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Repair and Rehabilitation of RCC Structures

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ABSTRACT
RCC has been used extensively in the last 50-60 years. During this period, we have created large number of infrastructure assets in terms of buildings, bridges, sports stadium, etc., which are lifeline for the civilize society. Buildings and other structures have a certain useful life, which depends on the specifications adopted. The large numbers 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. These have been created with huge investment o 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 phenomenon and has started exhibiting in large number of structures, a systematic approach is needed in dealing with such problems. The purpose of this paper is to justify the latest techniques, advanced materials and various requirements of repairing work to obstruct the deterioration which is necessary and economical than to reconstruct the building.

Keyword- Building, Rehabilitation, Repair, Structure, concrete, plaster, Shotcrete, Epoxy

I. INTRODUCTION

A large stock of existing structures and infrastructure are deteriorated with use and time and might have passed their design life and require retrofitting and rehabilitation. Many of the existing structures were designed to codes that have since been modified and upgraded. Change in use or higher loads and performance demands require modifications and strengthening of structural elements. The need to improve the ability of an existing building to withstand from weathering action, chemical attack, embedded metals, alkali-aggregate reactivity, fire, due to overload, seismic forces, etc. arises usually from the evidence of damage and poor behaviour. These types of structures are deteriorated with use and time and might have passed their design life and require repair and rehabilitation. Therefore, the solutions for RCC structure or structural elements are essential and for this different technique are utilized. Strength assessment of an existing structure or any element of structures is essential to cover all the criteria in which maintenance is required.

Structural Failure

- Site Selection and Site Development Errors:

Failures often result from unwise land use or site selection decisions. Certain sites are more vulnerable to failure. The most obvious examples are sites located in regions of significant seismic activity, in coastal regions, or in flood plains. Other sites pose problems related to specific soil conditions such as expansive soils or permafrost in cold regions.

- Design Errors:

These failures include errors in concept; lack of structural redundancy; failure to consider a load or combination of loads; deficient connection details; calculation errors; misuse of computer software; detailing problems including selection of incompatible materials, failure to consider maintenance requirements and durability; inadequate or inconsistent specifications for materials or expected quality of work and unclear communication of design intent.

- Construction Errors:

Such errors may involve excavation and equipment accidents; improper sequencing; inadequate temporary support; excessive construction loads; premature removal of shoring or formwork; and nonconformance to design intent.

- Material Deficiencies:

While it is true that most problems with materials are the result of human errors involving a lack of understanding about materials, there are

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failures that can be attributed to unexpected inconsistencies in materials.

- Operational Errors:

Failures can occur after occupancy of a facility as the result of owner/operator errors. These may include alterations made to the structure, change in use, negligent overloading and inadequate maintenance.

Repair, Rehabilitation and Retrofitting Concepts

- Repair

The main purpose of repairs is to bring back the architectural shape of the building so that all services start working and the functioning of building is resumed quickly. Repair does not pretend to improve the structural strength of the building and can be very deceptive for meeting the strength requirements. The objective of any repair should be to produce rehabilitation – which means a repair carried out relatively low cost, with a limited and predictable degree of change with time and without premature deterioration and/or distress throughout its intended life and purpose. To achieve this goal, it is necessary to consider the factors affecting the durability of a repaired structural system as part of a whole, or a component of composite system.

- Rehabilitation

Structural rehabilitation involves the upgrading or changing of a building's foundation in support of changes in the building's owners, its use, design goals or regulatory requirements. In every case it is determined that it is cheaper to rehabilitate the structure and make the building improvements instead of demolishing and constructing a new building in the allotted space.

- Retrofitting

The engineering which involves in modifying the existing buildings for structural behaviour without hampering its basic intent of use is termed as retrofitting. It becomes necessary to improve the performance of structures including those facing loss of strength due to deterioration or which have crossed their anticipated lifespan. The realization of retrofitting depends on the authentic cause and measures adopted to prevent its further deterioration. This development includes repair, retrofit, renovation and reconstruction wherever required. A proper load path has to be analysed by a structural engineer and a decision has to betaken if any additional member like shear walls, etc needs to be added.

General areas of repair/rehabilitation work

- Repair, removal, replacement and maintenance of mechanical supports, sanitary treatment plant and pipelines.
- Repair and modifications to diffuser ports, aeration systems, and discharge pipelines.
- Installation and maintenance of dewatering structures.
- Pile restoration and wood pile concrete encapsulation.
- Anode installation for cathodic protection.
- Repair and replacement of trash-rack and debris screen.

