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New Repairs & Rehabilitation of Buildings (A Study Concept)

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Abstract:-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. 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.
To determine a rational approach for repair and rehabilitation work, to find out the source of the problem and to adopt the proper methodology to achieve durable, effective and economic repairs. The Scope of the research will be:
*To identify the causes of distress and their sources.
*To select and plan the effective remedy using appropriate methodology.

Keywords: Repairs, Rehabilitation, Deterioration, Rational approach, Causes of distress

I. Introduction

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.

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. A comprehensive inspection data helps in making an effective strategy for repair and rehabilitation

II. Repair Management:

Three distinct stages are to be recognized while taking up a repair job.

Stage 1: 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.

Stage 2: 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.

Stage 3: The third stage is actual execution of repairs. This is a specialized 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.

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.

Types of cracks

- Structural cracks.
- Non Structural Cracks.

Structural Cracks

Structural cracks are those which result from incorrect design, faulty construction or overloading and these may endanger the safety of a building and their inmates.

Non Structural Cracks

Non Structural cracks occur mostly due to internally induced stresses in building materials. These cracks normally do not endanger the safety but may look unsightly, create an impression of faulty work or give a feeling of instability.

Fig.1.Cracks reappear over repaired surface as rust scales were not removed

Defects in Concrete

Concrete defects can be broadly classified into two categories:

Macro Defects
These defects are clearly visible to the naked eye, for instance, like honeycombs

Fig. 2.Honeycombs at the foot of a RCC column


Fig. 3 Wide cracks on concrete wall and on plaster

If these defects are present, concrete has low strength and will rapidly deteriorate due to easy ingress of water and other chemicals. Invariably, structure will require repairs within a few years of its construction. Causes will have to be analysed and defects removed before doing any additional protective treatment. Often, waterproofing of concrete slabs is carried out superficially and it fails to give the desired benefit because the defective concrete below this waterproofing layer has not been treated to seal the macro/micro defects which existed within the concrete slab. The main causes of these defects are generally due to inadequacies in design and / or construction practices.

Micro Defects
These defects are not visible to the naked eye. They are usually very fine voids caused by large capillary pores resulting from the use of low grades (strength) of concrete with high water to cement ratio.

They could also occur due to addition of excess water or high water to cement ratio of concrete mix. Fine cracks are generally present in concrete and can occur due to various reasons. They do not pose a serious threat to concrete deterioration initially as they are generally not deep and are discontinuous. With lapse of time due to variations in temperatures, changes in weather conditions, changes in loading conditions they increase in depth, length and width and combine with other fine cracks to create continuous passage for moisture, chlorides, sulphates and other chemicals from the environment to enter and start corrosion of steel in concrete and other deleterious reactions.

Fig.4. Corrosion of steel and spalling of concrete due to ingress of moisture

To conclude, macro defects and micro defects in concrete are both harmful to the health of buildings and can cause deterioration of concrete depending on the extent of their presence, environmental conditions around the building and maintenance done during its life cycle. However macro defects by virtue of being larger can cause faster deterioration and more damage to the structure than the micro defects.

Causes of Cracks

The principal causes of occurrence of cracks in a building are as follows:

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, micro-cracks 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 given good quality materials, satisfactory proportioning and good construction practice; the permeability of the concrete is a direct function of the porosity and interconnection of pores of the cement paste.

Thermal movement:

Thermal movement is one of the most potent causes of cracking in buildings. All materials more or less expand on heating and contract on cooling. The thermal movement in a component depends on a number of factors such as temperature variations, dimensions, coefficient of thermal expansion and some other physical properties of materials. The coefficient of thermal expansion of brickwork in the vertical direction is fifty percent greater than that in the horizontal direction, because there is no restraint to movement in the vertical direction.

Thermal variations in the internal walls and intermediate floors are not much and thus do not cause cracking. It is mainly the external walls especially thin walls exposed to direct solar radiation and the roof which are subject to substantial thermal variation that are liable to cracking.

Creep:

Concrete when subjected to sustained loading exhibits a gradual and slow time dependant deformation known as

creep. Creep increases with increase in water and cement content, water cement ratio and temperature. It decreases with increase in humidity of surrounding atmosphere and age of material at the time of loading. Use of admixtures and pozzolonas in concrete increases creep. Amount of creep in steel increases with rise in temperature.

