Retrofitting and Strengthening of Structures

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In civil engineering since antiquity, structural repair has been a very particular problem. Throughout history, human-constructed buildings have been destroyed due to time, natural disasters, and even building mistakes. In this respect, the field of engineering related to structural reconstruction and recovery seeks to identify methods and techniques to accomplish this important task. The pace of the degradation of concrete buildings throughout the world is frightening. It has now been verified that even if the structural design complies with all particular building code criteria such as concrete quality, cover, and so on, there is still an acceptable high risk of concrete degradation and reinforcing corrosion. Steel corrosion has been identified as the most severe cause of reinforced concrete degradation, capable of causing fractures, spalling the concrete cover, reducing the effective c/s area of the reinforcement, and ultimately leading to collapse. In order to repair and rehabilitate other buildings, this study sought to compile the main ideas, methods, and technologies used by these influential engineers. In fact, this report contains case studies on functional restoration. The document further addresses various types of building, such as pre-stressing, post-tensioning, deployment, and pre-stressing.

Keywords: Structures ; Retrofitting ; Strengthening

1 – INTRODUCTION

1.1 General

The degradation degree in the type of fracture, corrosion and disintegration is demonstrated by the concrete structures. Each one can be identified clearly. Poor materials, poor design practices, poor monitoring or combination may be the reasons for their production[1, 2]. The creation of cracks in concrete is most important because sometimes the same causes create a different pattern of cracks, and sometimes the same pattern of cracking is created by different causes. Often concrete fractures can be found in areas where no origin is known, and elsewhere it does not fracture, where there is no reason to break. But 50% of the cases are straightforward [3, 4].

Cracks alone are seldom representative of structural hazard; replacements are therefore not usually strengthened. The modifications are therefore essentially designed to fix the cracks against an unacceptable water flow and improve the appearance of the house. It is common to find that substantial loss of section and/or pronounced corrosion of strengthening have occurred when the structure is repaired showing spread and disintegration. Both are structurally relevant issues and reconstruction is usually immediate and requires the recovery of lost power[5, 6].

1.2 Report Objectives

The study focuses on the R.C.C. system recovery. The study aims to highlight the methods of repair and restoration for structures that require rehabilitation and defects. The current methods of repair and rehabilitation are assessed on the basis of current knowledge and the value of a holistic system approach. The study focuses on visible symptoms and not noticeable, latent, or potential causes of the problem [7, 8].

The report covers the repair materials and the techniques used because it is important to use suitable repair materials and techniques for a good performance. This study analyzes different illnesses, treatments and problems that lead to unsatisfactory quality of rehabilitated concrete structures [9, 10].

1.3 Why Need to Retrofitting and Strengthening?

Globally, there is an alarming rate in the deterioration of the concrete structures. It has now been established that while structural design complies with all the specific building code requirements, such as the consistency of the mortar, the cover etc., the possibility of concrete degradation or oxidation of the structure remains highly acceptable [2-4, 11]. The most serious cause of degradation of reinforced concrete can cause corrosion from metal, producing fracture, breaking the concrete layer, increasing the reinforcing area efficiently and causing a failure [12, 13].

1.4 Importance of Retrofitting and Strengthening

Over time, it shows that there is an urgent need for the Retrofitting and Strengthening, below we show some of their importance to Concrete structures and sustainable future.

1.4.1 Concrete Structures Need to Be Strengthened for Any of The Following Reasons

1. Suitable modifications due to deflection restriction, elimination of metal reinforcement strain and/or reduced crack widths.
2. Change to the structural system by removing walls/columns and/or slabs openings.
3. Plan or build errors due to insufficient design and/or steel reinforcement dimensions.

2 - PROCEDURE FOR STRENGTHENING OF STRUCTURES

2.1 Introduction

Strengthening is carried out to enhance the ability of the structural elements to resist the internal forces that are generated due to any of the loading such as flexure, axial, shear or torsion. Various techniques are available to strengthen; however, the goal of the adopted technique must be to ensure a safe, durable and cost-effective means of upgrading the structure [14-16].

