or more coats of tar epoxy paint.

9.7.1.3 Measurements:

The projected length & breadth of the chajja shall be measured correct to a centimeter & area shall be worked out in square metres correct to second place of decimal.

9.7.1.4 Rates:

Rate for the item includes the cost of all labour, materials & T&P involved in operations stated above except for the scaffolding, which shall be payable separately.

9.7.2 AVERAGE 25 MM THICK FERRO-CEMENT CHAJJA/WEATHER SHADE ETC. (Schedule Item No. 8.7.2):

PURPOSE: *To protect the windows/ doors, etc located on the exterior of the building from heat and water due to Sun or rain etc with a suitably formed chhajja projection.*

9.7.2.1 General: In most of the cases the ferrocement chhajjas are factory made and they are fixed at site using partially cast in situ ferrocement components using existing embedded steel reinforcement or with suitable structural steel framework. However precautions are to be taken against seepage of water by providing Gola above the Chhajja at junction with wall as per CPWD specifications. Work shall be carried as per the specifications and directions of Engineer-in-Charge.

9.8 WATER PROOFING & PROTECTIVE COATINGS

9.8.1 POLYMER MODIFIED CEMENT SLURRY WATERPROOFING AND ANTICARBONATION COATING (Schedule Item No. 8.8.1):

PURPOSE: *To protect the RCC surface against ingress of aggressive environmental deteriorating agents like carbon dioxide, water vapours, etc to substantially reduce the rate of carbonation of concrete and ingress of water.*

9.8.1.1 General: The Para 9.4.1 generally applies for this item. The work shall accordingly be carried out as per nomenclature of Item and directions of Engineer-in-Charge.

9.8.2 UV RESISTANT ACRYLIC POLYMER BASED WATER PROOF COATINGS:

PURPOSE: *To protect the exposed surface of RCC roof against ingress of, water vapours, etc to provide a UV resistant, flexible, elastic, water proofing membrane.*

9.8.2.1 General: It is a thin water proofing membrane applied with brush comprised of UV resistant Acrylic Emulsion to be applied over a primer coat. The work shall be carried out as per manufacturer's specifications and as per directions of Engineer-in-Charge.

9.8.3 FERRO-CEMENT WATER PROOFING TREATMENT (Schedule Item No. 8.8.3):

PURPOSE: *To provide protection against ingress of water, etc through RCC surface with a structural membrane of cement matrix reinforced with layers of small diameter steel wire mesh and structurally connected to the exposed surface of RCC.*

9.8.3.1 General

The ferrocement being a structural membrane is gainfully utilised as a stiff membrane to resist ingress of water from exposed RCC terraces. It is also used as inside tanking membrane for RCC raft and walls to arrest leakage of water in existing basements.

Materials used for the work shall be strictly according to specification. Utmost care shall be taken to ensure good workmanship. On extremely hot days, the work shall be carried out only in the late afternoon or early morning.

9.8.3.2 Materials and T&P:

Cement shall be Ordinary Portland Cement of 33 grade conforming to IS:269 or 43 grade conforming to IS:1489 as may be specified.

Sand shall conform to grading Zone-II as per IS:383

Admixtures shall be used to improve workability, reduce water demand and to retard the mortar setting time.

Reinforcement: 22 gauge orthogonal woven G.I. wire mesh, 4mm dia G I wires

In most cases, hand mixing is satisfactory. If mixing is to be done for large structures or factory made components, horizontal paddle bladed mixer shall be required.

9.8.3.3 Procedure:

Step-1 **Remove & scrap** all treatment including non-cementitious tarfelt, bitumen, etc from the surface to be treated (Refer Para 9.2.3 payable separately).

Step-2 **Repair the exposed roofing and its junctions with parapets**, including sealing of cracks & honey combed area (Refer Para 9.3.2 payable separately).

Step-3 **Regrade the roofing, if required and re-lay the Khurrahs (**Refer Appendix 6.3). Provide adequate slope towards the rainwater spouts.

Step-4 **Cut a chase of 75 mm X 75 mm** in parapet at the junction with roofing for taking the Ferrocement water proofing treatment inside the chase.

Step-5 **Fix hot dip galvanised wire nails** 50 mm to 60 mm long & 4 mm dia to roofing along marked grid points at a spacing of 450 mm as shown in the Fig 9.8.3.1. The fixing shall be done by drilling 25 mm deep holes of appropriate diameter with high speed drill, blowing away the dust from drilled holes with a hand operated blow out pump or air compressor, injecting epoxy from the cartridges with epoxy dispenser/cartridge holder through PVC mixing nozzle and inserting the nails in vertical position with remaining length as projecting above the roof surface. The epoxy shall be allowed to air cure for 24 hours.

Step-6 **Lay over the roofing, 4 mm dia galvanised steel wires** laid parallel to each other spaced at 450mm c/c along the layout of GI wire nails. Wires shall be taken alternately along the either side of GI nails in order to fix their position.

Step-7 **Apply a coat of bonding slurry** (Refer Para 9.4.1 and payable separately)

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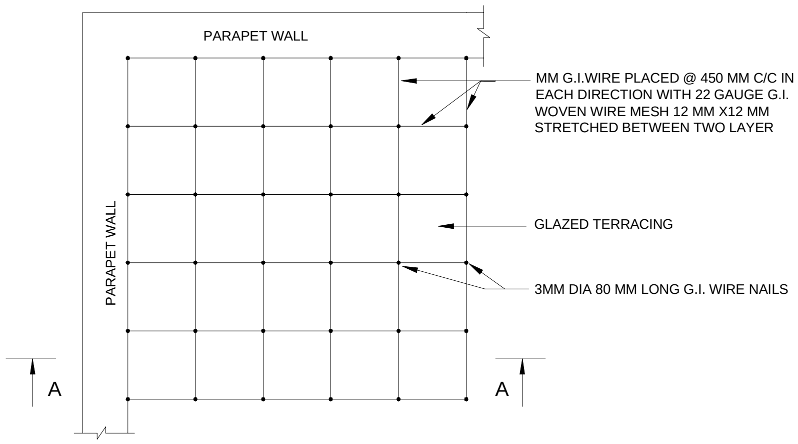
after saturating the surface with water but without excess water. The area to be covered with bond coat shall be in parts and just enough for all the operations of ferrocement to be finished by close of the day.

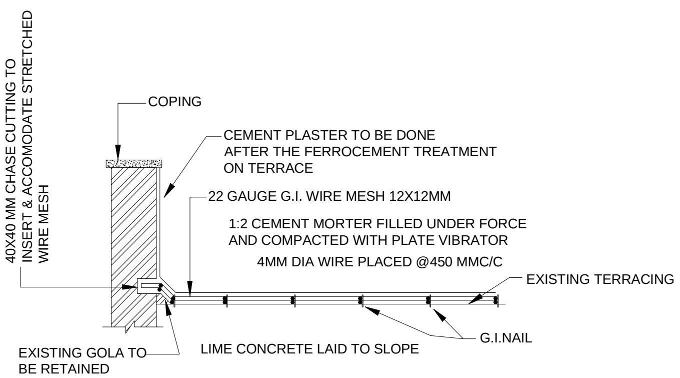
Step-8 **Lay the first layer of specified woven wire mesh and tightly stretch** over roof surface from one end so that the nails are inserted in the meshes to keep it in tightly stretched condition. The woven mesh shall be orthogonally woven with 22 gauge hot dip galvanised wires spaced at 12 mm c/c. The mesh shall be seated over 4 mm dia GI wires laid in step-6. In the laid woven wire mesh, the over laps of 100 mm shall be given along the sides and ends.

Step-9 **Weigh batch Cement and specified sand** (while operations of Steps-6,7, 8 & 9 are in progress), in proportion 1: 2 (1-cement: 2-sand) and dry mixed before adding a measured quantity of admixture and water. The water to cement ratio shall be maintained not more than 0.4. Mixing, if done in a mechanical mixer, shall be done for about three minutes to form a plastic mortar of uniform colour and texture.

Step-10 **Lay another set of 4 mm dia wires** at right angle to lower layer of GI wires at 450 mm c/c in same manner as at Step 4. This shall be done to provide a 4 mm clear gap between the first woven wire mesh & the next one yet to be laid. For 25 mm thickness of ferrocement the top 5 mm thickness shall only be made up by



PLAN SHOWING FIXING ARRANGEMENT OF G.I. WOOVEN WIRE MESH



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increasing the cover thickness in only mortar.

Step-11 **Spread second layer of woven square mesh** of 22 gauge hot dipped galvanised wire with wires spaced at 12 mm c/c as per procedure explained in Step-8.

Step-12 **Provide Levelling/Thickness gauges** by bending the projected nails to U shape, which will also ensure that the mesh is fixed in position. Mortar gauges of specified thickness shall also be provided in a square grid at an interval of about one metre c/ c.

Step-13 **Apply the mortar** using trowels by force, rubbing and pressing down with trowels so as to ensure penetration in the wire meshes. There shall be a minimum mortar cover of 4 mm below the mesh, between the meshes and over it. The mortar shall be compacted thoroughly using a vibrating trowel or an orbital vibrator and finished smooth to specified thickness. The surface shall be finished semi smooth and to the required slope.

Step-14 **Provide Cement Concrete Gola** in the Chase provided earlier at Step-4 as per CPWD Specifications 1996.

Step-15 **Curing:** Refer Para 9.6.1 But the period of wet curing shall be 14 days. For the next two weeks, it shall be gradually allowed to dry. Care shall be taken to ensure that ferrocement does not dry up in the first two weeks.

9.8.3.4 Measurement:

Dimensions of the area covered with ferrocement treatment shall be measured correct to a centimeter and area worked out in square metres correct to second place of decimal.

9.8.3.5 Rates:

The rates shall cover cost of all materials, labour and T&P involved in all the operations described above except step 15.

9.8.4 CEMENT PLASTER WITH POLYMERIC WATER PROOFING COMPOUND: (Schedule Item No. 8.4.4)

PURPOSE: *To provide a barrier against ingress of water/dampness through RCC/ Brickwork etc with plaster in cement matrix made impervious or hydrophobic by addition of polymeric pore sealants.*

9.8.4.1 Materials, Procedure, Measurements and Rates

The polymeric water proofing compound shall conform to the requirements given in Chapter-5. Others shall generally conform to the description of the item given in Para 8.8.5 of Chapter-8 and CPWD Specifications 96 Vol-IV.

9.8.5 INJECTION TYPE POST CONSTRUCTION WATER PROOFING TO CONCRETE STRUCTURES (Schedule Item o. 8.8.5)

PURPOSE: *To seal pores of existing concrete structures against ingress of water and moisture by pressure injection of pore sealing compounds through nipples fixed for the purpose.*

9.8.5.1 Materials, Procedure, Measurements and Rates

These shall generally conform to the description of the item given in Para 8.8.6 of Chapter-8 and Para 9.3.2.

9.9 MASONRY REPAIR

9.9.1 General:

Masonry repair is done by various types of repair material. Of those covered in sub paras of para 8.9, cement mortar and cement concrete the relevant sections of CPWD Specifications 1996 Vol-I & II may be referred. Whereas for gunite/ shotcrete, polymer modified cement mortar, bond coat relevant respective Paras at 9.5.2, 9.5.4, 9.4.1 are required to be referred. The work is required to be executed, measured and paid as per nomenclature of items of work. The individual specifications are not being given for the sake of brevity. The item of curing covered in Para 9.6.1 is required to be executed, measured before measuring and making payment of any of the items of masonry repair.

10.0 TESTING OF MATERIALS AND PRE / POST REPAIR STRUCTURE

The pre and post repair testing of a structure for evaluation purposes shall generally be carried out in accordance with sub paras of Para 8.10 and relevant standards mentioned therein and relevant tests indicated in Chapter-3 of this Handbook.

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Appendix 9.1

TEST METHODS FOR EXECUTION OF THE WORKS

A9.1.1 General

(1) Table A9.1-1 given hereinafter reviews the test methods to be used during execution of the works in accordance with these specifications.

(2) Column 1 shows the property to be tested for which requirements are specified Tables 9.1 to 9.7.

(3) Column 2 indicates whether the test can be performed using resources available on the construction site or whether a testing agency must be called in. The construction site and the testing agency cooperate in cases where specimens are taken on the site and tested at the testing agency. A specialist laboratory must be employed in cases where neither the construction site nor the testing agency possesses adequate facilities.

(4) Column 3 indicates the section of this Handbook or BIS code of practices in which the description of the method is given.

Table A9.1-1: Test methods for execution of the works

	Property	To be tested by	Description of test method, see section/BIS Code of Practice.
	Concrete substrate		
1.	Apparent nature	Construction site	A9.2.1.
2.	Concrete compressive strength	Construction site and testing agency	3.2.1
3.	Surface tensile strength	Construction site and testing agency	3.2.1.4
4.	Carbonation depth	Construction site	3.2.2.1
5.	Concrete cover, position and diameter of reinforcement	Construction site	A9.2.2
6.	Chloride content	Construction site and testing agency	3.2.2.2
	Moisture content of the concrete		
7.	- by heating surface	Construction site	A9.2.3
8.	- with CM apparatus	Construction site	A9.2.4
9.	- Gravimetrically	Specialist Laboratory	–
10.	Water penetration	Testing agency	A9.2.5
11.	Wettability	Construction site	A9.2.6.
	Roughness		
12.	- sand area method	Construction site	A9.2.7
13.	-With inductivement -displacement sensor	Specialist Laboratory	–
	Crack State		
14.	- Crack-width rule, crack magnifier, plaster mark	Construction site	A9.2.8
15.	Crack propagation- Glass Strip marker	Construction site	–

Property		To be tested by	Description of test method, see section/BIS Code of Practice.
16	Crack- indicating caliper and inductive displacement sensor	Specialist laboratory	–
	Processing Conditions		
17.	Air temperature and atmospheric humidity, component temperature, dew-point temperature	Construction site	A9.2.9
	2. Repair concretes or mortars		
	2.1 Aggregate		
18.	Granulometric composition	Construction site	IS:383
19.	Inherent moisture, surface moisture, core moisture	Construction site	IS:383
	2.2 Mortar		
19.	Consistency, apparent specific density, air content	Construction site	–
20.	Flexural tensile and compressive strength and apparent specific density	Construction site and testing agency.	IS:516
	2.3 Concrete (IS:456)		
21.	Consistency, apparent specific density, air content	Construction site	–
22.	Concrete composition	Testing agency	–
23.	Water content (dehydration test)	Testing agency	–
24.	Compressive strength	Construction site Testing agency	IS:516
25.	Impermeability to water	Construction site and testing agency	–
	2.4 Shotcrete		
26	Consistency	Construction site	9.5.3
27	Apparent specific density	Construction site	–
28	Water/cement ratio	Testing agency	–
29	Concrete composition	Testing agency	–
30	Compressive strength	Construction site and testing agency	9.5.3
	3. Surface protection systems		
	Coating thickness		
31	- Wedge-cut method	Testing agency	–
32.	- Drilled core	Testing agency	A9.4.1
33.	Adhesive strength	Construction site and testing agency	A9.4.2
34.	Voids content (SP 9 and 10)	Testing agency	A9.4.3
35.	Leakage resistance	Testing agency	–
36.	Grid test with tape test	Specialist laboratory	A9.4.4
	4. Treatment of cracks		
37.	Degree of filling	Testing agency	A9.5.1.
38.	Cement paste	Testing agency	A9.5.2

A9.2 Concrete Substrate

A9.2.1 Visual Checks

(1) **Visual checking** of the surface is done for the presence of:

- Hardened cement slurry, loose particles such as dust, etc
- Original Construction Defects e.g. gravel pockets, ridges, honey-comb, segregated concrete surface, powdering & sanding, etc
- Efflorescence, leaching and weathering of the fine mortar layer
- Concrete spalling (e.g. above reinforcement),
- Moisture penetration and its entry points,
- Growths (e.g. mosses, higher plant organisms).
- Contamination by foreign matter, e.g. oil, grease, paraffin, rubber particles, parting agents, after-treatment agents and residues of old coatings.
- Cracks (crack width, crack type and appearance).

(2) **Near surface cavities** can be detected by hollow sounds on percussion. Powdering, sanding and dust coatings can be quantified by applying an adhesive strip of defined size to the surface and pulling it off.

A9.2.2. Determination of Concrete Cover, Position and Diameter of the Reinforcement

(0) The concrete cover, position and diameter of the reinforcement are to be measured and recorded non – destructively using an electronic tester called rebar locator or profometer. The directions for use, as per manufacturer's instruction manual, govern the way in which the test instruments are used. The accuracy of the instruments is to be checked periodically for example on already exposed reinforcement or by exposing a localized area of the reinforcement.

(1) Destructive measurement of the concrete cover should be used only in exceptional cases.

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A9.2.3 Testing the Moisture Content of the Concrete Surface Zone by Heating the Surface.

Concrete surface is termed as "dry", "moist" and "wet" as follows:

- "Dry" – A freshly created fracture of concrete surface with depth of about 20 mm must not become visibly lighter in colour as a result of drying out than before. In case concrete contains equilibrium moisture for the environment, it is deemed to be dry.
- "Moist"- When the surface of concrete has a matt appearance without any shiny water film and the concrete surface absorbs fresh drops of water applied to its surface, leaving the surface matt again in a short time (i.e. the surface pore structure is not saturated), the surface is termed as moist.
- "Wet"- When the pore structure of concrete surface is water saturated, there may be a surface shine on the concrete but no excess surface water film

The surface of the concrete or of a roughly 2 cm deep freshly reptured surface may be heated, for example with a hot air dryer (i.e. hair dryer), to indicate the presence of concrete moisture exceeding the definition "dry". The moist concretes appear significantly lighter after heating.

A9.2.4 Testing the Moisture Content of the Concrete Surface Zone with a CM Device.

a) Purpose and Use:
The method may be used to determine the moisture content of the concrete substrate.

b) Brief Description:

(1) Pieces of concrete removed from the concrete surface zone are crushed rapidly with a pestle in a porcelain bowl and weighed. The sample (Table A9.2) is placed in a pressure bottle together with a quantity of calcium carbide (5 g glass ampoule). The bottle is shaken vigorously several times, so that previously added steel shot breaks the glass ampoule. The mixing of the sample and the calcium carbide allows a chemical reaction between the water in the sample and the calcium carbide, releasing acetylene gas. The resulting gas pressure is proportional to the moisture content of the sample, and is read off via a pressure gauge.

(2) The moisture content associated with a particular pressure reading is given in Tables A9.3. to A9.5

Table A9.2: Required weight

	Estimated moisture content 1	Required weight 2 Mortar	 Concrete
1.	1.05% to 2.5 %	50 g	50 g
2.	3.0 % to 5.0 %	20 g	20 g
3.	5.5% to 7.0 %	20 g	10 g
4.	More than 7 %	10 g	10 g

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Table A9.3: Pressure in bar for maximum grain size up to 4 mm

	Pressure for 50 g weight			Moisture content [%]
	1	2	3	4
	after 15 min	**after 20 min**	**after 25 min**	
1.	—	—	0.330	1.0
2.	—	—	0.495	1.5
3.	—	—	0.655	2.0
4.	—	—	0.820	2.5
	Pressure for 20 g weight			
	ater 15 min	**after 20 min**	**after 25 min**	
5	—	0.380	0.390	3.0
6	—	0.500	0.510	3.5
7	—	0.615	0.625	4.0
8	—	0.735	0.745	4.5
9	—	0.855	0.865	5.0
10	—	0.970	0.980	5.5
11	—	1.090	1.100	6.0
12	—	1.325	1.335	7.0

Table A9.4: Pressure in bar for maximum grain size up to 8 mm

	Pressure for 50 g weight			Moisture content [%]
	1	2	3	4
	after 15 min	**after 20 min**	**after 25 min**	
1	—	—	0.335	1.0
2	—	—	0.510	1.5
3	—	—	0.685	2.0
4	—	—	0.860	2.5
	Pressure for 20 g weight after 15 min	**after 20 min**	**after 25 min**	
5	—	0.405	0.415	3.0
6	—	0.550	0.560	3.5
7	—	0.690	0.700	4.0
8	—	0.835	0.845	4.5
9	—	0.975	0.985	5.0
10	—	1.120	1.130	5.5
	Pressure for 20 g weight after 15 min	**after 20 min**	**after 25 min**	
11	0.475	0.480	0.485	5.5
12	0.530	0.535	6.0	

Table A9.5: Pressure in bar for maximum grain size up to 16 mm

	Pressure for 50 g weight			Moisture content [%]
	1	2	3	4
	after 15 min	**after 20 min**	**after 25 min**	
1	—	—	0.340	1.0
2	—	—	0.605	1.5
3	—	—	0.870	2.0
4	—	—	1.130	2.5
	Pressure for 20 g weight after 15 min	**after 20 min**	**after 25 min**	
5	—	0.580	0.585	3.0
6	—	0.750	0.755	3.5
7	—	0.915	0.925	4.0
8	—	0.085	1.095	4.5
9	—	1.255	1.270	5.0
	Pressure for 10 g weight after 15 min	**after 20 min**	**after 25 min**	
10	0.715	0.725	0.730	5.5
11	0.845	0.850	0.855	6.0

c) Test apparatus and other materials required

- CM pressure bottle with pressure gauge.
- Electronic scales (accuracy 0.1 g)
- Analytical sieve with 2 mm mesh size
- Porcelain Bowl (with collar ring to prevent portions of the sample escaping) with a pestle
- Steel shot, calcium carbide ampoules, stopwatch
- Hammer and chisel
- Other accessories.

d) Procedure

Step-1 Use the hammer and chisel to remove fragments of the concrete under test to a depth of 2 cm (10 to 50 g).

Step-2 Use the hammer to crush the fragments in the porcelain mortar (do not crush individual aggregate grains)

Step-3 Pass the sample through an analytical sieve (mesh size 2 mm).

Step-4 Weigh out the required sample (see Table A9.2) on the electronic scales.

Step-5 Place first the steel shot and then the weighed sample in the bottle, without losing any of the sample.

Step-6 Tilt the bottle slightly and carefully slide in an ampoule of calcium carbide.

Step-7 Place the cap with pressure gauge on the bottle and secure it with the tightening levers.

The above operations must be carried out quickly, to avoid loss of moisture.

Step-8 Break the glass ampoule by shaking the bottle with a vigorous rotary motion.

Step-9 Repeat the shaking operation once every 5 minutes up to the final reading.

Step-10 Determine the moisture content (in W.%) as a function of sample weight and maximum grain size associated with the final pressure reading from Tables A9.3. to A9.5

Step-11 On completion of the test, open the bottle carefully (Caution : the bottle is under pressure) and allow the acetylene gas to escape (Caution : no naked flames).

Step-12 Carefully pour away the contents (Caution : un-hydrated lime and glass fragments) and clean the bottle with a clean bottle brush.

Step-13 Clean the steel shot with a dry cloth. Clean the bottom of the pressure gauge (rubber washer).

e) Likely sources of error

1) A substantial difference in temperature between the pressure bottle and the surroundings.
2) Bottle not gas-tight sealed (e.g. damaged washer, material residues under the rubber washer).
3) Calcium carbide ampoule leaking before insertion (light brown stain).

A9.2.5 Testing Construction Materials or Components for Water Penetration Using a Water Penetration Gauge

a) Purpose and Use

The water penetration test with a water penetration gauge indicates the behaviour of a construction material or component in response to the effects of water, it measures the volume of water penetrating per unit time in a construction material which is air-dry at the beginning of the test.

b) Test Apparatus and other materials required

(1) The penetration gauge is supplied in two versions, for vertical and horizontal test surfaces. It consists of a glass measuring tube with a calibrated ml scale, opening at the bottom into a bell with a diameter of 30 mm.