Corrosion of Reinforcement:

A properly designed and constructed concrete is initially water-tight and the reinforcement steel within it is well protected by a physical barrier of concrete cover which has low permeability and high density. Concrete also gives steel within it a chemical protection. Steel will not corrode as long as concrete around it is impervious and does not allow moisture or chlorides to penetrate within the cover area. Steel corrosion will also not occur as long as concrete surrounding it is alkaline in nature having a high pH value.

Concrete normally provides excellent protection to reinforcing steel. Notwithstanding this, there are large number of cases 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.
This increase in volume causes high radial bursting stresses around reinforcing bars and result in local radial cracks. These splitting cracks results in the formation of longitudinal cracks parallel to the bar. Corrosion causes loss of mass, stiffness and bond and therefore concrete repair becomes inevitable as considerable loss of strength takes place

Fig. 5.Corrosion of steel in a canopy

Moisture Movement:

Most of the building materials with pores in their structure in the form of intermolecular space expand on absorbing moisture and shrink on drying. These movements are cyclic in nature and are caused by increase or decrease in inter pore pressure with moisture changes.

Initial shrinkage occurs in all building materials that are cement/lime based such as concrete, mortar, masonry and plasters. Generally heavy aggregate concrete shows less shrinkage than light weight aggregate concrete.

Controlling shrinkage cracks:

Shrinkage cracks in masonry could be minimized by avoiding use of rich cement mortar in masonry and by delaying plaster work till masonry has dried after proper curing and undergone most of its initial shrinkage. In case of structural concrete shrinkage cracks are controlled by using temperature reinforcement. Plaster with coarse well graded sand or stone chip will suffer less from shrinkage cracks and is preferred for plastering for external face of walls.

Considering the building as a whole, an effective method of controlling shrinkage cracks is the provision of movement joints. The work done in cold weather will be less liable to shrinkage cracks than that in hot weather since movement due to thermal expansion of materials will be opposite to that of drying shrinkage.

Poor Construction practices:

The construction industry has in general fallen prey to non-technical persons most of whom have little or no knowledge of correct construction practices. There is a general lack of good construction practices either due to ignorance, carelessness, greed or negligence. Or worse still, a combination of all of these.

The building or structure during construction is in its formative period like a child in mother's womb. It is very important that the child's mother is well nourished and maintains good health during the pregnancy, so that her child is healthily formed. Similarly for a healthy building it is absolutely necessary for the construction agency and the owner to ensure good quality materials selection and good construction practices. All the way to building completion every step must be properly supervised and controlled without cutting corners.

Poor structural design and specifications:

Very often, the building loses its durability on the blue print itself or at the time of preparation of specifications for concrete materials, concrete and various other related parameters.
It is of crucial that the designer and specifier must first consider the environmental conditions existing around the building site. It is also equally important to do geotechnical (soil) investigations to determine the type of foundations, the type of concrete materials to be used in concrete and the grade of concrete depending on chemicals present in ground water and subsoil.

Fig. 6. Segregation of concrete causing honey comb

It is critical for the structural designer and architect to know whether the agency proposed to carry out the construction has the requisite skills and experience to execute their designs. Often complicated designs with dense reinforcement steel in slender sections result in poor quality construction. In addition, inadequate skills and poor experience of the contractor, ultimately causes deterioration of the building.

Closely spaced of reinforcement steel bars due to inadequate detailing and slender concrete shapes causes segregation. If concrete is placed carelessly into the formwork mould, concrete hits the reinforcement steel and segregates causing fine materials to stick to the steel, obstructing its placement and is lost from the concrete mix while the coarse material falls below causing large porosity (honeycombs).

Slender structural members like canopies (chajjas), fins and parapets often become the first target of aggressive environment because of dense reinforcement, poor detailing, less cover of concrete to the reinforcement steel. Added to all this, low grade of concrete and poor construction practices can make the things worse. It is necessary for the structural consultant to provide adequate reinforcement steel to prevent structural members from developing large cracks when loaded.

Fig. 7. Cantilever canopy showing honeycombing

Fig.8. Badly deteriorated slender cantilever balcony slabs.

To sum up, the following precautions are required to be taken by the Architects, Structural Consultants and Specifiers:

- Proper specification for concrete materials and concrete.
- Proper specifications to take care of environmental as well as sub - soil conditions.

- Constructable and adequate structural design.
- Proper quality and thickness of concrete cover around the reinforcement steel.
- Planning proper reinforcement layout and detailing the same in slender structures to facilitate proper placing of concrete without segregation.
- Selection of proper agency to construct their designs.