2.2 Tools for Evaluation of Concrete Structures

1. Visual inspection and observations
2. Questioning of concerned personnel
3. Scrutiny of field data and records
4. Design Checks
5. Non- destructive testing (NDT)
6. Extraction of cores and testing
7. Supplementary laboratory techniques
8. Load testing of a structural member

In addition, the following schematic diagram clearly describes the procedure for the strengthening of structures that covers the activities starting from the conditional assessment of the structures to the execution of the strengthening technique [17-20].

Figure 1: Procedure for the strengthening of structures [21]

3 - STRENGTHENING TECHNIQUES

3.1 Factors Affecting Selection of Strengthening Method

The reconstruction of a building structuring has several complex approaches for extension purposes [22-27]. Not only the strategies themselves but also needs to be considered the criteria and variables. External limitations such as When choosing strengthening methods and materials:

1. Access to work zones is restricted.
2. Timetable for operations (when the owner will allow work to take place),
3. Budget and financial constraints
4. Weather and its environmental effects
5. The impact of strengthening on other neighboring structural members' loading mechanisms.
6. Architectural specifications.

3.2 Strengthening Techniques

The fact that science is constantly evolving, it continuously explores many of the techniques of, and the following are offering some of them:

3.2.1 Section Enlargement

Another easy technique to reinforce structural leaders is to swiftly apply a fresh layer of reinforced and smooth cement, increasing its thickness:

1. mold casting on a regular basis
2. with the use of shotcrete

Figure 2: SECTION ENLARGEMENT

3.2.2 Strengthening Members with Prestressing Steel

Prestressing is most suited for strengthening parts in terms of flexural capability. Existing member prestressing works in the same way as internal post-tensioned tendons without bonding, but the tendons (or single strands) are only attached to the outside of an already existing structural member by end-anchors and deviators [27-31].

Deviators are used to modify the angle of the tendon in order to make greater use of the prestressing. Because the forces are transmitted to the concrete at the deviators and anchors, it is not feasible to trace the moment curve as easily as with internal tendons [32-36].

Figure 3: one possible way to apply external prestressing to a single span beam

By using constraint forces, prestressing improves the behavior of structural members. The prestressing action produces a force balance in which the prestressing steel is in tension and the concrete is in compression. This results in a part that can withstand tensile loading better [34-39].

It should be emphasized that no strain contact between the concrete and the exterior tendons is conceivable since the steel is not connected to the concrete. Instead, the impact may be determined by applying concentrated forces where the prestressing force is delivered as well as where the tendons change direction .

The strain in the prestressing steel is incompatible with the strain in the concrete at the same level. Due to the absence of contact, the tendon elongation is spread out along the length between the anchors.

Figure 4: Effect of external prestressing

The prestressing has no direct effect on the final load of the member. The preceding graphic clearly shows that vertical force at the deviator works as intermediate support. The moment in the member's midsection may therefore be minimized. One benefit of external prestressing is improved serviceability state behavior due to lower deflection [40-42].

Cracking will also be slowed, and any existing cracks may be joined. Because of their accessibility, external tendons may be readily inspected, replaced, and even re-tensioned. Because there is no contact between steel and concrete, low frictional losses are likewise to be predicted [43-45].

Figure 5: Strengthening Members with Prestressing Steel Techniques3.2.3 Strengthening with Fiber Reinforced Polymers

Fiber-reinforced polymers (FRP) are made up of fibers made of a composite material surrounded by a polymer matrix. The matrix is essential for fiber maintenance and force transmission between fibers. The matrix also protects the fibers.

The matrix may be used for a variety of materials, however epoxy is the most often utilized. However, the three most often utilized fibers in civil engineering are wood, aramid, and glass. Both fibers remain flexible until broken, and their tensile strength is frequently higher than that of metal. As a result, carbon fibers are the most often employed kind in building construction to create so-called coal fire enhanced CFRP polymer.

