B. RETROFITTING

Retrofitting is strengthening of existing structures or structural elements to enhance their performance with new technology, features, and components. Generally retrofitting can be classified in two categories:

1. Global retrofitting
2. Local retrofitting

C. Global retrofitting:

The global retrofitting technique targets the seismic resistance of the structures. It includes adding of shear structure, adding of steel bracings, adding of infill structure and base isolation. Shear structures can be introduced in a building with flat slabs or flat plates. These can be provided in the exterior frames with least disruption of the buildings use.

D. Local retrofitting:

Local retrofitting technique targets the seismic resistance of a member. The local retrofit technique includes the concrete, steel or fibre reinforced polymer jacketing to the structural members, like beams, columns, foundation, and beam column joint. Concrete jacketing involves adding a new layer of concrete with longitudinal reinforcement and closely spaced ties. The jacket increases both the flexural strength and the shear strength of the beam or the column.

There are several factors that control the choice of the retrofitting technique for RC structures, some of these factors are:

• The deficiency in the existing structure and its expected mode of failure.

• The goal of intervention (e.g. increased stiffness, strength, ductility, etc).

• Consequences of structure rehabilitation (e.g. increased demand on foundation, etc).

• The allocated budget for retrofit.

• Physical constraints (e.g. architectural requirements, accessibility of the building during the retrofitting process, etc).

E. PRINCIPLE OF REPAIR & RETROFITTING

The engineers responsible for maintaining buildings often begin repair activity without adequate understanding of the factors responsible for the defects. The repairs strategy adopted is replacement of damaged materials without dealing with the real problems. Many engineers unintentionally attempt treating the symptoms, instead of dealing with the cause and effect phenomenon. Such an approach may offer a quick action with minimum inconvenience to the occupants. But in this process, there is a strong possibility that the source and cause for the distress remain unattended and continue to cause problem even after the superficial repairs have been executed. If structural defects are dealt with in this fashion, it remains only as defects camouflaged beneath finishes, which gives a false sense of safety to the occupants allowing the problem to continue without getting treated. A rational approach to any repair and rehabilitation work is to consider the source of the problem and the symptoms together.

F. NECESSITY OF STRENGTHENING

Masonry structures were built on ancient times when no appropriate theory and good knowledge were available. People usually built their houses according to the available knowledge and experience. So many buildings which still exist do not satisfy the present guidelines. Also the recent worldwide earthquakes make people more conscious about the safety of life and property. Some of the famous building which becomes valuable in terms of culture and history demand longer service life.

G. APPLICATIONS OF STRENGTHENING TO MASONRY STRUCTURES

Masonry structures are the oldest structures ever made. With passage of time it needed restoration and strengthening as many of the structures became the cultural heritage and got a good social value. At the beginning of restoration process a lot of strengthening techniques had been suggested by the experts. Also depending on the structures, site and local availability of materials many strengthening techniques developed and used in different locations of the world. Recently retrofitting with external bars became the most popular material for strengthening as it overcomes a lot of disadvantages of other techniques, it can be applied to almost all type of structures though every structure is unique.

At the time of selecting possible repair or strengthening solutions, it is also essential to consider the principles of conservation and the modern criteria for the analysis and restoration of historical structures. These criteria are minimum intervention, reversibility, non-invasiveness, durability and compatibility with the original materials and structure. Cost should be considered also though it is not within the criteria. Generally considering these principles and criteria the best solution is found out among a Set of alternative possibilities or a combination of different techniques.

Below chart shows a flow diagram of the retrofitting process. This flow is based on the "General approach to maintenance".

(1) Inspections of structures to be retrofitted correspond to the "detailed inspections", these should be performed in particular to determine whether or not retrofitting should be performed and gather data needed for retrofitting.

(2) The primary criteria for determining whether or not retrofitting should be performed are whether the structure fulfils performance requirements at the time of the retrofitting study.

(3) If it is determined through performance evaluation and verification that the existing structure does not fulfil performance requirements, and that use of the structure can be continued through retrofitting, the design process should proceed.

(4) In some cases, the performance requirements for the structure after retrofitting will not be the same as those of the existing structure.

H. FLOW OF RETROFITTING PROCESS

Retrofitting of structures shall proceed as follows:

(1) Identify the performance requirements for the existing structure to be retrofitted and draft an overall plan from inspection through selection of retrofitting method, design of retrofitting structure and implementation of retrofitting work.

(2) Inspect the existing structure to be retrofitted.

(3) Based on the results of the inspection, evaluate the performance of the structure and verify that it fulfils performance requirements.

(4) If the structure does not fulfil performance requirements, and if continued use of the structure through retrofitting is desired, proceed with design of the retrofitting structure.

(5) Select an appropriate retrofitting method and establish the materials to be used, structural specifications and construction method.

(6) Evaluate the performance of the structure after retrofitting and verify that it will fulfil performance requirements.

Table 1 Different Techniques Used in Retrofit of RC Structures

Retrofit technique		**Examples of the previous experimental work**
Using traditional materials	Concrete replacement	Fiorato et al. (1983), Lefas and Kotsovos (1990), Vecchio et al. (2002), and others.
	Concrete Jacketing	Fiorato et al. (1983), and others.
	Using steel sections	Elnashai and Pinho (1997), Cho et al. (2004), and others.
	Using steel bracings	Taghdi et al. (2000), and others.
	Through thickness rods	Mosalam et al. (2003), and others.
Using new Materials	FRP laminates	Lombard et al. (2000), Kanakubo et al. (2000), Paterson and Mitchell (2003), Antoniades et al. (2003), Khalil and Ghobarah (2005), and others.
	Shape Memory Alloys	Effendy et al. (2006), and others.

(7) If it is determined that the retrofitting structure will be capable of fulfilling performance requirements with the selected retrofitting and construction methods, implement the retrofitting work.