Architects and Engineers are parents of the buildings they plan and design and therefore their contribution to the health and life of the building is quite significant. Once the plans are drawn the structural designs and specifications are prepared, it is then the turn of the agency to construct the building and bring the blue print to reality. Special care must be taken in the design and detailing of structures and the structure should be inspected continuously during all phases of construction to supplement the careful design and detailing.

Poor Maintenance:

A structure needs to be maintained after a lapse of certain period from its construction completion. Some structures may need a very early look into their deterioration problems, while others can sustain themselves very well for many years depending on the quality of design and construction.

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Fig.9. Leakage from roof slab

Fig.10. Spalled concrete due to corrosion of steel

Regular external painting of the building to some extent helps in protecting the building against moisture and other chemical attacks. Water-proofing and protective coating on reinforcement steel or concrete are all second line of defence and the success of their protection will greatly depend on the quality of concrete.

Leakages should be attended to at the earliest possible before corrosion of steel inside concrete starts and spalling of concrete takes place. Spalled concrete will lose its strength and stiffness, besides; it will increase the rate of corrosion as rusted steel bars are now fully exposed to aggressive environment. It is not only essential to repair the deteriorated concrete but it is equally important to prevent the moisture and aggressive chemicals to enter concrete and prevent further deterioration.

Movement due to Chemical reactions

The concrete may crack as a result of expansive reactions between aggregate containing active silica and alkalines derived from cement hydrations. The alkali silica reaction results in the formation of swelling gel, which tends to draw water form other portions of concrete. This causes local expansion results in cracks in the structure.

To control Cracks due to alkali-silica reactions, low alkali cement, pozzolona and proper aggregates should be used.

Indiscriminate addition and alterations

There have been some building collapses in our country due to indiscriminate additions and alterations done by interior decorators at the instance of their clients.

Generally, the first target of modifications is the balcony. Due to the requirement to occupy more floor area, balconies are generally enclosed and modified for different usages.

Balconies and canopies are generally cantilever RCC slabs. Due to additional loading they deflect and develop cracks. As the steel reinforcement in these slabs have less concrete cover and the balcony and canopy slab is exposed to more aggressive external environment, corrosion of steel reinforcement takes place and repairs become necessary.

The loft tanks are generally installed in toilets or kitchens, which are humid areas of the buildings. The structure in addition to being overloaded is also more prone to corrosion of reinforcement steel in these areas and therefore deteriorates and if not repaired, part of the building can even collapse.

RCC Repair and Rehabilitation – Concepts and Product Selection

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.

It should include method of repair and repair material. 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

Condition Survey

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 inspection to completion and subsequent life.
The four stages of Condition Survey described are:
a) Preliminary Inspection,
b) Detailed Inspection,
c) Planning,
d) Visual Inspection

Preliminary Inspection

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
- Notes and records of earlier repairs, if carried out,
- All possible relevant data and information

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

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.
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.

Detailed Investigation:

The detailed investigations must be carried out adopt the proper methodology for repairs and to know the accurate cause of deterioration of structure. It is carried out in the following manner:
- Sampling
- Depth of carbonation
- Type and grading of aggregates.
- Cement content of the concrete
- Type of cement
- Chloride content
- Sulphate content
- Assessment of void, honeycombs etc.

Planning Stage

Planning stage involves preparation of field documents, grouping of structural members and classification of damage.

i) Preparation of Field Documents
ii) Grouping of the Structural members
iii) Classification of Damage

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.

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

Requirements of Repair system

A repair system should satisfy the following requirements:

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

Factors affecting Repair methods

The following important factors should 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

Repair Stages

The following stages should be followed in order to repair the structure effectively

- Concrete Removal and Surface Preparation
- Fixing suitable formwork
- Repair Application

Concrete removal and surface preparation

The general procedure for preparing concrete and reinforcement services is to remove the external surfaces and remove dust and debris. 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.

Formwork

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.

Repair Application

The following general steps are to be followed for repair applications:
The defective (cracked) portion of the concrete or plaster has to be removed taking care that good concrete or plaster is not unnecessarily damaged or chipped off along with the defective portion.
During the repairs, structural load carrying members, e.g. Columns, beams, slabs, chajjas etc., must be supported/propped/isolated so that the load on these members is reduced and transferred to other good structural members of the RCC frame work. The supporting propping and isolating details must be obtained from the Consultant.