(2) The water penetration gauge is sealed water tight to the test surface, using a plastic sealant (e.g. Plastellin, butyl rubber). For tests over a lengthy period, it is advisable to use an elastic curing sealant (e.g. silicon rubber).

c) Measuring Points

- The measuring points must be positioned in such a way that the test results are representative for the concrete under test. The measuring points must therefore be distributed throughout the test area or must be determined on statistical principles. The measuring points must be marked and the markings recorded in the test report.
- At least 6 measuring points must be used for each test area.

d) Procedure

Step-1: The sealant is placed in a collar round the edge of the bell. The bell is pressed on to the measuring point to form a watertight seal with the component surface. The sealant inside the bell should leave a circular area of the component with a diameter of roughly 20 mm exposed.

Step-2: To carry out the test, tap water is poured into the tube up to the zero mark, so that water in contact with concrete surface remains under a pressure of approximately 100 mm water column.

Step-3: The fall in the water level is measured at appropriate intervals. As soon as 1 ml to 2 ml of water have penetrated the concrete, the tube is refilled with water to the zero mark, to maintain approximately constant water pressure. The times of measurement, fall in the water level, temperature conditions and moisture state of the concrete surface are to be recorded in the report.

e) Test Report

The following items are to be recorded in the test report:
Quantity of penetrating water per unit time

Temperature conditions
Moisture state of the test area.

A9.2.6 Testing the Wet-ability of Concrete Surfaces

a) Purpose and Use:

The method supplies indicative values for assessing the absorptive capacity of concrete surfaces.

b) Brief Description:

The wettability of a concrete surface is tested by spraying it with water and assessing the pearling effect (no pearling, slight pearling or strong pearling).

c) Procedure:

- A spray bottle is used to place a few drops of water on the test surface. The result may be penetration of the surface zone, recognizable through the formation of dark stains, or more or less pronounced droplet formation (pearling).
- The pearling effect is influenced by the nature of the surface – chiefly its porosity and the degree of contamination – and, where relevant, by the type of surface treatment and the materials employed. It does not usually constitute a sufficiently reliable means of assessing the efficacy of impregnation measures.

A9.2.7 Determination of Surface Roughness Using the Sand Area Method.

a) Purpose and Use:

The method is used to determine the mean peak to valley height of a horizontal substrate surface. The test is carried out after pretreatment of the substrate.

b) Brief Description

(1) A defined volume of sand (Volume V) is distributed in a circular configuration on the test surface, in such a way that the dips are just filled.

(2) The mean peak to valley height Rt is defined as the height of an imaginary cylinder with a diameter d and a sand volume V.

c) Equipment and ancillary materials

- Vessel with a known internal volume V, e.g. 50 cm^3.
- Dry quartz sand, grain size 0.2 – 0.5 mm
- Hardwood disc (diameter 5 cm, thickness 1 cm) with a handle in the top center.
- Rule.

d) Measuring points

The measuring points must be positioned in such a way that the test results are representative for the test concrete. The measuring points must therefore be distributed over the test area or selected according to statistical principles. The measuring points must be marked and the markings recorded in the report. At least 3 measuring points must be used for each test area.

e) Execution of the test

- Fill the vessel with quartz sand and pour the contents on to the dry, clean surface.
- Rub the sand into the dips in the surface without applying pressure and using a spiral rotary motion until the dips are just filled.
- Measure the diameter of the circle.

The mean peak to valley height is obtained from the sand volume V (cm3) and the diameter d (cm) of the roughly circular sand distribution using the formula:

$$Rt = \frac{40\ V}{pd^2}\ (mm)$$

f) Test report
The mean peak-to-valley height in mm must be given in the report.

A9.2.8 Establishing crack characteristics:

a) General

(1) Special care must be taken when establishing the characteristics of cracks, in order to allow qualified assessment of the need for and type of crack – filling.

(2) On exposed structures, the most important crack characteristics (crack width and changes in crack width) are subject to weather – related changes. When these characteristics are established, at least the following additional data must therefore be recorded:
- date, time
- whether conditions, i.e. air temperature, cloud cover / rain (including values on preceding days)
- component temperature in the crack-influencing zone, both in the interior and on the surface of the component.

(3) Whether the change in crack width during the course of the day is observed, the relevant data must be recorded several times each day. Where changes in crack-width are traffic related, characterization of the traffic may be necessary in order to allow more effective analysis of the results. The selected measuring periods should be such that adequate conclusions on short term and daily changes in crack width at the planned filling time can be inferred from the results.

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b) Measurement of crack width and changes in crack width

(1) Crack widths should be given to an accuracy of 0.1 mm. It will usually be sufficient to compare the crack width visually with a calibrated line on a line-width rule (draughtsman's rule). Experience is needed to use a crack magnifier; it does not invariably ensure greater accuracy and is not usually essential.

(2) Methods with differing sensitivity can be used to measure the changes in distance associated with changes in crack width:
Crack magnifier.
Thin plaster markers are applied by brush to the concrete surface. When the cracks in the concrete widen, cracks also appear in the plaster. Their width can readily be determined with the crack magnifier. Repeated readings to an accuracy of 0.01 mm can be used to follow slow changes in crack width, including long – term alterations. If necessary, a number of plaster markers may be applied at intervals to the same crack.
Laboratory methods:
These mechanically or electrically based methods can be used only by properly trained and experienced personnel. They register even extremely short-term changes to an accuracy of 0.001 mm.

(3) On superstructures of monolithic bridges and similar structures exposed to direct weathering, there are daily changes in crack width, in some cases dependent on insulation. The maximum changes are to be expected on cloudless days in the summer months, but not on days with high cloud cover and high air temperatures. At the maximum crack width, influences of traffic also usually lead to the extreme values of short-term changes in crack width.

c) Drilled cores

Drilled cores can be used to determine type of crack, the state of the crack and crack edges and any previous measures. Drilling cores invariably represents a disturbance, and should therefore be restricted to exceptional cases. Appropriately experienced personnel can often avoid the removal of drilled cores.

3.2.9. Testing the Processing Conditions

A9.2.9.1. Air Temperature

a) Apparatus and Instruments

(1) The following instruments may be used to measure the temperature of the air.:

- mercury thermometers
- bimetallic strip thermometers
- electrical digital thermometers
- thermographs.

(2) Automatic temperature recorders should be used in the open air and where there are severe fluctuations in temperature.

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(3) the accuracy of reading should be at least 1^{O}C.

b) Performance of the measurements

(1) the measurements should be made in the immediate vicinity of the works..

(2) the temperature sensor should not be exposed to direct solar radiation.

(3) The intervals between measurements must be such that temperature change > 2ºC are detected.

A9.2.9.2. Relative Atmospheric Humidity

a) Apparatus & Instruments

(1) The following instruments may be used to measure relative atmospheric humidity:

- hair hygrometers
- electrical digital hygrometers
- hygrographs.

(2) The accuracy of reading must be at least 1% relative atmospheric humidity (5% relative atmospheric humidity in the case of hygrographs). The instruments must be checked prior to commencement of the work, and adjusted as necessary. For this purpose, the senor is to be wrapped in damp cloths, avoiding any direct moistening. The instrument must then read 95-98% relative atmospheric humidity.

b) Performance of the measurements

The instruments must not be exposed to direct solar radiation.

A9.2.9.3. Component Temperature

a) Apparatus & Instruments

The instruments specified in A9.2.9.1. a) may also be used to measure component temperatures; the use of electrical digital thermometers is preferred.

b) Performance of the measurements

(1) Measurements of surface temperature should preferably be made on components whose temperature may be lower than that of the air, as a result of their position and size, and taking into account the preceding weather conditions. Thermometers with contact sensors must be used. The intervals between measurements must be such that any impending drop in temperature below the dew-point can be detected in good time.

(2) Measurements of temperature in the interior of components must be made in drilled holes with a diameter of approximately 8 mm and a depth of at least 50 mm. The holes must be sealed at the component surface with a heat insulating material.

A9.2.9.4 Dew-Point Temperature

(1) The dew-point temperatures corresponding to the measured air temperatures and relative atmospheric humidities may be taken from standard tables.

(2) The dew-point temperature determined in this way must be compared with the component temperature.

A9.3. Repair Concretes or Mortars

Testing the Inherent Moisture, Surface Moisture and Core Moisture of Aggregate.

(1) Inherent moisture is generally determined by the dehydration test. To determine the surface moisture, it will then generally be sufficient to employ the recommended core moisture values, which are measured during determination of inherent moisture normally vary from 0.5 to 2.2 % depending upon the type of aggregate for 0 to 32 mm aggregate,.

(2) The dehydration test is usually made with the samples envisaged for the sieve test, as the aggregates must in any case be dried for sieving.

(3) A quantity of roughly 3500 g is weighed out from an average sample and heated under continuous agitation until the surfaces of the individual grains are dry and the grains no longer adhere to one another. The sample is re-weighed after cooling. The inherent moisture is calculated from the loss in weight by reference to the dried materials.

(4) Para A9.2.4 can be used to determine the surface moisture of aggregate with a maximum grain size of upto 4 mm quickly, and, if used properly, with sufficient accuracy. The larger device holding 200 gm of aggregate is to be preferred, owing to its greater accuracy.

(5) The surface moisture of aggregate of any maximum grain size can also be determined by the flame method, using the AM device. The moist aggregate is weighed and an inflammable liquid is poured over it and ignited. The resulting heat causes the water to evaporate. The difference between the moist and dry weights indicates the water content; the surface moisture is determined by reference to the dry weight.

(6) The Thaulow test provided a further means of determining surface moisture. The core moisture of aggregate with a maximum grain size exceeding 4 mm is determined by immersed storage and subsequent drying of the grain surface. Approximately 1000 g

of the relevant grain class is kept immersed in water for at least 24 hours. The aggregate grains are then dried with a moist cloth and filter paper. The aggregate treated in this way is poured on to a 2 mm sieve and turned while being heated from below by a current of air, for example from a hairdryer or a fan heater, until the surface moisture has apparently dried out. The sample is then weighed to an accuracy of 1 g (mg.k), dehydrated and re-weighed (mg.0d). The difference between the two weights is the core water quantity of the sample. The core moisture is then

$$h_{g,k} = \frac{100mgk\ -mg\ Od}{mg.0d} \qquad (M.\%)$$

(7) If the sand is of the same mineral composition as the coarse grains examined, the same core moisture may be assumed.

(8) The same test can be employed to estimate the influence of dry aggregate on the stiffening of green concrete. In this case, however, immersed storage is for 30 minutes only.

A9.4 Surface Protection Systems

A9.4.1. Testing the Thickness of Coatings on a Drilled Core

(1) Small-diameter drilled cores (50 mm or less) are removed. Local changes in layer thickness due to drilling must be taken into account, and where necessary counteracted by appropriate measures. The layer thickness is determined on the surface area, using a measuring magnifier or microscope.

(2) The measurement is not non – destructive, and must therefore be restricted to justified cases, e.g. irregularities during performance of the works. Sections are required in order to determine the exact thickness of thin layers and of sub-layers in multi-layer systems. The work must be entrusted to a specialist laboratory.

A9.4.2. Testing Adhesive Strength

a) Terminology

The term adhesive strength denotes the tensile force, which must be applied perpendicular to the coating plane over a defined test area in order to detach a coating from its substrate. This definition means that specimens, which rupture in the substrate concrete or within the coating rather than at the interface may not be taken into account when calculating adhesive strength.

b) Test dies and test equipment

(1) Steel test dies (pulling plates) with a circular bonding face and a diameter of ds=50 mm $\pm$ 2 mm are employed. The test die must be at last 25 mm in thickness; the thickness remaining below central drillings or recesses must be not less than 15 mm.

(2) The tests may be carried out with portable or fixed tensile strength testing equipment. The measured value must be indicated with a resolution of 2% of the force range being measured. The equipment must possess a device for maintaining a constant loading velocity.

(3) Simpler equipment may be used for internal supervision.

(4) The equipment must be designed in such a way that the tensile force can be applied to the test surface free of shear forces and moments. It must be possible to adjust

the equipment above the test die in such a way that the axes of the test die and the working piston are in a straight line.

c) Performance of the tests

(1) The test areas must be selected in such a way that the distances of the test surface edges from one another or from the edge of the component are at least equal to the diameter of the test area.

(2) The test area must be freed of loosely – adhering dirt before the test die is bonded to it. The test surface must be bounded by a ring groove and must be sufficiently dry for bonding.

(3) On hard coatings, the ring groove is drilled wet or dry with a diamond – charged bore-crown. The bore-crown should drill through the coating and penetrate 5 to 10 mm into the concrete. The inside diameter of the ring groove and the outside diameter of the test die must be matched with one another in such a way that the die can be bonded flush to the exposed cylinder. A bore-crown in good cutting condition with rounded cutting edges must be used, to avoid notching of the ring groove root. The exposed cylinder may not be damaged in any way prior to the test. Drilling dust or sludge must be removed thoroughly.

(4) On soft coatings, the test area must be parted through to the concrete after the test die has been bonded on. The cut must be made flush with the circumference of the test die. A sharp knife can be used for cutting.

(5) In general, rapid hardening cold-curing resin adhesives in paste form should be used. The temperature range specified by the manufacturer is to be maintained during the bonding process.

(6) The test die must be placed on the surface in such a way that excess adhesive is pressed out of the joint and air entrapments are avoided. Any adhesive squeezed out of the joint or penetrating into the ring groove must be removed.

(7) After bonding, the die face must be parallel with the test face; the bonding layer must be as thin as possible.

(8) The tensile strength testing machine must be arranged and centred in such a way that the taxes of the test die and the piston lie in a straight line.

(9) On hard coatings, the force should be increased continuously in such a way that the tensile stress in the bonded joint rises by roughly 0.05 N/mm^2 per second. For ds = 50 mm, this is equivalent to a force increase of approximately 100 N/s.

(10) On soft coatings, the tensile stress should increase by roughly 0.15 N/mm^2 per second. For ds= 50mm, this is equivalent to a force increase of approximately 300 N/s.

d) Evaluation of the results

(1) The visual appearance of the rupture surface is to be evaluated, distinguishing between the following seven cases:

B	-	rupture in the concrete
B/D	-	rupture in the concrete /coating interface
D1/D2	-	rupture in the coating 1/coating 2 interface
D	-	rupture in the coating
D/K	-	rupture in the coating/adhesive interface.
K	-	rupture in the adhesive.
K/S	-	rupture in the adhesive / steel interface.

(2) Only cases B/D and D1/D2 are used in calculating adhesive strength. Supplementary consideration of cases B and D is permitted for estimation of a definitely exceeded adhesive strength in cases where concrete or coating strengths are relatively low.

(3) Where rupture takes place at various levels, the proportions of the different rupture surfaces are to be estimated. The relatively largest component area determines which case the rupture is assigned to.

(4) The adhesive strength is calculated from the maximum attained force F:

$$BHZ = \frac{4.\ F}{pd^2} \ (N/mm^2)$$

The adhesive strength must be given to an accuracy of 0.1 N/mm^2

e) Test report

The test report must cite:

- the test date
- construction site, component
- position and marking of the test area
- type of coating
- diameter of the test die
- weather conditions during preparation and execution of the tests
- preparation of the test area, type and depth of pre-drilling or cutting
- course of the rupture or description of the parting case
- maximum force and calculated adhesive strength (single values, mean value).
- Where relevant, the definitely exceeded adhesive strength.

A9.4.3 Voids Content of Surface Protection system

(1) At the beginning of, during and at the end of each days work, and at least once for every 250 m² of area treated, sprayed specimens distributed uniformly over the area must be taken. The specimens must be taken under sealant spraying conditions directly at the point of use. The specimens are sprayed onto a foil or plate measuring at least 50 cm x 50 cm, with a thickness of approximately 3 mm.

(2) A small specimen of the hardened coating material is cut out of the sprayed specimen and placed in a material – specific test liquid (corresponding to the density for the value H_{max} determined in the basic test minus 3% absolute; the test liquid is supplied by the manufacturer).

(3) The specimen piece must sink immediately to the bottom of the test vessel (e.g. 1 glass cylinder with measuring scale). If the specimen piece does not fall to the bottom, the test must be repeated with a number of specimen pieces. If the result remains the same, the precise value of the actual voids content must be determined.

(4) The mean value of the 3 single measurements must not exceed the maximum voids content H_{max} established in the basic test.

A9.4.4. Grid Test with Tape Test

(1) The coating under test and its substrate should have largely smooth surfaces. Textured shells and rough sawn shuttering without filling are unsuitable.

(2) At each measuring point, 4 cuts perpendicular to one another are made with Cutter, so that a grid with 9 squares are produced. The distance between the parallel cuts should be 4 mm. After the grid has been cut, the measuring point is assessed according to the grid test parameters.

(3) A commercial transparent adhesive tape with a width of 30 mm is then applied to the grid made for the grid test, keeping the pressure as even as possible (with a finger or a soft rubber roller), and is pulled off sharply after roughly 1 minute (tape test).

(4) Following each individual test (grid test plus tape test) the measuring point is assessed with the aid of an illuminated magnifier (magnification 6x) according to the grid test parameters.

A9.5. Treatment of Cracks

A9.5.1 Testing the Degree of Crack-Filling on Drilled Cores

(1) Drilled cores provide the only reliable means of determining the completeness of filling. A check should therefore be made only in justified cases, i.e. where there have been irregularities during execution of the works where faults in the filling are visible externally.

(2) Small-diameter drilled cores (50mm or less) are taken from characteristic sections of the filled cracks. The degree of crack-filling is determined from the visual appearance of the drilled core surface, where necessary with the aid of a magnifier or a microscope.

(3) the crack width and the lengths of the filled and un-filled sections of the cracks are determined on the surface of the drilled core.

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CASE STUDIES

Life is a series of exprіences, each one of which makes us bigger, even though sometimes it is hard to realise this.

..Henry Ford

CONTENTS

CASE STUDY - 10.1

FOUR STOREYED RCC FRAMED RESIDENTIAL QUARTERS AT MUMBAI

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(Source: Repairs & Rehabilitation Unit, CDO, CPWD, New Delhi)

SALIENT FEATURES

- Period of construction : 1964 – 68
- Investigation done : 1997
- Type of structure : Four storied RCC frame structure.
- Location : At 1.0 km from sea shore. Chemical and petroleum industries located in the immediate vicinity of the building.
- Number of quarters : 5000

VISUAL OBSERVATIONS

1. Excessive cracking, spalling of concrete in RCC elements.
2. At many locations the diameter of steel reinforcement reduced by more than 15% of the original area provided.
3. Concrete cover on reinforcement was mostly less than the specified.
4. The diagonal cracks observed in brick masonry walls at many places.
5. Gunited RCC columns and slabs heavily cracked and damaged.
6. The quality of repairs already carried out is not very good.
7. Few of declared dangerous building collapsed and few other on the verge of collapse.

IN-SITU EVALUATION AND LABORATORY TESTING

Core Test

The test results were as under-

Test	Average Value
Equivalent compressive cube strength	73.29 kg/cm^2
Density of concrete	2231 kg/m^3

Carbonation Test

Carbonation has taken place beyond the reinforcement levels in columns, beams and slabs. However, in case of slab top portion covered with flooring/terracing is generally not affected due to carbonation.

Rebound Hammer Test

The rebound numbers measured on concrete surfaces of RCC columns, beams and slab. Rebound values were as under-

Member	Rebound Value	Number of Reading (in %)
Columns	10-20	65
	20-25	35
	25-30	Nil
Beam	10-20	22
	20-25	56
	25-30	22

Ultrasonic Pulse Velocity Test

Values of the pulse velocity recorded by directed method varied mostly in the range of from 0.64 to 2.50 km/sec. The tests results were as under-

Pulse Velocity (km/sec)	Number of reading (in %)
0.0-2.0	60
2.0-2.5	25
2.5-3.0	15

Half- Cell Potential Test

Large numbers of observation were taken and it was observed that the range of corrosion potential measured from (-) 83 mV to (-) 530 mV. The test values were as below-

Electric potential	No of Reading (in %)	Probability of corrosion
< -200 mV	20	<10%
> -200 mV but < -350 mV	57	10% to 90%
> -350 mV	23	>90%

Chemical Analysis of Concrete

a) Water soluble sulphate ions express by weight of cement were within the permissible value of 4% by weight of cement.

b) Water soluble chloride ions expressed by weight of cement were 0.45% and exceeded permissible limits.

CONCLUSIONS

The main cause for early distress to RCC structures of the building is.

a) Excessive chloride content in concrete.

b) High level of humidity in air combined with hot climate throughout the year

c) Presence of atmospheric CO_2 combined with other industrial polluting gases (like CO_2,SO_2,CO,SO_3,H_2S etc), environment is highly acidic causing accelerated carbonation of concrete and corrosion of reinforcement. Even, rainwater becomes acidic due to dissolution of such gases and adds to accelerated carbonation.

d) Quality of cover concrete and inadequacy of its thickness is another important factor for early deterioration of the structures under aggressive environment.

RECOMMENDED REPAIR METHODS

A) Slabs

Provide alternate structural system comprising of RSJ's spaced at about 1.00 Metre to Support RCC slabs as per Appendix 6.1.

B) RCC Beams

Carry out structural Repairs to RCC beams as per Appendix 6.1

C) RCC Columns

Carry out structural Repairs to RCC columns as per Appendix 6.1

Plate 1: Typical View of one Block of Type-III Qrs

Plate 2: Typical View of one Block of Type-I Qrs

Plate 3: Earlier repaired Column Damaged again due to corrosion

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Plate 4: Reduction of clear bay width due to increased volume of corroded reinforcement of RCC columns causing compression of balcony railing

Plate 5: Damaged RCC Chhajja

Plate 6: Cracked RCC column near plinth protection

Plate 7: Cracked RCC Column at corner due to Corrosion of steel reinforcement

Plate 8: Repaired column

Plate 9: Structural Repairs in progress

Plate 10: Structurally repaired block before finishing before finishing

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CASE STUDY - 10.2

FOUR STOREYED LOAD BEARING RESIDENTIAL QUARTERS AT NEW DELHI

(Source: Repairs & Rehabilitation Unit, CDO, CPWD, New Delhi)

SALIENT FEATURES

- Period of construction : 1979-84
- Investigations done : 1996
- Type of super-structure : Load bearing
- Type of foundation : Spread footing
- Total no.of quarters in colony : 2115

VISUAL OBSERVATIONS

1. Extensive cracking and spalling of concrte in slab, chajjas.
2. At some places reinforcement is exposed and corroded.
3. Cover of reinforcement was not proper.
4. Visual inspection of core reflect that concrete is porous in bottom portion of slab.
5. Reinforcement in chajjas is seen near bottom instead of top.
6. Terracing done with mud-phuska was having depression at places with joints of tiles opened up

IN-SITU EVALUATION AND LABORATORY TESTING

Rebound Hammer Test

Rebound numbers were measured on concrete surfaces of RCC slabs. Rebound values were as under—

Rebound Value	Number of Reading (in %)
10-20	nil
21-25	46
26-30	54
30-35	nil
36-40	nil

Evaluation of Carbonation Depth of Concrete

Carbonation depth of concrete in slab measured and bottom 40 to 60 mm depth observed as carbonated, whereas top is unaffected.

Bar Diameter

Bar dia was checked with verniers caliper and it is found that reduction in dia of reinforcement is about 10 to 40% of the original.

Core Test

Cores were cut at random and tested in laboratory. The test results reveal that concrete is of poor quality.

Chemical Analysis of Concrete

The chemical analysis was carried out to examine the chlorides and sulphates contents and it is observed that these are within permissible limits.