I. DISTRESS IDENTIFICATION

Before attempting any repair procedure, it is necessary to have a planned approach to investigate the condition of concrete and reinforcement. Particularly difficult are cases in which the cause and effect phenomenon cannot be readily explained or when prognosis in terms of long-term performance of restored structure is to be made. This will require a thorough technical inspection and an understanding of the behaviour of the structural component, which is being repaired. Inspection calls for detailed mapping of affected areas, documentation of type and location of symptoms and their history and photographic evidences.

The decision to retrofit or replace a structure or its components can be decided after the consideration of service life of structures that is established based on the economic and technical evolutions. It is based on preliminary investigations that carried out on the structural members. Table 1.1 shows different retrofit techniques for RC structures and examples of experimental work conducted by pervious researchers.

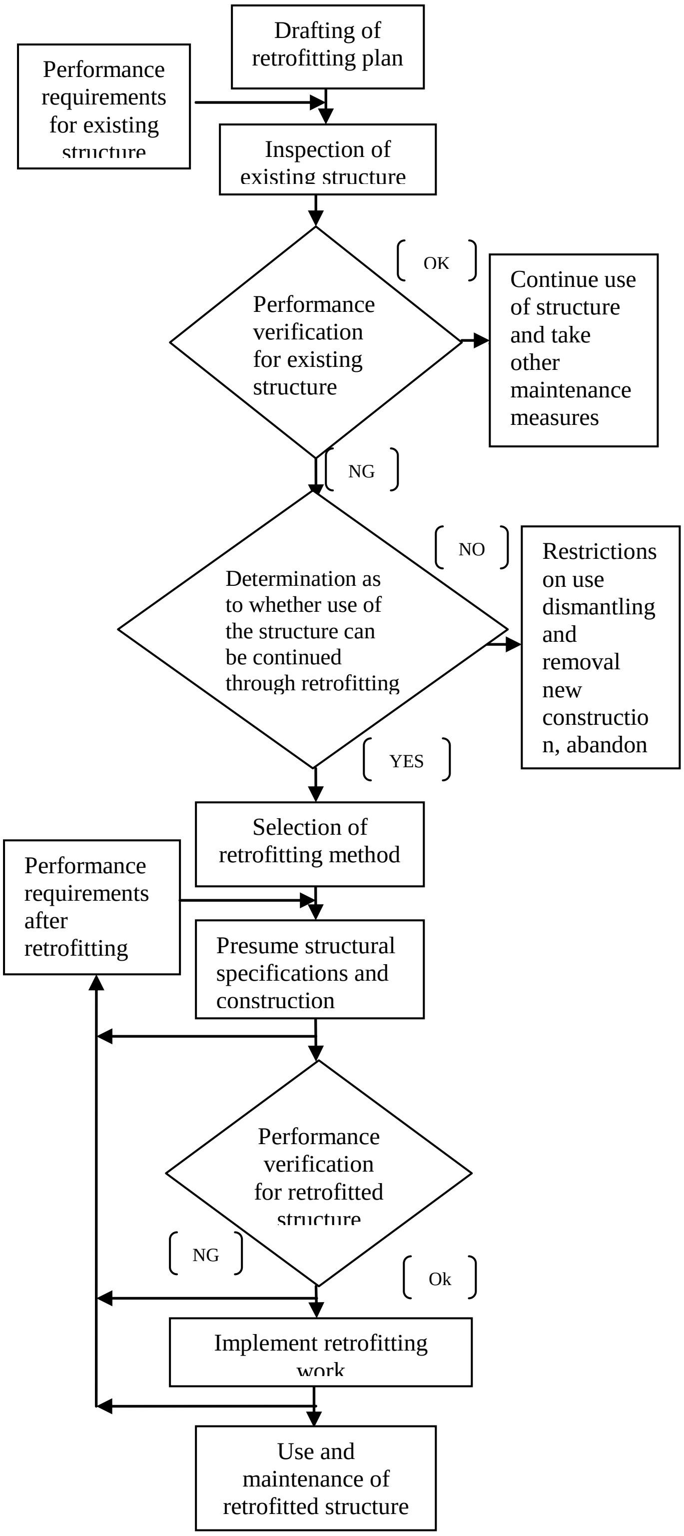

Figure 1 Flow of Retrofitting Process

II. METHODS AND MATERIAL

Some of the retrofitting methods are explained below. Figure 2 shows the methods of retrofitting techniques. And they are discussed in the detailed as below.

J. Concrete replacement

Concrete replacement is the simplest and cheapest technique that can be used to restore strength and ductility of RC structures (Fiorato et al. 1983). In this technique, the damaged concrete is removed, the aggregate of the old concrete is exposed and the surface of the old concrete should be cleaned to remove any loose material and to ensure a strong bond between the old concrete and the new one. If the reinforcing steel bars in the compression zone were slightly buckled after concrete crushing, they should be straightened (Lefas and Kotsovos 1990). The formwork of the web is prepared; the new concrete is mixed and poured from one side of the structure. The top part can be completed using a high-strength epoxy grout to ensure a proper bond with the old concrete (Vecchio et al. 2002). After the removal of formwork, the new concrete should be cured. Therefore, repairing the shear structure by concrete replacement is causing disturbance to the building function, and hence it is not suitable if the building has to be accessible during repair. In some cases, in order to improve the strength and ductility of the RC structure, the major flexural cracks could be sealed using low-viscosity epoxy resins (Lefas and Kotsovos 1990).

