# Retrofitting of Concrete Structure with Fiber Reinforced Polymer

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Retrofitting is the modification of existing structures to improve the performance and durability of the structure. Day to day concrete structure to need retrofitting due to various factors like corrosion, lace of detailing, and failure of bonding etc. In retrofitting, fiber reinforced polymers (FRP) is relatively new technique to strengthen and repair damage of the structures. In this paper, the application of FRP in concrete structures is being investigated for its effectiveness in enhancing structural performance both in terms of strength and ductility. The structural components tested so far include slabs, beams, columns and bridge culverts. So far indicate that retrofitting with FRP offers an attractive alternative to the traditional techniques. In many circumstances, it can provide the most economical (and superior) solution for a structural rehabilitation problem. The manufacturing process of FRP and the field application of FRP is very easy and selected results from experimental and analytical. Seismic retrofit with FRP materials has gained notable acceptance from the civil engineering community in recent years.
**Keywords: Retrofitting Of Concrete, CFRP, GFRP, BFRP, Seismic Retrofitting, Retrofitting Of Beam, Column**

## I. Introduction

Fiber-reinforced polymers (FRP) as a composite material which was first presented in 1940s. Although in 1950s composite materials have been used in architectural applications, such as, in construction industry, particularly concrete application. Various use of FRP reinforcing products was invented in Europe and Asia in 1970s & 1980s [38]. Concrete is relatively very strong in compression but poor in tension; it has little resistance to cracking and tends to brittle. The weakness in tension can be exceeded by man Performance Improvement of Concrete Structures using Natural Fiber Composites. Fiber reinforced polymers (FRP) composite has been established in the structural field as a additional gift for renovating and increasing the strength of RCC structures. Retrofitting is the art of modification of present structures to make them more unaffected, more cost-effective and technically superior alternative to the traditional techniques in many situations. Fiber Reinforced polymer (FRP) composite materials has industrialized because it is economically and structurally workable construction materials for load bearing elements in building and bridges over the last two decades. The use of FRP composites in civil infrastructures can expand innovation, increase productivity, enhance performance and provide extensive service lives [2]. Fiber reinforced polymer (FRP) is a composite material made of a reinforced with fibers and polymer matrix. The fibers are commonly used carbon, aramid, glass although other fibers such as wood or paper have been used sometimes. Fiber reinforced polymers are commonly used in the aerospace, automotive, marine and construction industries. Fiber reinforced polymers are a group of composite plastic that specifically use the fiber materials to mechanically enhance the strength and elasticity of plastics. The novel plastic material without fiber reinforcement is identified as the matrix. The matrix is tough but relatively reinforced by stronger, stiffer reinforcing filaments or fibers. The components preserve their original form and contribute its own unique property that effect in a new composite material which enhanced overall performance and improves their strength and stiffness [1]. Some of the structures are damaged by environmental effects which include corrosion of steel, freeze thaw cycles, variations in temperature and exposure to ultra-violet radiation. Many polymers are also disposed to deprivation caused by weathering in photo- chemical reactions; including ultraviolet solar photons and atmospheric oxygen [4]. The conservation, preserving and restoration of historical structures belonging to the cultural heritage, strengthening their main structural members have become a very important issue in Asia. Therefore, the structures need renovation to survive their life as a result, aging and increasing load demand. Many historical structures have been restored in order to resist these effects [20].Now a day's Repair and retrofitting of existing structures has become a major part in construction industry at many cities. This innovative way of thinking in architecture field, need a change in building methods and consequently the materials that are used in designs and buildings. For these reasons, construction is introducing a new family of materials that are generated in response to the final product needs. "FRP composites" can be included in this range of new materials [5] and Traditional retrofitting methods that use steel and cementations material does not always offer the most appropriate solutions. Retrofitting with fiber reinforced polymers (FRP) may provide more economical and technically superior alternative to the traditional procedures in many situations. The FRPs is more durable, lighter in weight and also higher strength-to-weight ratios than traditional reinforcing materials such as steel and which can result in less labor-intensive and less equipment-intensive retrofitting work [57]. The problems associated with using of steel fibers as a retrofit method have led to invent new rehabilitation and strengthening techniques. Among these techniques fiber-reinforced polymer (FRP) composites as retrofit materials has gained much notable success in recent year [58]. This paper have been focused on the recent improvements in retrofitting of RC columns, beams, beam-column joints, slabs, masonry walls and steel structures using various FRP retrofitting schemes, with a view to improve the seismic performance of the depreciated structure. The main objective is to present a representative overview of the current state of using FRP composite materials as a retrofit technique as well as evaluations of seismic retrofit method, field of strengthening and repair of steel structures using fiber reinforced polymers (FRP)[60]. Composite materials have a great potential of application in structures, which subjected to compressive loads, compressive strength and good adaptability in fabricating thick composite shells, low weight and corrosion resistance [4].