CONCLUSIONS

1. Inadequate thickness and poor quality of cover concrete, carbonation depths from bottom face of RCC slabs were invariably beyond reinforcement level whereas from top face, the concrete was generally uncarbonated.
2. At many locations steel reinforcement reduced to less than 85% of cross sectional area.
3. Most distressed portions were the chajjas, terrace slabs, sunken slabs in kitchen and toilet areas, connecting corridor directly exposed to atmosphere and frequented by wetting/drying.
4. In projected portion of terrace steel reinforcement is provided at top level.

RECOMMENDED REPAIR METHODS

a) Slabs

Provide alternate structural system comprising of RSJ's spaced at about 1.00 Metre to support RCC slabs as per Appendix 6.1.

b) Beams

Carry out structural Repairs to RCC beams as per Appendix 6.1

c) RCC projection at terrace level

Reduction of large terrace level slab projection to about 200 mm beyond the outer face of wall with drip course at its end as under:

1. RCC slab to be cut/broken along notch made with diamond cutter to a depth of 40 mm or more at 200 mm beyond outer face of wall.
2. Polymer modified cement plaster 12 mm thick to be applied over a bond coat of polymer modified cement slurry to seal the exposed cut face of slab.
3. The disturbed mud phuska to be restored.

d) RCC Chhajjas

1. RCC chajjas to be restored as per Fig 8.1.
2. Additional chajjas to be provided over the doors/windows at top floor wherever not provided originally.

e) Terracing

Redo the terracing after cleaning the RCC slab, application of Kerosene primer and application of bituminous coating, laid to adequate slope and joints of tiles properly sealed with cement mortar admixed with water proofing compound.

CASE STUDY – 10.3

FOUR STOREYED LOAD BEARING RESIDENTIAL QUARTERS WITH RCC COLUMNS AT CORNERS AT NEW DELHI

(Source: Repairs & Rehabilitation Unit, CDO, CPWD, New Delhi)

SALIENT FEATURES

- Period of construction : 1979
- Investigation done : 1997
- Type of structure : Four storeyed load bearing brick masonry buildings with RCC columns at corners without any connecting beams.
- Number of quarters : 248

VISUAL OBSERVATIONS

1. Extensive cracking and spalling of cover concrete in RCC elements.
2. The projection of the main roof slab at terrace level either pulled down or collapsed at places due to wrong placement of steel, porous concrete and due to excessive thickness of mud phuska at free edge.
3. At some places reinforcement exposed and corroded.
4. Many RCC balcony slabs and end beams were in seriously unsafe condition. Deflection was observed to be excessive at places.
5. The cross sectional area of some reinforcement reduced to the extent of 50% and in many columns ties on external face totally vanished due to corrosion.
6. In many flats, longitudinal cracks observed in door/ windows lintels.
7. Bathrooms, W.C. and kitchen slabs damp and distressed.
8. The floors of bathrooms, W.C. and kitchen in ground floor flats generally settled and damaged due to leakage from floor traps and poor compaction of plinth.
9. The external plaster damaged at places.
10. Horizontal cracks observed running at bedding level of RCC slabs and RCC shelves in all single storyed scooter/ cycle garages.

IN – SITU EVALUATION AND LABORATORY TESTING

Core Test

The test results were as under-

Test	Average Value
Equivalent Compressive Cube Strength	124 kg / cm^2
Density of Concrete	2271 kg / m^3

Carbonation Test

Carbonation has taken place beyond the reinforcements levels in almost all the cases.

Rebound Hammer Test

The rebound values on concrete surface of column, beams and slab were as under-

Rebound Value	Number of Reading (in %)
11-15	31
16-20	43
21-25	14
26-30	12

Ultrasonic Pulse Velocity Test

The test was carried out extensively and values observed are given below-

Pulse Velocity (km/s)	Number of Readings (in %)
Below 2.50	84
2.50-3.00	5
3.00-3.50	11

Half-Cell Potential Test

Test results were as under-

Electric potential	No of Reading (in %)	Probability of corrosion
< -200 mV	42	<10%
> -200 mV but < -350 mV	50	10% to 90%
> -350 mV	8	>90%

Chemical Analysis of Concrete

Water-soluble chloride and sulphate ions expressed by weight of cement were within permissible limit.

CONCLUSIONS

1. The main cause for distress to RCC elements was poor quality of concrete
   a) Inadequate thickness of cover concrete.
   b) Highly permeable and porous cover concrete.
   c) Inadequate curing or improper proportioning of concrete.
2. Early corrosion of reinforcement and spalling of concrete due to carbonation of concrete.

RECOMMENDED REPAIR METHODS

RCC Slabs

Provide alternate structural system comprising of RSJ's spaced at about 1.00 Metre to support RCC slabs as per Appendix 6.1

Terrace Projections

Reduction of large terrace level slab projection to about 200 mm beyond the outer face of wall with drip course at its end as under:

1. RCC slab to be cut/broken along notch made with diamond cutter to a depth of 40 mm or more at 200 mm beyond outer face of wall.
2. Polymer modified cement plaster 12 mm thick to be applied over a bond coat of polymer modified cement slurry to seal the exposed cut face of slab.
3. The disturbed mud phuska to be restored.

RCC Chajjas

ALTERNATIVE I –

RCC chajjas to be restored as per Fig 8.1.

ALTERNATIVE II -

1. Existing RCC chajjas to be dismantled, without removing the steel.
2. The rust to be removed from existing reinforcement.
3. Additional reinforcement if required to be embedded in existing beams/ lintels.
4. Casting of RCC chajjas to be carried out with M 20 concrete.
5. RCC chajjas to be finished with cement plaster in cement mortar1: 3 (1cement: 3 fine sand).

RCC Beams of Cantilever Balcony

Carry out structural Repairs to RCC beams as per Annexure 6.1

RCC Columns

Carry out structural Repairs to RCC beams as per Annexure 6.1

Terracing

1. Reduce the dead load due to excessive earth at locations.
2. Redo the terracing after cleaning the RCC slab, application of Kerosene primer and application of bituminous coating, laid to adequate slope and joints of tiles properly sealed with cement mortar admixed with water proofing compound.
3. Correct the expansion joints.

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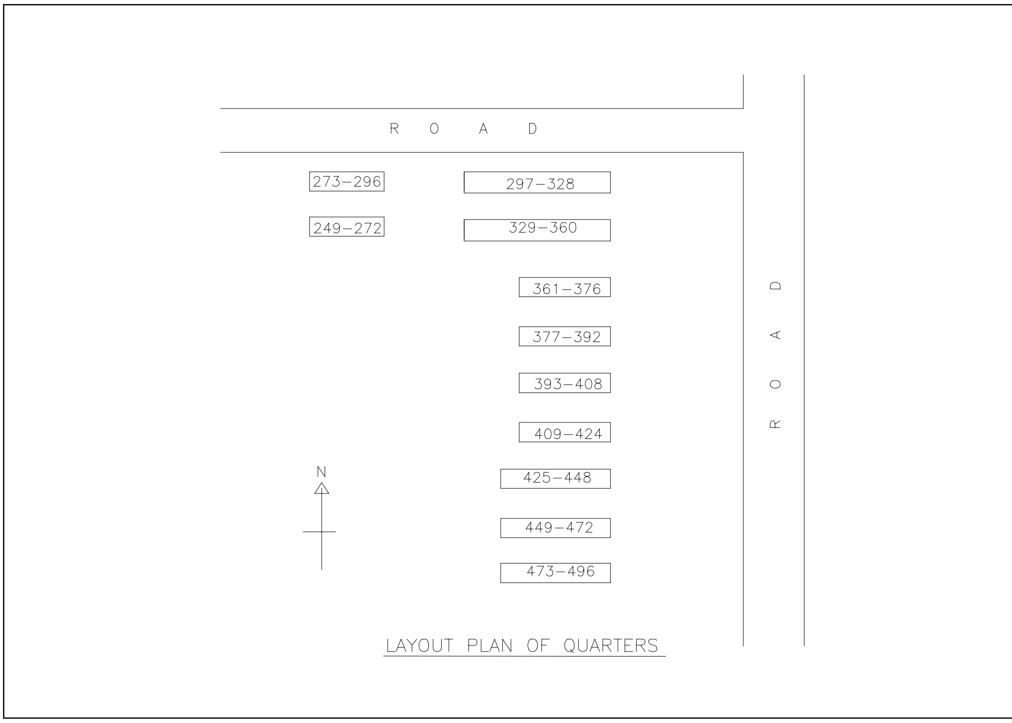

Fig 10.3.1: Lay out of 248 nos Type-II Residential Qrs under Distress

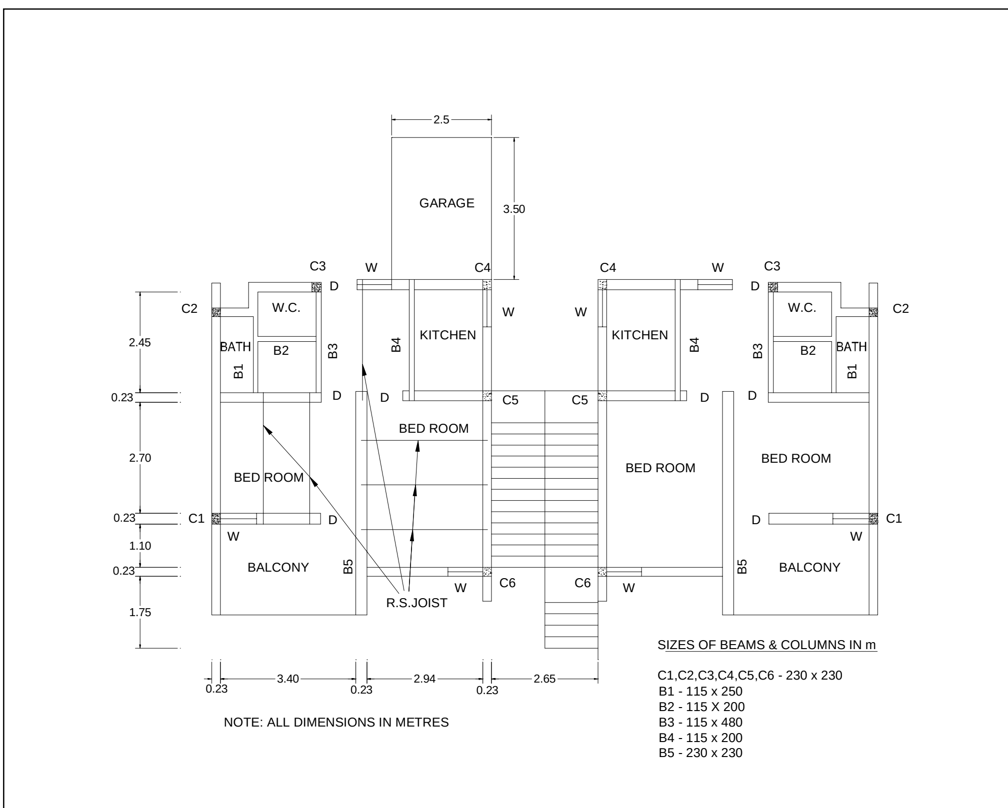

Fig 10.3.2: Typical Floor Plan of a Pair of Residential Type-II Qrs

Plate 1: Typical Front View of two Top Storey Qrs

Plate 2: Typical Rear View of Top Storey Qrs

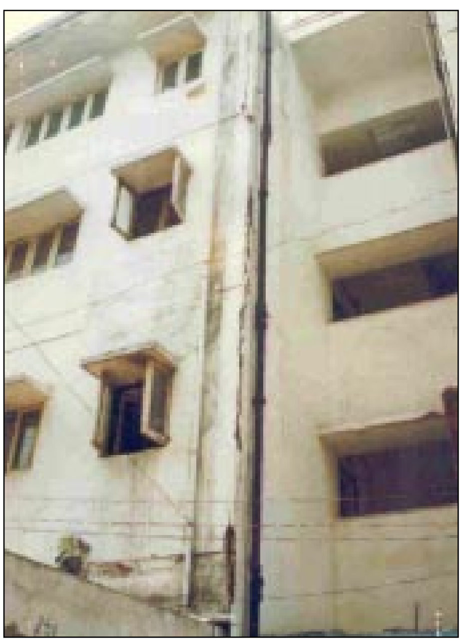

Plate 3: Typical Side View of Qrs

Plate 4: Cracked Column at Rear

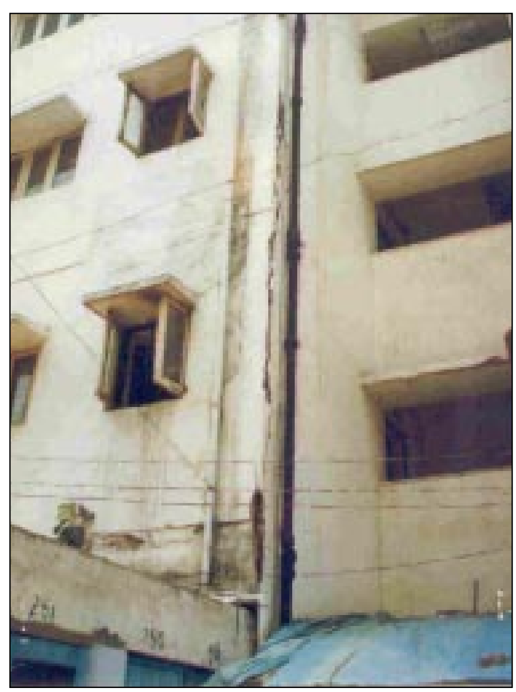

Plate 5: Cracked Column and Vegetation Growth

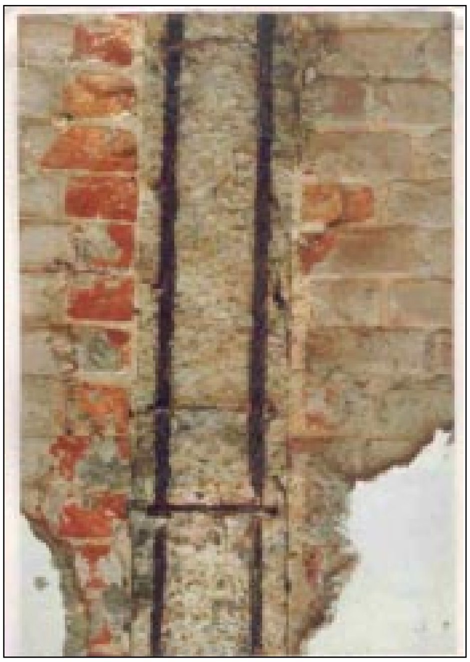

Plate 6: Spalled cover concrete and exposed corroded reinforcement

Plate 7: Spalled Cover Concrete of RCC Slab

Plate 8: Horizontal cracks in Masonry Walls of Single storeyed Garages

CASE STUDY - 10.4

SIX STOREYED RCC FRAMED HOSTEL BUILDING AT NEW DELHI

(Source: Repairs & Rehabilitation Unit, CDO, CPWD, New Delhi)

SALIENT FEATURES

- Period of construction : 1978-79
- Investigation done : 1997
- Type of structure : Six storeyed RCC framed structure with four wings having residential suites and a central portion comprising of staircase and lift lobby.
- No of residential suits : 132

VISUAL OBSERVATIONS

1. Spalling, cracking and splitting of concrete in RCC elements like columns, beams, slabs etc.
2. 4-6 mm wide cracks in columns at lower most storey near the ground level.
3. Cracks noticed along the reinforcement in RCC structural members and at the junction of RCC and brickwork.
4. At some locations, the diameter of reinforcement reduced due to corrosion.
5. RCC columns gunited earlier, developed heavy cracks.
6. The water tank at terrace had earlier leaked continuously.
7. Spalling of concrete observed at bottom of RCC tank and on walls of tank
8. Seepage in the building observed at several places.
9. Leakage observed in G.I pipelines to supply the water to kitchen
10. GI water supply pipe lines passing through the garbage chute damaged due to impact of falling garbage, causing dampness in walls.
11. Vertical Stacks of rain water pipes were observed missing from some places.
12. Washed stone grit plaster fell at many places.
11. Grooves of washed stone grit were not finished properly and allowed water to seep in.

IN- SITU EVALUATION AND LABORATORY TESTING

Carbonation Test

Carbonation has taken place beyond the reinforcement levels.

Rebound Hammer Test

The rebound values were as under-

Rebound Value	Number of readings (in %)
15-20	9
21-30	72
31-40	19

Ultrasonic Pulse Velocity Test

Pulse Velocity (km/sec)	Number of reading (in %)
0.0-2.5	47
2.5-3.0	29
3.0-3.5	12
3.5-4.5	12

Half-Cell Potential Test

Half Cell potential values were as below-

Electric potential	No of Reading (in %)	Probability of corrosion
< -200 mV	77	<10%
> -200 mV but < -350 mV	23	10% to 90%
> -350 mV	nil	>90%

Chemical Analysis of Concrete

a) Soluble chlorides ions expressed by weight of cement was 0.213% and exceeded permissible limit.

b) Sulphate content in mix was 1.293%, which was within permissible limit.

CONCLUSIONS

1. Poor quality of RCC.
2. Inadequate and permeable cover concrete.
3. Excessive chloride content in concrete.
4. Inadequate level of maintenance.
5. Improper workmanship of external finish.

RECOMMENDED REPAIR METHODS

1. Improvement and repair to Civil Services

a) Replace the broken/ damaged drainage and water pipes.

b) Replace the worn out GI pipelines.

c) Relocating of service lines from garbage chute to protect them from damage.

2. Structural Repairs

A) Slabs

Provide alternate structural system comprising of RSJ's spaced at about 1.00 Metre to support RCC slabs as per Appendix 6.1.

B) RCC Beams

Carry out structural Repairs to RCC beams as per Appendix 6.1

C) RCC Columns

Carry out structural Repairs to RCC columns as per Appendix 6.1

D) RCC Parapet Wall

The wall to be reconstructed by using super plasticizer admixed concrete of mix 1:1.5: 3 with w/c ratio not exceeding 0.45.

3. Non Structural Repairs

a) Remove the vegetation growth from roof and other places to avoid further deterioration of building.

b) Routine maintenance defects to be attended to.

c) Concealed service pipes to be shifted to external face of walls.

Plate 1: Front view of F Block

Plate 2: Cracks in column earlier repaired by guniting

Plate 3: Crushed cover concrete and cracking along main reinforcement

Plate 4: Signs of leakage and seepage

Plate 5: Spalled cover concrete in RCC slab ➔

Plate 6: Spalled concrete in RCC parapets ➔

Plate 7: Broken & missing rainwater pipe ➔

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Plate 8: Inaccessible and inadequately sized Service Shafts ➔

CASE STUDY – 10.5

AN OVER HEAD TANK WITH RCC FRAMED STAGING AT DELHI

(Source: Repairs & Rehabilitation Unit, CDO, CPWD, New Delhi)

SALIENT FEATURES

- Year of construction : 1972
- Distressed reported : May 1998
- Period of investigation : January 1999

VISUAL OBSERVATIONS

1. No signs of distress observed in RCC container
2. Signs of initial leakage at the bottom slab of tank could be noticed but no leakage history was reported for the known past.
3. Spalling of concrete cover in bracing beams and columns of staging.
4. Bottom reinforcement of bracing beams exposed and corroded.
5. Congestion of reinforcement in bracing beams was observed to be responsible for honeycombed and hollow bottom cover concrete.
6. Cracks running along the reinforcement were observed in bracing beams and columns.
7. Spalling of concrete also observed in the soffit of stair case slab.
8. Corrosion stains and cracks observed in slab of gallery around water container.

IN-SITU EVALUATION AND LABORATORY TESTING

Carbonation Test

Depth of Carbonation in columns and bracing beams, wherever tested, was beyond reinforcement level.

Chemical Analysis of Concrete

a) The soluble chlorides are within permissible limit of 0.15%.

b) The sulphate content in mix exceeding the permissible limit of 4% but no signs of sulphate related distress observed visually.

CONCLUSIONS

1. Corrosion of reinforcement was due to carbonation of concrete cover.

RECOMMENDED REPAIR METHODS

I) Structural Repairs to RCC columns, bracing beams and slabs

Carry out structural Repairs as per Appendix 6.1

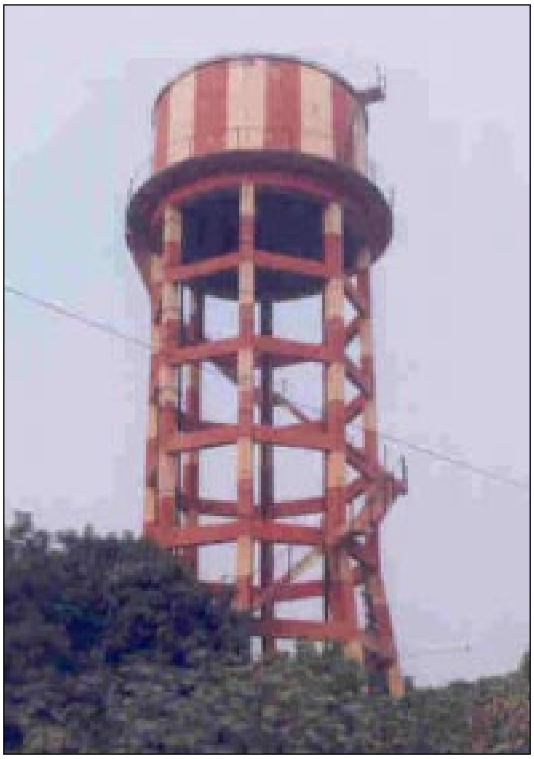

Plate 1: General view of OH Tank

Plate 2: Spalled cover concrete and cracks in waist slab and bracing beams.

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Plate 3: Spalled cover concrete and exposed corroded reinforcement of beam. Longitudinal crack in the top cover concrete.

Plate 4: Spalled and honey combed cover concrete and congested bottom reinforcement of bracing beam.

CASE STUDY – 10.6

A DOUBLE STOREYED LOAD BEARING RESIDENTIAL BUILDING AT MUMBAI

(Source: Shri. J. Bhattacharjee, Additional Chief Engineer, MES)

SALIENT FEATURES

- Year of construction : 1965
- Investigation done : 1998
- Type of strucutre : Double-storeyed load bearing strucutre
- Type of foundation : Spread footing .
- Number of quarters : 44

VISUAL OBSERVATIONS

1. Extensive cracking and spalling of concrete in sunshades, chajja, staircase, beams etc.
2. At some places reinforcement was exposed and corroded heavily.
3. Minor crazing observed on plastering on all faces.
4. Severe seepage seen in most of the roof slab and external walls.
5. Waist-slab of staircase and soffit of beams exhibited delamination over 50%.

IN-SITU EVALUATION AND NON-DESTRUCTIVE TESTS

Delam Survey

Every column and beam was tapped by three different type of hammers. Most effective was the medium hammer, which gave, delams for 15 mm to 25 mm depth. The hollow sound was recorded as hollow and the results of each strucutural members recorded on to observation sheet and that area evaluated for remedial measures.

Rebound Hammer Test

The rebound numbers measured on concrete surfaces.

Ultrasonic Pulse Velocity Test

Values of the pulse velocity varied in the range of from 3.00 km/sec. to 4.8 km/sec.

Half-Cell Potential Test

Electrical potential values indicate that severe corrosion had taken place in some area, as observed during the visual survey.

Carbonation Test

Carbonation has taken place beyond the reinforcement levels.

CONCLUSIONS

1. The main cause for distress to RCC element -

a) Inadequate thickness of cover concrete.

b) Highly permeable and porous cover concrete
c) Carbonation of concrete
2. Most distressed portions were the chajjas along with lintel / beam, which is directly exposed to marine atmosphere and frequented by alternate wetting and drying.
3. Seepage observed in roof slab was due to leekage from pipe line.