Evaluation of Structures

Non-destructive testing can be applied to both old and new structures. For new structures, the principal applications are likely to be for quality control or the resolution of doubts about the quality of materials or construction. The testing of existing structures is usually related to an assessment of structural integrity or adequacy. In either case, if destructive testing alone is used, for instance, by removing cores for compression testing, the cost of coring and testing may only allow a relatively small number of tests to be carried out on a large structure which may be misleading. Non-destructive testing can be used in those situations as a preliminary to subsequent coring. Some situations where non-destructive testing may be useful are, as follows:

- Quality control of pre-cast units or construction in situ
- Location and determination of the extent of cracks, voids, honeycombing and similar defects within a concrete structure
- Determining the concrete uniformity, possibly preliminary to core cutting, load testing or other more expensive or disruptive tests
- Determining the position, quantity or condition of reinforcement.

A. Rebound Hammer Test:

Objective:

The rebound hammer method could be used for:

(i) assessing the likely compressive strength of concrete with the help of suitable corelations between rebound index and compressive strength,

(ii) assessing the uniformity of concrete,

(iii) assessing the quality of the concrete in relation to standard requirements, and

(iv) assessing the quality of one element of concrete in relation to another.

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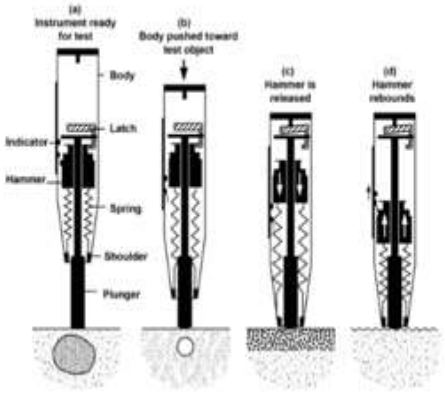


Principle:

When the plunger of rebound hammer is pressed against the surface of the concrete, the spring-controlled mass rebounds and the extent of such rebound depends upon the surface hardness of concrete. The surface hardness and therefore the rebound is taken to be related to the compressive strength of the concrete. The rebound is read off along a graduated scale and is designated as the rebound number or rebound index.

B. Ultrasonic Pulse Velocity Meter:

Objective:

The ultrasonic pulse velocity method could be used to establish:

(i) the homogeneity of the concrete,

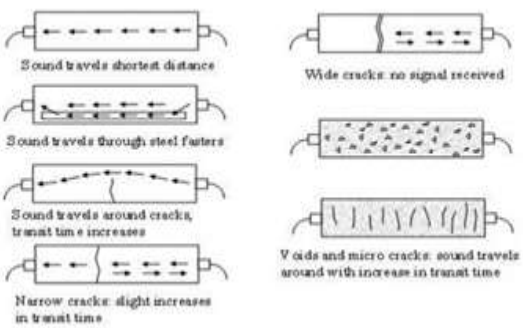
(ii) the presence of cracks, voids and other imperfections,

(iii) changes in the structure of the concrete which may occur with time,

(iv) the quality of the concrete in relation to standard requirements,

(v) the quality of one element of concrete in relation to another, and

(vi) the values of dynamic elastic modulus of the concrete.



Principle:

The ultrasonic pulse is generated by an electroacoustical transducer. When the pulse is induced into the concrete from a transducer, it undergoes multiple reflections at the boundaries of the different material phases within the concrete. A complex system of stress waves is developed which includes longitudinal (compressional), shear (transverse) and surface (rayleigh) waves. The receiving transducer detects the onset of the longitudinal waves, which is the fastest. Because the velocity of the pulses is almost independent of the geometry of the material through which they pass and depends only on its elastic properties, pulse velocity method is a convenient technique for investigating structural concrete. The underlying principle of assessing the quality of concrete is that comparatively higher velocities are obtained when the quality of concrete in terms of density, homogeneity and uniformity is good. In case of poorer quality, lower velocities are obtained. If there is a crack, void or flaw inside the concrete which comes in the way of transmission of the pulses, the pulse strength is attenuated and it passes around the discontinuity, thereby making the path length longer. Consequently, lower velocities are obtained. The actual pulse velocity obtained depends primarily upon the materials and mix proportions of concrete. Density and modulus of elasticity of aggregate also significantly affect the puise velocity.

Major types of repair

- **Brick Wall Repairs**
- **Plaster Wall Repairs**
- **RCC Repairs**

- **BRICK WALLS**

Basically, brick is durable and long-lived as long as the mortar joints are sound. Brick houses are susceptible to moisture - more so than wooden framed houses - but require very little maintenance.