## II. Retrofitting of Concrete Structure

In very early 20th century some buildings and bridges that have been build are in deprived state and therefore those structure need to be exchanged or retrofitted. In retrofitting, the structure must be designed for both safety and durable, with responsiveness given to the case of retrofitting construction and post-retrofitting maintenance, as well as overall economy and environment-friendliness. Retrofitting is required for those structures which is not being fitted with the newest criteria of earthquake engineering or have experienced significant damages due to earthquakes. In times of economical limitations and decreasing state budget, replacing old infrastructures is too costly. Over past few years, the enlargement of innovative techniques to strengthen structures allows for low retrofitting cost of those infrastructures. One of the most effective ways to increase the structural performance of these buildings is to use fiber reinforced polymers (FRP). Masonry is a composite material prepared of brick units and mortar that has been used for centuries in building construction. It has an extensive use in seismic-prone areas, especially in the form of infill panels within reinforced concrete (RC) or steel frames [21]. Retrofitting of existing foundations implies changing the structural characteristics of the existing foundations and improving the fundamental soil condition [24]. By proof of identity the most significant factors related to seismic rehabilitation of structures, the important parameters involved in the technique selection of the retrofitting process are introduced and categorized by using the concept of value management, new scheme evaluate for relative advantage of each proposed retrofitting design [25]. The study will be implemented for RC slabs, column, beams, walls etc and sometimes retrofitting is also used in wall thicknesses and the walls will be exposed to different exterior and interior climatic conditions for insulation and energy saving[22].The directives aimed to accelerate the transformation of existing buildings towards net zero energy/emissions buildings [23],Sometimes they need to be retrofitted to have better behavior under earthquakes, Ventilation, heat recovery, low-temperature heating in Retrofitting, energy conservation, environmental impacts and indoor air quality.

## III. Natural Fiber Reinforced Polymers

The natural fiber-reinforced polymer composite is rapidly developing in both terms of their industrial applications, fundamental research and completely or partially recyclable and biodegradable [9]. In medical world and bio engineering application, the study touches on various aspect of FRP such as its biocompatibility advantages and as well as critical analysis in informative way [10]. Coir, jute, bagasse, cotton, bamboo, hemp are used as a Natural fibers which come from plants. These fibers are eco-friendly; lightweight, strong, renewable, cheap and biodegradable. The natural fibers can be used to reinforce both thermosetting and thermoplastic matrices. Thermosetting resins such as epoxy, polyester, polyurethane, phenolic are commonly used to make composites for higher performance applications [9]. Fibers like sisal, coconut and bamboo jute, coir and many others in their natural form as well as several have been used as reinforcing agents of different thermosetting and thermoplastic composite. Recently natural fibers have become attractive area for researchers, engineers and scientists as an alternative reinforcement for fiber reinforced polymer (FRP) composites due to their low cost, fairly good mechanical properties, high specific strength, non-abrasive and eco-friendliness. The various advantages of natural fibers are low density, low cost, low energy inputs and comparable mechanical properties and also better elasticity of polymer composites reinforced with natural fibers [2,7,6] This paper investigated with fiber reinforced polymer (FRP) composites where high strength reinforcing fibers are combined with a polymer (plastic) matrix.

## IV. Fiber Reinforced Polymer (FRP)

Fiber reinforced polymers is a composite material which is made of two entities: a matrix, which is usually made of resin such as epoxy, and fibers. The fibers are essential which will give its mechanical properties to the material [7]. There can be a mix of different types of fibers used such as Glass, Carbon or Aramid, (Kevlar) and the matrix which is basically a resin made of polyester, epoxy. Carbon Fiber Reinforced Polymer (CFRP) is a composite Polymer matrix reinforced with carbon fibers, which are very strong and light. Carbon, aramid and glass fibers are strong; they have strengths as fibers of the order of 3000 Mpa [68]. These strengths are higher even in prestressing steels and there is no doubt that they are attractive to structural engineers. The stiffness's of fibers are so high enough as they are stiff as aluminum and steel. A fiber does not rust, at least in the same way as steel [1]. In particular, they are resistant to attack by chlorides, which are the important advantages of fibers. Some other advantages of fibers are durable and light weight. All these materials creep, but studies have shown that the amount of creep is negligible for reinforced concrete and gives losses of force for prestressed concrete that is similar to the structures with steel tendons [3]. Fibers are capable of forming round tubes, rectangular tubes, plates, rods or any other linear sections [34].