RECOMMENDED REPAIR METHODS

1. All sunshades/chajjas including balcony wall, side wall of steps and slab (partly) to be dismantled. To be rebuilt using richer mix of concrete (minimum grade M-25) and adequate reinforcement cover (atleast 10 mm more than normal cover).
2. In the joints between old and new concrete, epoxy based bonding material to be applied on old concrete surfaces.
3. Before removing affected RCC portion, temporary support to the structure to be provided properly.
4. The use of lightweight pre-cast lintels/chajjas in lieu of cast-in-situ was suggested. Accordingly corrugated sheets were provided.
5. For RCC members, where overall integrity found good, cracks to be filled by putting epoxy grouting under pressure. For spalled concrete, polymer modified mortar/concrete with epoxy bond coat to be provided.

The painting to complete surface to be applied with ceemnt based paint with addition of polymeric compound.

Plate 1 : Part view of quarters before repair

Plate 1(a)

Plate 1(b)

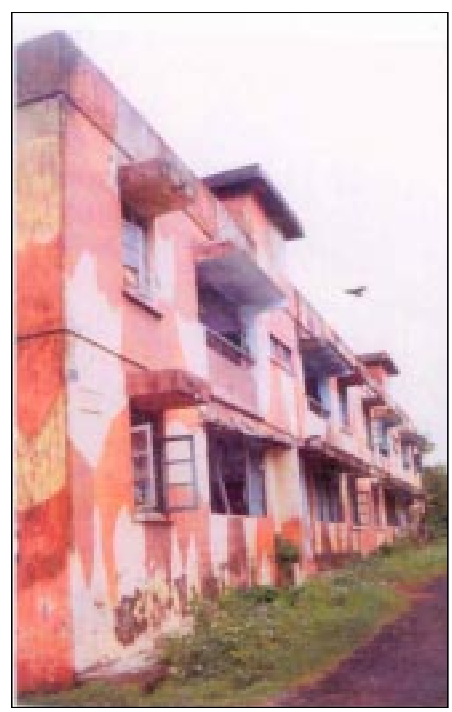

Plate 1(c)

Plate 2 : Part view of quarters before repair

Plate 1(a)

Plate 1(b)

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Plate 1(c)

CASE STUDY – 10.7

A HOTEL BUILDING AT SEYCHELLES

(Source: Shri H. S. Bakshi, Consultant, Engineering Development and Consultant)

SALIENT FEATURES

- Year of construction : 1975
- Investigations done : 1996
- Type of super-structure : Load bearing / RCC framed construction
- Type of foundation : Spread footing
- Total no. of blocks in hotel : 7 blocks and one main central block
- Location : Sea coast

VISUAL OBSERVATIONS

It was evident from visual inspection that there was a very serious and widespread problem relating to degradation of the reinforced concrete structures in the hotel complex. Based on experience, it was emphasized that it is highly desirable, to identify accurately the cause of the deterioration before embarking upon expensive remedial work. Therefore it was recommended a programme of concrete sampling and laboratory testing. It was reported that there had been previous attempts at fixing the problem by patching the concrete with sand cement mix. These had retarded the deterioration, but not contained it, and problems had reappeared.

IN-SITU EVALUATION AND LABORATORY TESTING

Core Test

Over 38 cores were taken. They were drilled in columns, beams and slabs either horizontally or vertically as appropriate. The number of cores was kept large as the initial cores indicated very weak concrete. The strength results showed a wide scatter ranging from 10 Mpa concrete to 20 Mpa.

Carbonation Test

The depth of carbonation was generally extensive. The poor quality concrete resulted in rapid carbonation with the consequence of depassivation of the reinforcement and resultant deterioration of the concrete. The cover to the reinforcement was inadequate in many instances and this would have compounded the problem.

Chloride Test

Chloride content was the order 0.04 to 1 % of the mass of cement in the sample. The chloride concentration showed no definite trend of concentration near the concrete surface. It appeared that chloride was present in the material used in the concrete. It is also probable that in addition to chlorides present in the aggregates etc. chloride ingress occurred relatively easily because of the weak and permeable properties of the concrete. This could explain the variability of chloride concentration in core specimens.

RECOMMENDED REPAIR METHODS

Basically all loose unsound concrete at spalled, cracked and hollow sounding areas were carefully removed until sound concrete was reached. Breaking out of concrete continued to expose the full circumference of corroded reinforcing bars and to a further depth as directed. All exposed reinforcement was cleaned of corrosion products by an approved manual method or sand blasting. The reinforcement was treated with a pacifier immediately following preparation and cleaning. The repair to reinstate the concrete was effected by shotcrete or a proprietary mortar or fluid micro concrete either rendered or placed behind shuttering respectively. It was considered essential that the work be done to the highest possible specifications and standards. The finished surfaces was cured as specified. In addition an effective membrane such as a saline or high build alkyd was applied to surfaces to prevent the ingress of water vapour.

Plate 1: Rehabilitation work in progress.

Plate 2: Rehabilitation work of beam in progress.

CASE STUDY - 10.8

A PUBLIC BUILDING AT PORBUNDER

(Source: Shri A. K. Gupta, Chief Engineer, Bharat Sanchar Nigam Limited)

SALIENT FEATURES

● Period of construction	:	1971-72
● Investigation done	:	1984
● Type of foundation	:	Isolated and combined RCC footings
● Type of super structure	:	Three storeyed RCC framed structure
● Location	:	200 metre from sea shore

VISUAL OBSERVATIONS

1. Extensive cracking and spalling of concrete in columns, beams, extension brackets, cantilevers, slabs etc.
2. Reinforcements in most of the external members were found to be severely corroded.
3. Cover of reinforcement was not adequate which was varying from 10-30 mm depending upon the RCC elements.
4. Reinforcement in columns was found to be twisted along the axis.
5. Inspection of concrete shows that though it may not have been deficient in cement content but it was porous in character because of inadequate compaction.
6. The cross-sectional area in some of the reinforcement bars has been reduced to just10% and some other reinforcement bars had completley snapped. Reduction in area of the beam/column reinforcement was of the order of 25-30 percent.
7. The concrete was found to be in friable mass having whitish deposits, which indicated presence of ettringite.

REPAIR STRATEGY

1. Mechanical cleaning of reinforcement and thorough cleaning of damaged concrete surface after removal of spalled concrete and weak concrete.
2. The reinforcement augmented where severe deterioration had taken place with the help of additional reinforcement fixed with 'U' clips and also supporting reinforcement on shear anchors fixed with expansive cement (shrinkomp)
3. The visible cracks were grouted either with cement injection or epoxy injection.
4. The exposed concrete surface and the reinforcement bars were covered with epoxy mortar made of epoxy and cement (acting as filler material). This provided an imperious membrane against further ingress of corrosive agents.
5. In some columns concrete was jacketed with richer reinforced cement concrete and low water cement ratio.
6. The repaired surface was treated with rich cement plaster with low water cement ratio.
7. Some of the badly damaged concrete elements such as extension bracket etc. were recast in richer reinforced cement concrete.
8. The steel windows were changed to wooden windows to avoid rusting.

Plate 1 : Concrete Spalling in Columns and Beams ➔

🡐 Plate 2 : Rusting of reinforcement

Plate 3 : Honeycombed Concrete and Corrosion of Steel ➔

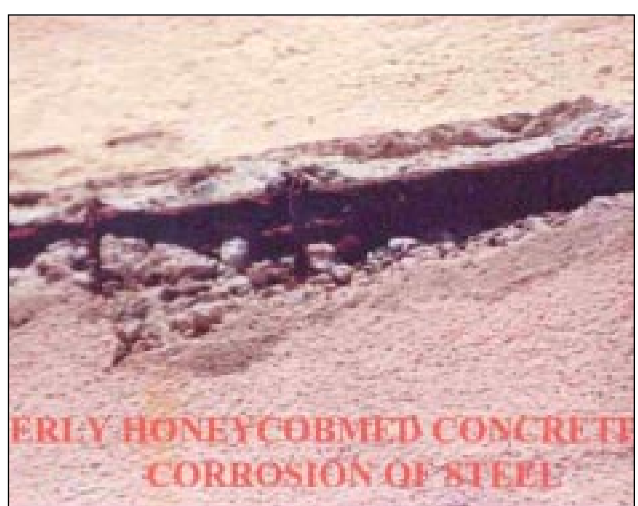
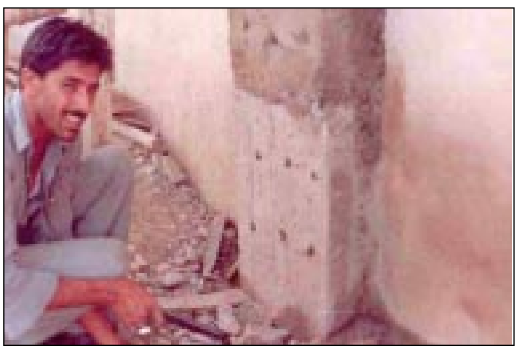


Plate 4 : Rehabilitation work in progress ➔



🡐 Plate 5 : Injection Grouting

Plate 6 : Concrete Repair with Epoxy Mortar ➔

🡐 Plate 7 : Building after rehabilitation

CASE STUDY – 10.9

REHABILITATION OF COUNTER FORT RETAINING WALL

(Source: Repairs & Rehabilitation Unit, CDO, CPWD, New Delhi)

SALIENT FEATURES

- Period of construction : 1972
- Investigation done : 2000
- Type of structure : Counter fort retaining wall for approach to a Road Over Bridge (Fig 10.9.1).

VISUAL OBSERVATIONS

1. The concrete cover to main reinforcement of retaining wall was delaminated, cracked and spalled.
2. Steel reinforcement was found exposed and rusted. The diameter of bars reduced considerably due to corrosion.
3. Walls found bulged at places apparently due to swelling of corroded rebars.
4. Thickness of concrete cover over steel reinforcement was not uniform.
5. The damage to exposed surface was mostly on Northern side of the approaches.
6. The damage to RCC on southern side observed only near ground level, apparently due to its frequented misuse by passers as 'Public Urinal' due to ingress of harmful chemicals.
7. RCC railing on both sides of the bridge was damaged and steel reinforcement bars were broken due to corrosion.
8. Vegetation growth observed in the wall.

LABORATORY TESTING

No laboratory testing on concrete could be performed, however the carbonation of concrete was found to be beyond reinforcement level at most of the places. The work was to be executed after ascertaining through laboratory tests as to whether chloride/sulphate contents were within permissible limits or not.

CONCLUSIONS

1. The major deterioration due to corrosion of steel reinforcement was on account of alternate wetting and drying of poor quality of cover concrete. The deterioration was observed mainly on the retaining wall that was exposed to the direction most likely to be wetted during rains due to most favourable wind direction during monsoon.
2. Accelerated carbonation of inadequate cover concrete for RCC.
3. Penetration of chlorides and chemicals in to concrete due to urination by passers by.
4. RCC Railing was observed to be beyond economical repairs.

RECOMMENDED REPAIR METHODS

1. **RCC Railing**

   Replacement of side railing of bridge with durable material like structural steel protected with primer and paint or by precast RCC railing with protective coating.
2. **Retaining Walls**

   The repair to required height of the RCC retaining wall between the two counter forts shall be done in alternate horizontal strips of one metre height starting from the lower most strip in a sequence of steps as under:

Step-1: Design and fabricate the adequate number of ‘stress relieving girders’ to span between the two counter forts to be able to safely transfer the maximum earth pressure on a one metre wide horizontal strip.

Step-2: Provide and fix anchor fastener system, mechanical/epoxy based of standard make at vertical spacing of 0.5 metre on each of the two exposed faces of adjacent counter forts. This fastener system shall be designed to hold the stress relieving Girders and transfer tensile force reactions safely to counter forts from such portions of one metre wide strip of wall (Fig 10.9.2) due to lateral earth pressure.

Step-3: The aforesaid specially designed stress relieving girders shall be fixed on counter forts at one metre c/c vertical spacing with a clear gap from the face of such retaining wall panel, which is to be relieved of stress. The clear gap shall be enough to accommodate reaction jacks to be used for transfer of load to the stress-relieving girder.

Step-4: The stress relieving shall be done by putting the reaction pressure on wall through jacks horizontally spaced at least at one metre c/c.

Step-5: The RCC slab in a width of middle 0.5 m vertical width between the stress relieving girders as above and the two counter forts shall be carefully repaired by method of structural repairs explained for RCC slabs in Appendix 6.1.

Step-6: Allow the structurally repaired slab to be cured for the requisite period and attain strength.

Step-7: Shift the stress relieving girders by 0.50 metre so as to be at centre line of the earlier repaired horizontal strip and repeat the steps 3 to 6 as above and remove the stress relieving girders.

Step-8: Repeat the above steps for all the panels between the counterforts.

Step-9: Provide anti-carbonation protective coating over the entire concrete surface, whether repaired or not repaired, as per nomenclature of item and related specification as given in Chapter 8 & 9.

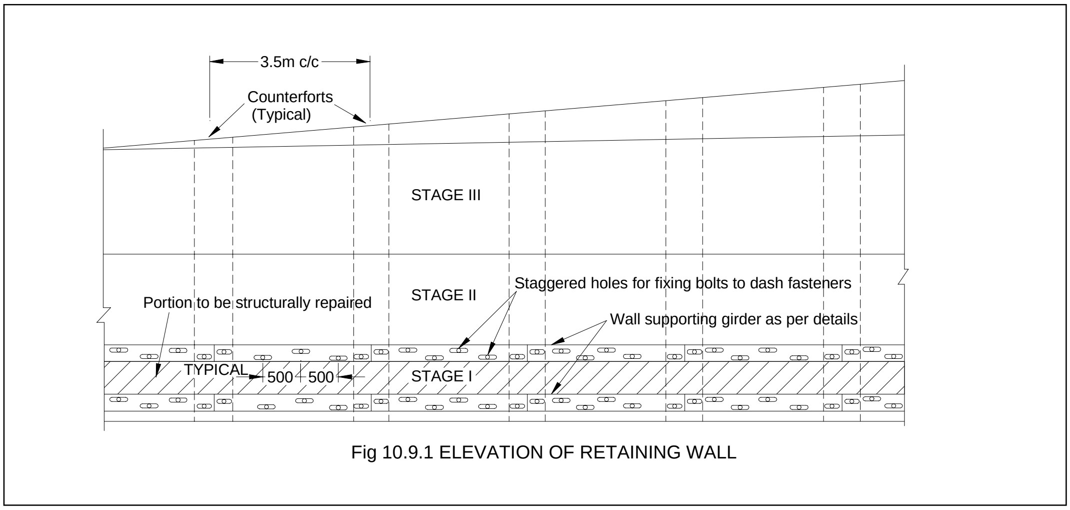


Fig. 10.9.1 : Typical arrangement of counter fort retaining wall

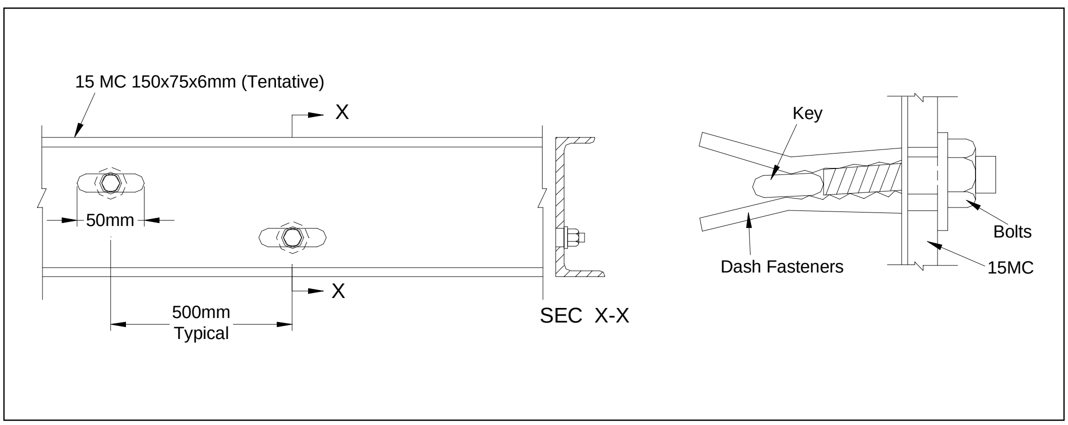


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Fig. 10.9.2 : Details of fastner system and stress relieving girder

Plate 1: General View of the Counter-fort Retaining Wall →

Plate 2: Typical damage of the Counter-fort Retaining Wall

Plate 3: Typical damage of the Counter-for Retaining Wall

Plate 4: Damage due to urination near ground level of Counter-fort Retaining Wall

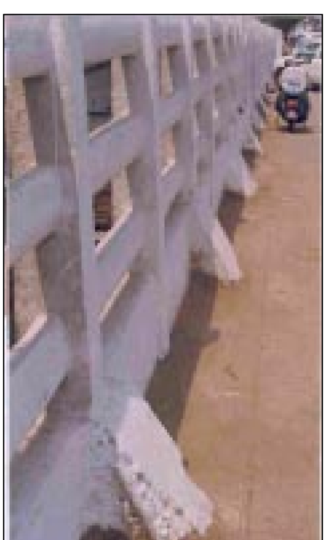

Plate 5: Counter-forts of Retaining Wall and RCC railing as visible from top

CASE STUDY - 10.10

OFFICE BUILDING FACING SEA AT MUMBAI

(Source: Repairs & Rehabilitation Unit, CDO, CPWD, New Delhi)

SALIENT FEATURES

- Period of construction : 1968
- Investigation done : 1997
- Type of structure : Seven storied RCC framed structure as per framing plan shown in Fig 10.10.1. Glazed windows provided at edge of cantilevered slab. In front face of RCC columns of main structure protected by 1.02 metre cantilevered projections (Fig 10.10.2). No such protection to structure available along sides and back of building.
- Location : Facing sea

VISUAL OBSERVATIONS

A. RCC

a. Columns, beams and lintels cracked at places.
b. Spalling of cover concrete also noticed at other places.
c. 1.02 metre cantilever slab (Fig 10.10.2) along the length of the building deflected to varying degree.
d. Front masonry facia at edge of cantilevered slab tilted out.

B. Flooring

a. Tiles flooring upheaved at several places.
b. At the location of floor upheaval, the bed mortar was checked and found loose, weak and powdery.

C. Terracing

a. Air bubbles observed in bituminous felt waterproofing treatment at terrace and slope was found inadequate.
b. Marks of leakage and seepage of water observed in the ceiling of RCC slab and terrace level beams

IN-SITU EVALUATION AND LABORATORY TESTS

Core Test

Test results were as under:

Test	Average value
Equivalent compressive cube strength	142.43 kg/cm^2
Density of concrete	2179 kg/m^3

Rebound Hammer Test

Rebound values at 3rd and 4th floor level slab and beams were as under-

Rebound Value	No of Reading (in %)
11-15	5
16-20	46
21-25	49

Ultrasonic Pulse Velocity Test

This test was carried out on selective members and found that values varied from 0.88 to 2.76.

Carbonation Test

Top 35mm thickness in cantilevered slab observed as carbonated at third and fourth floor.

Half- Cell Potential Meter Test

It was observed that the range of corrosion potential measured from (-) 50mv to (-) 405mv. Electrical potential values were as below –

Electric potential	No of Reading (in %)	Probability of corrosion
< -200 mV	31	<10%
> -200 mV but < -350 mV	66	10% to 90%
> -350 mV	3	>90%

CONCLUSIONS

a) The cantilevered slab (Fig 10.10.2) had unduly deflected and was susceptible to collapse in view of reduced cross-sectional area of main reinforcement due to corrosion. It needed immediate attention.

b) Restoration of cantilevered slab necessitated additional reinforcement to supplement the loss of cross-sectional area due to corrosion. Whereas it did not meet serviceability and deflection criteria.

c) The level of carbonation and consequential corrosion of reinforcement was more than permissible.

d) The water proofing treatment on terrace failed and permitted penetration of rainwater to cause alternate wetting and drying and consequential accelerated carbonation and corrosion of reinforcement of terrace level beams and slabs.

e) Upheaval of tiles in cantilevered portion in front and also near column supports were due to upheaval of top cover concrete owing to corrosion of top reinforcement.

RECOMMENDED REPAIR METHODS

1. In view of the reduced cross-sectional area of reinforcement due to corrosion and necessity to stiffen the cantilevered slab at floor level from serviceability considerations, it was recommended to structurally connect it with another RCC slab at lintel level and form a boxed cantilever with stiffening diaphragms as per the Fig 10.10.3 and procedure given as under:

   Sequence of steps:

   a) The cantilevered slab be got temporarily vacated and separated from occupied area by erecting temporary 115 mm brick masonry wall in weak mortar as safety barrier [Fig 10.10.4(a)].

b) Brick masonry wall supporting the glazing be removed.
c) Projecting cantilevered slabs one at floor level and the other at lintel level below be demolished beyond the beam/column faces but their reinforcement to be retained in position **[**Fig 10.10.4(b)].
d) After dismantling the two slabs, all rusted bars to be cleaned of rust including even traces of rust.
e) Deficiency in steel reinforcement to be made up with additional reinforcing bars.
f) The reinforcement of the two cantilevered slabs, one at floor level and the other at lintel level below to be connected with RCC vertical facia with proper designed over laps **[**Fig 10.10.4(c)].
g) Stiffen the proposed boxed cantilever as above with 100 mm thick RCC diaphragm provided at column support as well as at mid span**[**Fig 10.10.4(d) and (e)].
h) Re-cast with M 20 grade concrete in stages as shown in Fig 10.10.4
i) The RCC facia and other exposed structural elements to be covered with suitable weather resistant permanent finish material and internal face to be finished with synthetic enamel paint or acrylic emulsion.
j) After structural rehabilitation is completed, the temporary masonry wall shall be removed and area merged with rest of building.

2. Improvements of water proofing treatment and drainage of roof.

Sequence of steps:

a) Existing water proofing treatment to be removed and condition including the slope of terracing to be assessed.
b) The whole terrace to be re-graded, to rectify depressions. If necessary, the existing terracing could be re-laid to achieve proper slope.
c) Number of rain water pipes to be increased commensurate with the area to be drained to ensure efficient disposal of rainwater.
d) Surface cracks in existing terracing to be identified and marked. Polymer modified cement slurry to be injected through nipples fixed along crack lines.
e) Regraded roof to be covered with two coats of polymer modified cement slurry coating containing 20 % acrylic polymer by weight of cement. Subsequently cover this coating with 20mm thick polymer modified non shrink cement plaster with 300x300mm sized square thread indentation thereon.
f) The adequacy of the water proofness of roofing to be checked by ponding of water after the curing period is over.

3. Improvement of structural strength of columns/ beams/ slabs at fourth floor level

Stepwise sequence of steps and method of structural restoration and strengthening of RCC columns, beams and slabs shall be as given in Annexure 6.1.

4. Removal of floor tiles and relaying with cement mortar as below

Sequence of steps:

a) Tiles to be removed carefully and stacked, bed mortar to be removed and surface to be totally cleaned with wire brushes.

b) RCC slab to be tapped and checked for hollow sound. If found hollow, the slab to be propped and supported as per item 1.1 in Chapter-8.
c) The top cover concrete to be removed and rusted reinforcement exposed all around. The exposed reinforcement to be cleaned of concrete and rust as per item no 2.6 and 2.7 in Chapter-8.
d) A bond coat of polymer modified cement slurry as per items 4.1 and 4.2 in Chapter-8 to be applied over the surfaces of concrete and reinforcement before covering it with repair material.
e) This to be covered in layers as per item 5.7 in Chapter-8 with polymer modified mortar 1:2.5 modified with 5 % SBR by weight of cement.
f) The finished surface as well as surrounding sound but un-repaired surface to be coated with two coats of polymer modified cement slurry containing 20 % SBR polymer by weight of cement.
g) Flooring tiles to be re-laid as per standard specifications.