- One must be extremely careful during repairs as the weakened member may further lose its strength due to chipping and other removal procedures. Supporting/propping of the structural members must be insisted upon before actual repair work starts on it.
- Chipping of defective or deteriorated concrete should be done till all defective concrete work (porous honeycombed concrete) - and rust scales are removed.
- Remove all rust from steel bars (reinforcement) by tapping lightly on the rusted bars, wire brushing and cleaning. Rust on steel in concrete is like cancer in a human body. It must be removed completely before repairs are taken up. If the bars have rusted too much, they will have to be replaced with fresh reinforcement steel

and fixed as per the details given by the Consultant. Apply, if specified, rust converter on rusted steel bars after they are reasonably cleaned.

- Wash and clean the entire surface before taking up repairs. Inspect concrete once again, carefully, for weak spots, rusted steel and any type of porosity. If defects are observed repeat steps (c) & (d). If no further defects are observed, then start the repairs.
- Repairs as specified by consultant should be carried out. Generally concrete columns are either gunited or jacketed with concrete or treated with cement or non-cement based polymer concrete. The slabs and beams are either gunited or treated with Polymer concrete Generally, guniting method is now not being adopted as it is a messy job and the quality of work greatly depends on the skills of the nozzle men or operators who are scarcely available. These days concrete is mainly resorted to but it is costly. Jacketing columns with concrete is most economical. However, due to this the size of the column often increases and results in reduction of the carpet area of the floor around the column locations.
- The replaced surface must be scratched and roughened to give a good mechanical bond with subsequent finishing coats of mortar or plaster.
- After the application of gunite /concrete jacket / polymer concrete the repaired member should be cured for 7 days. Curing means to maintain over98% humidity around the repaired surface. This is generally done by ponding water or spraying water at regular intervals. Proper curing is a must as it helps repaired material to gain strength and improves the surface hardness thereby making it impermeable and free from porosity and cracks
- The substrate is then allowed to surface dry and finishing coats of mortar (sand and cement mix) is applied thereafter in two coats. This is also called plastering. Curing is once again done for 7 days after application of each coat of plaster.
- Safety of occupants and other persons moving in and around the building must be considered at the planning stage itself. Safety of workers is equally important. Proper insurance cover needs to be taken by the Contractor to avoid unforeseen liabilities on the building owners.

Selection of Repair materials

For the selection of material of repairs it is necessary to understand the properties of various such materials and their limitations. The selection of materials also depends upon the basic nature of structure repaired. Selection of material thus depends on the following:

- Type of concrete to be repaired and its age.
- Magnitude and thickness of repairs.
- Site conditions, temperature &environmental influence.

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.

Sprayed Concrete and Shotcreting

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 basic steps followed in this technique are

- Chipping and removal of loose concrete
- Fixing of weld mesh of appropriate size.
- Putting of flash strips
- Guniting
- Finishing spray.

Normally cement: sand mix of the ratio 1:3.5 is used for guniting. Water cement ratio is maintained as low as 0.3 to 0.4. Guniting is a very good technique in civil engineering, but it is not advisable for rehabilitation of structurally distressed RCC members due to following reasons:

- In this methodology generally good concrete is also removed along with the bad concrete.
- Practically it is not possible to de-stress the deteriorated RCCmembers before restoration in a majority of cases, (due to many constraints) and therefore removal of good concrete, which is sharing the load, must be avoided.
- Guniting creates dust and noise pollution and therefore it is a health hazard for the occupants who stay in their premises during the repair work.
- On account of bad quality materials and poor workmanship, there have been cases where guniting work gave way within 3 to 5 years.

JACKETING

Jacketing results in increasing column section on all four sides with additional concrete and re-bars, to strengthen the column or to increase it's load carrying capacity. Entire height of the column from the top of the foundation should be jacketed. At times jacketing is done incorrectly only up to the ground floor slab level. There are cases where columns were rehabilitated by jacketing even though the columns were not required to take extra load. In the process, also good concrete is often removed which is not desirable.

There are instances where a column section was increased only on one face and not on all four faces. This is not jacketing. Here rehabilitation should have been done by cementitious acrylic polymer based mortar or by ready to use non-shrink micro concrete. This treatment does not result in increasing the column section and also does not deprive the flat occupants the floor space lost in jacketing work.

