Repair and Rehabilitation of RCC Structures: A Case Study

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Abstract

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. Further, distress gets aggravated due to overloading and misuse of buildings. A few Buildings have also failed due to faulty design or construction. The various causes of structural failure and the principles of rehabilitation of structures are discussed. In the structures, the cracks are generated due to different causes e.g. in some cases cracks are caused after the structure has been completed for a few years which results in shortening of life and strength of structure. The main criteria is how to repair a reinforced concrete elements of structures and for this the skills, knowledge, and experience required to repair damaged or deteriorated structures are decidedly different from those required to build new structures. 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, Retrofitting, Structure

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I. INTRODUCTION

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 behavior. These type 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 techniques 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. Thus, some numbers of non-destructive, partially destructive and destructive techniques in the existing structures are used for assessment of concrete structure and to predict the cause of deterioration of the concrete. Some reasons of deteriorations due to ageing and error in design and detailing can be analyzed. The old buildings in which ancient temples, monuments, heritage buildings and some residential buildings are included and need some maintenance of repair due to which the regain of strength, durability and stability of those buildings should be done. Hence, here some specifications are discussed about repair and rehabilitation of residential buildings.

II. REPAIR, REHABILITATION AND RETROFITTING CONCEPTS

A. 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.

B. 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.

C. Retrofitting

The engineering which involves in modifying the existing buildings for structural behavior 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 analyzed by a structural engineer and a decision has to be taken if any additional member like shear walls, etc needs to be added.

D. Origin of Deterioration

1) Drying Shrinkage
2) Temperature stresses - This may be due to difference in temperatures between the inside of the building with its environment and variation in internal temperature of the building or structure.
3) Absorption of moisture by concrete
4) Corrosion of reinforcement - This could be caused by entry of moisture through cracks or pores and Electrolytic action
5) Aggressive action of chemical
6) Weathering action
7) Poor design details at re-entrant corners, changes in cross section, rigid joints in precast elements, deflections - this lead to leakage through joints, inadequate drainage, inefficient drainage slopes, unanticipated shear stresses in piers, columns and abutments etc, incompatibility of materials of sections, neglect in design
8) Errors in design
9) Errors in earlier repairs
10) Overloading
11) External influences such as earthquake, wind, fire, cyclones etc.

III. 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

The method of using the hammer is explained. With the hammer pushed hard against the concrete, the body is allowed to move away from the concrete until the latch connects the hammer mass to the plunger. The plunger is then held perpendicular to the concrete surface and the body pushed towards the concrete. The hammer can be used in the horizontal, vertically overhead or vertically downward positions as well as at any intermediate angle, provided the hammer to the surface under test. The position of the mass relative to the vertical, however, affects the rebound number due to the action of gravity on the mass in the hammer. This movement extends the spring holding the mass to the body. When the maximum extension of the spring is reached, the latch releases and the mass is pulled towards the surface by the spring. The mass hits the shoulder of the plunger rod and rebounds because the rod is pushed hard against the concrete. During rebound the slide indicator travels with the hammer mass and stops at the maximum distance the mass reaches after rebounding. A button on the side of the body is pushed to lock the plunger into the retracted position and the rebound number is read from a scale on the body.

