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Strengthening of Structure by Repair, Rehabilitation, Retrofitting and Restoration

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Abstract: *All structures have a assumed use able life, which depends on the weathering action, chemical attack, embedded metals, alkali-aggregate reactivity, fire, due to overload, seismic forces, quality of materials used, techniques, workmanship etc. The large numbers of monuments, which are cherished heritage structures have stood well over a period of time due to best material and periodical maintenance. But some of these have shown signs of distress due to age, aggressive natural environment/industrial pollution etc. Further, distress gets aggravated due to overcrowding and misuse of buildings. Some Buildings have also failed due to faulty design, construction, bad quality materials, poor workmanship etc. 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.*

Keywords: Weathering action, Techniques, Structures, Buildings, Knowledge, Materials, Techniques, Deterioration

I. INTRODUCTION

Periodic inspection is required for the repair & maintenance of reinforced concrete structures but in civil engineers and other discipline has little knowledge about it. Due to which several times importance is not given to the repair and maintenance of the structure. But today it is essential to give more attention to the repair and maintenance of old and damaged building structure. So for repair, restoration and strengthening of RCC structures requirement has been generated. In the repairs of concrete structures new and innovative techniques have been developed. In India large numbers of old existing buildings which are deteriorated because of their use, age and may be due to fully consumption of design life. For these deteriorated structures it requires repair with quality material, proper technique, skilled workmanship.

Repair works should be carried out at regular time so that the building will be serviceable up to its full life span to avoid any kind of accident of such deteriorated buildings. It required strengthening of structural elements for any recreational activity.

II. CAUSES/ ORIGIN OF STRUCTURES DETERIORATION

- **Geography** of location as type of strata, water table, earthquake, fire, wind, cyclone, flood, snow, pollutant, landslide and tree location etc.
- **Building materials** includes cement, lime, fine sand, coarse sand, quality of water, bamboo or wood, brick etc.
- **Technology** includes various aspects such as architectural design, construction methods, and quality practices etc.

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- **Workman ship** includes various aspects such as structural work, finishing work, waterproofing work, maintenance of building etc.
- **Temperature stresses** - This may be due to difference in temperatures between the inside of the building and the outside of the building or structure.
- **Corrosion of reinforcement** - This could be caused by entry of moisture through pores,cracks and Electrolytic action.

Poor details at re-entrant corners, rigid joints in precast elements, deflections - this lead to leakage through joints, inefficient drainage slopes, unanticipated shear stresses in piers, columns and abutments etc, incompatibility of materials of sections, changes in cross section, inadequate drainage

- Absorption of moisture by concrete
- Damage due to accidents
- Aggressive action of chemical
- Overloading

III. Strengthening by Repair, Rehabilitation, Retrofitting and Restoration

The underlying concepts in the operations are stated below:

A) Repairs

The objective of repair should be to bring back the aesthetics of the building so that starts proper functioning of all building services precisely with low cost throughout its intended life and purpose. It includes the following:

1. Patching up of defects such as fall of plaster and cracks.
2. Repairing doors, windows, replacement of damaged glass panes and electric appliances.
3. Checking and repairing damaged plumbing services.
4. Re-building non-structural walls
5. Re-plastering of walls as required.
6. Re-arranging disturbed roofing tiles.
7. Relaying cracked flooring at ground level.
8. Re- paint if required.
9. Change curtains if required.

B) Rehabilitation

Rehabilitation involves the changing of a building foundation in support of changes in the building owner, upgrading, 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

Retrofitting is termed as the engineering which involves in modifying the existing structure for structural behavior without hampering its basic intent of use. It becomes essential to improve the performance of structures including those facing loss of strength due to deterioration or which have crossed their assumed lifespan. The realization of retrofitting depends on the authentic cause and measures adopted to prevent its further deterioration. This development includes renovation, repair, retrofit and reconstruction wherever required. A proper load 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) Restoration

The structure restoration is done after the damage. In this process mainly the strength of the structure is restored. The structure restoration is done when there is clear evidence that the damage occurred is due to a phenomenon which

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is not likely to occur again and the strength restored is enough considering the safety of the occupants. The main objective of the restoration is to carryout structural repairs and to make the structural elements strong to bear the loads coming on them and transfer all loads safely. The process of restoration may involve cutting portions of the elements and reconstructing them or strengthening them by adding more structural materials so as to achieve the aim. The process of structure restoration involves inserting temporary underpinning, supports etc. Some of the common steps used in structure restoration are listed below:

1. Cracked walls and piers portions are to be removed and rebuilding them with richer mortar. In that non shrinking mortar should be preferably used.
2. On both sides of the cracked walls reinforcing mesh should be placed; spikes or bolts are used to hold the mesh on wall.
3. Injected epoxy materials which are also strong in tension so as to fill up cracks in walls, beams and columns etc.
4. Prior structural repairs and architectural repairs should be carried or simultaneously so that the total planning of work could be done in coordination manner and wastage will be avoided.

