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REPAIRS AND REHABILITATION OF R.C.C. STRUCTURES BY FIBER REINFORCED PLASTIC- A REVIEW

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ABSTRACT

The purpose of the paper is to highlight the methods of repair and rehabilitation to be undertaken for structures with defects and deficiencies that necessitate rehabilitation. Repair and Rehabilitation methods currently used are reviewed on the basis of present knowledge and the merit of a holistic system approach. This paper focuses on visible symptoms of the problem rather than on visible and invisible problems as well as the possible causes behind them. This paper focuses about the repair materials and the techniques are essential for the satisfactory performance of the repaired structure.

1. INTRODUCTION

The term rehabilitation in broad sense implied restoring a structure to its original condition. Technique developed for rehabilitation may also be used for modifying a structure to meet new functional or other requirements.

In general, structures may need rehabilitation for one of the following:

1. Normal deterioration due to environmental effect.
2. New functional or loading requirements entailing modifications to a structure.
3. Damage due to accidents.

Repair and Rehabilitation engineering is a specialized field, which calls for skills and abilities beyond design and construction engineering. The systematic approach to deteriorate structure is necessary and there should be balance between technology management and economics. The first task when a structure shows sign of cracking, spalling or any other sign is to determine whether the damage is structural or non-structural. The engineer in-charge of rehabilitation should have qualities of an investigator, structural designer, material technologist and awareness of application techniques.

The Repair and Rehabilitation of structures include the following

- Inspection methods, assessment, monitoring, maintenance of structures.
- Concrete durability, fatigue issues in bridges, laboratory studies, dynamic testing & analysis
- Seismic strengthening
- General repairs

The repair and rehabilitation methods involve the attachment of new materials to existing structures or applying protective coatings to the structures. Research in rehabilitation includes the prevention of corrosion of steel which is the most important structural member used in the construction. Research in design, behavior, and analysis of reinforced building and bridge construction includes studies in materials, components, and complete structural systems. Materials studies have included normal- and high-strength concretes; effects of materials aging and materials deterioration on component properties; bond between concrete and steel reinforcement, and use of headed reinforcement.

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2. REPAIR AND REHABILITATION OF R.C.C. STRUCTURES

Structure repair and rehabilitating is a process whereby an existing structure is enhanced to increase the probability that the structure will survive for a long period of time and also against earthquake forces. This can be accomplished through the addition of new structural elements, the strengthening of existing structural elements, and/or the addition of base isolators. Deterioration of concrete and corrosion of embedded reinforcement structure might make the R.C.0 structure structurally deficient. Corrosion can be controlled to some extent by fixing of chloride or protective coating (Powder coatings based on thermosetting epoxy, polyester or acrylic technology, are electro statically sprayed.) or cathodic protection. Once this has happened, two alternatives of fixing the problem are to replace the structure or to strengthen it. Economically, repair and strengthening are often the only viable solution.

Different types of reinforcement require various demolition and surface preparation techniques. Typically, structural deterioration of reinforced concrete members can occur as surface scaling, spalling, cracking, corrosion of reinforcing steel, weathering, post-tension losses, deflection beam shortening, volume shrinkage and strength reduction. Moisture, chlorides, carbonation, and chemical attack induce these; freeze thaw disintegration, and sulfate attack, erosion and alkali aggregate reaction.

The rehabilitation measures includes epoxy mortar, epoxy bonding coat, epoxy grout, polymer based bonding slurry and mortar, jacketing of columns, shotcreting, epoxy grouting, cement grouting accordingly to the type of distress. The member's load bearing capacity, structural shape and location greatly influence material placement techniques and material selection.

The techniques to achieve earthquake resistant design includes; adding base isolators, wrapping columns, strengthening footings, adding hinge restrainers, and increasing the width of supports at abutments so that the superstructure will not fall off the support.

In repair and rehabilitation process good/sound concrete sharing the load should not be removed for any reason, as is being done today. The second principle of restoration of structurally distressed RC members is to restore the building portion by portion.

3. SURFACE PREPARATION AND INTERFACIAL BOND FOR APPLICATION OF PATCH REPAIRS, SEALERS AND COATINGS IN CONCRETE REPAIR

The main purpose of surface preparation is to provide maximum coating adhesion and to increase the surface area by increasing the roughness of the surface. Achieving an adequate lasting bond between repair materials and existing concrete is a critical requirement for durable concrete repair. Good surface preparation using proper concrete removal methods and workmanship is the key element in a long-lasting concrete repair technique.