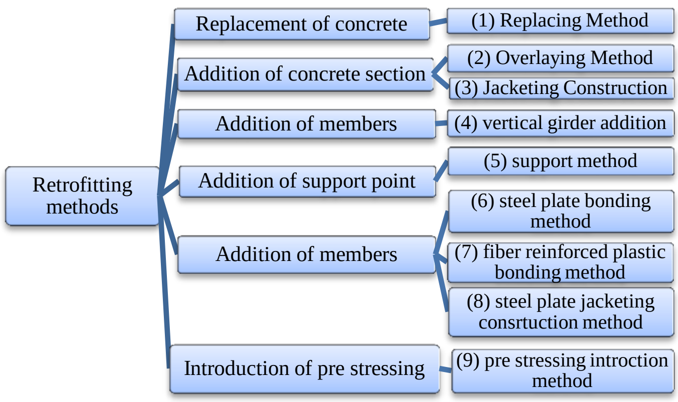

Figure 2 Retrofitting M ethods

K. Concrete jacketing

In this technique, the structure dimensions are increased by adding new concrete to the original web. Additional reinforcement could be used to increase the strength and ductility of the structure. The new reinforcement can be vertical and horizontal bars that form the reinforcement mesh or it can be diagonal bars. The new reinforcement should be anchored to the structure foundation. One way of anchoring is by placing the reinforcement in holes that are drilled in the foundation, and then it is grouted with epoxy. The new concrete is casted with the new dimensions and cured after solidification. Fiorato et al. (1983) tested two RC structures, one rehabilitated using diagonal bars after removal of the damaged web concrete in the plastic hinge region and the other one is rehabilitated by increasing the web thickness (jacketing).

Figure 1 Reinforced concrete jacketing

The tests showed that the strength and deformation capacities of the rehabilitated structures had increased, while their initial stiffness was almost half that of the original structures. It should be noted that, in some cases when the structure foundation is not over-designed, it will be needed to strengthen the foundation as well in order to be able to carry the additional weight of the structure and the increased lateral load expected to be carried by the structure.

L. Retrofitting using steel material

Steel is the most common material that was used for retrofitting of RC structures. Steel sections were used to retrofit RC shear structures with different schemes to enhance different response parameters. The lower added weight to the structure (compared to concrete jacketing) and the minimum disruption to the building occupants are advantages of using steel retrofitting systems (Ghobarah and Abou Elfath 2001). On the other hand, steel vulnerability to corrosion, the need for scaffolding, the difficulty of handling the heavy steel plates at the site are problems that arise when retrofitting using steel (Bakis et al. 2002).

Figure 2 Retrofitting by Steel plate bonding

M. Using steel sections

In this technique, steel plates are attached to the structure to increase the structure strength, stiffness, ductility or a combination of them. The steel plates can be attached vertically or horizontally according to the enhanced property. Elnashai and Pinho (1997) studied the effect of rehabilitation scheme used for retrofitting shear structures using steel plates on the enhancement of a certain property (e.g. structure stiffness, strength or ductility) without altering the other properties. Figure 5 shows different rehabilitation schemes of the structures studied by Elnashai and Pinho (1997). They concluded that enhancing the structure stiffness without altering the strength can be achieved by using external steel plates bonded along the structure length near the edges as shown in Figure 5(a), the plates can be bonded along the whole height or along the expected plastic hinge height, and a gap should exist between the plates and the foundation or the top slab in order not to affect the structure strength as the critical section will remain as before. Increasing the structure strength without altering the stiffness can be achieved by using external un bonded steel plates or bars connected with an Interaction Delay Mechanism (IDM) as shown in Figure 5(b). The IDM allows the added plates or bars to work only after a certain displacement is exceeded. The plates or bars can be attached to the slabs between the structure heights, and then enclosed by a ductile material that provides corrosion and fire resistance to the steel.

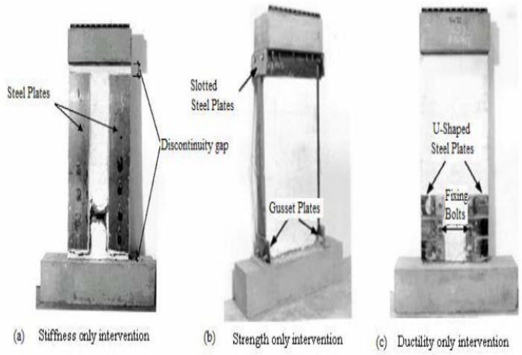

Figure 3 Retrofitting by steel sections

This retrofitting scheme can be used provided that the concrete will be able to carry the additional shear and compression forces applied on it due to strengthening without crushing. Increasing the structure ductility with a minor increase of the stiffness and strength can be achieved by using U-shaped external confining steel plates that are bonded to the structure using epoxy, and bolted using pre stressed bolts as shown in Figure 5(c).

Increasing the structure ductility will increase the energy dissipation capacity of the structure which will enhance the seismic behaviour of the retrofitted structure.

N. Using steel bracing

Steel bracings are mostly used for rehabilitation of nominally-ductile moment resisting frame structures. They can provide the adequate strength, stiffness and ductility required for the structure, provided that a special attention should be directed to their connections with the existing structure. Steel bracings can be also used to enhance the seismic performance of RC shear structures. In that case, the steel bracing can be anchored to the RC structure at small intervals to minimize the buckling length, which will increase the capacity of the bracing member compared to the case of retrofitting the moment resisting frames that is governed mainly by buckling of the compressed bracing member.

It is usually recommended to add vertical steel strips at the structure edges when using diagonal bracings, due to the fact that the diagonal forces in bracing members will have a vertical (compression/tension) components that will add higher forces on the structure, in that case it is better to provide vertical strips at the structure ends to resist a part of these forces with the concrete. Taghdi et al. (2000) tested a RC structure that is retrofitted using this technique. Figure 6 shows the retrofitted structure at 1.0 % drift.