IV. EXISTING BUILDINGS STRENGTHENING

The old existing buildings behaviour is affected by their structural inadequacies, degradation of material due to age of the building, and the structural or non structural change carried out during the life of the structure such as making new doors and windows, construction of any part which induces dis-symmetry in the plan and elevation, etc. The possibility of substituting the old structures with new earthquake resistant structures is neglected because of social, economical, historical reasons and artistic view. The complete replacement or rehabilitation of old structures in the given area could also result in destroying a number of social and human links. Strengthening means an improvement in the structure over the original strength. After the damage and evaluation of the structures it indicates that the strength available in the structural members before the damage was insufficient and only restoration of strength in the structure alone will not be sufficient for the future. Generally the objectives of strengthening the structure are as below:

1. The building strength increased, by providing extra reinforcement, increasing the number of walls and columns.
2. To connect the building in frame structure by providing connections in its resisting elements, in this way the inertia forces generated by vibration of the building can be transferred to the members that have the ability to resist these inertia forces. Some of important aspects are the connections between foundations, roofs, floors, walls, and also between intersecting walls.
3. Some feature sources of weakness eliminating or that producing concentration of stresses in some of members. e. g. asymmetrical distribution of resisting members, large openings in walls without a proper peripheral reinforcement.
4. By proper reinforcement and connection in between of resisting members to avoid the possibility of brittle failure.

A) Repair Materials

Cement and steel are the most common material in the repair of damages. In most of situations non-shrinking cement or an admixture like aluminium powder in the ordinary Portland cement is admissible. Steel can be required in many forms, like bolts, channels, angles, rods. For providing temporary supports and scaffolding timber and bamboo are the most commonly used, and they are required in the form of sleepers, planks, rounds etc. There are other methods of repair also which gives good results in repair and strengthening works

B) Shotcrete

Shotcrete is a method in which combination of sand and Portland cement are applied on the required area. This sand and cement is mixed pneumatically and then conveyed in dry state itself to the nozzle of a pressure gun, where water

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gets mixed and the hydration takes place just before to the expulsion. By this technique the material bonds perfectly to prepared surface. While application on irregular or curved surfaces, its high strength and good physical characteristics, make it an ideal means to achieve added structural capability in walls and other elements of building. With this there are some of minor restrictions to the technique as clearance, thickness, direction of application etc. 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.

V. TYPES OF SHOTCRETE

A) 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.

B) 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

C) Applications

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

D) Routing and Sealing Methodology:

Repairing dormant cracks routing and sealing is a common method. 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. 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).

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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

a) Epoxy Resins

As repair material Epoxy resins is excellent binding agents and gives high strength in the repair works. This is composed of chemicals with proportions which when changed gives results as per requirement. These epoxy components are mixed just prior to their application. The product formed by the addition of epoxy resin has low viscosity and it can be injected in small cracks also. The epoxy resins having higher viscosity could be used for the purpose of surface coating or for filling the larger cracks or holes also. The strength of epoxy mixture depends upon the temperature of curing as lower the temperature higher will be the strength achieved.

b) Epoxy Injection

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 steps involved are:

1. **Preparation of the Surface:** The cracks are cleaned by removing oil, grease, dirt and fine particles of concrete which prevent the epoxy penetration, bonding and removed by flushing the surface with water or a solvent and the surface should 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 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.

c) Epoxy Mortar

In case of larger void spaces, epoxy resins of either low viscosity or higher viscosity are combined with sand or aggregate to form epoxy mortar. This mixture of epoxy mortar has much higher strength than the Portland cement