At the moment, neither the Euro codes nor any other standards address the reinforcing of concrete structures using FRP composites. Other strengthening procedures may be more suited if the part has experienced substantial corrosion damage. Alternatively, preceding member strengthening, such as section expansion, might be followed by further CFRP strengthening. The graph below shows typical stress-strain relationships for steel and several types of FRP. Steel, as shown, exhibits a ductile behavior, but FRP acts practically elastically until brittle fracture occurs. This implies that the fibers will continue to transport loads even after the steel yields at the specified stress level.

Figure 6: typical stress-strain relations for steel and different kinds of FRP

The behavior of FRP may be customized. Carbon fiber reinforced polymers (CFRP) may be made with a high modulus of elasticity (HM) or a high strength (HS). The manufacturer typically provides two or three stiffness levels: low, medium, and high.

CFRP is useful for tensile force strengthening because to its high tensile strength. The strength is greatly reduced under compression because the fibers act similarly to those in wood and buckle away from one other. CFRP offers a high tensile strength while being lightweight. It is used to retrofit concrete structural elements such as columns, beams, and slabs, and it may offer large capacity without adding significant weight, which would raise the stress on foundations and other structural parts [46-50].

Figure 7: Strengthening with Fiber Reinforced Polymers Techniques3.2.4 Ferrocement

Ferro-cement is a thin-walled composite with a total thickness of 12 to 30 mm. It is made up of a minimum of two layers of continuous and relatively small diameter orthogonally woven wire mesh separated by 4 to 6 mm dia galvanized spacer wires. Plasticizers and polymers are put into the cement mortar to close pores. The wire mesh is mechanically attached to the parent surface by U-shaped nails that are secured using an epoxy bonding technique. The mesh might be composed of hot-dip galvanized MS wire or another metallic or appropriate material. To achieve adequate encapsulation of wire mesh in mortar, a specific method for compacting Ferro-cement layer is applied using orbital vibrators [5, 7, 11].

It is a long-lasting composite material with evenly distributed shrinkage cracks owing to the presence of closely spaced, thin woven galvanized wire mesh. It also has good corrosion resistance and is impervious to water incursion. This restoration method provides a protective reinforced membrane for the rehabilitation of troubled RCC structures. This serves as a barrier against the vagaries of the environment. It is also used to waterproof reinforced concrete shell constructions and RCC slabs because it offers an impermeable thin membrane that prevents water seepage and leakage [9, 10].

Figure 8: Typically, cross-sections of Ferrocement3.2.5 Plate Bonding

Plates are a low-cost, versatile, and specialized healing treatment that is mechanically attached to concrete buildings by bolting and adhering to epoxy surfaces. Platform bonding may greatly increase the strength, stiffness, ductility, and stability of reinforced concrete components and can be employed effectively for earthquake restoration.

Bolts, which were originally employed in construction to hold the plates in place, now act as permanent cutting connections and integrated limitations. The bolts can also sustain interface stresses if the epoxy glue used fails, is destroyed by fire, corrosion, or just bad manufacture.

Because epoxy is prone to early debonding, mechanical anchoring with epoxy bonding is thought to be more dependable. Assuming that the steel plates are discrete, this process does not appreciably alter the initial size of the structural components. This strategy is preferred when the members' expanded headrooms, existing windows, portals, and other devices may be impacted [12, 13, 15].

Figure 9: Plate Bonding Techniques3.2.6 RCC Jacketing

The concrete jacket enhances the member's size greatly. It enhances the stiffness of the association and is important for managing deformation. If the columns of a tower are thin, RC jackets are a preferable option for preventing buckling. Because the new jacket will be composing with the parent, it can only absorb more loads if the stresses and strains of the elder jacket are enhanced. When an issue arises;

1. Old concrete has reached its limiting strain and is unlikely to withstand any further considerable strain.
2. Old concrete is weak and porous, and it has begun to deteriorate as a result of weathering and reinforcing corrosion.