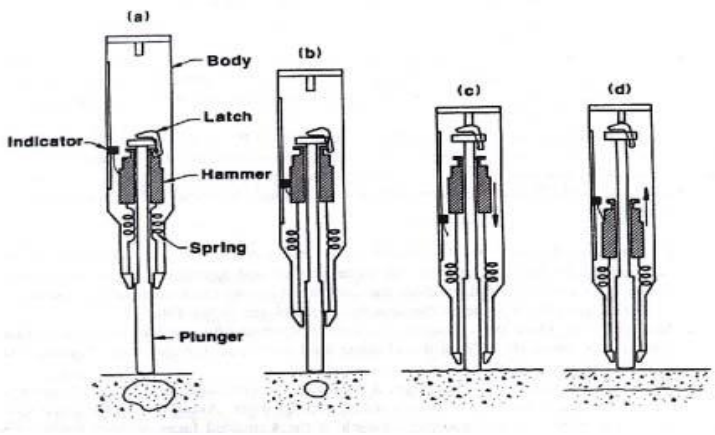

Fig. 1(a): Method of Rebound Hammer

B. Ultrasonic Pulse Velocity Test

UPV methods can be considered as one of most promising methods for evaluation the concrete structures once it makes possible an examination of material homogeneity. The total control of the structure is also possible by using the variations of properties with the time. The tests can also be used to explore the relation between the concrete qualities with the compressive strength. The main idea is to explore the fact that ultrasonic velocity waves are a function of the material density, which is correlated with the compressive strength. The relation is not always trustworthy once there are a lot of variables that affect the concrete strength such as the water/cement ratio, the size and type of aggregate, the molding procedure, the specimen size and the cement type.

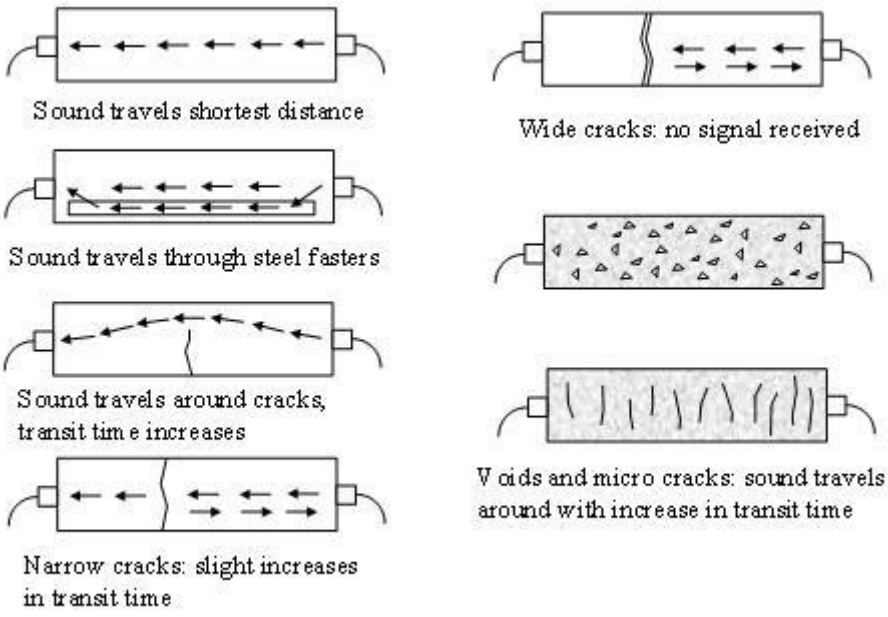

Fig. 1(b): Method of Ultrasonic Pulse Velocity

A pulse of longitudinal vibrations is produced by an electro-acoustical transducer, which is held in contact with one surface of the concrete under test. When the pulse generated is transmitted into the concrete from the transducer using a liquid coupling material such as grease or cellulose paste, it undergoes multiple reflections at the boundaries of the different material phases within the concrete. A complex system of stress waves develops, which include both longitudinal and shear waves, and propagates through the concrete. The first waves to reach the receiving transducer are the longitudinal waves, which are converted into an electrical signal by a second transducer. Electronic timing circuits enable the transit time T of the pulse to be measured.

Longitudinal pulse velocity (in km/s or m/s) is given by:

$$V = L/T$$

Where,

V is the longitudinal pulse velocity,

L is the path length,

T is the time taken by the pulse to traverse that length.

IV. METHODS FOR REPAIR AND REHABILITATION OF STRUCTURES

The various methods are available for carrying out the structural repair to distressed structures. The basic methods, which can be used singly or in combination of more than one, are as following:

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/m^3 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.

