Retrofitting on Reinforcement Concrete Structures

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Abstract- *In the current situation, concrete building deterioration is a global issue. There are numerous reasons for this, including the occurrence of natural hazards such as earthquakes, a lack of awareness of several critical and essential codal rules in construction, insufficient supervision, and so on. These factors result in structures that are weak. Overloading structures can result in significant deformations and corrosion, which require immediate treatment. Repair, retrofitting, and strengthening are periodically required actions in the construction business today to overcome all of these effects on reinforced concrete structures. Even newly constructed structures may require repair and strengthening in order to address faults caused by design or construction errors. Damaged structural elements caused by unexpected events such as fire, earthquake, foundation movement, impact, and overload require specialized strengthening, increasing the strength, and restoration techniques.*

Retrofitting is one of the most effective ways to make a current insufficient structure safe from future earthquakes or other natural disasters. Retrofitting decreases the risk of damage to an existing structure due to seismic activity in the near future. It tries to reinforce a structure in order to meet the requirements of contemporary seismic design codes. In recent years, a significant amount of research has been done to create various strengthening and rehabilitation procedures to improve structural seismic performance. This paper intends to provide an overview of many innovative and cost-effective local retrofitting strategies for strengthening damaged structures.

Keywords- Retrofitting, Strengthening, Restoration, Ductility.

I. INTRODUCTION

Any structures or buildings may show some sign of distress during their service period and also under the effect of natural calamity like earthquakes, etc. The safety of these buildings is of great concern especially because the loss of most of the lives during collapse of buildings has been reported in the past. The most of the old buildings made of stone masonry/ brick masonry are in existence and require adequate maintenance. At present, most of the buildings are being constructed in Reinforced Cement Concrete, which is assumed to be more durable and stable. The new materials and techniques in the field of construction and maintenance are developed and adopted in strengthening of existing buildings.

Many existing buildings do not meet the seismic strength requirements due to design inadequacy, material degradation over time or alteration carried out during the service life of the building. There maybe some of the reasons for deterioration of buildings.

The term ‘retrofitting’ is mainly used in context with the strengthening of weak buildings to make them strong enough to withstand seismic forces through various repairing methods. The main purpose of retrofitting is to structurally treat the buildings with an aim to restore its original strength or more than that. The retrofitting may be adopted, if the cost of repair and strengthening of building is less than about 40% of the reconstruction cost.

The main types of damage in reinforced concrete structures are cracking in tension zone, diagonal cracking in the core and loss of concrete cover, stirrups bursting outside and buckling of main reinforcement. The complete replacement of such buildings is just not possible due to a number of social, cultural and financial problems. Therefore, strengthening of existing undamaged or damaged buildings is a definite requirement. It will involve actions for upgrading the seismic resistance of an existing building so that it becomes safer under the occurrence of probable future natural disasters.

Different Techniques have been used in the years to restore that structural integrity of the member by restoring or increasing its strength. Researchers across the globe are studying on the retrofitting techniques those are advantageous and most cost effective.

II. LITERATURE REVIEW

[1] **Halil Sezen and Eric Miller “Retrofit of Circular Reinforced Concrete Columns using FRP, Steel and Concrete Jackets” (2007)** tested a circular column with concrete jackets reinforced with spiral rebar, welded wire fabric, and a new reinforcement called PCS (Pre-fabricated Cage System) under varied axial load conditions. The author evaluates the axial load-

displacement relationships for the base specimen with seven other sample retrofitted specimens in this research. The welded wire fabric reinforced concrete jacketing and FRP composite retrofit methods have the lowest strength and deformation capacity, according to the experimental data. Both procedures produced similar results, with brittle failure occurring shortlyafter reaching maximum strength. The authors believe that steel tube jacketing was the most successful retrofit option for increasing strength and deformation capacity after comparing these results. Authors also highlighted that specimens with spiral rebar and Pre-fabricated Cage System reinforced concrete jackets behaved similarly, there was a significant difference in the post-cracking behaviour of concrete jackets with spiral rebar.

[2] **Stephen Pessiki et al., "Axial Behaviour of Reinforced Concrete Columns Confined with FRP Jackets" (2012)** investigated the performance of circular and square RC column jacketing with FRP and found that FRP jacketed concrete members have better axial load-carrying and deformation capacities than unjacketed concrete members, as well as factors influencing the axial stress-strain behaviour of FRP confined concretes. The jackets provided to specimens with square cross sections were not as successful as those provided to specimens with circular cross sections, according to he comparatives between square and circular columns, because square cross sections contain zones of ineffectively confined concrete.

[3] **Ismail M.I. Qeshta et al., "The Use of Wire Mesh–Epoxy Composite for Enhancing the Flexural Performance of Concrete Beams" (2014)** studied behaviour of a reinforced concrete beam strengthened using a new type of strengthening material of wire mesh-epoxy composite was compared to that of an RC beam reinforced with CFRP sheet. The findings of this tests showed that using a wire mesh-epoxycomposite improves the performance of strengthened beams.

[4] **T. P. Meikandaan, Dr. A. Ramachandra Murthy "Flexural Behaviour of RC Beam Wrapped with GFRP Sheets" (2017)** conducted an investigation of the flexural behaviour of an RC beam wrapped in GFRP sheets, which included an experimental study using externally bonded GFRP sheets to the RC beam and testing under a two-point static loading system. They prepared six reinforced concrete beams for this, noted that all six are flexural weak and have the same reinforcement details.

[5] **Hadi and Tran et al., (2014),** The failed piece was repaired by fixing fractures with epoxy materials, glueing the concrete cover, and wrapping it with CFRP. The first specimen was a vertical and horizontally reinforced circular concrete segment with CFRP. The loading was applied to both specimens at the same time. The crack pattern in concrete and CFRP was examined, and they prepared load vs deflection and shear force vs rotation curves. They observed that the joint performance of both specimens improved significantly when compared to theoretical calculations for identical specimens, but that the strengthened specimen performed better than the repaired specimen. The wrapped CFRPs on the modified circular section reduce the risk of fibre debonding and also act as a shear load resistor.

[6] **Waghmare P.B. (2011)** presentedthe material selection and processes that should be considered for Reinforced Concrete, steel, and FRP jacketing. He has mentioned the many technical features of beam, column, and beam-column joint jacketing, such as the width and thickness of the jackets, the minimum area of longitudinal reinforcement, the minimum area of transverse reinforcement, and so on.

[7] **E. Chalioris and N. Pourzitidis (2012)** introduced a new self-compacting RCJ method to repair a shear-damaged reinforced concrete beam. The jacket was 25 mm thick and encompassed the bottom section of the beam as well as the vertical side (U shaped jacket). Small diameter mild steel longitudinal rebar and U-shaped stirrups make up the jacket's steel reinforcement. They found that the load bearing capacity and overall structural performance of the jacketed beams were improved over the previously tested specimens.

III. NEED OF RETROFITTING

There are several problems that structural members experience and needed to be tackled among them some common problems include:

- Structural cracks
- Damage to structural members
- Excessive loading
- Errors in design or construction
- Modification of the structural system
- Seismic damage
- Corrosion due to penetration-honeycombs

IV. METHODS OF RETROFITTING OF BEAM, COLUMN & BEAM-COLUMN JOINTS

i. Jacketing Method
ii. Fibre Reinforced Polymer(FRP)Wrapping
iii. External Plate Bonding Method

i. Jacketing Method

Jacketing is a structural strengthening and retrofitting technique. It's utilised to boost bearing load capacity after a structural design change or to restore structural design integrity after a structural member failure. Vertical surfaces such as walls, columns, and various combinations such as beam sides and bottoms areall used with this technique. It consists of added concrete with longitudinal and transverse reinforcement around the existing column. Jacketing is the process of restoring or increasing the size of a section of an existing structural element by encasing it in suitable materials. Around the damaged portion, a steel reinforcement cage or composite material wrap can be built, then shotcrete or cast-in-place concrete can be applied. Jacketing is commonlyused to repair deteriorated columns, piers, and piles, and it can also be used in underwater applications. The method can be used to prevent concrete, steel, and wood components from further deterioration as well as to strengthen them. Jacketing improves the axial and shear strength of columns, avoiding the need for extensive foundation reinforcement.

Different Types of Jacketing:

a. Reinforced Concrete Jacketing

improving column flexural strength by extending the jacket longitudinally through the slab system and anchoring it to the foundation. By drilling holes in the slab and adding new concrete to the beam-column joints, the new reinforcement can be passed through, as shown in the figure 1.By adding new concrete to the previous web, the structure's dimensions are increased. Additional reinforcement could be employed to improve the structure's strength and ductility. The new reinforcement can be diagonal bars as well as vertical and horizontal bars that create the reinforcement mesh. The new reinforcement should be anchored to the foundation of the structure. Placing the reinforcement in holes drilled in the foundation and groutingit with epoxy is one method of anchoring. After solidification, the new concrete is casted with the altered proportions and cured.

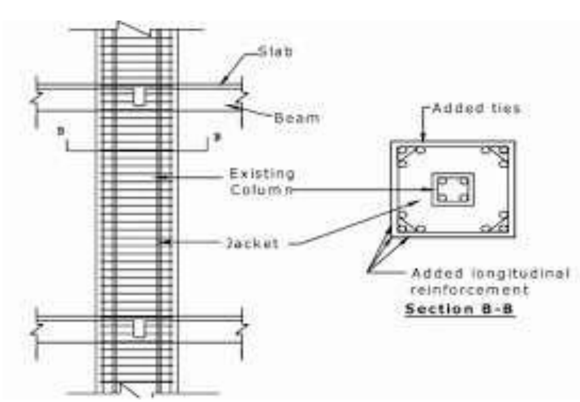

Figure 1: Construction Technique for Concrete Jacketing

Advantages of Concrete Jacketing

- To increase the shear &flexural capacity of Beam.
- To improve the compressive strength & Moment caring capacity of column.
- Ease in construction.
- Easily available material.

Disadvantages of Concrete Jacketing

- The sizes of the sections are increased and the free available usable space becomes less.
- Huge dead mass is added.
- Requires adequate dowelling to these existing column.
- Longitudinal bars need to be anchored to the foundation and should be continuous through the slab.
- Requires drilling of holes in existing column ,slab, beams and footings.
- Placement of ties in beam column joints is not practically feasible.
- The speed of implementation is slow.

b. Steel Jacketing

Steel jacketing is also an effective method to increase basic strength capacity. Steel jacketing not only provides enough confinement, but it also prevents shell concrete deterioration, which is the primary cause of bond failure and longitudinal bar buckling. Encasing the portion with steel plates and filling the gap with non-shrink grout is referred to as steel jacketing. It is a very effective approach for correcting shortcomings such as in adequateshear strength and longitudinal bar splices at critical locations. However, it is likely to be costly and its fire resistance must be addressed. Steel strips and angles are the most widely employed strengthening technique in practical application. Steel jacketing appears to be useful in retrofitting columns because it helps to restore column strength, ductility, and energy absorption capacity. In addition, the steel jacket helps in strengthening the lap-spliced column's flexural strength and ductile behaviour, hence improving lateral performance.

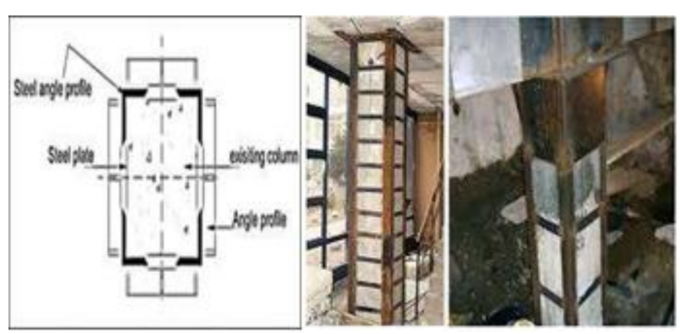

Figure 2: Construction Technique for Steel Jacketing

Advantages of Steel Jacketing

- Steel plate reinforcement is durable and the quality of reinforcement works can be guaranteed andthe strength and rigidity of beams can meet the design requirements. The structural test after strengthening with bonded steel proves that the design method of strength and rigidity is correct and reliable.
- The construction of steel plate reinforced is fast. The construction task can be completed quickly.
- The construction of steel plate reinforced is simple and light as compared with other reinforcement methods. The construction of beam and stick steel reinforcement is clean, simple and simple, and no wet work in the field.
- After the completion of the reinforcement, the appearance of the structure is not changed.
- It is relatively light and thin, and the weight of the beam will increase slightly. It will not cause any other components in the building to be interconnected.
- Steel plate reinforcement is flexible and adaptable.
- The construction of steel plate strengthened is economical and reasonable.

Disadvantages of Steel Jacketing

- The limitation of the application scope of the steel plate reinforcement is not applicable to the beam strengthening of the plain concrete components.
- The environmental temperature for its long-term uses hold not be higher than 60.

ii. Fibre Reinforced Polymer(FRP)Wrapping Method

Fiber Reinforced Polymer(FRP) wrapping is one of the most commonly used retrofitting techniques. FRP is widely utilized due to its characteristics such as high strength to weight ratio, stiffness, good impact capabilities, high corrosion resistance in hard environmental and chemical conditions, and the fact that it alters the geometry of structural elements with less effort than other methods. FRP is utilized to strengthen damaged rectangular columns at various levels of corrosion and volumetric ratios and the test findings show that FRP and column shear resistance increases with increasing volumetric ratio and falls with increasing levels of corrosion. Shrinkage is one of the mechanisms that causes cracks in structural materials such as beams and slabs. Shrinkage compensating concrete made of hybrid fiber-reinforced polymer (FRP) is used to reduce shrinkage.

(a) FRP full wrapping (b) FRP ring partial wrapping (c) FRP spiral strip partial wrapping

Figure 3: FRP Wrapping Techniques

Different Types of FRP Wrappings:

a. Glass Fibre Reinforced Polymer (GFRP) Wrapping

In recent years, the use of composite materials for jacketing has developed in the strengthening and retrofitting of concrete structures, resulting in many concrete structures being strengthened by these materials. One of these applications is Glass Fiber Reinforced Polymer (GFRP) material used in strengthening and retrofitting of reinforced concrete columns. Basic properties under tensile, compressive, bending and shear forces are included in the design of glass-fiber-reinforced materials, as well as estimations of behavior under secondary loading factors such as creep, heat response, and moisture transport. Glass fiber-reinforced concrete is made up of alkali-resistant, high-strength glass fiber embedded in a concrete matrix. Both the fibers and the matrix retain their physical and chemical identities in this state, while providing a synergistic combination of qualities that neither of the components could achieve on their own. In general, fibers are the principal load-carrying members, with the surrounding matrix acting as a load transfer medium between the fibers and protects them from environmental degradation while keeping them in the desired locations and orientation. Continuous or discontinuous lengths of glass fibers can be integrated into a matrix.

Figure 4: GFRP Wrapping Technique

b. Carbon Fibre Reinforced Polymer (CFRP) Wrapping

For several years, fiber reinforced composites have been considered to replace metallic components in a variety of industries. Because, when compared to traditional metals, fiber reinforced composites have a lower density, better corrosion resistance, higher specific strength and stiffness, and better fatigue performance. For the design of structural components, the performance of fiber reinforced composites under various loading conditions, such as axial, torsion, and impact loading is essential. The mechanical properties of fiber-reinforced polymer composites are dependent on the fiber, matrix, and interface between them. Carbon fiber reinforced polymers are gaining popularity among all fiber reinforced composites due to the unique features of carbon fibers and polymer matrix combinations. Carbon Fiber Reinforced Polymers are extensively employed in industrial masonry structures for the retrofitting of existing structures that have been damaged by earthquakes, chemical reactions, environmental effects, and other factors. Carbon fiber reinforced polymers (CFRPs) are one of the stiffest and lightest composite materials available, and they surpasses traditional materials in a variety of applications. The reinforcement material in CFRP is carbon fiber which provides strength and stiffness and the matrix is a polymer resin, such as epoxy, that bonds the reinforcement in an orderly manner. As a result, CFRP is made up of extremely thin carbon fibers with diameters of 5-10m embedded in polyester resin. CFRP is currently being utilized to repair structural damage caused by ageing and harsh conditions. The goal of utilizing CFRP as reinforcement is to improve the tensile strength of reinforced concrete by substituting steel. The main benefit of using CFRP as reinforcement is that it prevents rusting and corrosion. Column wrapping using CFRP composites, a popular alternative for enhancing the seismic resistance of columns, provides a promising solution. To boost strength and stiffness, fiber fabrics and prefabricated FRP composite jackets or tubes are used to cover the full area of the concrete part. Materials such as carbon fiber reinforced plastic (CFRP) have become increasingly popular in industry applications for the creation of aircraft fuselages, vehicle chassis, and wind turbines. It can be attributed in large part to CFRP's excellent features, including as high strength-to-weight ratio, corrosion resistance, and increased fatigue performance.

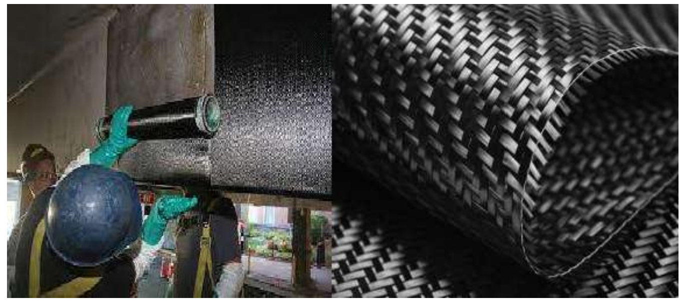

Figure 5: CFRP Sheet Wrapping Technique

Advantages of Fibre Reinforced PolymerWrapping

- Ease and speed of installation.
- Corrosion resistance.
- Minimum modification to geometry and aesthetics of structure.
- Minimum disruption of occupancy.
- High durability ,high strength-to-weight ratio.
- Better work safety and minimum risk hazard.
- Enhancement in both strength/ductility.

Disadvantages of Fibre Reinforced Polymer Wrapping

- Costly material.
- Low efficiency(30 to35%) due to deboning.
- Poor properties on exposure to high temperature and wet environment.
- Increase in strength is relatively small.
- In specific cases, the existence of beams may necessarily require integrating the majority of additional longitudinal bars into the jacket's corners.
- It is difficult to supply cross ties for new longitudinal bars that are not at the corners of the jackets because of the existing column.

iii. External Plate Bonding Method

External plate bonding is a type of reinforcement that involves gluing a steel plate to the component's surface with a high-strength building structural glue to increase the component's bearing capacity. The method of bonded steel plate reinforcement has evolved over time and is now commonly employed in concrete flexural, eccentric compression, and tension member reinforcement projects. The objective of the bonding steel plate reinforcement method is to use adhesive to adhere steel plate to the surface of the original component, forming a new bearing system in which the steel plate contributes in the force and so achieves the goal of reinforcing the concrete structure.

Figure 6: External Plate Bonding Method

Advantages of External Plate Bonding Method :

- Fast construction and a short period of construction. This reinforcement method has a rapid building time. It only takes 1-2 days from cleaning, levelling, and adhering steel plate to pressure solidification, allowing for significant time savings and cost savings.
- It has good overall mechanical performance. In general, adhesive bond strength is greater than concrete tensile strength, allowing the steel plate and original components to produce a better whole.
- Steel consumption is low and utilization is high.
- The small space occupied by the bonded steel plate has minimal effect on the cross-section size and weight of the strengthened members, and has little effect on the usage clearance and shape of the building. It also has little effect on the members' appearance.

Disadvantages of External Plate Bonding Method :

- The steel plate reinforcement applications cope limitation does not apply to the beam strengthening of plain concrete components.
- For long-term use, the ambient temperature should not exceed 60 degrees.

III. CONCLUSION

One of the most difficult challenges that structural engineers face in the outcome of an earthquake is retrofitting seismically inadequate or earthquake-damaged buildings. There are currently no seismic retrofitting codes of practice, but guidelines provided by various departments are available in the country. The paper provides up-to-date information about local retrofitting methods, as well as their advantages and disadvantages.

1. The paper gives the brief literature review of various retrofitting techniques with suitable methodologies and differentiation according to applications as well as limitations.
2. According to the comparison, study among various techniques of retrofitting jacketing is the most efficient technique for increasing member's strength.
3. However, before implementing any seismic retrofit approach on a damaged or inadequate structure, a thorough and accurate evaluation of the structure's seismic performance and current state is required.
4. The retrofitting of structural element is depend upon the assessment strategies which gives the condition index to select suitable technique for retrofitting.
5. A comparative examination of several retrofitting techniques based on effectiveness also been conducted in this paper.

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