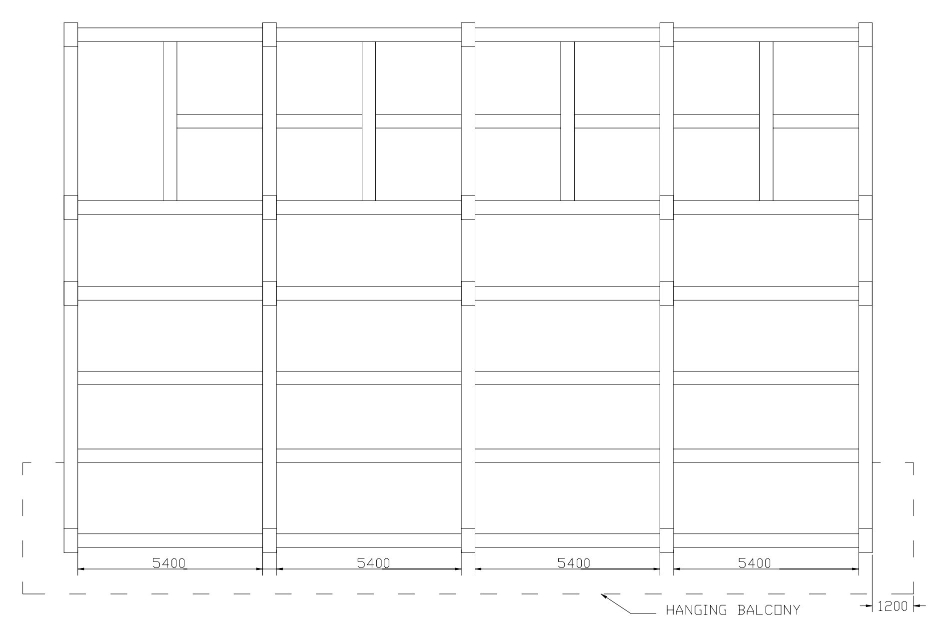

Fig. 10.10.1(a): Layout Plan

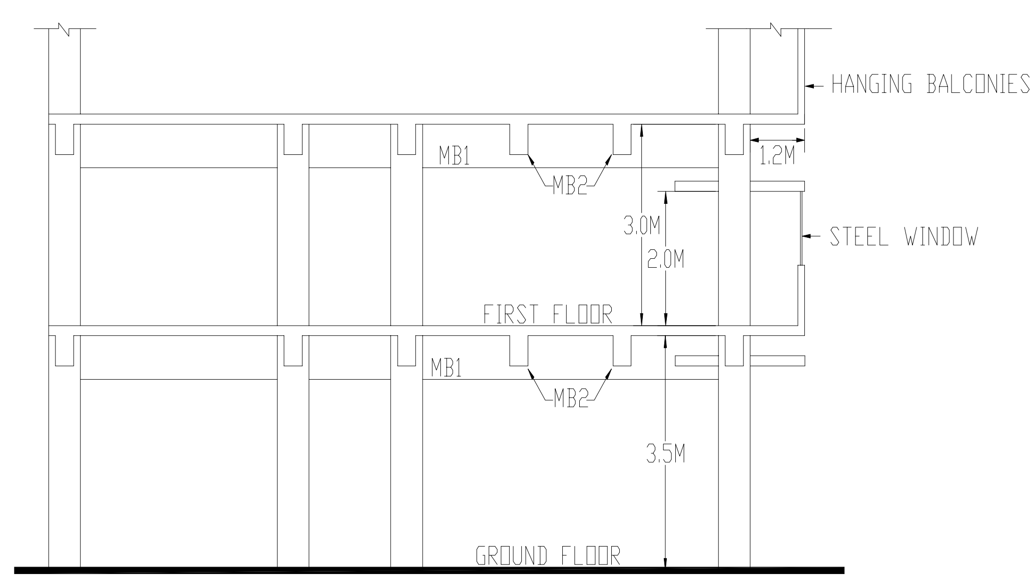

Fig. 10.10.1(b): SectionA-A showing cantilevered portion in front

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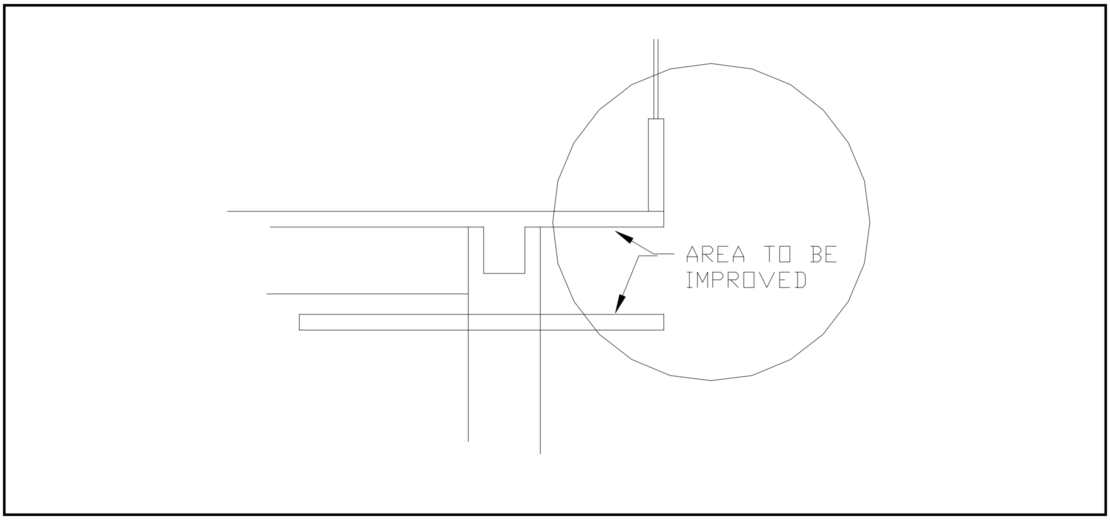

Fig. 10.10.2: Existing Arrangement in Front Cantilevered Portion

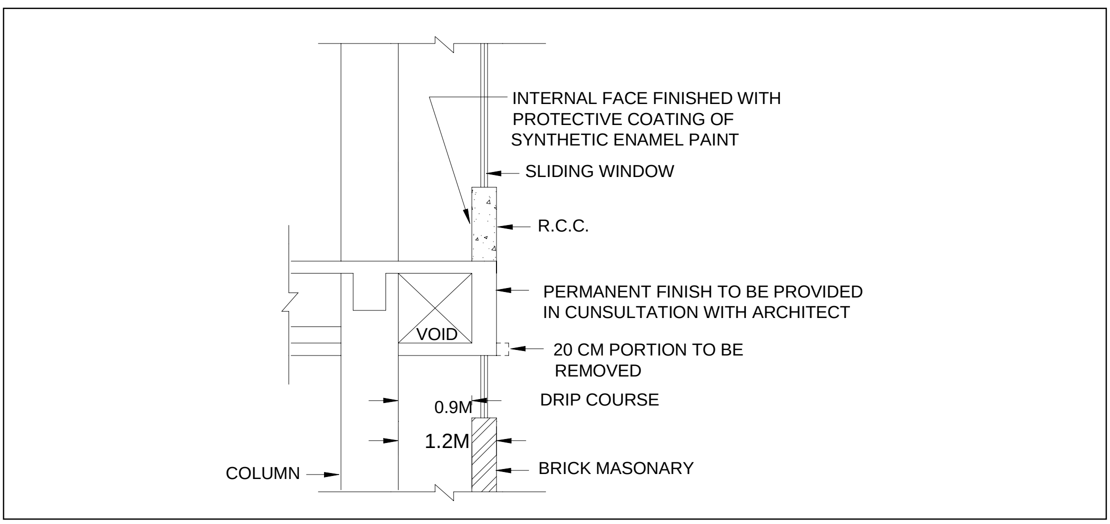

Fig. 10.10.3: Proposed Arrangement Stiffened Cantilevered Portion in Front

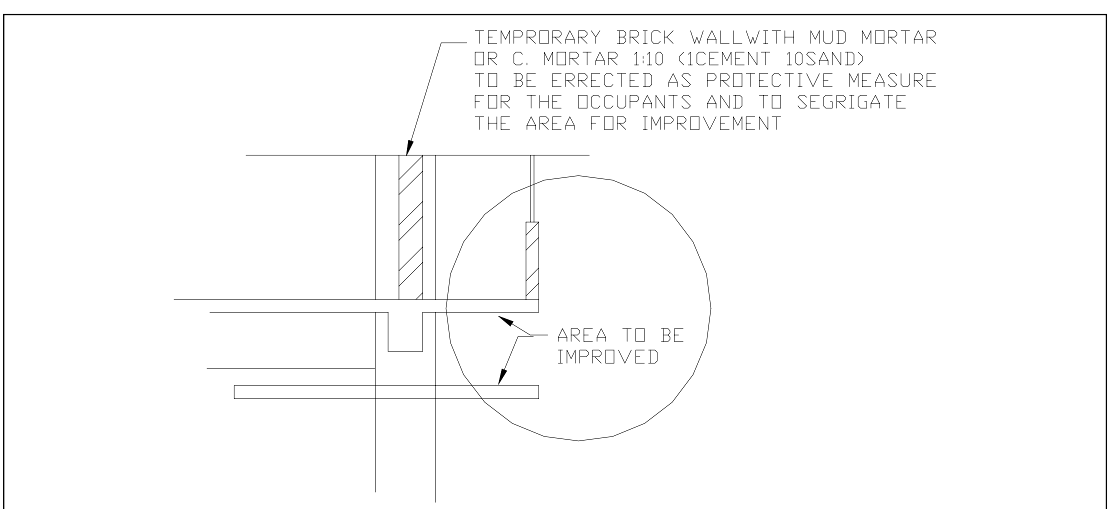

Fig. 10.10.4(a): Area Isolated

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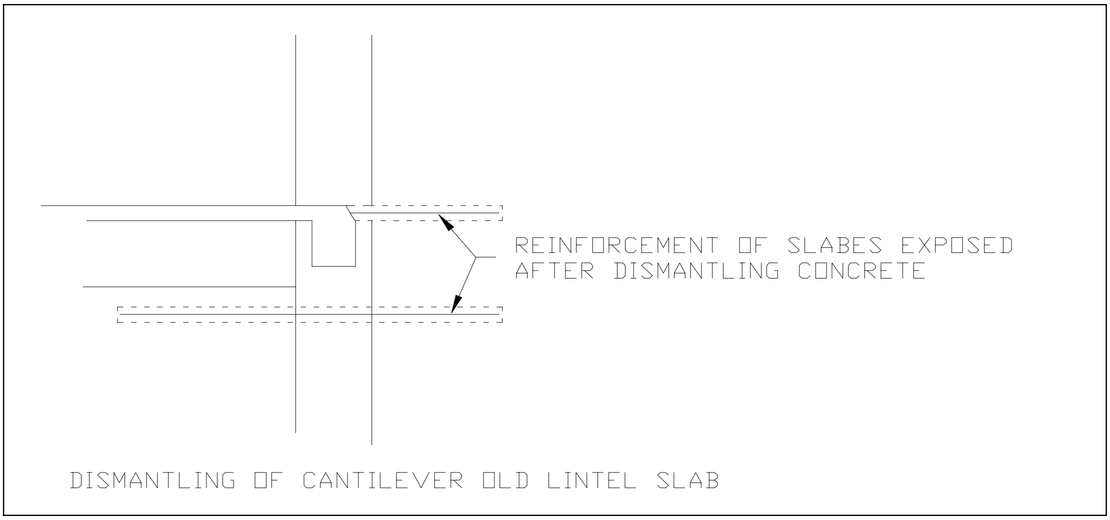

Fig. 10.10.4(b): Concrete of Cantilevered slabs dismantled

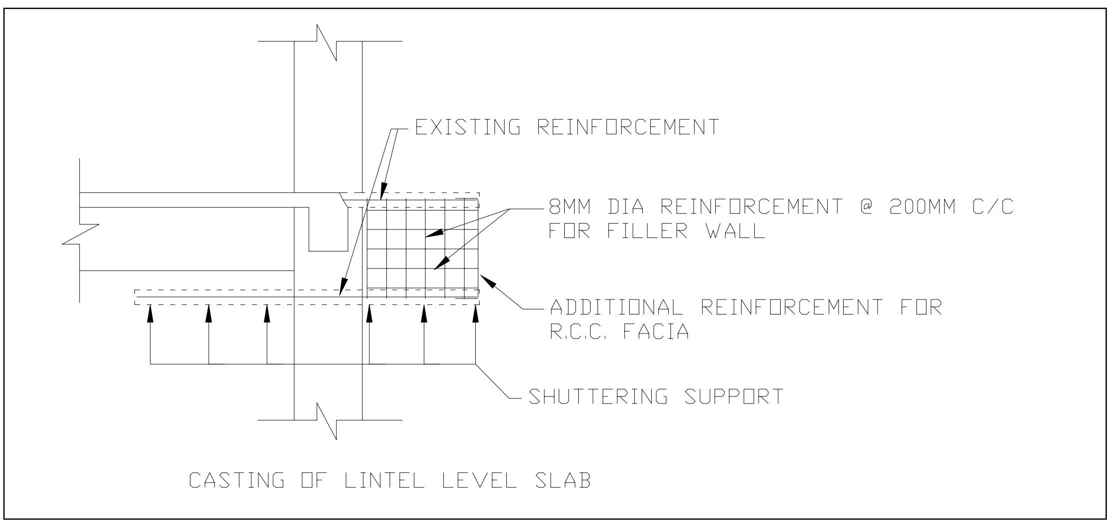

Fig. 10.10.4(c): Lintel level Slab cast

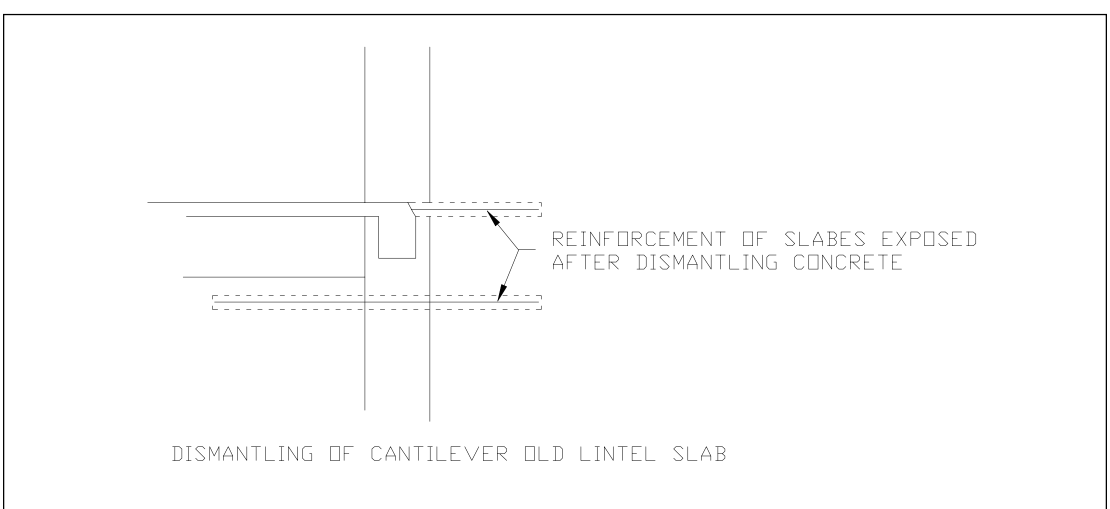

Fig. 10.10.4 (d): Vertical front facia and diaphragms cast

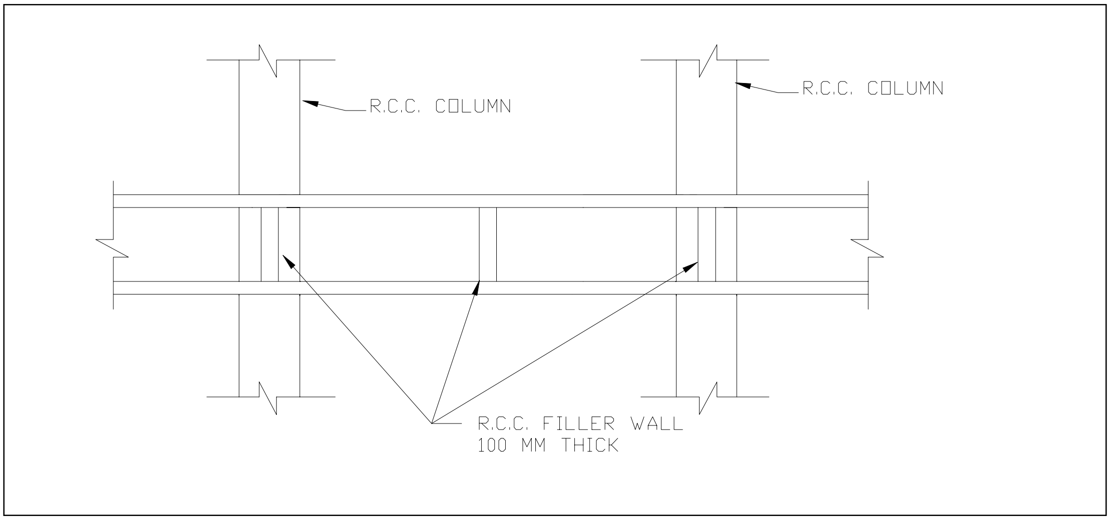

Fig. 10.10.4(e):Sectional Elevation through cantilevered box showing diaphragms/filler walls

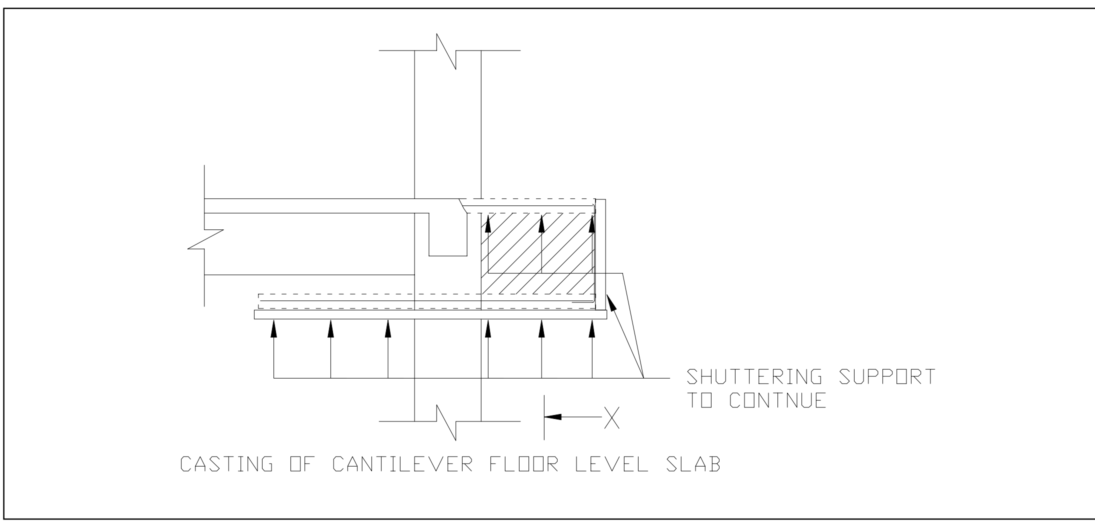

Fig. 10.10.4(f): Floor level slab cast

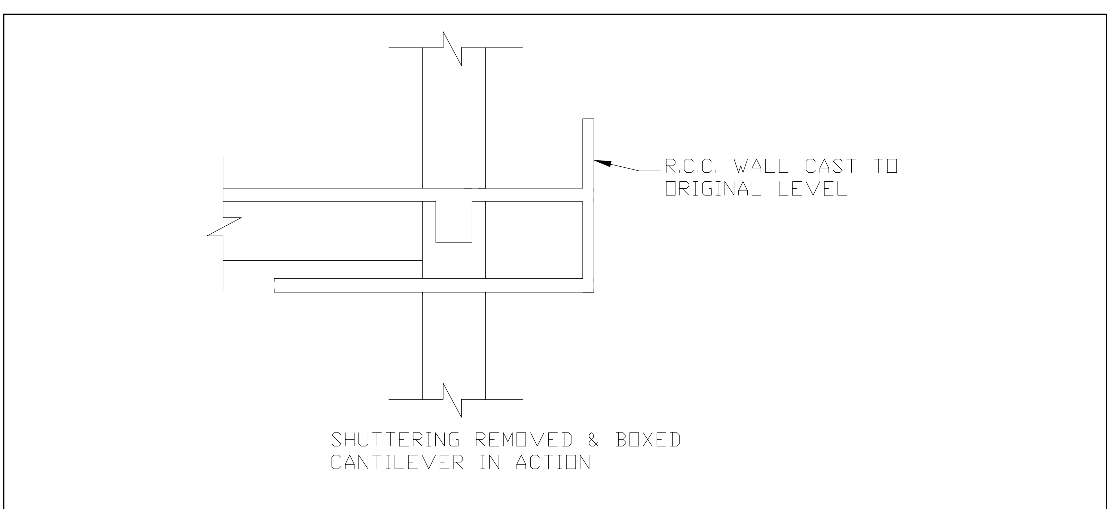

Fig. 10.10.4(g): Shuttering Removed & boxed Cantilever in position

Plate 1: Front View ➔

Plate 2: Upheaved Flooring ➔

Plate 3: Corroded top reinforcement causing in-plane splitting of cantilever slab and de-bonding of reinforcement ➔

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Plate 4: Cracked terrace level Beams and slabs ➔

CASE STUDY –10.11

DOME OF A CHURCH BUILDING AT DELHI

(Source: Shri. P.C. Sharma, Former Senior Scientist, SERC, Ghaziabad)

SALIENT FEATURES

- Period of construction : 1835
- Referred for investigationn : 1995-96
- Investigation carried out : 1996-97
- Type of construction : Brick masonry dome structure in lime surkhi mortar with embedded steel sections as horizontal bands at few locations in dome.

VISUAL OBSERVATIONS

1. The dome consists of two shells, the inner and the outer. The outer shell, called as Florentine dome, is ribbed and rests on eight octagonal columns.
2. The dome was plastered in cement mortar on both inner and outer faces. This plaster was done at a later date.
3. Extensive spalling of plaster in soffits of the outer-most dome observed. Plaster had no bond with masonry at most of the places.
4. Cracks on soffits of the outer-most dome along the construction joints and along vertical, ribs. Few bricks have fallen out from horizontal and vertical joints exposing embedded steel sections.
5. Mortar from brick masonry was ending and degraded due to seepage from outsides.

IN-SITU EVALUATION AND LABORATORY TESTING

Determination of Geometry

The geometry of dome was determined using Wild T1000 Electronic Theodolite fitted with DI 3000 timed – pulse EDM (Electronic Distance Measuring Equipment with effective least count of 0.001M)

Mapping of Cracks

The loose plaster from inner surface was removed by tapping and all visible major cracks on soffits of the outer dome were marked and plotted.

Rebound Hammer Test

The average compressive strength assessed as follows:

Bricks	4.848 and 5.208 Mpa on outer and inner surfaces respectively.
Mortar	2.895 and 1.466 Mpa in lower and upper portions of dome respectively

Core Test

Core of both bricks and mortars were taken to evaluate the properties like compressive strength, water absorption and density.

The core tests revealed the compressive strength of the masonry was 3.20 Mpa, which shows bricks are generally, not affected strength wise.