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concrete. Thus the mortar is not a stiff material for replacing reinforced concrete. It has also been reported that the epoxy is a combustible material and not used alone. The epoxy mortar formed from mixing of sand and aggregates gives a heat sink for heat generated and with this it also provides increase in modulus of elasticity.

d) Gypsum Cement Mortar

Regarding its structural application gypsum cement mortar has very limited use. This gypsum cement mortar has lowest strength at the failure among other materials of repair.

e) Quick-Setting Cement Mortar

Quick setting cement mortar was actually manufactured for the use as a repair material for reinforced concrete floors that are adjacent to steel blast furnaces. This mortar is a non-hydrous magnesium phosphate cement with two components, a liquid and a dry; these are mixed in similar way of Portland cement concrete.

f) Mechanical Anchors

Mechanical type of anchors gives wedging action to provide anchorage. Some of the anchors provide both shear and tension resistance. In the purpose of achieving strength these type of manufactured anchors are used. Alternatively for chemical anchors bonded in drilled holes polymer adhesives are used.

VI. CONCLUSION

- Where we had applied protective coatings there should be keen observation.
- Periodic maintenance of structures are essential.
- Each repair technique and material is suitable only for its particular application for which it is prepared.
- Surface defects requires immediate repairs like honey combing, cracks, efflorescence and bug hole.
- The damaged part of structures should be repaired on priority basis. structures affected by corrosion of reinforcement need special treatment.
- Before repairs & rehabilitation of damaged structures it is essential to carryout detailed condition assessment of the building with non destructive and destructive tests so that suitable remedial measures and repair techniques could be employed.

It is recommended Repair and Rehabilitation for old buildings which have some signs like cracks, corrosion of embedded materials, etc. Therefore timely inspection/ maintenance of structures is required. The selection of technique likewise Rebound Hammer Testing, Ultrasonic Pulse Velocity Evaluation, etc. are used as per cost, location of site and other factors. After analyzing the problem of building, than apply the appropriate repair methods which are described above.

REFERENCES

[1]. HalilSezen, M.Asce (2012), "Repair And Strengthening of Reinforced Concrete Beam-Column Joints With Fiber-Reinforced Polymer Composites" Journal of Composites For Construction © ASCE.

[2]. J. Bhattacharjee (2016), "Repair, Rehabilitation & Retrofitting of RCC For Sustainable Development With Case Studies" International Journal (CIVEJ) Vol.3, No.2.

[3]. Jay H. Paul (2002), "Repair, Renovation And Strengthening of Concrete Structures"

[4]. Manish Kumar (2016), "Structural Rehabilitation, Retrofitting And Strengthening of Reinforced Concrete Structures" International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering Vol: 10, No: 1.

[5]. S. Raja Subramaniam (2016), "A Review on Repair and Rehabilitation of Heritage Buildings" International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056 p-ISSN: 2395-0072 Volume: 03 Issue: 04.

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[6]. Shri. Pravin B. Waghmare (2011), "Materials And Jacketing Technique For Retrofitting of Structures" International Journal of Advanced Engineering Research And Studies E-ISSN2249 – 8974, Vol. I, Issue I 15-19.

[7]. Surresh Chandra Pattanaik, E. Gopal Krishnan And Mohan Kumar(2011), "Repair And Rehabilitation of Nehru Memorial College of K.V.G. Group of Institutions At Mangalore - A Case Study" Paper Published In The Proceedings of International Conference Cemcon 2011 Organised By Indian Concrete Institute, Pune

[8]. Handbook of Repair and Rehabilitation of RCC Buildings.

[9]. Mr. Pavan D. Tikate, Dr. S. N. Tande, "Repair and Rehabilitation of Structures", International Journal of Engineering Sciences and Research Technology, 2014, Vol. 3(Issue No. 10), PP. 511-515.

[10]. Mr. S. S. Chandar, "Rehabilitation of Buildings", International Journal of Civil Engineering Research, ISSN 2278-3652 Volume 5, Number 4 (2014), pp. 333-338.

[11]. Repair, Restoration and Strengthening of Buildings, IAEE Manual, Chapter 9.

[12]. Indian Standard: 13311:1992 (Part 1) NDT methods of Test- Ultrasonic Pulse Velocity.

[13]. Indian Standard: 13311:1992 (Part 2) NDT methods of Test- Rebound Hammer.

[14]. Prof. M. Vijayalakshmi, "CE 2031: Repair and Rehabilitation of Structures".