Figure 4 Retrofitted RC structure using steel bracings at 1.0 % drift

O. Retrofitting using composite materials

Fibre-reinforced polymer (FRP) composite materials have received an increasing attention in the past few decades as a potential material for retrofitting of existing structures due to their high strength, light weight, ease of application, Figure 6 Retrofitted RC structure using steel bracings at 1.0 % drift (Taghdi et al. 2000 and their high resistance to corrosion. FRP laminates, sheets or rods can be used, and the fibres might be pre-stressed to increase the efficiency of retrofit. The use of FRP composites offers also a faster and easier retrofit alternative, especially when the evacuation of the entire building during the retrofit is not possible, in that case FRP will provide the required strength without interrupting the use of the building.

P. ADVANTAGES

All structural problems have more than one technical solution, and the choice of solutions will ultimately rest upon economic evaluation of the alternatives. Enlightened clients will ensure that this evaluation includes the total cost that will be incurred during with a minimum initial cost.

The potential advantages of FRP composites plate bonding are as follows:

Strength of Plates: FRP composites plates may be designed with components to meet a particular purpose and may comprise varying proportions to different fibers. The ultimate strength of the plates can be varied, but for strengthening schemes the ultimate strength of the plates is likely to be at least three times the ultimate strength of steel for the same cross-sectional area.

Weight of Plates: The density of FRP composite plates is only 20% of the density of steel. Thus composite plates may be less than 10% of the steel weight with same ultimate strength. Apart from transport costs, biggest saving arising from this is during installation. Composite plates do not requires extensive jacking and support system to move and hold in place. The adhesive alone will support the plate until curing has taken place. In contrast, fixing of steel plates constitutes a significant proportion of the works costs.

Versatile Design of systems: Composite plates are unlimited length, may be fixed in layers to suit two directions may be accommodated by varying the adhesive thickness.

Reduced Mechanical Fixing: Composite plates are much thinner than steel plates of equivalent capacity. This reduces peeling effects at the ends of the plates and thus reduces the likelihood of a need for end fixing. The overall depth of the strengthening scheme is reduced, increasing head-room and improving appearance.

Durability of Strengthening System: There is the possibility of corrosion on the bonded face of steel plates, particularly if the concrete to which they are fixed is cracked or chloride contaminated. This could reduce the long term bond. Composite plates do not suffer from such deterioration.

Improve Fire Resistance: Composite plates are a low conductor of heat when compared to steel, thus reducing the effect fire has on the underlying adhesives. The itself chars rather than burns and the system thus remain effective for a much longer period than steel plate bonding.

Maintenance of Strengthening System: Steel plates require maintenance and painting and access costs as well as the works costs. Composites plates will not require such maintenance, reducing the whole life cost of this system.

Ability to Pre Stress: The ability to pre-stress composites opens up a whole new range of applications for plate bonding. The plate bonding may be used to replace lost pre-stress and shear capacity of the section be increased by the longitudinal stresses induced. Formation of cracks be inhibited and the serviceability of the structure enhanced. Strengthening of materials such as cast iron also becomes more practicable**.**

III. LITERATURE REVIEW ON FLEXURE RETROFITTING OF RC BEAMS

Many researchers proposed many materials, methods and techniques for strengthening flexure deficient RC beams. A sample of a few works among them is presented in this chapter.

Markandeya raju, Purushothamrao, and Sankaramouli (2017) [1] have researched on Experimental Study on Effect of Stitching Depth on Performance of Flexure Retrofitted Beams. A total number of nine beams of 120mm × 210mm×1500mm are casted as one of the beam is stood as control beam and remaining all beams are categorized in to two series of beams with 4 beams in each series. While the first series of beams were retrofitted with 2 – 10 mm dia., bars the second series of beams were retrofitted with 2 – 12 dia., bars. Among the 4 beams in each series, the first beam was retrofitted with bars without stitching depth while the remaining beams were retrofitted with a stitching depth of 40 mm, 70 mm and 100 mm respectively. All the beams were cast using M25 grade concrete and Fe 500 steel and effective span of 1440mm and a clear cover of 20mm were adopted. Both the control beam and the retrofitted beams were designed for a Moment of Resistance of 28.72kN-m. Beams in both the series behaved similarly in terms of increase in load carrying capacity that was inversely proportional to the stitching depth.

Doredla Nagaraju (2017)[2] have researched the flexural behavior of reinforced concrete beam retrofitted with Ultra High Strength Cementanious Composites (UHSCC) overlay. Here four numbers of beams were casted are of size 1500×100×200mm, one of them as stood as controlled beam and tested under four-point bending up to failure, and remaining two RC beams have been loaded up to 70% of ultimate load and other one is preloaded up to 65% of ultimate of controlled beam, then strengthening of preloaded RC beam carried out using UHSCC overlay, at beneath the tension face of the beam. For one of 70% preloaded RC beams, the overlay is provided throughout the span of the beam and the remaining 70%, 65% preloaded RC beam overlay only at the bending moment zone. And he observed parameters such as load, deflection, crack, failure pattern, and he compared the numerical investigation to experimental, by using FEA software ABAQUS. He concluded that from the experimental investigation and FEA (finite element analysis) the load carrying capacity & ductility are improved in the case of beam with UHSCC overlay.

Pmeikandaan, Ramachandra Murthy (2017)[3] conducted an investigation is based on flexural behavior of RC beam wrapped with GFRP sheets, an experimental study is carried out by externally bonded GFRP sheets to the RC beam and to tested under the two point static loading system. For this they prepared six reinforced concrete beams, noted that all six beams are weak in flexural and having same reinforcement detailing. They separated three beams are used as control beams and other three are strengthened using GFRP in tension zone, by the experimental results they concluded that the bottom of GFRP sheet wrapping in 70% preloaded beam can increase flexural capacity of the beam by 14%(on ultimate load) as compared to the control beam.