Determination of Steel

A cover meter was used to ascertain the presence and position of steel sections in the dome. The steel sections were about 3mm thick and 40 to 45 mm wide and were embedded circumferentially at every junction of two lifts about 10 mm away from the inner surface. The steel had almost completely corroded.

Chemical Analysis

Mortar was crushed to get fine powder and its chemical analysis was done. The mortar found to be made up of lime and surkhi in the ratio 1:8.

Theoretical Analysis

The dome was analysed by Finite element method and checked for stability. Changes in stresses due to different temperatures were also studied.

CONCLUSIONS

1. The steel sections provided in the dome are completely corroded leading to cracks in the masonry.
2. The mortar in upper portion has degraded due to seepage of water from upper surface.
3. Brick strength is low compared to present standards and bricks show higher porosity.
4. Mortar is porous and poor in strength.
5. The dome is stable from tension and stresses point of view

RECOMMENDED REPAIR METHODS

External Surface of Dome

1. Entire old plaster to be removed and all visible cracks sealed.
2. Fix grouting ripples and using cement base non-shrink slurry grout all the joints.
3. Provide first layer of Ferrocement as per specifications.
4. Lay second layer and level upto required level.
5. Cure for 14 days.
6. Apply anti-carbonation treatment in two layers.

Internal Surface of Dome

1. Remove old plaster and repack old joints after raking up the joints and clearing with wire brushes.
2. Remove corroded steel in such a way that unsupported length is not more than 1 m. Pack with non-shrink concrete produced using Portland cement 53 grade.
3. Repack all exposed masonry joints with non-shrink cement sand mortar.
4. At the Dome junction with bottom drum , provide grouting nozzles and pressure grout with non shrink cement slurry.
5. Provide specified layer of ferrocement as per specification.
6. Cure for 10 days.
7. Apply two coats of polymer cement water proofing.

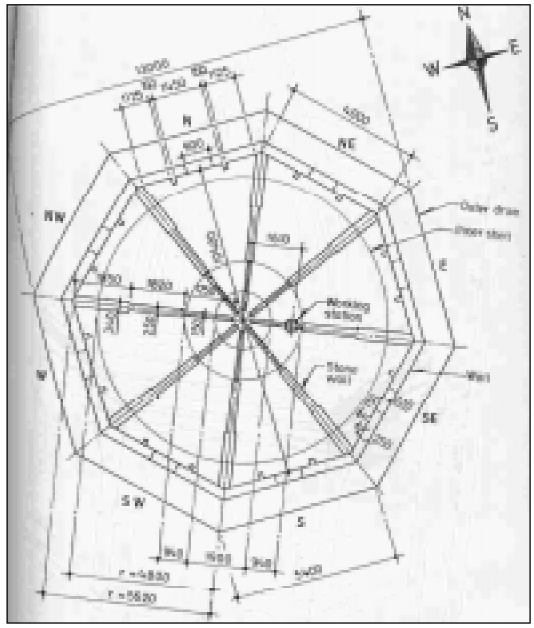

Fig. 10.11.1: Plan of the Dome of Church

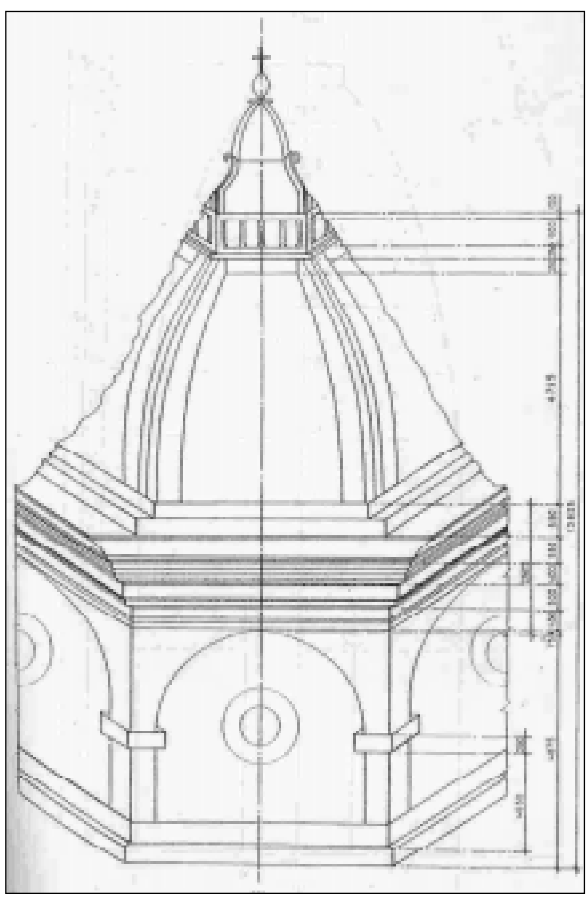

Fig. 10.11.2: Front Elevation

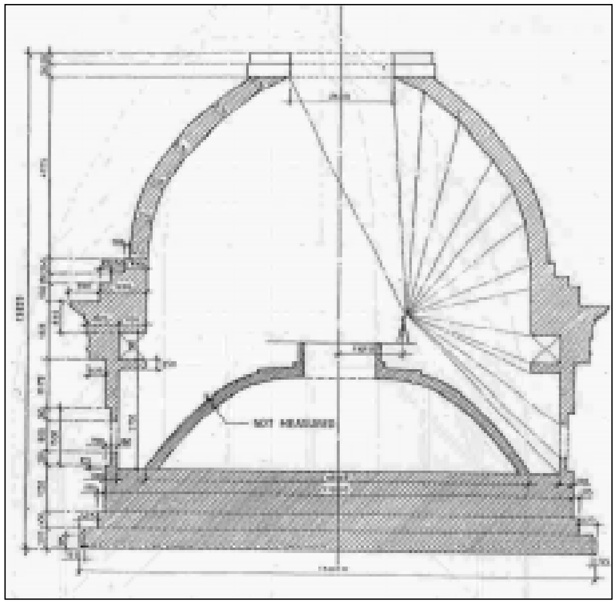

Fig 10.11.3: Sectional Elevation of the Octagonal Outer Dome of Church

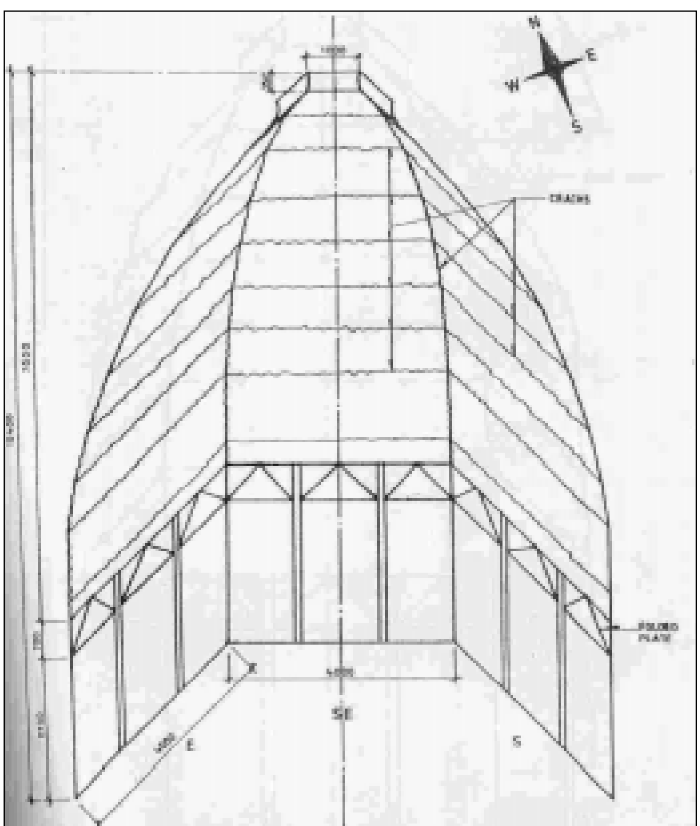

Fig. 10.11.4: Cracks on three sides of inner octagonal upper Dome

CASE STUDY – 10.12

A VIP MONUMENTAL BUILDING AT DELHI

(Source: Repairs & Rehabilitation Unit, CDO, CPWD, New Delhi)

SALIENT FEATURES

· Period of construction	:	1929
· Investigation done	:	1997
· Type of structure	:	Load bearing brick & stone masonry historical structure having very thick walls with lime concrete terracing
· Problem referred to Investigators	:	Leakage in to the rooms below roof, Seepage in stone masonry walls and damage caused to ornamental Chhajjas due to spalling of cover concrete and exposure of reinforcement

VISUAL OBSERVATIONS

A) AT ROOF

1. Lime concrete terracing is provided with proper slope. Tarfelt treatment is laid over the terracing. Drains, laid to proper slope, were covered with steel gratings.
2. In the tarfelt treatment, at some places

a) air bubbles were observed

b) it had debonded with its base.

c) water was observed to have been trapped below the felt.

3. No thermal expansion joints were provided in the structure, whereas size of the building necessitated such provision as per present codal practice.

4. Cracks were seen along corners at junction of roofing and parapet.
5. Cracks were present in lime terracing at some places.
6. Dome over library room had cracked at the junction of ring beam.
7. Cracks were observed in ceiling of North Block Room, Dwarka Suite.
8. Parapet plaster had cracked at some places.

B) JOINTS OF STONE MASONRY AND FOUNTAIN BOWL

1. Pointing of stone masonry joints had got weathered and joints had become hollow at places due to removal of disintegrated mortar.
2. Mild steel nails fixed in the joints for electrical lighting caused loosening/opening up of joints due to expansive forces caused due to increased dia of rusted nails.
3. Crazy cracks in bowl type tank of fountain were observed.

C) RCC CHAJJAS IN FRONT COURT

1. Ornamental RCC chhajjas's reinforcement had corroded and spalling has taken place.

CONCLUSIONS

1. Cracks at the junctions of roof and parapet, lime terracing, other places and disintegration of joint mortar at exposed locations are due to cyclic nature of diurnal and seasonal temperature variations

over a long period on account of direct exposure to environment and consequential thermal expansions and contractions of the structure.

2. Cracks at the junctions of roof and parapet and other places are the most probable areas for ingress of rainwater.
3. The quality of lime terracing is very good except that it has cracked at few locations. It needed to be retained but with crack treatment.
4. Being an old and historical structure, it is advisable that no additional loads due to any water proofing treatment are put over roof.
5. The exposed joints of stone/brick masonry had opened up, mortar disintegrated and became hollow due to rusting of mild steel nails fixed in the joints and extreme temperature variations.
6. Carbonation of concrete caused the corrosion of reinforcement and the spalling of the concrete in ornamental RCC chhajjas.

RECOMMENDED REPAIR METHODS

A) Water proofing treatment

1. Existing plaster on inner face of parapet and from other walls to be removed to expose the masonry.
2. Existing tar felt and all rubbish to be removed completely and surface to be cleaned of bitumen properly.
3. Cracked and damaged terracing, terrace-parapet junctions, etc to be identified and marked.
4. The nipples for injection grouting to be fixed at a close spacing not farther than 300 mm along the crack line and crack sealed with putty.
5. Water to be injected through nipples for cleaning the cracks of any debris and saturating the cracked surface with water.
6. Polymer modified cement slurry grout to be injected into all cracks in RCC/ lime terracing/ terrace-parapet junctions, etc as per nomenclature of item and related specification given in Chapter 8 & 9.
7. Depressions and undulations, if any, to be repaired.
8. 15 mm thick Ferro-cement water proofing teatment to be done over lime concrete terracing with appropriate expansion joints and laid to proper slope as per nomenclature of item and related specification given in Chapter 8 & 9. The water proofing treatment to be taken into 75X75 mm cut chases in the parapet walls.
9. Surface of the finished ferro-cement waterproofing treatment to be kept wet continuously for a period of seven days.
10. After completion of water proofing treatment, walls to be replastered.

B) Leakage/ seepage from masonry joints of terrace fountains and parapet.

1. Water supply lines for the fountain to be checked thoroughly and leaking pipes to be replaced.

(a) For vertical sides of fountains and masonry

1. Joints to be raked and all loose material to be removed.
2. Joints to be plugged and made impermeable by injecting polymer modified cement slurry through aluminium nipples which to be driven into the joints without damaging the stones.

(b) Horizontal surface of fountain

1. All containers to be thoroughly cleaned of existing water proofing teatment.
2. Containers to be treated by injecting non shrink cementitious slurry with pigment of matching shade through aluminium nipples which is to be driven into the joints without damaging the stones.

C) Leakage into the basement below from stone cobbled court yard

1. The leakage to be controlled by pressure grouting of stone cobbled joints and repair of covered drains.
2. Cement slurry for grouting to be made of polymer modified cement, which to be made by using 1 part of O.P.C with 1 part of water and 20% polymer (solid contents) by weight of cement as per directions of Engineer in charge/ manufacturer.

D) Repair to Ornamental RCC chhajja

Repair to RCC chhajja shall be carried out as per procedure described in Annexure 6.1 but after matching the shade of finished colour with that of existing colour

CASE STUDY – 10.13

TEN STOREYED RCC FRAMED OFFICE BUILDING AT DELHI

(Source: Shri D S Sachdeva, Chief Engineer, CPWD, Siliguri)

SALIENT FEATURES

- Year of construction : 1981-82.
- Investigation done : Building, when taken over for repairs and modifications in 1998, it was an unfinished, unprotected and uncared structure.
- Type of super-structure & its usage : Ten storeyed R.C.C. framed structure. Originally planned and constructed as a hotel and now its use was envisaged as office building.
  Total plinth area of the building 38900 sq.m. Ground coverage 9000 sq. m having 1600 floor columns, 3200 main beams and 1200 slab panels.
- Type of foundation : Pile foundation

VISUAL OBSERVATIONS

i) The central core of building was mostly unaffected, and practically no distress was observed in the area except honey-combs in coffer beams and segregated concrete in columns.
ii) Relatively more number of structural elements above 30.75 m and 37.9 m levels at the top and 8.15 m and 5.0 m levels at bottom were distressed compared to other levels.
iii) Longitudinal cracks observed in columns and beams. Typical crack pattern corresponds to rebar corrosion.
iv) Spalling of concrete noticed at places.
v) Exposed reinforcement exhibited signs of rusting.
vi) External column elements were distressed more as compared to internal structural elements.
vii) Among the internal elements, those beams, which were near vertical openings, expansion joints and sunken floors, were distressed more as compared to internal beams located at other places internally.
viii) Upper floor slabs were more severely affected.
ix) Ponding of water observed in sunken slabs.
x) Expansion joint beams distressed due to seepage of rainwater from terrace of various floors and consequential wetting/drying cycle.

IN-SITU EVALUATION AND LABORATORY TEST

Rebound Hammer, UPV and Core Test

A) Slabs

i) From UPV test, quality of concrete of slabs at 27.05m level was found to be of doubtful category. The mean rebound number index was 32 and strength of concrete obtained

12 Mpa. Panels were recommended to be recast with reinforcement as per design requirements.

ii) Generally the slab concrete marginally satisfied the requirement of M 15 grade of concrete.

B) Beams

i) UPV results generally indicated medium or better than medium quality of concrete. At few locations it was doubtful and at some other, it marginally failed to satisfy the requirements of medium grade concrete.

ii) At 30.75/27.05m levels, UPV tests identified quality of concrete as doubtful, which could be due to existing fine corrosion cracks.

iii) From the results of above tests, it was concluded that concrete in some beams at 8.15 m, 27.05 m and 37.9 m levels was of poorer grade than M15 and required recasting.

C) Columns

i) UPV tests indicated that few columns at 37.9 m level were of doubtful quality.

ii) In columns, mostly medium or better than medium quality concrete was assessed through UPV tests.

iii) Average characteristic strength of concrete in columns was 16.4 Mpa

Carbonation Test

Out of 33 tests, it was found that depth of carbonation was more than the concrete cover in 11 cases. Though significant carbonation was observed, but corrosion of rebar was not attributed to carbonation due to its depth generally being less than cover by and large.

Half-Cell Potential Test

Large number of observations were taken where visible cracks were yet to appear. The results indicated high chances of corrosion in future.

Chloride Content

Free chloride content of the entire 13 test-samples test exceeded the permissible limit.

CONCLUSIONS

1. **Service floor,** located at the second floor level of the building had a number of inverted beams, which caused ponding, for water collected from various shafts and open sides. The intermittent collection of water and its evaporation caused accelerated carbonation and consequential damage to large number of structural members viz columns, beams and slabs due to corrosion of reinforcement.
2. **Reinforcement at bases of columns** was corroded due to accumulated water, which rose up in cover concrete through capillary action from the bases of columns at unfinished & unlevelled floor level, where it had accumulated due to its entry from open sides.
3. **External columns and beams:** The building was originally planned for bay windows. The water accumulated in pot like structure formed between the window sill, which was curved in plan and the straight faces of the building. Due to this reason, almost all the columns and beams adjacent to this pot formation were affected.
4. **Slabs, beams and columns** around the shafts and the sunken slabs were also affected because of accumulation of water.

5. **Large number of slabs affected** due to corrosion on account of inadequate concrete cover and exposed surface being not plastered.
6. **Columns and beams adjacent to expansion joints** were also severely affected due to unfinished expansion joints and through which the rainwater traveled unhindered.

STRATEGY FOR REHABILITATION

Two pronged strategy was suggested:

1. **Strategy-I: Repair of distressed structure.**
   The structural system of the building is basically an RCC framed with in filled masonary walls. Based on the field and laboratory test results, residual strength calculations were done. Despite the loss in strength of concrete and steel, the building was capable to sustain normal office loading. The some locations, strengthening measures were suggested. Since, majority of structural members, some to small extent and others to large extent, were affected by corrosion, mass scale replacement was discouraged. Instead it was decided to carry out localized repairs to the damaged areas using latest repair materials available. The process also helped in minimizing chipping off of healthy concrete. The full circumference of corroded reinforcing bars were exposed by chipping, and were cleaned of corrosion products by approved manual methods, mechanical brushes and/or sand lasting. The reinforcing bars were then treated with rust passivators soon after their cleaning. After application of bond coat over the old concrete surface, micro concrete was poured. Appropriate designed formwork for the columns & beams were provided. At places particularly in beams, proprietary repair mortars were also applied.
2. **Strategy-II: Load Reduction**
   Due to change of its use from residential to office purpose, it was felt necessary to plan reduction of dead loads during remodelling with the use of:
   i. Aerated cellular concrete blocks, gypsum blocks in walls to substitute bricks.
   ii. Lightweight SMC panel water tanks at terraces.
   iii. Light weight flooring, like ceramic tiles in large areas.
   iv. Lightweight false ceiling of gypsum board, metallic and mineral fibre tile ceilings.
   v. Light weight weather proof, composite aluminium sheet cladding as external façade,
   vi. Adoption of open plan modular office system.
   vii. Elimination of sunken floors in toilets.
   viii. Full bay large window openings reducing brick work in jambs and cills.
   ix. Additional four bays added at 9th floor in each wing during 1987-88 were removed to reduce** the imposed load.

RECOMMENDED REPAIR STRATEGY

I. All structural members, which were distressed, identified.
II. The repair priorities were assigned first to all columns and were treated first, then all beams and slabs in the last.
III. The surface preparation started from visible signs of distress like opening of cracks, expose the corroded reinforcement and proceed along corroded reinforcement till good steel was reached.
IV. The reinforcement was cleaned of rust, coated with zinc rich epoxy to check further corrosion.
V. It was decided to provide concrete richer than parent concrete of the structural member being repaired.

VI. For columns, epoxy was selected as bonding coat, where as for beams and slabs acylic based bonding coat was selected from importance and cost considerations.

VII. Beams were repaired with polymers modified cement mortar where as columns were treated with flowable non-shrink micro concrete.

VIII. Areas affected with honey combed concrete were repaired by injection grouting with either cement admixed with non-shrink compounds or epoxy grout. Most of the honeycomb was found at beam-column junction.

Plate 1: Building As Taken Over

Plate 2: Closer Look

Plate 3: Corrosion cracked column

Plate 4: Rust Signs in RCC column

Plate 5: Inverted Beams on Service Floor responsible for ponding of water

Plate 6: Honey combed Column-Beam Junction

Plate 7: Beam at Expansion Joint Location

Plate 8: Hollow Voided RCC Slab due to loosened cover concrete on account of corrosion of reinforcement

Plate 9: Rusted Shear Stirrups in Beam

Plate 10: Chipped Column with exposed reinforcement being cleaned by sand blasting

Plate 11: Exposed reinforcement and chipped concrete after sand blasting

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Plate 12: Micro-concreting being done to RCC jacket

Plate 13: Passivating and Bond Coat Applied over Prepared Surface of steel and concrete in a Beam →

Plate 14: Repair material application to Soffit of RCC Beam →

Plate 15: Repaired Beam →

Plate 16: Cement Grouting in Honey Combed Concrete →

Plate 17: Epoxy Grouting

Plate 18: Chipping of Loose Cover Concrete of RCC slab

Plate 19: Reinforcement and shear key after sand-blasting

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Plate 20: Recasting of RCC slab

CASE STUDY – 10.14

INSTITUTION BUILDING AT MUSCAT

(Source: Shri H. S. Bakshi, Consultant, Engineering Development and Consultant)

SALIENT FEATURES

- Period of construction : 1992-93
- Investigation done : 1999
- Type of foundation : Isolated footings
- Type of superstructure : Two storeyed RCC framed construction

VISUAL OBSERVATIONS

No sooner the building was completed in the year 1994 cracks started appearing in the beams. Investigations were undertaken by local consultants and Sultan Qaboos University at Muscat. Repairs were carried out using bonded steel plate concept, which were later found to be inadequate and problem further investigated.

1. Steel plates, which were used to strengthen beams, were not well bounded to the bottom of beams. In fact at some places one could move the plate by gentle push of hand.
2. The grout used between concrete beam face and steel plate was not uniformly dense and as such unreliable.
3. The bottom steel plates used were too thick for use in such systems. Normally thin plates were used for complete transfer as composite system on the interface.
4. Some beams required strengthening for hogging moments. These beams had not been attended.
5. There were no signs of foundation settlement and associated cracking of the in-fill walls.
6. There were some separation cracks on concrete face of the column and the block walls. These cracks were of no consequence, structurally.
7. There was no sign of any corrosion setting-in.
8. The quality of concrete was tested and the strength was found to be more than adequate. In fact inspection of concrete showed strength results more than 25% of the required value.
9. The slabs had been checked and found adequate.
10. Foundations were checked with Soil bearing capacity 35 t/m^2 and were found to be adequate.

REPAIR STRATEGY

The repairs required can be classified into three different categories..

Type – 1

Beams, which were not repaired earlier with steel plates, but on examination now, needed to be strengthened for sagging moment and shear.

Type – II

Beams, which already had strengthening steel plates for sagging and shear but the bonding to concrete was poor and the adhesive grout not dense.

Type – III

Strengthening was required for hogging moment.

(a) The steps followed in strengthening for sagging moment and shear were as follows:

(i) All loose concrete from beams were chipped off and the surface was kept wet for 24 hours. Using repair mortar, the beam surfaces were also made even for Type 1 beams. This was not possible in Type II beams.

(ii) Holes were drilled for epoxy grouted bolts at bottom of beams through concrete for type 1 beams. Steel plate was then fixed to beam bottom by bolts. In case of Type II beams holes had to be driven through existing steel plate.

(iii) Finally epoxy grout was injected between beam bottom and steel plate for Type 1 beams. Whereas for Type II beams the existing poor quality grout was made dense by injecting epoxy grout.

(b) The steps followed to overcome the problem of hogging moment were as follows:

(i) Part of the existing flooring was dismantled to expose R.C.C. in this portion.