Injection Grouting

Injection grouting technique is used for filling the cavities and cracks in massive concrete members and crack which pass through the structural member. Epoxy resins and polymer modified cement slurry with chemical admixtures are used for this purpose.

The grouting materials should have following properties:

- Low viscosity
- Excellent in bonding property with damp & old concrete.
- Suitable for injection in wide temperature range.
- Low-curing shrinkage.
- Durable and resistance to aggressive chemicals.

Chemical and Electro-chemical method

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. Though the electro-chemical methods 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.

Cathodic Protection

Corrosion of reinforcement due to chloride in concrete leads to reduction of life of repair system. The main method to deal with this problem is to use cathodic protection. Corrosion in steel is an electrochemical process and exposed steel in an moist environment will be corroded due to difference in electrical potential on the surface of metal itself. These areas form anodes to cathodes.
Electric current flows from anode to cathode. Metal suffers corrosion at anodic areas. The Principle in this system is that steel to be protected from the cathode. There are two ways to use the cathodic protection they are:

- Sacrificial anodes
- Impressed current

Among these, the sacrificial anode system is used in many places.

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.
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. 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.

PROTECTIVE COATING

Protection Coating are important part of repairs because of the following reasons:

- To resist passage of water under hydrostatic pressure, outwards as in water retaining structures.
- To resist ingress of chloride ions.
- To prevent ingress of underground water.
- To prevent concrete from chemical attacks.
- To protect against abrasion and high velocity water erosion

Following materials are normally used for protection coating:

- Hot applied and cold applied Bitumen.
- Chlorinated rubber.
- Acrylic-water dispersed.
- Epoxies
- Polyurethanes
- Silicones and silanes
- Polymers

POLYMER MORTAR

The present methodology entails use of cementitious acrylic polymer modified mortar or ready to use micro concrete. It overcomes all problems faced in the sprayed concrete system

This is the best method available today as all conditions for sound and excellent rehabilitation are satisfied.

The advantages are as follows:

- Only loose, Spalled and bad concrete is removed. Good concrete is not disturbed at all.
- Work is done part-by-part, completing one part then moving on to another.
- There is neither dust nor noise nuisance.
- It is recommended that rehabilitation work of structural distress must be started from the ground floor and continued upwards, both externally as well as internally.
- Patch repairs are possible
- High compressive and flexural strength
- Impermeable structure
- Excellent bond strength easy to use.

In this category of repairs wide range of products are available and every product manufacturer claims a series of advantages for his product. Thus a precise selection of polymer component of repair has become difficult.

Keeping in view the above aspects AC-Polymer Acrylic- Repair system has been developed by Apple Chemie, They are:

- AC-Corine:

  It acts as an active corrosion inhibiting primer coating on exposed and corroded reinforcement in RCC. It prevents further corrosion of structural steel. It provides bonding with surrounding coating.

- AC bond aid:

  It provides efficient and excellent bonding agent for old and new concrete. It is also suitable for bonding of new repair composite mortar with old concrete surface and also provides excellent bonding with steel reinforcement.

- AC- Repair -10:

  It exhibits good adhesive property with concrete. It gains strength rapidly and has resistance to abrasion. It is extremely suitable for damaged repair edges, joints and honey combed portions.

- AC- Acrylate Repair:

  It is suitable for preparation of shrinkage free plasticised retention capabilities. Increase in the flexibility of hardened mortar/ concrete is possible so that stresses in the repaired portion is avoided. It is universally applicable for repair mortar/concrete and screeds for all type of RCC repairs.

- AC-Flex-CL:

  It helps crack bridging and arrests carbonation effect with waterproofing protection. It resists environmental attacks and severe pollution. It also provides decorative and Solar reflection cum ultraviolet radiation resistant coating, and therefore economical.

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.

II. CONCLUSION

Early deterioration of buildings within a period of 10 to 30 years is due to neglect at architectural planning, structural design and construction stage. It has been observed that cracking is the most common indication of distress in the concrete structure. Cracks at different locations have been observed due to various reasons and must be prevented using various methodology. Rich cement mortar should be avoided in the masonry to eliminate shrinkage cracks. Expansion joints, slip joints and control joints should be provided to avoid thermal expansion. Concrete with low permeability should be used to avoid corrosion of reinforcement.

The appropriate method should be selected with a good understanding of the nature of the repair for repair and rehabilitation of RCC structure. Proper understanding of the products to be used, correct application and basic knowledge of civil and structural engineering will lead to long lasting and economical repair. 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.

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