4. CONVENTIONAL STRENGTHENING METHODS

4.1 Grouting Process : - Grouting is the process of placing a material into cavities in concrete or masonry structures for the purpose increasing the load bearing capacity of a structure, restoring the monolithic nature of a structural member, filling voids around pre cast connections and steel base plates, providing fire stops, stopping leakages, placing adhesives and soil stabilization. Primary grouting materials and their common uses are: Methods of application normally used include: hand pumps, piston pumps, single and plural component pumps, gravity and dry packing placement, micro capsules and single component pressurized cartons.

4.2 Guniting Process: - Guniting is an effective technique, which has been extensively used in the rehabilitation of structurally distressed RC members. There have been cases of heavy rusting of the mesh in the form of powder or in the form of a sheet coming out. De- stressing before restoration is possible only in the case of overhead tanks which can be restored when the tanks are empty.

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The guniting technique suffers from other drawbacks like dust and noise nuisance.

The following points need to be kept in mind for better results of guniting:

- Coating of existing as well as new bars by zinc rich epoxy primer to guard against corrosion.
- Mesh reinforcement is not advise

5. APPLICATION OF EPOXY RESINS TO STRENGTHEN THE STRUCTURAL MEMBER WITH EXTERNAL REINFORCEMENT

In these methods of strengthening, an epoxy adhesive normally consisting of two components - a resin and a hardener is used to bond steel plates to overstressed regions of RC members. Normally, the steel plates are located in the tension zone of concrete to enhance the flexural capacity. The plates can also be placed in the compression and shear regions for enhancing the axial and shear-capacities of the RC structural elements. As the adhesive provides a continuous shear connection between the RC member and the external plates, a concrete-adhesive-steel composite structural member is developed to cater for the additional live load effects on the structures.

5.1 Section Enlargement/jacketing-

In this method the entire height of the column section is increased and a cage of additional main reinforcement bars with shear stirrups is provided right from the foundation as per the requirement of additional load, etc. However, there are many instances where the column section is increased with additional reinforcement bars only on one face, and that too starting from the floor slab level of a particular floor and only up to the height of deterioration of the column. The enlargement should be bonded to the existing concrete to produce a monolithic member a composite system, Cement mortar is used for these enlargements.

A later development was the use of sprayed concrete and mortar, the process referred to as shotcrete. The process was introduced in 1911 at the time when innovations in reinforced concrete technology were evolving. The widest use of section enlargement is in bridge deck rehabilitation and strengthening. The section enlargement method is relatively easy to construct and economically effective. The disadvantages of this method are a high risk of corrosion of embedded reinforcing steel and concrete deterioration. These problems are associated with relative dimensional incompatibility between existing and new concrete. The restrained volume charges of new material are inducing tensile stresses that may lead to cracking and delimitation when the induced tensile stresses are greater than tensile strain capacity of tile new material. The way to make this strengthening technique effective in the future is to use materials with higher tensile strain capacity, with low shrinkage properties.

5.2 Post tensioning

External prestressing is now widely developed for concrete strengthening in the United States, Japan, and Switzerland. External prestressing techniques have been employed with great success to correct excessive and undesirable deflections in existing structures. They have also been used to strengthen existing concrete structures to carry additional loads.
Prestressing may be used on tile inside of box girders or the outside of I girders to increase the capacity of existing bridges and to provide improved resistance to fatigue and cracking.
The following are the advantages of external prestressing.

5.3 Simple Construction Methods:-

Simple strand or tendon profile resulting in simple construction on tile site. Few or no problems with tendon grouting. Possibility of inspection during the lifetime of the structure with x-ray or other nondestructive detection techniques. Replaceabilty of strands and tendons.

The disadvantages of external prestressing are those which arise from it location outside the structure.

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Three disadvantages in particular are mentioned below.

- Vulnerability to corrosion.
- Vulnerability to fire.

Protection of an externally mounted prestressing system against aggressive exterior elements and fire is usually provided by encasement in concrete.