Problems with Brick (Structural Problems)

- Deteriorated Pointing affects many old houses. Mortar starts to disintegrate between the bricks, which can cause the entire wall to collapse, or single bricks to crumble.
- Dirty or stained brickwork can be caused by moisture, time, dirt along with rain or sprinklers.
- Efflorescence results from bricks getting wet, which leaves deposits of salts that are drawn out of the masonry as the moisture evaporates the brickwork and find the source of the moisture.

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- Spalled brickwork is also common. Once bricks have been wet, the expansion of freezing water breaks off the top surface of the brick, leaving the inner surface exposed.

After a time, most of these bricks will crumble completely.

A couple of Don'ts for brick

- Don't assume that old mortar needs to be replaced. Old mortar is usually of higher lime content than the newer replacement mortar we are likely to find to repoint, and the high Portland cement content of new mortar can damage old walls beyond repair.
- Don't seal bricks with a water repellent (i.e., water seal) - it can mean that any moisture that is already in the brick stays in the brick, and interior moisture may not be able to escape.
- Don't use hydrochloric acid to clean brick, it can cause discoloration or mottling that is permanent.
- Never sandblast old brick! Sandblasting can damage the hard surface of fired brick and open the bricks up to water damage.
- Never use expansion joints in historic masonry - they can pulverize brick and ruin mortar joints.

Repair Work

Cleaning Brickwork

- For normal dirt and grime, simply use plain water, rinsing with a hose and scrubbing with a stiff bristled brush.
- For stubborn stains add 1/2c ammonia to a bucket of water.
- Don't use a power washer except as a last resort - if we have a crumbling brick problem, this will make it worse (old windows don't stand up to high pressure water very well).

Removal of Organic Growth

A moist brick will often lead to growth a variety of molds and mosses.

- First, scrape the moss or mold off the surface with a non-metallic spatula (the same kind used on Teflon).
- Second, apply a wash of 1-part bleach to 4 parts water to kill the spores.
- After a couple of days, scrape again and rewash. It will probably take a few applications to kill everything off.

❖ PLASTER WALLS

Repair or Replace

It is usually better to go in favour of repairing plaster walls, regardless of what they look like. But honestly, this is not always possible. Basically, if:

- there is more than 1 large hole per 4 x 8 area, or
- there are more than 3-4 cracks in 100ft2, or
- the cracks are more than 1/4" wide

Then replace the section of wall. It will take more time and failed attempts to repair this wall than it is worth. Old plaster should be cherished - it is stronger and more soundproof than current walls made of gypsum board or sheetrock. Even cracking or crumbling plaster walls should be repaired, not replaced.

Plaster Damage (Non-Structural Problems)

Plaster is pretty tough stuff, but like any wall, it's going to get banged or gouged, and age will take it's toll.

- Impact Damage can be serious problem in an old house. Over the years, the walls are going to get banged and dented. Generally we have to replace the plaster 6-12" from the visible hole to reach plaster that is still keyed to the lath tightly.
- Nearly every wall has a few nail holes. These can usually be fixed with a tiny bit of spackle applied with the finger. Not perfect, but they will be unnoticeable when the wall is painted.
- Water is the enemy of plaster. Brownish stains on the walls or ceilings are evidence for bowing out of plaster. Water-damaged plaster can be very friable.
- Old walls and old houses often have cracks. Stress cracks are a sign of possible structural shifting, extreme temperature changes, incorrect plaster mix, improper curing or leaks. Diagonal cracks over doorways signal settlement, or a nearby source of vibration, such as a highway or railroad.
- Bulging plaster is an indication that the plaster keys have broken off and allowed the plaster layers to separate from the lathe behind them. Bulging can be repaired with plaster washers.

Repairs.

- For repair of minor cracks, use fiberglass mesh tape then go over with a wide trowel and joint compound. There are also plaster patch compounds available that are excellent.
- For larger cracks and holes, we need to remove all the debris and enlarge the crack until we

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reach solid plaster and fill the crack with joint compound or plaster patch.