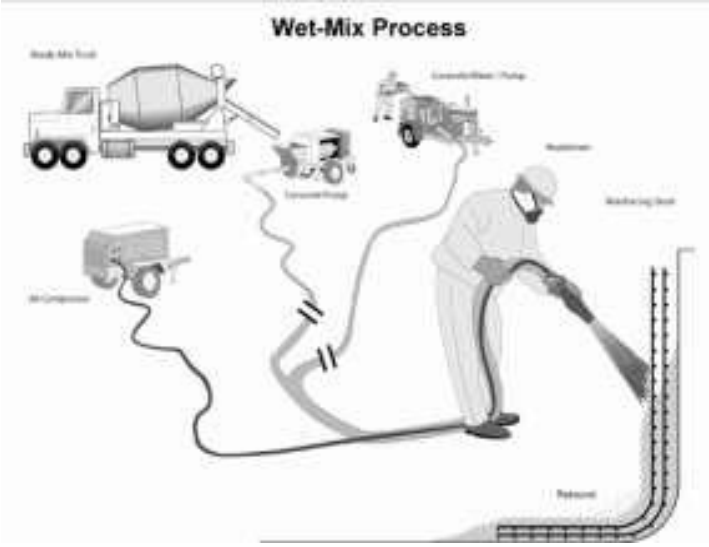

Fig. 1(c): Wet Mix Process

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

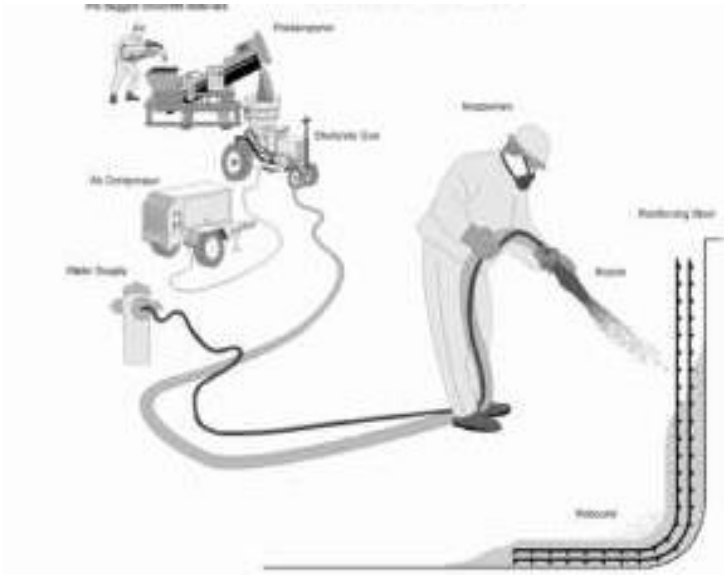

Fig. 1(d): Dry Mix Process

3) 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 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 (Fig.(e)). 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).

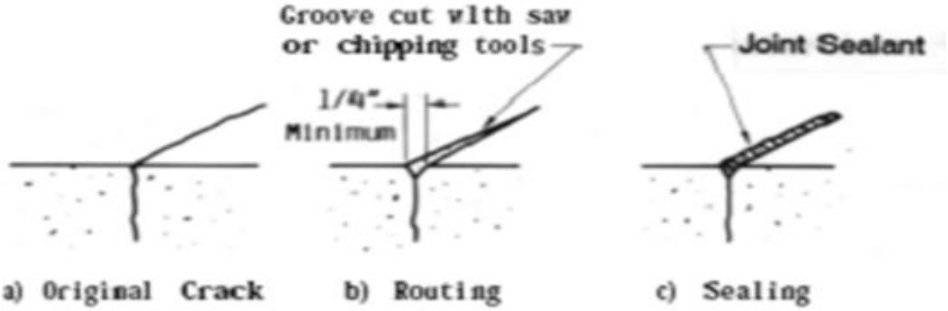

Fig. 1(e): Repair of cracks by Routing and Sealing

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 location 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 have 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:

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.

V. 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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