Praveenkumar, Chiranjeevi, Kowshiken, and Dineshmarthu. Chiran et. al. (2017)[4] has examined the possibility of using externally bonded hybrid fibre reinforced polymer (HYFRP) with combination of glass(GFRP) and carbon(CFRP)based laminates to strengthen the reinforced concrete beam(RC)against flexure. The study is on total number of five beams of cross section 150mm×250mm×3000mm long and

2800mm simply supported span were casted and tested under four point bending was applied to examine the flexure strength. Out of five beams one beam is stood as reference beam and the other four were made with hybrid FRP laminates, the parameters observed spacing of stirrups, thickness of HYFRP laminates and composite ratio. The test results showed that the hybrid fibre reinforced polymer (HYFRP) strengthened RC beam exhibit increased strength and composite action until failure.

Poorna Prasad Rao, Ramamohan Rao (2016)[5] conducted experimental work on the retrofitting of reinforced concrete beam using rubberized fibre sheet tested under two point loading, the criteria of this experiment is to rehabilitate the structurally deficient beams and to make it serviceable both flexure and shear. And they make the retrofitted to ensure stiffness and strength values are greater than those of control beam. The parameters values are greater than those of control beams. The parameters that noticed in this studies first crack, load deflection and RCFS de bonding, crack propagation patterns. They used shear straps to enhance the shear strength and have the dual benefit of strengthening. The test results showed that the stiffness of the RCFS retrofitted beams are greatly increased compared to the control beams and also the deflection of retrofitted beams were reduced predominantly at the early stage of loading .The ultimate loads at failure are increased.

Mohamed Asick Umar,and Manikandan (2016)[6] have examined flexural retrofitting of reinforced concrete beam using hybrid laminates, in this the studies shows an idea to strengthen reinforced concrete beams by combining CF (carbon fiber) & GF (glass fiber) sheets. A total number of nine beam specimen of (150mm×200mm×1000mm) of M20 grade of concrete, all the beams are designed to fail in flexure only, beams are casted and preloaded with 75% of ultimate load by two point load method, later retrofitted with hybrid laminates (GFRP+CFRP) of different thickness at u-wrap bonding techniques used to examine the flexural behaviour of reinforced concrete beam to determinate parameters are flexure strength, ultimate load, deflection behaviour, cracking and failure mode, energy absorption and ductility failure and he concluded from the results obtained is by HFRP laminates strengthened beams increase the ultimate load carrying capacity compared to control beam, from the observations the strengthened (retrofitted beams) are more stiff as compared to control beams.

Abhishek Sharma1, Tara Sen, Joyanta Pal (2016)[7] have conducted experimental research on Flexural Characteristics of RC Beams Retrofitted using FRP and Cement Matrix Composite. In this study flexural strength of beams retrofitted using cement matrix composite and conventional epoxy binder are compared. The matrix is made using cement, fly ash, admixtures and fibres. A total number of ten beams of cross section 100×135 mm. And overall length of 1000mm are casted. Concrete of grade M-25 and reinforcement of HYSD 500 steel bars are used. In those total beams two of the beams treated as control beams. The other eight beams are strengthened using EB technique. All the beams are reinforced with 2 bars of 8mm in the tension (bottom) zone and 2 bars in the compression (top) zone. 8mm bars are used as longitudinal bars for both compression and tension side while 6mm are used as shear stirrups. All the beams are designed as fails in flexure only. Group 1 having 2 beams strengthened with glass fibers and other 2 beams with sisal fibers using cement matrix composite. Group 2, having 2 beams strengthened with glass fibers and 2 beams with sisal fibers using sikadur lp 32 epoxy binder. Both the fibers are applied in the flexure zone in both above describe groups.

Table 2 Percentage increase in strengths

Fiber used in retrofitted method	% increase in strength
sisal fiber using cementitious matrix and using epoxy as binder	11.8% and 17.2% more strength than the control beams
fiber using cementitious matrix and using epoxy	21.5% and 29.03% more strength respectively than the control beams
sisal fiber sheets using epoxy	4.8% more strength than the retrofitted beams of cement matrix composite using sisal fiber.
glass fiber sheets using epoxy	6.19% more strength than the retrofitted beams of cement matrix composite using glass fiber.

Ismail M.I Qeshta,Payam Shafigh, and Mohd Zamin Jumal(2015)[8] researched on the failure behavior of reinforced concrete beam Strengthened with a new type of strengthening material of wire mesh-epoxy composite. And it was compared with RC beam strengthened with CFRP sheet (carbon fiber reinforced polymer). In this the test results showed that use of wire mesh-epoxy composite gives enhancement in the performance of strengthened beams by this results concluded that used method is involved to improvement in the first crack load, stiffness and yield strength, in addition the use of hybrid wire mesh-epoxy-carbon fibre composite indicated better post-yield behavior and prevented the de-bonding of CFRP sheets.

Ayyubi, and Sharbatdar(2015)[9] have conducted an experimental study on the flexural retrofitting of the partial damaged reinforced concrete beams by using high performance fiber reinforced cement based composite (HPFRCC). In this an experimental research has been performed on the three hinge support beam. In this study a total number of three beams are of 2500mm length, 200mm width, 250mm height casted, the first beam is referred as reference beam (RC beam) without strengthening, second beam named as B35H1 reinforced concrete beam is loaded at 35% ultimate load of reference beam (RC beam), retrofitted by HPFRC layer and the third beam is B35H2 reinforced concrete beam loaded at 35% ultimate load of reference beam, retrofitted by HPFRC layer. In this research one of three beams has loaded until its final crack and destruction (Pmax), and next in order to analyze the flexural behavior of a damaged beam, the two other beams were loaded with 35% of ultimate load (Pmax), the reason that 35% of ultimate load of the reference specimen has the fact that under this load, the beam behavior is between the elastic point and yielding point of it, and has not been subjected to severe loads. The retrofitting is done at the soffit layer of HPFRCC. The studied parameters in this research work is load-deflection response, ductility of beam, energy absorption of beam, path of increased load and initial samples, the results that concluded that in the reference reinforced concrete beam, cracking the beam in addition to softening of the stress-strain curve will lead to reduce the bearing capacity of structure and it is worth noting that this reduce rate is in a direct relation with the number of the cracks. Due to retrofitting, yielding force of tensile reinforcement (steel bars) has been raised about 75%, the Final force (destruction force) of samples increased about 50% in comparison to reference samples.