The relationship between old and new concretes, on the other hand, should be secured by the provision of shear keys and productive bond cover with epoxy or polymer-modified cement slurry, which gives the same strength as new concrete. Plate binding and RC jacketing are two prominent ways for reinforcing RCC constructions. The two approaches have no discernible cost difference. The two approaches must be chosen based on real demands and the suitability of each technique for structural/architectural features and other construction aspects [16, 17, 19, 20].

Figure 10: RCC Jacketing Techniques

3.2.7 Fiber Wrap Technique

The fiber wrap method, also known as the Composite Fiber System, is a non-intrusive structural strengthening technology that improves the load-carrying capacity (shear, flexural, and compressive) and ductility of reinforced concrete elements without destroying or distressing the existing concrete. There are two systems used in implementing this technique:

3.2.7.1 Bi-Directional Woven Fabric

This technique comprises of an epoxy-precoated cloth that is added to a layer following epoxy priming. The woven fiber fabric is composed of high strength bi-directional fibers that are joined with specifically manufactured epoxy to make a composite material in a predetermined proportion.

Such a structural component is wrapped around a reinforced concrete or steel part that requires strengthening or protection. The relevant layers of unidirectional fiber may be added after providing the needed overlap along the fiber channel in accordance with the design requirements.

3.2.7.2 Uni-Directional E-Glass Fibers

Precut unidirectional E-glass fiber is wrapped in a prepared layer of the material with an epoxy base that needs mechanical support and/or surface protection in this system. After it has been sealed, it is covered with epoxy using rollers or manually stamping broses, if any, to remove air bubbles.

The concept underlying these two systems is identical, however the actual processes and fundamental materials used differ somewhat. Each of the methods discussed above has advantages and disadvantages. This method may also be used to improve lateral drift ductility and horizontal shear strength by concentrating the member.

With the proper orientation of the composite primary fibers, structural components may boost their bending, shear, and axial load-bearing capabilities. The cured membrane not only shields the reinforced concrete component, but it also provides excellent protection against corrosive elements that might otherwise harm the concrete and reinforcement. The use of lightweight jackets prevents air, oxygen, and carbon dioxide from accessing the concrete component's exterior layer [22, 23, 25].

Because of its mechanical improvement and safety, the device is suited for hard environmental situations. The retrofitter may be utilized on a variety of constructions, including bridges, overflows, chimneys, water tanks, buildings, and big diameter pipelines.

Figure 11: FIBER WRAPPED COLUMNS

Figure 12 : a) UNI-DIRECTIONAL E-GLASS FIBER b) BI-DIRECTIONAL WOVEN FABRIC

4. STRENGTHENING COLUMNS, BEAMS, SLABS AND WALL

4.1 Strengthening of Columns

Column reinforcement may be necessary for the following reasons:

1. Section expansion may increase the capacity of the column.
2. Column ductility and confinement may be improved by extra panels, steel plates, and fiber wrap.
3. Joints: Joints are necessary for resisting earthquake forces. An expansion, jacketing, and fiber wrap may be used to strengthen the joints.

gure 13: STRENGTHENING COLUMNS

4.3 Strengthening of Slabs

Overlays and underlaying may enhance the performance of the slabs while also increasing the tightness of the slabs and controlling the difficulties associated with unwanted deflections. Shears are typically safe in shears, therefore shear reinforcing is unnecessary except for flat sheets towards the capital of the pole [17, 39, 51].

4.3.1 Cracks/Joints

In tension, both the concrete and the maceration are weak. The fissures indicate the material's tensile breakdown. The reason of creak age should be thoroughly investigated, and appropriate corrective actions should be implemented.

Non-shrink grouts may also be used to fix these types of fissures. Effective cracks necessary for thermal movements are repaired by carefully locating and filling expansion joints with elastic materials such as poly-sulphides, bituminous fillers, and so on.