- If we choose to put wallboard over the plaster, use the following tips:
  - Apply wallboard horizontally
  - Use the largest boards available.
  - Use screws, not nails, 12" apart in ceilings, 16" on walls
  - Use a floating joint - the wall holds up the ceiling sheets
  - Use corner clips at all corners
  - Use fiberglass meshes tape, not paper, and special compound that is available for plaster walls.
  - Seal interior corners with acrylic latex caulk its not historically correct, but the effect is smooth and unnoticeable

❖ RCC STRUCTURES

Problems In RCC Structures (Structural Problems)

- Flexure, Shear, Torsion, Shrinkage And Tension cracks
- Splitting, Diagonal, Horizontal cracks in Columns
- Rusting, Buckling, Bending, Twisting Distress in Steel structures

A. Guniting/Shotcreting Methodology:

Shotcrete is defined as pneumatically applied concrete or mortar placed directly on surface The cement and sand are batched and mixed in the usual way and conveyed through a hose pipe with the help of compressed air. A separate pipe line brings water under pressure and the water and cement aggregate mix are passed through and intimately mixed in a special manifold and then projected at high velocity to the surface being repaired. In good quality work, a density around 2100kg/m3 is achieved. For effective guniting, the nozzle should be kept at 60cm to 150cm from the work normal to the surface. Before guniting is applied, the old concrete surface is prepared properly, all the cracks treated and the new reinforcement fixed in position. Cracks wider than about 0.5 mm should be cut out and filled with hand-applied mortar or with gunite.

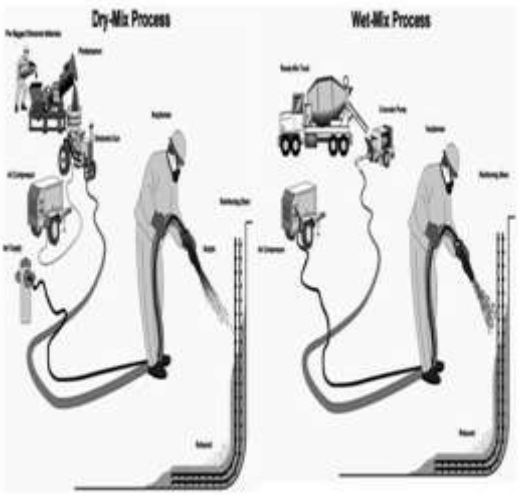
B. Types of Shotcrete

1. Wet Mix Shotcrete

Wet mix Shotcrete is a method that involves premixing of all ingredients including binder, water, aggregates and admixtures. The wet mix process shall consist of thoroughly mixing all the ingredients with the exception of the accelerated admixture (if used). Then mixtures have to be feed into the delivery equipment and deliver it by positive displacement or compressed air to the nozzle. This mixture is jetted 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.

2. Dry Mix Shotcrete

Dry mixing involves premixing of binders and aggregates which are fed into special mechanical feeder metering the premixed materials into a hose. The mix is jetted out along with compressed air from a nozzle connected to the hose having a water ring outfitted to it. This mix is injected to the repair spot. The resultant hardened properties include increased flexural, compressive strengths and more durability.



Problems associated with Dry mix Shotcrete

- Presence of voids due to encapsulated rebound
- Shrinkage cracking caused by high cement concrete, improper curing or excessive water control

Applications: Shotcrete has been used to repair:

- Canal and spillway linings and walls
- The faces of dams, tunnel linings
- Highway bridges and tunnels
- Deteriorating natural rock walls and earthen slopes
- To thicken and strengthen existing concrete surfaces

C. Routing and Sealing Methodology:

Routing and sealing is a common method of repairing dormant cracks. The procedure should

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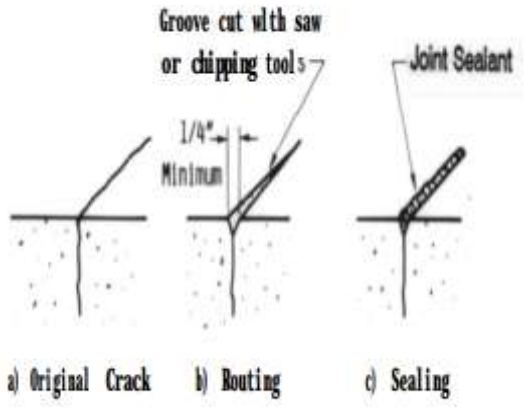
not be used on active cracks. A minimum surface width for a crack to be routed and sealed is one-quarter inch. When you are dealing with pattern cracks or narrow cracks, the routing will enlarge the cracks to make them suitable for sealants. Sealants are used to prevent water infiltration. This involves enlarging the crack along its exposed face and sealing it with crack fillers. Care should be taken to ensure that the entire crack is routed and sealed. Routing and sealing of cracks can be used in conditions requiring remedial repair and where structural repair is not necessary. This method involves enlarging the crack along its exposed face and filling and sealing it with a suitable joint sealant. This is a common technique for crack treatment and is relatively simple in comparison to the procedures and the training required for epoxy injection. The procedure is most applicable to approximately flat horizontal surfaces such as floors and pavements. However, routing and sealing can be accomplished on vertical surfaces (with a non-sag sealant) as well as on curved surfaces (pipes, piles and pole).