Chandran et. al. (2015)[10] from researched article says about the Flexural behavior of strengthened RC beams with multi-directional basalt fiber – reinforced polymer composites. The paper describes an experimental behavior of the basalt fiber reinforced polymer composite by external strengthening to the concrete beams. The BFRP composite is wrapped at the bottom face of RC beam as one layer, two layers, three layers and four layers. From this investigation, the first crack load is increased depending on the increment in layers from 6.79% to 47.98%. Similarly, the ultimate load carrying – capacity is increased from 5.66% to 20%. The crack’s spacing is also reduced with an increase in the number of layers. Most of the strengthened beams in unidirectional BFRP showed flexure cum crushing of compression modes. The stiffness of the beams is increased by increasing the number of layers. Curvature of strengthened beams is also decreased by increasing the basalt fiber layers increase. In cracking behavior the number of cracks increase crack spacing decreased by basalt fiber layers increase.

Maheboob et. al. (2015) [11] examines the article about Comparative evaluation of different retrofitting techniques. Concrete is an important and successful material in the construction industry for a long time. It has so many applications and utilization in the construction field. From this experiment by using retrofit all beams with different techniques like HFRC, FRC, SIFCON, SIMCON, Ferro cement. Take SIMCON and cover to full beam then mortar will be applied to full beam. Take slurry infiltrated fiber concrete (steel fiber) mixed with mortar and applied over a surface of beams and same process will be done with polypropylene fiber. In Ferro cement retrofitting welded and chicken mesh is used which is cover to beams and then mortar is applied over the surfaces. Thus it can be concluded that the concrete beam retrofitted with SIFCON yields higher flexural strength and the percentage in the flexural strength as compared to the beam without retrofitting is found to be 85.03% and the concrete beam retrofitted with Ferro cement yields higher flexural strength.

Ragheed Fatehi Makki(2014)[12] have studied response of reinforced concrete beams retrofitted by ferrocement, and investigate the behaviour of reinforced concrete beam retrofitted by ferrocement to increase the strength of beam in both shear and flexure, for this study a total number of ten beams of size

140mm×240mm×2000mm were casted and cured under laboratory conditions, all the specimens are designed considering it to be an under reinforced section, subjected to two point loading condition. Out of ten beams four beams are strengthened and four beams are repaired, remaining two beams stood control beam. In this study retrofitting is done by applying the U-wrap of steel wire mesh of ferro cement finishing by mechanical method to eliminate the de-bonding of ferro cement, trying to reduce full maximum tensile strength of ferrocement. The rehabilitation technique (strengthening and repairing) of RC beams by using ferro cement system is applicable and can increase the ultimate load, The use of ferro cement meshes as external strengthening or repairing have a significant effect on crack pattern of the reinforced concrete beams by delaying the crack appearance and reducing the crack width, also causing in large deflection at the ultimate load.

Piero Colajanni, Maurizio Papia, Nino Spinella And Antonino Recupero (2014)[13] have done an experimental investigation on RC beams retrofitted in flexure and shear by pre tensioned steel ribbons, by three and four point bending test. As per this investigation the stainless steel pre stressed ribbon play role of adjunctive transversal reinforcement as well as it confine the structural element. In the present six beams of flexural deficiency and nine beams of shear deficiency were casted and tested. In the first group four beams were retrofitted with bottom stainless steel angles and transversal ribbons, with two different spacing, while in the second group three specimens were retrofitted by wrapping the beam with ribbons, and other three specimens were strengthened by perforation of the beam beneath the slab height, and by partially wrapping the beam by inserting the ribbons through the hole, and concluded that the test results obtained are prove effectiveness of the retrofitting system for both flexure and shear deficiency beams.

Sridhar, Malathy, and Sangeetha(2014)[14] had Investigated on flexural behavior of reinforced concrete (RC) beams were strengthened with Ferro cement laminates by steel slag as a partial replacement material for fine aggregate. Selected parameters varied includes volume fraction of mesh reinforcement 1.88% and 2.35%, (0% and 30%) replaced slag to fine aggregate in Ferro cement laminates. For this five beams of size 1220mm×100mm×150mm and four beams of Ferro cement laminates of size 1220mm×100mm×25mm were casted and strengthened with Ferro cement laminates using epoxy resin as bonding agent. One control specimen and four strengthened beams were subjected to flexural test under two point loading. The parameters that should be noted on first crack load, ultimate load & mid span defection. By the results here concluded that the beams strengthened with Ferro cement having a volume fraction of 2.35% and 30% replacement of steel slag increases the load carrying capacity under flexural load.

Balamuralikrishnan et. al. (2013)[15] from this research says about the Retrofitting of Externally Bonded Thin Cement Composites. This paper presents the results of experimental and analytical studies concerning the flexural strengthening of RC beams using externally bonded High Performance Fiber Reinforced Cementitious Composites (HPFRCCS) like Slurry Infiltrated Fiber Concrete (SIFCON) and Slurry Infiltrated Mat Concrete (SIMCON). Eight beams were strengthened with bonded SIFCON and SIMCON laminates at the bottom under virgin condition and tested until failure. Static responses of all the beams were evaluated in terms of strength, stiffness, ductility ratio, energy absorption capacity factor, compositeness between laminate and concrete, and the associated failure modes. Comparison was made between experimental results of SIFCON and SIMCON. The results show that the strengthened beams exhibit increased flexural strength, enhanced flexural stiffness, and composite action until failure. SIFCON and SIMCON laminates properly bonded to the tension face of RC beams can enhance the flexural strength substantially.