4.3.2 Masonry

Masonry may be reinforced to resist earthquake stresses by using internal pretension, splinting, and bandaging techniques. The techniques are described in IS 13935-1993.

Figure 15: Slab Strengthening: Concrete Overlay

Figure 16: Stitching Method of Repairing Wall/Slab Cracks

Figure 17: Elevation of Brick Masonry Wall Showing Typical Cracks

4.4 Strengthening of Walls

The following steps increase the wall dimensions and its stability:

1. The whole concrete surface is roughed out.
2. Steel connections are used in both directions for a total surface area of 25-30 cm.
3. Install steel connectors with the same numbers and diameter as the main vertical steel bars into the wall sockets using epoxy substance.
4. Steel wires hold the steel mesh in place and secure it to the steel connections.
5. Apply a suitable epoxy substance to the wall layer.
6. Before the epoxy composition dries, spray the cement jacket with high recessing concrete.

5. FOUNDATION REHABILITATION METHODS

5.1 Shoring

Before beginning any shoring work, the structure should be properly examined and a record of levels, cracks, and tilts established. The observations should be carried out throughout the shoring and underpinning process and until identifiable measurements stop [17, 39, 51]. The following terms are used:

1. raging seas Angles from the beaches are normally 60o to 75o when external support is necessary. Flying coasts that rise against a separate structure or wall may be produced when the foot of rivets are kept exposed.
2. Shores that fly Simply provide a ban on construction or inclination.
3. In combination with flying beaches or horizontal linkages, dead shores are certified struts with the requisite ground distance and a vertical wall load.

Raking shores and flying shores are organized in such a way that they bear on the wall at floor or ground with a solid bearing. Folding wedges should be installed at the foot of beaches to absorb any ground yielding and elastic shortening of the struts. Needles beams may shore up columns individually. To meet the precise specifications, the needle device must be properly manufactured. Jackets may also be properly positioned and designed for upward pressure [3, 4].

a b c

Figure 18: Types of Shores: a)Raking Shores, b) Flying Shores, c) Dead Shores

5.2 Underpinning

If underpinning is required to stop settlement, the underpinned foundation must fulfill the standards of proper allowed bearing forces. Depending on the aim of the arrangement, a smaller base may be suitable in certain circumstances, while in others, the base should be brought to a bigger and somewhat incompressible layer [3, 4].

The surface is iron in the event of a somewhat shallow foundation. Only if the new support stratum is deep enough will piles or piers suffice [7, 10].

Figure 19: UNDERPINNING

- Underpinning piles are often installed in pairs, groups around columns on both sides, or in load-bearing walls.
- Micro-piles are an effective method of underpinning. They may be built from the ground without requiring extensive excavation, and the machinery used to construct the piles is ideal for working in limited places. When compared to the percussion approach, rotary drilling causes less damage and ground loss.
- Inventive jacked heaps Another method of supporting using pre-cast parts. The basement is preloaded using patented pretest procedures before the load of the structure eventually transfers between the tilted old structure and the new foundation.

Figure 20: MICRO PILES

Underpinning via injection of cement or chemicals into the ground to fill voids or penetrate and reinforce the earth is occasionally utilized [7, 10].

1. It cannot, however, be caused to permeate clay or clay silts by using high pressures or closely spaced points — the hydrofracture process can be used to raise the weight of the clay and self and thus provide the basis for a rendering of the grit in granular soils or caver rock formations to improve its strength and minimize its compressibility grooves.
2. In many circumstances, however, it may be preferable to employ a deeper and more incompressible layer rather than attempting to compensate for and stop the settlement using batteries. Plant irrigation, for example.

7 - CONCLUSION

One of the most important maintenance chores is the reinforcement of reinforced concrete structures. There are several home renovation goods available on the market. Sprayed concrete ferrocement, a steel plate, and reinforced polymer fiber are among them (FRP).

Steel plate and FRP plating are often used because of their many benefits, including ease of construction, little structural size changes following platform connection, and less traffic disturbances during reinforcing.

Conflicts of interest / Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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