5.4 Bonded Steel Plates

In the 1960s in Switzerland and Germany, a method of strengthening reinforced concrete structure by application of bonded steel plates was developed based on the work of L'Hermite and Bres son. The principle of the method is quite simple steel plates or other steel elements are glued to the concrete surface by a two- component epoxy adhesive creating a three-phase concrete glue steel composite system. The wide acceptance and at attractiveness is due to negligible changes to overall dimensions of the structure and minimum disruption to its use. At the same time, adequate design, specification and execution of the job will ensure the necessary composite action for the deigned loading range. It was demonstrated that steel plates bonded to the tension face of concrete beams can lead to increase in flexural capacity, along with increase in flexural stiffness and associated decreases in deflection and cracking.
The bonded steel plate’s area supplement to the existing embedded reinforcing steel, and are considered secondary reinforcement provided to reduce stress in existing steel to allowable levels. This is a method of exterior strengthening via the "cover Crete" is of critical importance.

The composite behavior depends on the adhesive concrete and adhesive plate bonding interface shear stresses, as well as tile stiffness, flexibility, and viscosity of the adhesive. Over strengthening and excessive deflection are to be avoided.

Bonding of steel plates to concrete has been shown to be an effective strengthening method when three important factors are followed. First, the surfaces to be bonded must be clean. Abrasive blasting for the steel and concrete surfaces is preferred, although other methods have been used effectively. Second, the epoxy should have bond strength of at least that of the concrete. The epoxy should be usable under the prevailing environmental regulations. Third, plates must be long and thin to avoid undesirable brittle plate separation failure, although additional anchorage at the ends of the plate can also be used to avoid this type of failure. By following these guidelines, steel plates have been used effectively and economically to improve tile strength and serviceability of existing reinforced concrete structures. Problem associated with the use of steel plates is heavy weight, bond durability and potential corrosion at the steel adhesive interface.

6. CFRP (CARBON FIBER REINFORCED PLASTICS) FOR REPAIR AND STRENGTHENING

Meier in Switzerland started the pioneering application of composite plate bonding in 1982.An overview of CFRP strengthening is given below.

CFRP has high strength, lightweight, excellent strength to weight ratio, resistant to chemicals (acids and bases), good fatigue strength, and nonmagnetic, non-corrosive and nonconductive properties. As with any composite system, bond of the strengthening plates to the existing concrete is very critical. Therefore, the surface preparation of both phases of tile system, concrete and CFRP plates is very important. The plates should be ground on tile bonding side, immediately before bonding; the surface should be cleaned with acetone. After mixing, the epoxy glue component should be placed oil tile plate without delay, after assembling the plate in the designed position, a slight pressure is applied to squeeze out excessive adhesive.

6.1 Disadvantages:

- Lack of codes of practice and design standards.
- Limitation in application to certain geometrical shapes.

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- Necessity of personnel skilled in polymers.
- Fire and ultraviolet (UV) radiation protection required. Materials are being used in most cases to repair and strengthen concrete beams and columns.

The latest studies and experience demonstrate that repairs of concrete slabs require less FRP material to achieve equivalent increases in stiffness and strength compared with reinforced concrete beams.

7. MATERIALS USED IN REPAIRS

7.1 Polymer modified concrete/cement mortar
Polymer cements concrete, which is prepared by adding polymer or monomer to ordinary fresh cement concrete during mixing. This is based on first hand experiences of repair and restoration works of high rise buildings, bridges, marine installations and bomb- blast affected structures.

7.2 Fiber-Reinforced Plastics
These materials that are used for cracks are applied over it like a patch, using high strength epoxy adhesive increasing their service life and fortify steel or concrete structures against earthquakes or other natural hazards.

7.3 Epoxy resins
The epoxy resins are widely used in the repairing of cracks, patching and grouting of concrete, industrial flooring, structural adhesives, anti-corrosive linings, etc. Various types of resins, hardeners and modified epoxy systems are commonly used in structures.

7.4 Polymer-based materials
Polymer-based materials are being widely used in the building industry in various forms such as coatings, membranes, adhesives, sealants, etc because of their high durability.

7.5 High performance cement
High performance cement is the cement along with new complex admixture. High performance cement based mortars possess low permeability, high resistance to chemical attack, thermal resistance, and excellent freezing and thawing resistance.

7.6 Fibre reinforced polymer tubes for pile/column
Fibre reinforced polymer (FRP) can be used for bridges to prevent corrosion. The FRP tube filled with concrete seems to be a good alternate to address this problem. The FRP tube can be engineered to provide sufficient confinement to filled concrete and to increase the capacity of the section in shear and compressive strength and also provide increased resistance to earthquake forces.