Khair Al-Deen Bsisu ,Yasser Hunaiti , and Raja Younes (2012)[16] have examined on Flexural Ductility Behavior of Strengthened Reinforced Concrete Beams Using Steel and CFRP Plates is done by mostly used other retrofitting materials are; high strength galvanized steel plates (HSGS plates) and normal strength steel plates (NSS plates). And study the behavior of retrofitted beams with each of these three materials. A total number of ten beams of fy= 420 MPa, *fck*= 25 MPa. Cross sectional dimension 200mm, 250 mm and a span of 1500 mm are caste. And used reinforced with 3#12 bars (A_s = 339 mm²) with an effective depth of 220 mm. The beams were adequately reinforced for shear using #10 stirrups placed at 150 mm spacing. These beams were tested using a 1000 kN test frame (TONI-MFL) under flexural. In the casted beams one is **Control Beam,** and remaining all beams are retrofitted with **CFRP Plates**, **HSGS Plates** , **NSS Plates.** The experimental results are observed as of this study (HSGS plates) can be used to increase the strength of reinforced concrete. CFRP plates ductility of beams retrofitted with these plates is low. HSGS plates have ductility value is higher. Modulus of elasticity of NSS plates little higher ductility than the un-retrofitted.

Kothandaraman, and Vasudevan(2010)[17] have studied flexural retrofitting of RC beams using external bars at soffit level. An experimental study the authors proposed the external bars to be kept at the soffit level of the beam section, thus eliminating the use of deflectors, mechanical anchoring devices and making it amenable, simple and effective. Additional advantages of the present technique are the enhanced moment carrying capacity, reduced deflection and crack width and improved ductility. Existing retrofitting technique such as section enlargement, bonded steel plating, external post-tensioning strengthening with FRP composite sheets have innate demerits such as high coast, need of sophisticated instruments, increase sectional area, surface preparation. Occurrence of de-bonding failures, low benefit-cost ratio high maintenance, etc., The proposed technique of keeping reinforcement externally at soffit level has many advantages, such as simple and speedy execution, minimal disruption during installation; involve less in the self weight and no appreciable reduction in headroom.

Appa Rao & Vijayanand (2007) [18] have examined about the Studies on Ductility of RC Beams in Flexure and Size Effect. For this Beams of depth 100mm, 200mm, 400mm at different flexural reinforcements namely 0.15, 0.30, 0.60 are taken. And 1.0 % tested under uniform bending moment. i.e., the yield Four-point bending set-up was used for testing of RC beams. The beams were made of 30 MPa concrete. Used steel reinforcement fy 415 N/mm2. The diameter of the bars varied from 3 to 12mm depending on the size of beam. Used 10mm aggregates for small beams of size 50mm × 100mm ×500mm and 100mm×200mm × 1000mm, while 20mm aggregate used in large beams of size 200mm × 400mm × 2000mm. The ratio of reinforcement cover-to-depth was 0.05 in all the beams. The concrete mix proportions were 1: 2.75: 5.1. The cement content was 250 kg/m3 and the water cement ratio was 0.75. The compressive strength of concrete at 28 days on 100mm size cubes was 30 N/mm2. As well as the split tensile strength of 150mm×300mm cylinders was 2.62 N/mm2. The steel reinforcement consisted of 3mm, 6mm, 10mm, and 12mm diameter bars as flexural reinforcement. The LVDT was used to measure the deflection at the center of beams. Where the measured parameters are Load-deflections curves, Flexural strength, Ductility factor Ductility number. From this experimental studies the following conclusions are driven the ultimate strength is inversely proportional to the beam depth. As the percentage flexural reinforcement increases, the ultimate load and the corresponding the beam deflections increase. As the depth of beam increases the ductility factor decreases. The ductility number of RC beams increases with increasing beam depth and with decreasing percentage reinforcement. The optimum ductility number is 0.20 in 30 MPa concrete. The minimum percentage reinforcement is inversely proportional to beam depth. It indicates that the formula for minimum steel reinforcement provided by the codes needs to be modified.