Routing and sealing is used to treat both fine pattern cracks and larger, isolated cracks. A common and effective use is for waterproofing by sealing cracks on the concrete surface where water stands, or where hydrostatic pressure is applied. This treatment reduces the ability of moisture to reach the reinforcing steel or pass through the concrete, causing surface stains or other problems.

D. Epoxy Injection Methodology



The Injection of polymer under pressure will ensure that the sealant penetrates to the full depth of the crack. The technique in general consists of drilling hole at close intervals along the length of cracks and injecting the epoxy under pressure in each hole in turn until it starts to flow out of the next one. The hole in use is then sealed off and injection is started at the next hole and so on until full length of the crack has been treated. Before injecting the sealant, it is necessary to seal the crack at surface between the holes with rapid curing resin.

For repairs of cracks in massive structures, a series of holes (Usually 20mm in diameter and 20mm deep spaced at 150 to 300mm interval) intercepting the crack at a number of locations are drilled. Epoxy injection can be used to bond the cracks as narrow as 0.05mm. Epoxy injection is a highly specialized job requiring a high degree of skill for satisfactory execution. The general steps involved are as follows.

1) Preparation of the Surface

The contaminated cracks are cleaned by removing all oil, grease, dirt and fine particles of concrete which prevent the epoxy penetration and bonding and removed by flushing the surface with water or a solvent. And the surface has to be dried, the crack should be routed to a depth of about 12mm and width of about 20mm in V-shape, filled with an epoxy, and stuck off flush with the surface.

2) Installation of Entry Ports

The entry port or nipple is an opening to allow the injection of adhesive directly into the crack without leaking. In case of V-grooving of the cracks, a hole of 20mm diameter and 12 to25mm below the apex of V-grooved section is drilled into the crack.

3) Mixing of Epoxy

The mixing can be done either by batch or continuous methods. In batch mixing, the adhesive components are premixed in specified proportions with a mechanical stirrer, in amounts that can be used prior to the commencement of curing of the material.

4) Injection of Epoxy:

In its simplest form, the injection equipment consists of a small reservoir or funnel attached to a length of flexible tubing, so as to provide a gravity head. For small quantities of repair material small hand-held guns are usually the most economical. They can maintain a steady pressure which reduces chances of damage to the surface seal. For big jobs power-driven pumps are often used for injection. The injection pressures are governed by the width and depth of cracks and the viscosity of resin and seldom exceed 0.10Mpa. The low pressure for fine cracks is a common practice to increase the injection pressure during the course of work to overcome the increase in resistance against flow as crack is filled with material.

5) Removal of Surface Seal:

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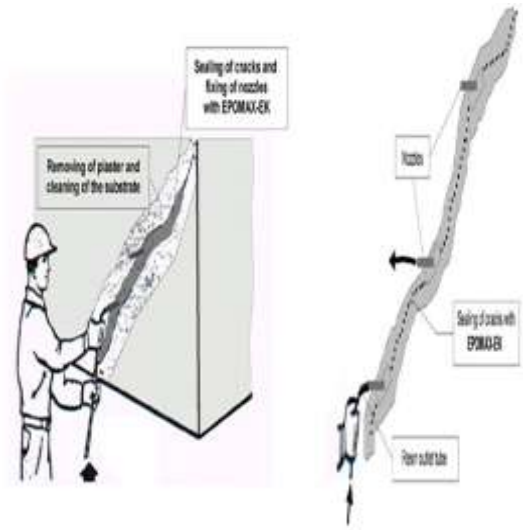
After the injected epoxy has occurred; the surface seal may be removed by grinding or other means as appropriate. Fittings and holes at the entry ports should be painted with an epoxy patching compound.

II. CONCLUSION



Repair and Rehabilitation is necessary to save hazardous failure of structures due to deterioration. It is recommended for old buildings which have some signs like cracks, corrosion of embedded materials, etc. Therefore timely maintenance of structures is required. The selection of technique is used as per cost, location of site and other factors. Thus for proper maintenance, the techniques likewise Rebound Hammer Testing, Ultrasonic Pulse Velocity Evaluation, etc. are utilized. After analyzing the problem of building, we can apply the appropriate repair methods which are described above i.e. Guniting, Routing and Epoxy Injection.

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