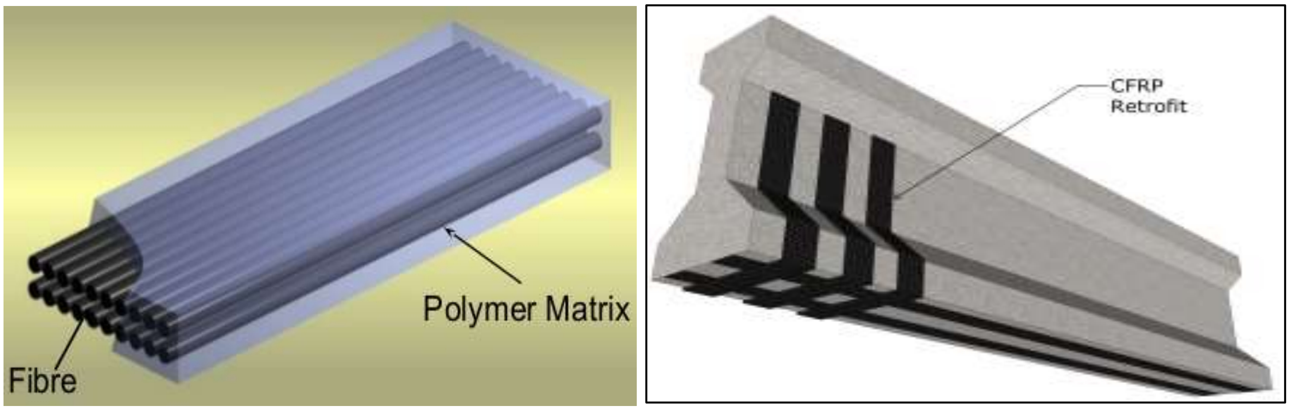


Fig. 1: Fiber Reinforced Polymer (FRP)

## V. THE DIFFERENT TYPES OF FIBERS

### *A. Carbon Fibers*

Fiber reinforced composites are reviewed to replace metallic components in many industries for past several years. Because, compared to conventional metals component fiber reinforced composites have low density, higher corrosion resistance, high specific strength and stiffness, and improved fatigue performance. Performance of fiber reinforced composite under different loading condition; such as axial, torsion and impact loading is very essential for the design of structural components. Mechanical properties of fiber reinforced polymer composites depend on the fiber, matrix and the interface between them [11]. Among all fiber reinforced composites, carbon fiber reinforced polymers are developing because of remarkable properties of carbon fibers and polymer matrix combination. Carbon Fiber Reinforced Polymers are most commonly used in industrial masonry structure for the retrofitting of old structures that already damaged due to earthquakes, chemical reaction, environment effect etc. Carbon fiber reinforced polymers (CFRPs) are one the stiffest and lightest composite materials, they are much substantial than other conventional materials in many fields of applications. In CFRP the reinforcement material is carbon fiber that provides the strength and stiffness and for matrix commonly used polymer resin like epoxy, which binds the reinforcement in organized way. Thus, the CFRP is a combination of extremely thin carbon fibers of 5-10μm in diameter, embedded in polyester resin [13]. At present CFRP is being used for structural repair for damage structure due to aging and extreme condition. Norazman et al investigated the purpose of using CFRP is to improve the tensile strength of reinforced concrete, replacing steel, totally and he concluded that the main advantage of using CFRP as reinforcement is to avoid rusting and corrosion of reinforcement [14]. The use of (CFRP) composite reinforcement provides a prospective solution like Column wrapping with CFRP composites, is a popular alternative for improving the seismic resistance of columns. Fiber fabrics and prefabricated FRP composite jackets or tubes cover the entire area of the concrete element to increase strength and stiffness as shown in fig [12]. For development of aircraft fuselage, automobile chassis, wind turbines (CFRP) materials have become increasingly popular in industry applications. It can be largely endorsed to the superior properties of CFRP, such as high strength-to-weight ratio, corrosion resistance and improved fatigue performance [15].

### *B. Glass Fibers*

Glass Fiber Reinforced Polymer (GFRP) is a fiber reinforced polymer made up of a plastic matrix reinforced by fine fibers of glass. Fiber glass is a lightweight, strong, and tough material used in different industries due to their excellent properties. Although strength properties are lower than carbon fiber and it is less stiff, but material is typically far less brittle and raw materials are much less expensive [6]. Today, (GFRP) bars are becoming more attractive to the construction industry because cost is less than other types of FRP materials. Additionally, the cost of GFRP bars has dropped in recent years, mostly due to a larger market and greater competition. GFRP bars have been used magnificently as a main reinforcement in concrete bridges, parking garages, tunnels, and water tanks [18]. FRP can be realistic to strengthen the beams, columns, and slabs of buildings and bridges, Two techniques are typically adopted for the strengthening of beams, relating to the strength enhancement anticipated and those are flexural strengthening & shear strengthening. In many cases it may be required to provide both strength enhancements. For the flexural strengthening of a beam, FRP sheets or plates are applied to the tension face of the member. