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RETROFITTING TECHNIQUES FOR REINFORCED CONCRETE STRUCTURAL MEMBERS USING DIFFERENT MATERIALS - A REVIEW

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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 specialised 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.

<u>Keywords</u> – Retrofitting, Strengthening, Restoration

1. 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 may be some of the reasons for deterioration of buildings, for example, the construction of the buildings is never exactly as per designer's specifications and a number of defects and uncertainties crop up during the construction; the quality of the material deteriorates with time and the assessment of an existing building becomes a time dependent problem. It is, however, most important to ensure the safety of such buildings against various loads including loads of natural disasters like earthquakes, floods, cyclones and landslides etc. by applying appropriate retrofitting techniques. 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.

2. Brief 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 shortly after 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] Consuelo Beschi et al., "Beam-Column Joint Retrofitting with High Performance Fibre Reinforced Concrete Jacketing" (2011) investigated on retrofitting of beam-column joints using high-performance fibre reinforced concrete jacketing. They started testing specimen on a column with cross section of 300×300 mm in the upper part and 400×400 mm in the lower part, and a beam cross section of 300×600 mm. The beam was 5 metres long and the column was 3.55 metres high. A R.C. corbel was put at the beam-column joint to replicate the presence of the transverse beam in the real construction. A static load is applied on this beam-column joint, followed by cyclic loading. The column is wrapped in FRP sheets that have been bent at a 90 degree angle. They were eventually wrapped in the HPFRC. During the test, a horizontal load was applied with increasing amplitude cycles till failure. The use of HPFRC jacketing improves the bearing capacity of the column, as well as its ductility and overall performance of the beam column junction. The results of the suggested technique can be used to strengthen existing RC structures with low concrete strength and low reinforcement ratios.

[3] A Obaidat et al., "Retrofitting of reinforced concrete beams using composite laminates" (2011) investigated the results of an experimental study on the behaviour of structurally damaged full-scale reinforced concrete beams retrofitted with CFRP laminates in shear and flexure are presented in this work. Twelve beams were examined under four point bending after six months of curing for this experiment. The beams were separated into two categories. The focus of group RF was on flexural behaviour, while group RS focused on shear behaviour. Two beams were employed as control beams for group RF. The remaining six were preloaded until flexural cracks showed, then CFRP was installed. There were three distinct lengths of CFRP employed, each with two nominally equal beams. Finally, the retrofitted beams were loaded until they failed, with the results compared to the control beams. Two beams were used as control beams in group RS, while the other two were preloaded until shear cracks formed, then retrofitted and tested to failure. Internal reinforcement ratio, retrofitting position, and CFRP length were the important factors studied. The experimental results for the flexure group of beams indicate that they are similar to the control beams. The beam's crack propagation and final crack pattern differ significantly from that of the control beam. The control beam had a few large flexural cracks, while the modified beam had many minor flexural cracks. This shows that the CFRP laminates acted as a barrier to crack propagation. The results for the shear beam clearly show that the control beam softens more due to crack propagation, but the cracks in the retrofitted beam are arrested by the CFRP, making the retrofitted beam curve slightly straighter than the control beam curve. The reinforced beam could withstand a maximum load of 270kN. When compared to the control beam, it can be shown that strengthening raises the maximum load by over 23%. Based on these findings, the authors concluded that the CFRP-laminated beams retrofitted in shear and flexure are structurally efficient, with stiffness and strength values almost equivalent to or greater than the control beams. The efficacy of the CFRP strengthening approach in flexure was discovered to vary depending on the length. Plate debonding in retrofitted beams was the most common failure mode in the experiments.

[4] 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 the comparative study between square and circular columns, because square cross sections contain zones of ineffectively confined concrete.

[5] 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-epoxy composite improves the performance of strengthened beams. These findings show that the applied approach improves initial crack load, stiffness, and yield strength; also, the usage of a hybrid wire mesh-epoxy-carbon fibre composite showed better post-yield behaviour and prevented CFRP sheet debonding. The authors conclude that specimens bonded with a hybrid wire mesh–epoxy–carbon fibre composite showed a significant increase in energy absorption. Specimens bonded with a hybrid composite had a 64% and 356% increase in flexural load capacity and energy absorption, respectively, as compared to control concrete specimens.

[6] N. F. Grace et al., "Strengthening Reinforced Beam Using Fibre Reinforced Polymer (FRP) Laminates" (2014) presents the various types of Fibre reinforced polymer laminates are tested with the 14 simply supported cross section beams. All of the beams were the same size and had the same flexural and shear reinforcements. Firstly, each beam was cracked by delivering a 44.8kN midspan force. Each beam was strengthened with a FRP material after it had cracked. The beams were then subjected to a concentrated force at midspan until they failed completely. In this study, five different FRP strengthening systems were used. These systems consist of two types of CFRP sheets, two types of GFRP sheets and CFRP plates. In these systems, four different types of epoxies were used. Each beam was reinforced with FRP laminates that were originally loaded higher than the cracking load and then tested till failure. The authors discovered beam deflection, strain, and ductile behaviour. The author found that using the right combination of vertical and horizontal sheets, as well as the right epoxy, the ultimate load carrying capacity of the beam can be doubled. To summarise, the behaviour of beam strengthening is expressed in a greater design factor of safety.

[7] 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. Three beams were isolated and used as control beams, while the other three were strengthened with GFRP in the tension zone. According to the findings, the bottom of GFRP sheet wrapping in a 70 percent preloaded beam can boost the beam's flexural capacity by 14 percent (on ultimate load) when compared to the control beam. According to the authors, strengthening the beam up to the neutral axis improves the beam's ultimate load carrying capacity. Since the earliest cracks generated by wrapping GFRP sheets on beams are not evident until they reach a higher load, this invisibility of initial cracks provides less warning than beams strengthened only at the soffit of the beam.

[8] Ruiz-Pinilla, Pallarés, et al., "Experimental tests on retrofitted RC beam column joints under designed to seismic loads-General approach" (2014) tested steel jacketing as a strengthening system for reinforced concrete framed structures on 20 full size interior beam column joints. The primary goal of this study was to examine the behaviour of strengthened beam column joints that were originally designed to withstand just gravity loads. The experiment was carried out with a strong beam and weak columns under gravity and cycle loads. To obtain this conclusion, the author created a load displacement envelope for each specimen. Steel jacketing prevents column failure, increases column bending strength, and transfers the failure section to the next weakest zone, as per the research.

[9] Hadi and Tran et al., (2014), proposed a new approach for retrofitting exterior beam-column joints with a segmental circular concrete cover reinforced with carbon fibre reinforced polymer (CFRP). They cast two identical RC T connections, one of which was strengthened, while the other was subjected to a load that caused serious failure, and the damaged piece was restored using the same technique. 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.

[10] Waghmare P.B. (2011) presented the 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.

[11] Karayannis, et al., (2008) experimentally investigated and addressed a new type of RC jacket for seismically damaged external beam-column joints. The researchers focused at 10 outside beam column joints that were evaluated under increasing cyclic loads, then retrofitted with proposed RC jackets and retested under the same conditions. The dissipated hysteretic energy area of the original beam–column joints is compared to the hysteretic energy dissipation of the retrofitted specimens, which is measured in terms of the area of the entire load–deformation envelopes of the original beam–column joints. The seismic performance of the original and retrofitted specimens were compared.

[12] 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.

[13] Marlapalle, Salunke and Gore (2014) described the effectiveness of RCJ of beams and columns as per IS15988:2013. The author also addressed the disadvantages of the RCJ technique, such as the fact that the available space is limited due to the increase in section, a considerable quantity of dead mass is introduced, and the implementation time is very long.

[14] Tahsiri, et al., (2015) observed in an experimental investigation that it improves energy dissipation capacity as well as ductility. They studied 12 reinforced and three reference specimens which were all subjected to three-point loading. For further strength, unidirectional carbon fibre reinforced polymer (CFRP) laminates were attached to the beam's soffit. For RCJ, ready-mix concrete was used. They also conducted an analysis to compare with the experimental programme.

3. 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

4. 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 are all 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 commonly used 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

Reinforced concrete jacketing can be employed as a repair or strengthening scheme. Existing members that have been damaged should be repaired before they are jacketed. Jacketing of columns serves two purposes: (i) increasing column shear capacity in order to achieve a strong column–weak beam design, and (ii) 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 grouting it with epoxy is one method of anchoring. After solidification, the new concrete is casted with the altered proportions and cured.

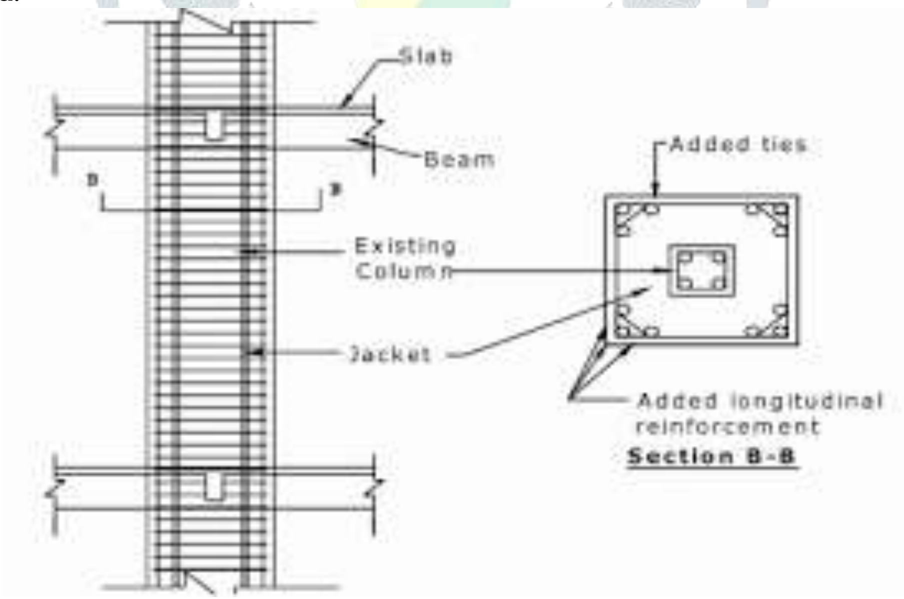

Figure 1: Construction Technique for Concrete Jacketing

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 the 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 inadequate shear 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.

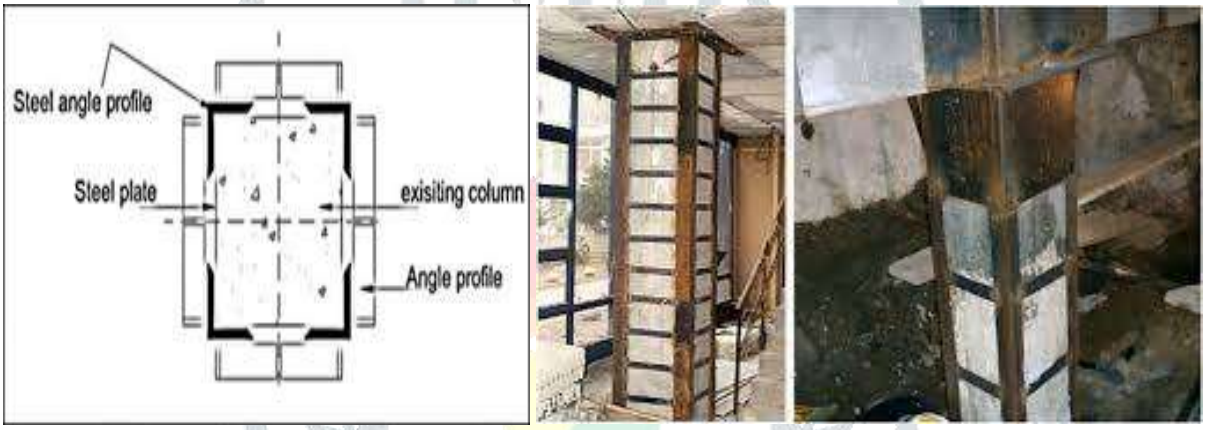

Figure 2: Construction Technique for Steel Jacketing

Advantages of Steel Jacketing

- Steel plate reinforcement is durable and the quality of reinforcement works can be guaranteed and the 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 use should not be higher than 60.

ii. Fibre Reinforced Polymer (FRP) Wrapping Method

Fibre Reinforced Polymer (FRP) wrapping is one of the most commonly used retrofitting techniques. FRP is widely utilised 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 utilised 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 fibre-reinforced polymer (FRP) is used to reduce shrinkage.

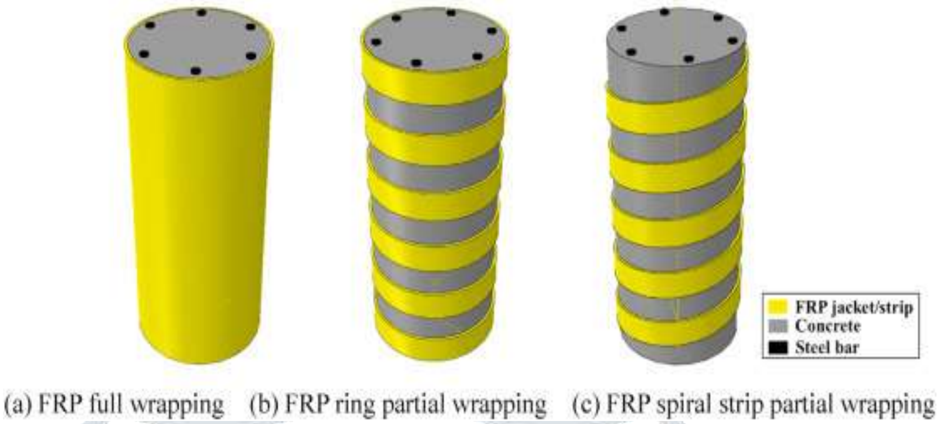

Figure 3: FRP Wrapping Techniques

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 Fibre 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-fibre-reinforced materials, as well as estimations of behaviour under secondary loading factors such as creep, heat response, and moisture transport. Glass fibre-reinforced concrete is made up of alkali-resistant, high-strength glass fibre embedded in a concrete matrix. Both the fibres 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, fibres are the principal load-carrying members, with the surrounding matrix acting as a load transfer medium between the fibres and protects them from environmental degradation while keeping them in the desired locations and orientation. Continuous or discontinuous lengths of glass fibres can be integrated into a matrix.

Figure 4: GFRP Sheet Wrapping Technique

b. Carbon Fibre Reinforced Polymer (CFRP) Wrapping

For several years, fibre reinforced composites have been considered to replace metallic components in a variety of industries. Because, when compared to traditional metals, fibre 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 fibre 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 fibre, matrix, and interface between them. Carbon fibre reinforced polymers are gaining popularity among all fibre reinforced composites due to the unique features of carbon fibres and polymer matrix combinations. Carbon Fibre 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 fibre 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 fibre 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 fibres with diameters of 5-10m embedded in polyester resin. CFRP is currently being utilised to repair structural damage caused by ageing and harsh conditions. The goal of utilising 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, fibre fabrics and prefabricated FRP composite jackets or tubes are used to cover the full area of the concrete part. Materials such as carbon fibre 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: GFRP Sheet Wrapping Technique

Advantages of Fibre Reinforced Polymer Wrapping

- 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 to 35%) due to debonding.
- 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 glueing 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 utilisation 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 application scope limitation does not apply to the beam strengthening of plain concrete components.
- For long-term use, the ambient temperature should not exceed 60 degrees.

5. Discussion

Table 1 Retrofit Discussion

Retrofit Strategy	Merits	Demerits	Comments
1. Concrete Jacketing	1. Increase flexural and shear strengths and ductility member. 2. Easy to analyse. 3. Compatible with original substrate.	1. Size of member increases. 2. Anchoring of bars for flexural strength involves drilling of holes in existing concrete 3. Needs preparation of the surface of existing member.	1. Low cost 2. High disruption 3. Experience of traditional reinforced concrete construction is adequate.
2. Steel Jacketing	1. Increases shear strength and ductility. 2. Minimal increase in size.	1. Cannot be used for increasing the flexural strength. 2. Needs Protection against corrosion and fire.	1. Can be used as temporary measure after an earthquake. 2. Cost can be high. 3. Low disruption. 4. Needs skilled labour.
3. Bonding of Steel Plates	1. Increase either flexural or shear strength. 2. Minimal increase in size.	1. Use of bolts involves drilling in existing concrete. 2. Needs protection against corrosion and fire.	1. More suitable for strengthening against gravity load. 2. High cost. 3. Low disruption 4. Needs skilled labour
4. Fibre Reinforced Polymer Wrappings (GFRP and CFRP)	1. Increase ductility. 2. May increase flexural or shear strength. 3. Minimal increase in size. 4. Rapid installation.	1. Needs protection against fire.	1. High cost. 2. Low disruption. 3.Needs skilled labour.

Conclusion

1. 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 practise, 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.
2. The paper gives the brief literature review of various retrofitting techniques with suitable methodologies and differentiation according to applications as well as limitations.
3. According to the comparison, study among various techniques of retrofitting jacketing is the most efficient technique for increasing member's strength.
4. 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.
5. The retrofitting of structural element is depend upon the assessment strategies which gives the condition index to select suitable technique for retrofitting.
6. A comparative examination of several retrofitting techniques based on effectiveness also been conducted in this paper.

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