(ii) The R.C.C. slab was cut to a depth of 85 mm without damaging existing reinforcement bars in this area.

(iii) New bars were inserted in this portion and welded to existing reinforcement bars in this area.

(iv) A coat of epoxy bonding agent was applied for joining old concrete to new concrete.

(v) Concrete M-35 was poured and finished to the existing level of RCC in slab.

CASE STUDY – 10.15

AN INDUSTRIAL SHELL STRUCTURE

(Source: Repairs & Rehabilitation Unit, CDO, CPWD, New Delhi)

SALIENT FEATURES

Period of construction	:	1964-70
Distress noticed	:	1992 and worsened in 1996-97
Investigated done	:	1998
Type of super-structure	:	4.90 m high single storeyed shutter finished RCC framed shell structure with 80 mm thick shell roof.(For lay out plan refer Fig 10.15.1 and typical cross-section refer Fig 10.15.2) The expansion joints are provided in form of GI Sheet cradle filled with bituminous board and top sealant (Fig 10.15.3).

VISUAL OBSERVATIONS

1. Rusting stains were observed at few locations, which gave an impression of onset of corrosion.
2. A number of cracks were seen on the soffit of shell roof. The width of cracks varied from hair cracks to 3mm(Fig 10.15.4).
3. Leakage signs through construction joints were seen.
4. Existing tar felt treatment was cracked/debonded at several places and had out lived its life. The tar felt treatment had been damaged at locations by dash fasteners of lightning fixtures.
5. Expansion joints have failed due to rusting of GI sheet cradle.At some places, expansion joints were filled with unwanted concrete material.
6. Leakages were also noticed from bay windows through joint of masonry and window frames.
7. Mild steel reinforcement exposed at few locations and found to be in passivated and good condition

REVALIDATION OF STRUCTURAL DESIGNS

The stuctural analysis for the shell roof was carried out which indicated that the existing provisions are satisfactory.

NON-DESTRUCTIVE TESTS

Carbonation Test

Carbonation depth of concrete in shell roof measured and top 3 to 6 mm thickness observed as carbonated and had not reached reinforcement level.

Half-Cell Potential Test

It was observed that the range of corrosion potential measured from (-) 69mV to (-) 161mV indicative of 90% probability that corrosion is not active.

CONCLUSIONS

The distress is at initial stage and following are the most probable causes:

1. Failure of expansion joints due to corrosion and damage to GI sheet cradle caused ingress of rain water
2. Failure of existing tarfelt treatment and exposure of concrete surface of shell roof at places.
3. Entry of rain water through overlaps and leakage through cracked and/or honey combed RCC shell roof at shuttering joints of shutter finished surface.

RECOMMENDED REPAIR METHODS

A. Remove tarfelt treatment and injection grout all cracks and honey combed concrete with non-shrink polymer modified cement grout.

B. Replace the tarfelt water proofing treatment with UV ray & abrasion resistant thin water proofing polymeric membrane after cleaning surface and preparing the same by filling the depressions, preparing slopes of valley drains, etc.

C. North light windows to be treated with silicon sealants

D. Provide a remodelled and improved the expansion joint(Refer Fig 10.15.5)

The repairs to be done as under :

1. Existing tarfelt treatment to be removed and roof surface to be cleaned.
2. The roof surface to be carefully inspected and all affected area to be marked.
3. All fasteners and fittings to be removed and replaced by small size fasteners and fitings.
4. Holes of fasteners and fittings to be plugged with polymer modified cement mortar.
5. V- grooves to be made along the cracks and aluminium nipples to be fixed along the grooves and on honeycombed RCC surface, if any.
6. Non-shrink polymer modified cement grout to be injected through nipples and nipples to be cut and sealed with nonshrink suitable compound.
7. Then entire roof to be cleaned by wire brushes and depressions to be filled with polymer modified cement mortar over a bonding coat of polymer modified cement slurry.
8. After curing, specified waterproofing treatment to be applied to the surface.
9. Expansion joints shall cleaned properly improved to work effectively.
10. Drain between the two shells to be treated with water proofing treatment as explained above and wearing surface to be treated with 10mm thick 1:3 polymer modified cement mortar, upto a height of 150mm above the bed level of drain.
11. The gap of windows and walls to be filled with suitable polymer compound.
12. Proper checks on quality / progress to be maintained.

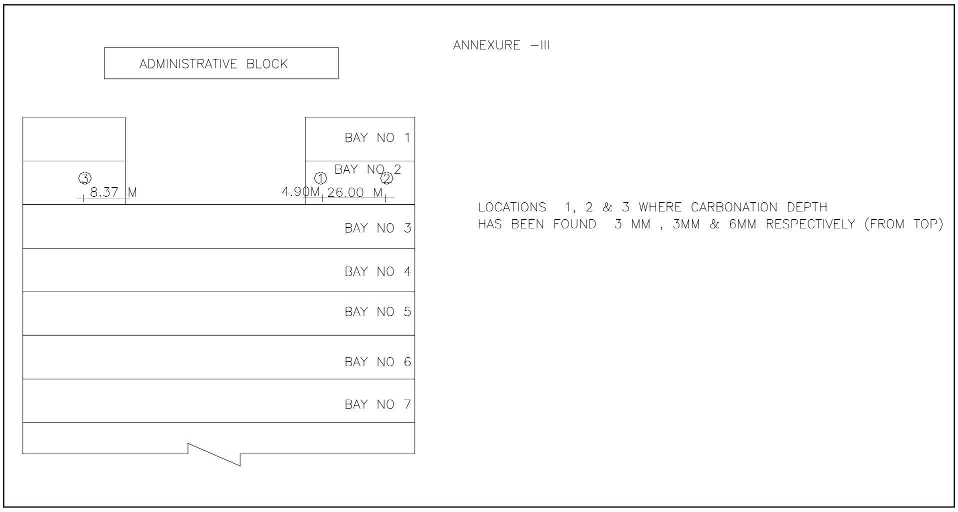

Fig 10.15.1: Lay Out Plan

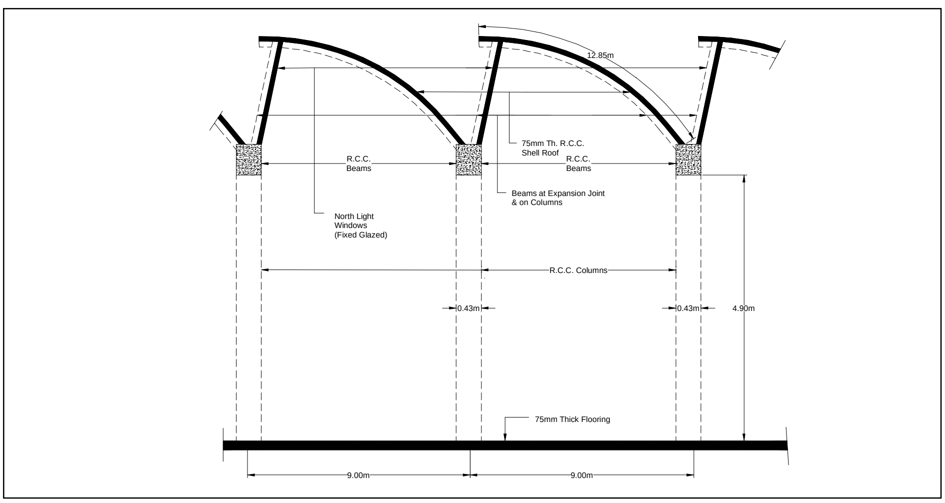

Fig. 10.15.2: Typical cross-section of Shell Roof

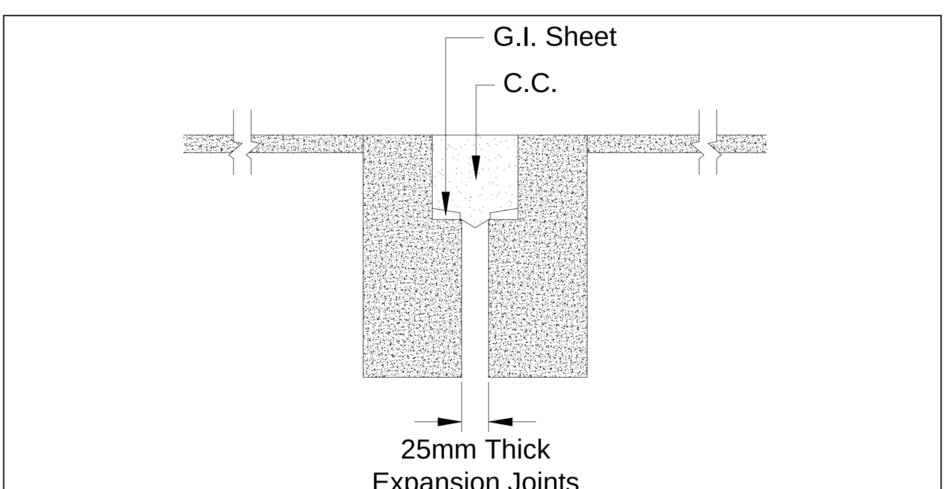

Fig. 10.15.3: Typical detail of Existing Expansion Joint

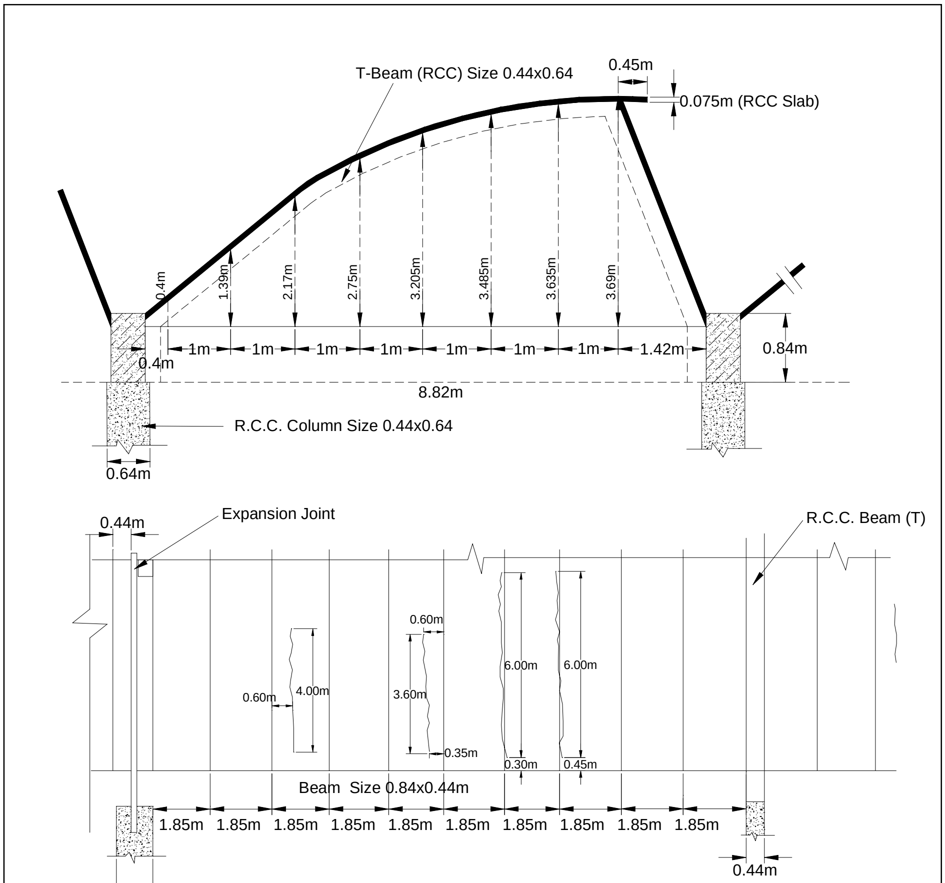

Fig 10.15.4 CRACKS DEVELOPED ON CEILING

Fig. 10.15.4(a): Typical curved profile of shell roof as per site measurement
Fig. 10.15.4(b): Typical pattern of cracks observed in soffit of shell slab

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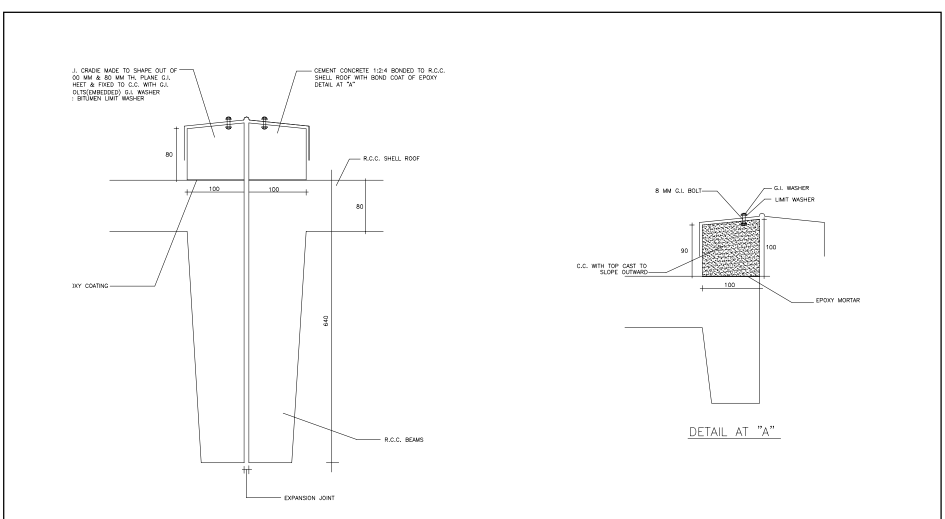

DETAIL OF IMPROVED EXP. JOINT

Fig 10.15.5: Detail of improved Expansion Joint

Plate 1: Inside view of a typical shell ➔

Plate 2: Damage caused to water proofing Treatment by fixtures for Electrical lighting ➔

Plate 3: Expansion Joint as provided originally. The outlived tarfelt visible. ➔

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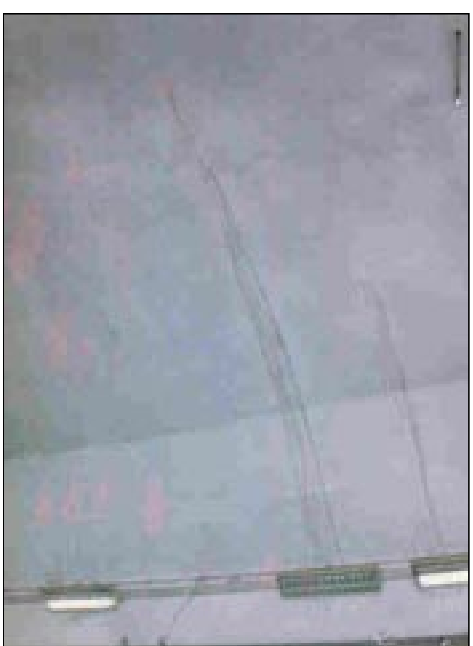


🡐 Plate 4: Seepage through cracks in RCC Shell roof

CASE STUDY – 10.16

FOUR STOREYED RCC FRAMED RESIDENTIAL QUARTERS AT BANGLORE

(Source: Repairs & Rehabilitation Unit, CDO, CPWD, New Delhi)

SALIENT FEATURES

- Period of construction : 1983
- Investigations done : 2000
- Type of Superstructure : Four storied RCC framed structure with masonry filler walls
- Type of foundation : Isolated footing

OBSERVATIONS

Based on Structural Drawings & Soil Investigation Report:

1. Filled- up soil extends to about 1.8-2.0 metre below ground level. The natural sub-soil water level was reportedly more than 100 metres below GL.
2. The foundation was resting on clayey soil strata.
3. The depth of RCC footing was observed at 1.80 metre below GL.
4. Internal partition walls at ground floor were without grade beams and supported direct on flooring.
5. The outer walls were supported on grade beams.
6. The outer RCC footings were having lower foundation pressures as compared to internal RCC footings

Based on Visual Observations:

Linked to Damage at Ground Floor

1. About five years back, diagonal cracks reportedly developed in the internal masonry walls at ground floor only.
2. Cement concrete flooring and internal partition walls on ground floor developed more severe settlement cracks with horizontal cracks in the walls and skirting.
3. A storm water drain existed with dry masonry lining outside the complex at a distance of above 2.0 metre from the two blocks of quarters. The drain is cut off during road construction about five years back and has no disposal point. No complaint was ever heard of stagnant storm water in such a dead end drain. Naturally, the rainwater continued to seep intermittently into foundation of quarters.

Linked to Damage at other floors

4. The two blocks under distress were located at the lowest ground surface level in the complex.
5. Diagonal cracks were indicative of relative settlement of internal columns. The pattern of cracks in panel walls observed identical on all the upper floor. These cracks were observed only in the recent past.
6. No damage to or cracking of RCC beams or columns due to over loading was observed.
7. The crack pattern was symmetrical and mirror-image about the central axis drawn through the connecting stair lobby.

8. Across the road, which was constructed over filled up soil, a low-lying park is located. In the recent past, this park is in disuse and being used as dumping ground, which resulted in blockade of drainage points to the adjoining nallah. This caused continued ponding of water at a level higher than the foundation level.

Linked to Corrosion Damage

9. The thickness of concrete cover to RCC columns found non-uniform and inadequate at places.
10. Some RCC chajjas and facias damaged and a few others split along the reinforcement, apparently due to corrosion of embedded steel.

FIELD TESTS

Trial Pits

1. Though, the natural sub-soil water level was reported to be much deeper, sub soil water was encountered even above foundation level understandably due to seepage of water through filled up soil from a water pond recently developed across the road.
2. It was all filled up soil strata above foundation level and the foundation was resting on pure clayey soil.

Carbonation Depth of RCC Columns

The carbonation test on all the external columns of the buildings were carried out. It was observed that concrete in columns had carbonated in the range of 5mm to beyond reinforcement.

Carbonation depth	Number of Reading (in %)
Upto 10mm	26%
11mm-25mm	18%
26mm-40mm	11%
Beyond reinforcement	45%

CONCLUSIONS

1. Damage at ground floor in the form of cracks in internal panel walls and floor settlement noticed about five years back occurred due to settlement of filled up soil underneath the floors and walls on account of intermittent seepage of storm water from dry pitched masonry drain around the buildings.
2. Cracks in internal panel walls at upper stories including ground floor and settlement of floors in the recent past is attributed to:
   a) Percolation of water in clayey sub-soil strata below foundation level due to continuous ponding in the nearby low lying ground and consequent differential settlement on account of highly varying bearing pressures below the footings.
   b) Poor drainage of rainwater due to non-functioning of surface/storm water drains in the complex, responsible for percolation of rainwater into foundations below.
3) The main cause for early distress of RCC members in the building attributed to
   a) Inadequate thickness of cover concrete.
   b) Accelerated carbonation of cover concrete due to alternate wetting and drying of concrete in exposed RCC members.

REHABILITATION MEASURES

1) Arresting further differential settlement of footing.

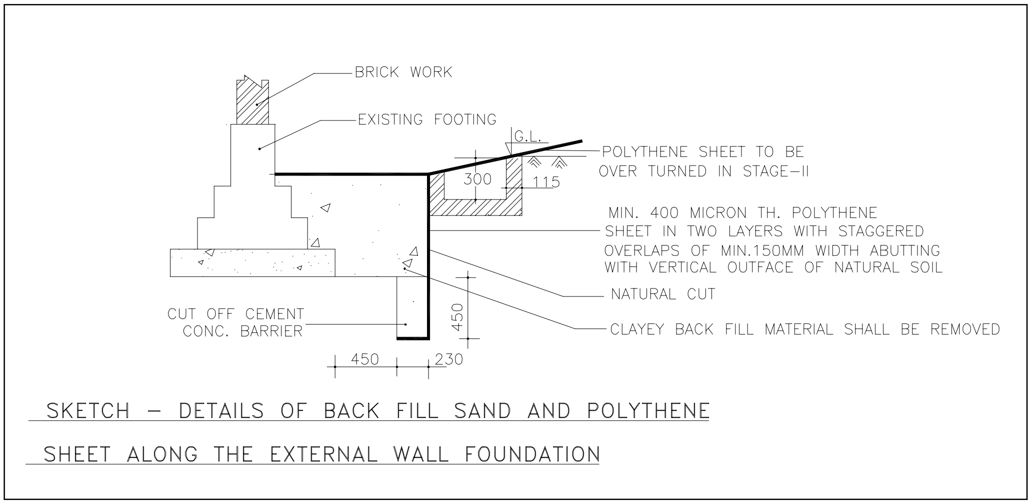
a) PVC sheet barrier as per the arrangement shown in the figure to be provided near the building upto the level below the footing of columns to prevent flow of rain/subsoil water from sides to save the buildings from damage due to settlement.

b) The ground surface in the complex to be dressed and provided with adequate slope to discharge the rain water as quickly as possible. The plinth protection provided all round the building to be repaired and made pucca to ensure that no rain/surface water accumulates or percolates into the soil near the building.

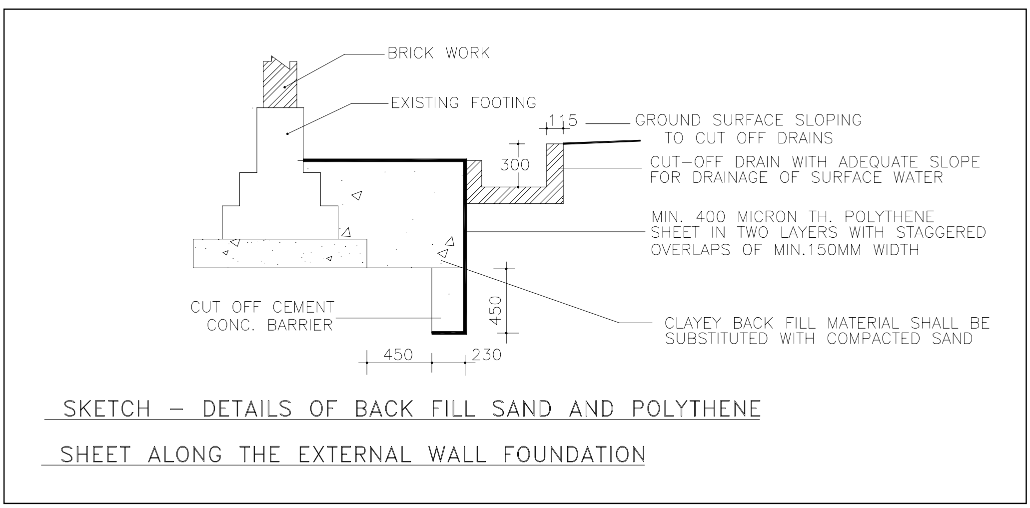
c) After allowing the settlement to stabilize for a period of at least 12 months, the repair to masonry to be carried out as specified. Flooring to be redone wherever damaged.