7.7 Epoxide resin latex and polymer-based latex
The structural integrity of chemically deteriorated reinforced concrete beams is restored by repairing one set of beams by epoxide resin latex and another by polymer-based latex system. It is interesting to observe an increase in the load-carrying capacity and rigidity of the beams after repair and rehabilitation work of the structure.

7.8 Fiber-reinforced polymer
Fiber-reinforced polymers or FRP's are robust materials that are highly resistant to corrosive action, have a high strength to weight ratio and are well suited for assembly line production into modular components that can be rapidly erected. However, FRP material costs are significantly greater than traditional concrete and steel materials. Therefore, cost savings due to either reduced weight, increased speed of construction or lower maintenance and increased life expectancy must offset this higher cost to make sensible use of FRP materials. Because of the severe environmental conditioning that bridge decks are subject to and the fact that they account for a major percentage of a bridge structures dead load, they are the most suitable bridge application for FRP materials. An 8-inch deep FRP deck weighs approximately 20-lbs./sq. ft. as compared to

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100-lbs./sq. ft. for a concrete deck of the same depth. In addition, FRP decks can be constructed faster than conventional cast-in-place decks that take more time due to formwork construction, rebar placement and concrete curing. Other FRP material systems that utilize carbon or armid fibers and epoxy resins offer superior structural performance characteristics.

8. REHABILITATION MEASURES TO BE TAKEN BEFORE CONSTRUCTION

8.1 Long term durability with selection of sand

Quartz sand does not contain silt and gives high strength along with polymer mortar. Both river sand and quartz sand have similar properties. The strengths of the RCC members, which are taken up for restoration, are designed for M-15 or M-20 and strength of the polymer mortar gives good strength even when river sand is used. This should be a point to consider especially since quartz sand costs almost three times as much as good river sand.

8.2 Long term durability with selection of concrete

High performance concrete of grade M 75, using silica fume, is being used for the purpose of long durability. Silica fume is not only used as a part replacement or addition to cement in a concrete mix but also to enhance the performance characteristics of concrete.

8.3 Corrosion protection with hot-dip galvanizing

HOT-dip galvanized steel has been effectively used. The value of galvanizing stems from the relative corrosion resistance of zinc, which under most service conditions is considerably better than iron and steel. In addition to forming a physical barrier against corrosion, zinc, applied as a galvanized coating, cathodically protects exposed steel. Furthermore, galvanizing for protection of iron and steel is favored because of its low cost, the ease of application, and the extended maintenance-free service that it provides. Galvanizing primary component is zinc. The fundamental steps in the galvanizing process are:-

a) Soil & **grease removal -** A hot alkaline solution removes dirt, oil, grease, shop oil, and soluble markings. Pickling - Dilute solutions of either hydrochloric or sulfuric acid remove surface rust and mill scale to provide a chemically clean metallic surface.

b) Fluxing - Steel is immersed in liquid flux (usually a zinc ammonium chloride solution) to remove oxides and to prevent oxidation prior to dipping into the molten zinc bath. In the dry galvanizing process, the item is separately dipped in a liquid flux bath, removed, allowed to dry, and then galvanized. In the wet galvanizing process, the flux floats atop the molten zinc and the item passes through the flux immediately prior to galvanizing.

c) Galvanizing - The article is immersed in a bath of molten zinc at between 815-850 F (435-455 ° C). During galvanizing, the zinc metallurgical bonds to the steel, creating a series of highly abrasion-resistant zinc-iron alloy layers, commonly topped by a layer of impact- resistant pure zinc.

d) Finishing - After the steel is withdrawn from the galvanizing bath, excess zinc is removed by draining, vibrating or - for small items - centrifuging. The galvanized item is then air-cooled or quenched in liquid.

Galvanizing is used throughout various markets to provide steel with unmatched protection from the ravages of corrosion. A wide range of steel products from nails to highway guardrail to the Brooklyn Bridges suspension wires to NASA's launch pad sound suppression system benefit from galvanizing superior corrosion prevention properties. Galvanizing delivers incredible value in terms of protecting our infrastructure. Less steel is consumed and fewer raw materials are needed because galvanizing makes bridges, roads, buildings, etc., last longer. Additionally, because galvanized steel requires no maintenance for decades, the rehabilitation against corrosion of steel is insufficient.

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