Wael Almajed, **and Robert Xiao**, **(2006) [19]** have conducted an Experimental study of Retrofitted Flexural Reinforced Concrete Beams in Tension and Compression Areas with Fibres. Research is based on damaged reinforced concrete beams retrofitted with various type of fibrous concrete, on the basis of experiment study to observe the parameters like ultimate loads, load-deflection curves and cracking and crushing patterns. These results have been compared with the controlled plain reinforced beams. For this eighteen reinforced concrete beams were cast. In those twelve beams selected for retrofitting at the tension and compression sections, while other beams were selected for controlled plain reinforced beams and damaged beams. Beams were divided into five categories and each category was divided into two zones of retrofitting, and each zone of retrofitting has two beams. Category 1 consist of two controlled plain reinforced beams, while category 2 consist of four damaged beams; two beams from this category to simulate the damage of concrete at the compression area at the top of beams between the two point loads and the other two beams simulate the damage of concrete at the tension zone at the bottom of the beams. Categories 3, 4 and 5 are the retrofitted beams at the tension and compression zones with polypropylene, steel and hybrid fibrous concrete. All mixes, plain and fibrous concrete, were designed for compressive strength of *fck* = 40N/mm2 at 28 days. Coarse aggregate was crushed limestone, maximum size of 10mm, and fine aggregate was uncrushed sea sand. The water cement ratio was 0.51. Concrete cubes of 150×150×150 mm were taken for the compressive strength test and concrete cylinders of 150×300 mm were taken for the splitting tensile strength test for all mixes. Beams of 500×100×100 mm were taken for the modulus of rupture test for fibrous concrete only. All specimens were tested at the 28th day after casting. The fibre volumes used in the concrete mixes are; 0.6% for steel fibres, 0.8% for polypropylene fibres and hybrid fibres with volumes of 0.2% and 0.4% for steel and polypropylene respectively. Eighteen beams (1000×150×120 mm) were designed to fail in bending under the applied loads. Beams were cast and tested up to failure under four points loading to study the behaviour of retrofitted beams with polypropylene, steel and hybrid fibrous concrete. The observed results of Ultimate load Compared to plain reinforced beams, an increase in the ultimate applied load up to 6.11%. All beams retrofitted with fibrous concrete on bottom exhibit an increase of the ultimate load of 3.97%, 4.99% and 6.11% for steel, polypropylene and hybrid fibrous concrete respectively. Beams, which were retrofitted with fibrous concrete on top, experienced a dropping in ultimate load of 5.94% when using steel fibres concrete due to shear failure, while an increase of 3.05% and 5.44% was obtained for using polypropylene and hybrid fibres on top respectively. The observed results of Ultimate load Compared to plain reinforced beams, Deflection behaviour that all beams retrofitted with fibrous concrete on top behaved in a ductile manner. Beams retrofitted with steel and polypropylene fibrous concrete at the top deflect relatively less, curves were ascending conventionally up to the elastic point, and subsequently curves were descending to a certain point, then ascending again and gaining more loads.

Hussain et. al. (1995)[20] had researched on repaired pre-loaded beams by bonding steel plates of varying thickness to the tension face. Eight test beams 150 × 150 × 1250 mm were discussed. The steel reinforcing plates were 1100 mm long, 100 mm wide, and varied in thickness from 1 to 3 mm. The yield stress of the steel plate was 269Mpa. Strain gages were mounted to the main reinforcement, the concrete upper surface at mid-span, and to the plate at 50 mm intervals to monitor distribution along the plate. Deflection was monitored at mid-span of the beam and at the load points. The beams were supported over a span of 1200 mm with loading applied at third points. The beams were all preloaded to 85% of their ultimate load capacity, equivalent to a centerline deflection of 10 mm. They were then unloaded allowing the different reinforcing methods to be applied. The repaired members were then reloaded to failure. The deflection rate during loading, unloading, and reloading was 1 mm per min. The method of strengthening the beams included epoxy-bonding steel plates of different thickness to the bottom of the beam. For each reinforcing scheme, two identical beams were made with one of the beams having anchor bolts installed at the end of the plate arrangement. Preparation for application of the epoxy was extensive including sandblasting the beam soffits and then washing them to remove dust. Also, the steel plates were sandblasted to remove the oxide layer and roughen the surface. Experimental results showed that as the reinforcing plate thickens, the failures became brittle (shear-type). This implies that the beams did not have adequate shear strength prior to application of external reinforcement. The inclusion of end anchorage increased the ductility of the beams with the thicker plates, but the percentage increase in ductility decreased as the plates got thicker. The prediction of ultimate load strength for the beams with thin plates (1 mm, 1.5 mm) was successful. The beams with thicker plates (2 mm, 3 mm) failed prematurely due to plate separation, never reaching ultimate capacity. The addition of anchor bolts did not have any effect in improving ultimate load capacity, with these Beams also failing prematurely.

Q. Research Needs

The previous background information shows that there is promise with externally provided reinforcement bars as a RC upgrading method; however, further research is required. Although some data and field applications were reported, the very limited depth of validation is acknowledged in the literature (Sankaramouli, Markandeya Raju and Purushottam, 2017). More promising research results are vital to expanding the introduction of this method in the civil engineering industry. This is especially the case when noting the location of research completed thus far. The majority of research has been completed in this studies Doredla Nagaraju (2017), Pmeikandaan, Ramachandra Murthy (2017); Praveenkumar, Chiranjeevi et. al. (2017); Poorna Prasad Rao, Ramamohan Rao (2016); ohamed Asick Umar, and Manikandan (2016); Abhishek Sharma1, Tara Sen, Joyanta Pal (2016); Ismail M.I Qeshta, Payam Shafigh, and Mohd Zamin Jumal (2015); Ayyubi, and Sharbatdar (2015); Chandran et. al. (2015); Maheboob et. al. (2015); Ragheed Fatehi Makki (2014); Piero Colajanni, Maurizio Papia, Nino Spinella And Antonino Recupero (2014); Sridhar, Malathy, and Sangeetha (2014); Balamuralikrishnan et. al. (2013); Khair Al-Deen Bsisu ,Yasser Hunaiti , and Raja Younes (2012); Kothandaraman, and Vasudevan (2010); Appa Rao & Vijayanand (2007*);* Wael Almajed, and Robert Xiao, (2006); Hussain, M. Sharif, Alfarabi; et. al. (1995); Sharif, Alfarabi; Al-sulaimani, et. al. (1994); Chajes, Michael J; Thomson, et. al. (1994); Thus far, to the best of the knowledge, there are some of reported experimental results of flexural strengthening. This shows a need for local results completed using Indian construction methods and materials. These documents are instrumental to the acceptance of a new material and lead to the use by the local engineering industry. Further, all flexural tests completed used small or medium scale beams; therefore, there is a need for larger scale specimen in the research repertoire.

IV. CONCLUDING REMARKS

The studies performed on the various retrofitting methods. The discussed on flexure retrofitted RC beams using traditional method like stitching are limited. Further it is required to study the effect of stitch depth on flexure carrying capacity of flexure deficient beams by retrofitting with stitching.

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