2) Repairs to distressed RCC columns, beams and slabs

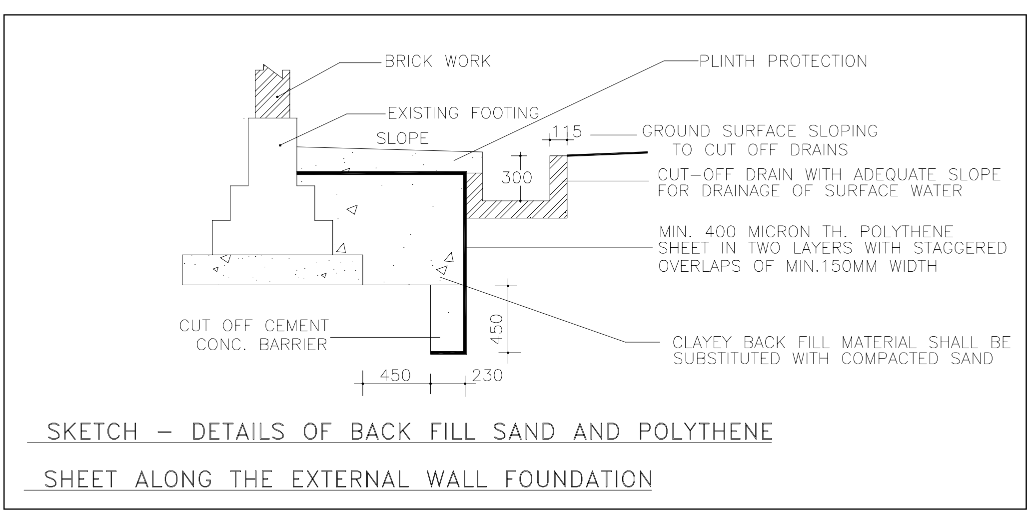
Carry out structural Repairs as per Appendix 6.1



(a) Stage-I



(b) Stage-II



(c) Stage-III

Fig. 10.16.1: Operation for Providing Moisture/water Cut off Barrier

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CASE STUDY – 10.17

AUDITORIUM PORTION OF AN INSTITUTIONAL BUILDING AT DELHI

(Source: Repairs & Rehabilitation Unit, CDO, CPWD, New Delhi)

SALIENT FEATURES

- Year of consruction : 1994
- Distress noticed : 1997
- Year of investigation : 1999
- Type of structure : An RCC Framed Auditorium on stilts with circular-curved shape in plan at two ends (Refer isometric framing view at Fig 10.17.1).

VISUAL OBSERVATIONS

1. Sagging of the curved beams in plan viz 52-59 and 12-19 of ground floor roof supporting 230 mm thick brick wall.
2. Brick masonry wall resting on left beam showed horizontal and inclined cracks at chhajjas level.
3. Cracks became wide and out ward deflection of wall increased after the earthquake in February' 99.
4. Gola on the roof separated from the beam/ parapet walland waterproofing treatment also delaminated and failed.
5. The size of curved beam provided was 230x900 mm for span of 12m to take a load of brick masonry 230mm thick and about 5m high.
6. There was no sign of distress at site due to loss of structural integrity of curved beam at its junction with RCC column.

CONCLUSIONS

1. Failure of curved beam in combined bending, shear and torsion due to its inadequate size and insufficient reinforcement.
2. The structure without additional supports below curved beams is unsafe and could collapse over a period of time.

RECOMMENDED REPAIR METHODS

1. Provide two additional columns located at ¼ span of curved beams
2. The rehabilitation and strengthening of RCC curved beams by jacketing.

   The above repairs/ strengthening shall be done in the following steps: -

   (i) Removal of masonry wall over curved beams.
   (ii) Jacking up curved beam and RCC slab at first floor level.
   (iii) Provision of column supports below curved beams at first floor level.
   (iv) Strengthening of curved beam by additional reinforcement and increasing its size.
   (v) Extending column supports beyond curved beams at first floor level up to roof level.
   (vi) Removal of props and supports below curved beam at first floor level and reconstruction of masonry wall.

(vii) Jacking up the curved beam and sagged RCC slab, at terrace level.

(viii) Concreting of the left over height of column.

(ix) Strengthening of curved beam at terrace.

(x) Rectifying the gola on roof wherever damaged or detached from wall / beams as per the normal practice.

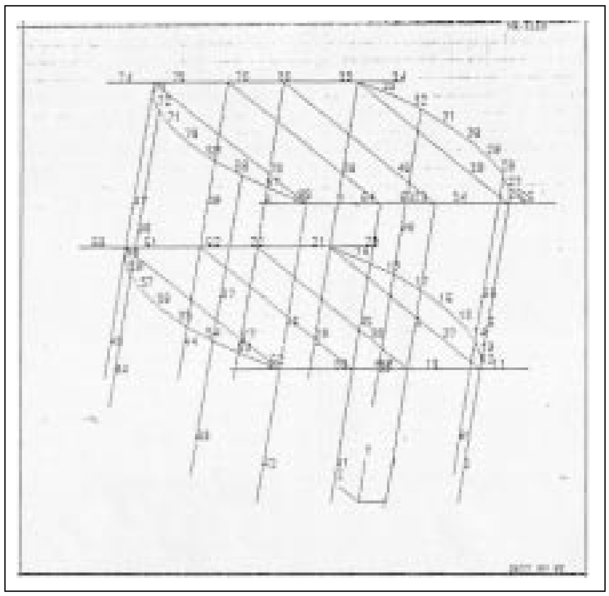

Fig 10.17.1: Isometric View of Framing System of the Auditorium Hall

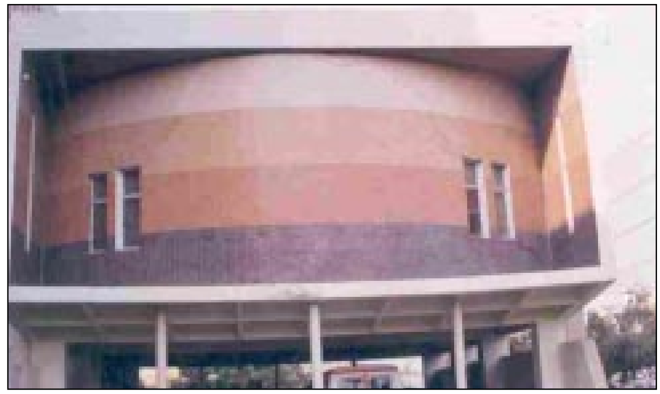

Plate 1: View of curved wall supported over inverted beam

Plate 2: Separation gap between the curved wall and the straight wall

Plate 3: View of cracked curved masonry Wall showing outward deflection of lower portion.

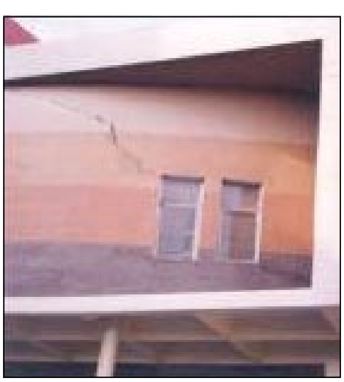

Plate 4: Cracks in curved wall resting on circular beam

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CASE STUDY – 10.18

A VIP CONFERENCE CENTRE AT DELHI

(Source: Central Designs Organisation, CPWD, New Delhi)

SALIENT FEATURES

● Year of constrution	:	1957, large scale renovation and modification in 1983
● Investigation done	:	1990
● Type of structure	:	Building with a total plinth area of 6500 sq.m. and consisted of three components a) **Auditorium:** RCC framed construction with foundation consisting of isolated/combined footings. The floor slab supported over the columns with the basement below. The roof slab was with C.G.I. Sheet roofing supported over steel roof trusses. b) **Administrative Block:** The three storeyed load bearing structure with RCC floor slab/roofs and load bearing walls, supported over RCC strip footing. c) **Rear Block:** The three storeyed RCC framed construction with beam/slab arrangements for intermediate floors and C.G.I. sheet roofing supported over steel trusses.
● History of Fire	:	The fire started from false ceiling of the room on second floor of rear block. The fire soon spread to other parts of the rear block. Later ,it gutted the roof of the auditorium which was completely burnt down.The fire had caused severe and extensive damage to the building and its content.
● Duration of fire	:	More than 1 hour.

VISUAL OBSERVATIONS

1. Collapse of the roof trusses.
2. Severe and significant cracks observed in a few concrete members.
3. Minor to considerable spalling of concrete noticed in columns, beams and slabs.
4. Reinforcement exposed in some columns, beams and slabs.
5. Minor peeling to total loss of plaster seen in the filler walls, RCC columns, beams and slabs.
6. Excessive distortion observed in a few columns.

IN-SITU EVALUATION AND LABORATORY TESTING

a) Estimation of Temperature

Based on the inspection of debris like charring wood, softened glass panes, bitumastic layered coatings, molten CGI sheets, PVC material, aluminium frames, damaged/destroyed false ceiling and wall panels, plaster on walls etc, estimation temperature at floor level was 200^{O} C and at roof level 1100^{O} C at specific locations,

b) Non-destructive Test

Core Test

The test results were as under-

Sl. No	Member Classification	No of cores	Equivalent Cube Strength of Concrete in N/sq mm			
			Min.	Max.	Av.	σ
1	Columns	23	8.64	26.60	16.10	4.78
2	Beams	12	13.16	25.06	18.90	4.39
3	Slab	18	11.75	23.96	17.27	3.06

Ultrasonic Pulse Velocity Test

The results were as under-

Pulse Velocity (km/sec)	Number of reading (in %) for			Quality of Concrete
	Column	Beam	Slab	
0.0-2.5	22	12	33	Poor
2.5-3.0	14	64	40	Doubtful
3.0-3.5	32	18	17	Medium
3.5-4.5	32	6	-	Good

Rebound Hammer Test

The rebound values as under-

Sl. No	Member Classification	No of cores	Equivalent Cube Strength of Concrete in N/sq mm			
			Min.	Max.	Av.	σ
1	Columns	12	34 to 39	38 to 56	37 to 52	2.62-5.00
2	Beams	2	28 to 50	39 to 50	33 to 50	-
3	Slab	5	30 to 37	40 to 45	34 to 40	3.88-3.55

c) Laboratory Testing

Thermogravimetric Analysis (TGA)

The results were as under-

Number of samples	Estimated temperature range	Residual strength
27	100-200^{0}C	80-90%
12	200-300^{0}C	70-80%
2	> 300^{0}C	60-70%

Differential Thermal Analysis (DTA)

This test was carried out on the samples taken from bottom of balcony slab and beam, slab of the main foyer and some columns. It was found that slab and beam were not subjected to temperature higher than 500^{0}C but columns were subjected to temperature more than 500^{0}C but less than 570^{0}C.

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X-ray Differaction (XRD)

The test was carried out on selective members and found that the main foyer beam was subjected to temperature higher than 500^{0}C while balcony slab, beam and adjacent slabs were not subjected to temerature more than 500^{0}C.

CONCLUSIONS

The various fire damaged structural members were classifed into class of damage 1, 2, 3 & 4. This damage classification was based on the visual inspection and non-destructive tests conducted on the members. The residual strength of concrete was assessed on the basis of the results of various tests done on the damaged strucutre.

RECOMMENDED REPAIR METHODS

For the purpose of formulating the recommendations, the extent of damage and their repair, measures were classified into four major categories.

1. For class of damage-1 (Superficial repairs), consisting of
   (i) Cement plaster application over treated surfaces.
2. For class of damage-2 (General non structural or minor strucutral repairs) consisting of
   (i) Cement based polymer modified mortar over cement slurry bonding coat.
   (ii) Epoxy mortar treatment over epoxy primer coating with or without wiremesh reinforcement.
3. For class of damage -3 (Principal repairs on members with significant strength reduction) consisting of
   (i) Shotcreting on slabs/beams/columns by providing steel wire mesh reinforcement.
   (ii) RCC jacketing of column members.
   (iii) Sealing of structural cracks by epoxy grout injection
   (iv) Sealing of honey combed portions by cement grouting.
4. Class of damage -4 (major structural repairs),consisting of
   (i) Demolishing the heavily damaged members and recasting with fresh concrete with or without additional reinforcement.
   (ii) Strengthening existing or addition of new structural members.

Plate 1: Main Auditorium after Fire

Plate 2: Other part of building after fire

Plate 3: Main Auditorium after repairs and finishing

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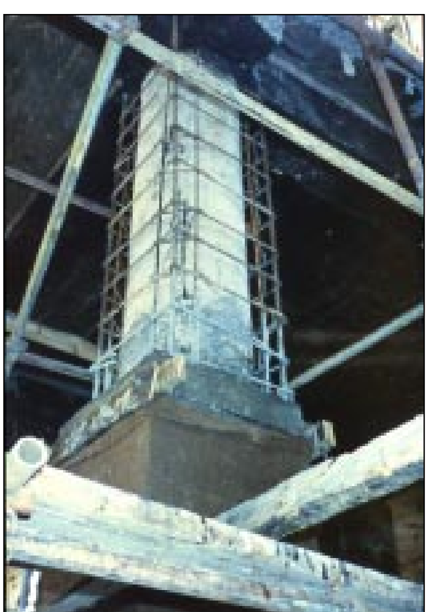

Plate 4: Columm Jacketting.

Plate 5 : Nipples fixed and cracks sealed for injection grout.

Plate 6 : Injection grouting in progres.

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Plate 7 : Epoxy mortar repairs in progress.

Plate 8 :Shotcreting in progress.

CASE STUDY – 10.19

MULTI-STOREYED OFFICE BUILDING

(Source: Dr. K. Mani, Scientist, SERC)

SALIENT FEATURES

- Type of stucture : Ten storeyed RCC framed structure having a plan dimension 35.0 m x 15.0 m, 7 bays of 5.0 m in the longitudinal direction and 3 bays of 5.0 m in the transvese direction.
- Investigation done : 1994
- Fire duration : 2 to 4 hours

VISUAL OBSERVATIONS

1. Fire occured in the 9th floor.
2. Extensive spalling of plaster in slab, beam and columns of that floor.
3. Surface cracking observed in slabs.
4. Leaching of lime through cold joints.

IN-SITU EVALUATION AND NON DESTRUCTIVE TEST

Estimation of Temperature

600 to 700^{0}C based on the visual observation of the materials burnt. Aluminium parts were on the verge of melting. The temperature of the concrete members was around 300 to 500^{0}C.

Ultrasonic Pulse Velocity Test

The test results were as under-

Sl. No	Member Classification	No. of Members	Statistical parameters of UPV values				No. of points
			Min. Km/sec	Max. Km/sec	Av. Km/sec	σ	
1	Columns	7	0.49 to 3.31	3.88 to 4.42	3.25	0.88	579
2	Beams	13	0.47 to 3.83	2.37 to 4.55	3.23	0.93	1332

The UPV values were relatively low in the bottom portion of the beam in the fire affected area.

Rebound Hammer Test

The test results were as under-

Sl. No	Member Classification	No. of Members	Statistical parameters of UPV values				No. of readings
			Min.	Max.	Av.	σ	
1	Columns	7	24 to 45	45 to 64	31.85	5.84	1214
2	Beams	20	23 to 39	45 to 70	39.27	4.83	1542
3	Slabs	11	27 to 43	51 to 64	44.54	5.76	2985

Carbonation Test

Carbonation has taken place beyond the reinforcement level.

CONCLUSIONS

1. The structural members had not been very seriously affected by fire but a few members had certain amount of deficiencies by way of loss of integrity and carbonation .
2. The high hammer test values were due to the carbonation of concrete surface.

RECOMMENDED REPAIR METHODS

1. Members with low UPV values were to be repaired by grouting with neat cement. Remove cover concrete to the required depth and gunite in layers with high strength gunite over a layer of welded mesh, 10G– 100mm x 100mm in each layer.
2. Members with exposure of steel reinforcement were repaired by grouting with neat cement. Remove cover concrete to the required depth, adding extra steel reinforcement if required and guniting in layers with high strength gunite over a layer of welded mesh, 10G– 100mm x 100mm in each layer.
3. The unaffected members were recommended for replastering with cement mortar.

Plate 1: Damaged Column & Beam Junction

GLOSSARY

Abrasion	The wearing away of material by friction. Surface particles become detached by a combined action of shearing and tearing.
Absorption	The surface penetration of fluid in small pores of a material.
Adhesion	The force acting on the interface of two solid materials
Admixture	A material other than water ,aggregates and cement used as a component of concrete or mortar and added to the batch during its mixing
Air Entraining	The capability of material or process to infuse air in the cement paste,mortar or concrete through a system of minute air bubbles.
Alkalinity	The condition of having or containing alkaline substances with hydroxyl(OH-) ions to cause its pH more than 7.
Ambient Temperature	The environmental temperature surrounding an object
Anode	The positive electrode where oxidation occurs due to electrons moving in to the electrode.
Capillary Action	Rise of fluid in a small diameter (capillary) tube due to surface tension of the fluids.
Carbonation	The process of conversion of calcium hydroxide in hardened cementitious material in to calcium carbonate due to reaction with atmospheric carbon dioxide
Cathode	At negative potential, electron are drawn away from it and chemical reduction reaction occurs.
Cathodic protection	The method of protection of a metal from corrosion by making it a cathode by impressed currant of by introduction of a lesser noble metal.
Chloride Content	The total amount of chloride ions including the fixed chlorides (non-soluble in pore water) present in concrete or mortar
Cold Joint	A construction joint formed due to setting of concrete/mortar before placing of next bach of material
Condition Survey	Condition survey is an examination of structure for the purpose of identifying and defining area of distress.
Corrosion	The process of deterioration of concrete or reinforcement due to chemical or electrochemical change caused in presence of moisture.
Corrosion Inhibitors	The chemical, when added to concrete in small proportions, checks or retards the process of corrosion of embedded steel reinforcement.
Cover	The least distance between the surface of the reinforcement and the outer surface of the concrete.
Creep	The irrecoverable strain caused to a material subjected to constant stress for a long duration.
Curing	The process of maintaining sufficient moisture and temperature in the concrete after its placing in position, which is absolutely necessary for its complete hydration.
Delamination	A separation, splitting or cracking roughly parralel and near to surface.
Depassivation	The loss of alkalinity in the immediate vicinity of steel reinforcement due to carbonation process so as to cause dissolution of its protective passive layer.
Design Service Life	The life specified for the structure at its design stage for it to adequately perform its functions.

Disintegration	Breaking into small fragments.
Dry Pack Concrete	Stiff mix of concrete / mortar usually compacted by ramming
Drying Shrinkage	The shrinkage caused due to loss of water from concrete after its hardening.
Durability	The characteristic of a structure to resist gradual degradation of its serviceability in a given environment for the design service life.
Electrolyte	Any substance which when dissolved in water or other suitable solvent forms a solution that conducts electricity, due to ionic dissociation of the dissolved substance in a solvent .
Environment of	The surrounding conditions of temperature, humidity, chemicals etc of a structure or structural member to which it is exposed to.
Epoxy	It is a high strength adhesive compound formed as a result of polyerisation of resin at ambient tempearture in presence of a specified proportion of hardener.
Ettringite	The expansive crystals that swell due to adsorption of water in alkaline environment. These crystals are formed due to reaction of alumina containing hydrates in hardened cement paste with sulphate ions in presence of calcium hydroxide.
Feather Edge	The bevelled edge of a repair concrete or mortar which is at an acute angle from the surface.
Ferrocement	It is thin walled reinforced cementitious construction using more than one layer of continuous small diameter metallic wire mesh.
Fibre Wrap Techniques	Integrating woven or non-woven high strength fibre (e.g. E-Glass fibre, Carbon Fibre,Aramid, Polyester etc.) with epoxy, around structural element to protect and/or enhence its structural capacity.
Gel	A semisolid jelly like condition of matter.
Grouting	Pumping of a fluid cementitious material in to crevices of a cracked material or the interconnected pores of a porous material with a view to enhence the density/ strength of the material.
Hydrophobic	Property of non-wetting or repelling water.
Joint Sealant	Compressible material used to exclude water and solid foreign materials from entering the joints
Latex	Natural or synthic rubber emulsion in water phase.
Leaching	The draining out of water soluble salts from concrete due to movement of water.
Load carrying capacity	The capacity of a structural member to carry loads based on non-destructive evaluation results and their analysis.
Maintenance	A general term for actions taken to ensure that a structure conforms to its original functional performance above a given level of acceptance.
Non Destructive Evaluation (NDE)	The sampling/testing in laboratory/field without affecting the functional utility of structure.
Original Construction Defects (OCDs)	Defects inherent in the original construction due to improper design, material selection or workmanship.
Passivation	Formation of a protective layer of ferric oxide around embedded reinforcement under highly alkaline environment.

Patch Repair	The repair to a portion of a structural member to restore it to its original state
pH	Hydrogen ion concentration of a solution expressed as negative of logarithm to the base 10
Polymer	It is a long chain of molecules formed by combination of molecules of monomers in presence of an initiator.
Polymer Impregnation	A process of filling the interstices of a cracked/porous material with polymeric compounds.
Polymerisation	Polymerisation is the process of formation of long chain molecules at desired temperature from monomers in presence of an initiator.
Seepage	Uncontrolled admittance of water through interconnected pores.
Re-alkanisation	The electro-chemical process of infusing alkaline environment in a carbonated concrete around steel reinforcement by converting calcium carbonate in to calcium hydroxide
Rebound	Aggregate & cement or wet shotcrete that bounces away from a surface against which it is being projected.
Rehabilitation	The process of repairing or modifying a structure to a desired useful condition.
Repairs	To replace or correct deteriorated, damaged or faulty materials, components, or elements of a structure.
Restoration	The process of re-establishing the original appearance, shape and materials of a structure.
Retrofitting	Upgrading the existing structure to meet the enhanced structural requirements in terms of load carrying capacity of existing structural element or by introducing additional structural members integral to the existing structure.
Service life	The time taken from the completion of a structure till the structure is no longer usable due to the deterioration process.
Serviceability	The necessary performance requirement of a structure to meet its intended function.
Shotcrete	Process of application of concrete by spraying under pneumatic pressure.
Spalling	Loss of strength and integrity of cover concrete with the interior of concrete due to expansive force.
Sulphate Attack	Dis-integration of concrete due to formation of expansive compounds as a result of chemical reaction of the constituents of hydrated cement with sulphates ions, present internally or from ingressed from external source.
Strengthening	Measures taken for a deteriorated structure or any of its structural member to restore its design load carrying capacity.
Workability	A property of freshly mixed mortar or concrete, which measures the ease of working upon it duiring its placement including compaction and finishing.
Bond Breaker	Material used to facilitate independent movement between two units, which would otherwise behave monolithically.
Burlap	Vurlap a course fabric of jute, hemp, or flax for use as a water retaining cover when curing cementitious materials.
Erosion	Progressive disintegration of a solid by the abasive or cavitation action of gases, fluids or solid motion.
Fatigue	The weakening of a material by repeated or alternating loads.

Hardener	A substane that enters into a chemical combination with other substances to form a new, more solid material.
Laitance	A layer of weak and non durable material containing cement and finds from aggregates, brought to the top of oval-wet concrete by bleeding water.
Shelf life	The useful life of the material.
Permeability	The property of the material which allows the fluid through a solid material.
Membrane/Coating	A thin, waterproof barrier consisting of polymeric material which may be prefabricated or applied as a liquid.
Plastic Shrinkage	Shrinkage that takes place before cement plaste, mortar, grout, or concrete sets.
Polymer Concrete/ Mortar	Concrete or mortar in which a resin serves as a binder.
Porosity	The ratio, usually expressed as a percentage of the volume of voids in a materials, to the total volume of a material, including the voids.
Pop Out	A shallow, corical depression on the surface of concrete.
Pot life	Storage time interval after mixing, during which a liquid material can be used without difficulty.
Quality Assurance	A system of proceeding that ensures that the intended levels of quality on a project are obtained.
Restraint	Restriction of free movement of fresh or hardened concrete, mortar, or grout; restraint can be internal and external and may act in one or more directions.
Retardation	A reduction on the rate of hardening or setting, I.e., an increase in the time required to reach initial and final set, or to develop early strength of fresh concrete, mortar, or grout.
Scaling	Local cracking or peeling away of the surface concrete or mortar.
Silicafume/Microsilica	Highly reactive pozzolana, a by-product of ferrosilicon production.
Siloxane	A silicon and oxygen-based compound, also containing carbon and hydrogen used as penetrating sealer for concrete surfaces.
Silane	A solution of a low molecular weight compsition of silicon and hydrogen used as penetrating sealer for concrete surfaces.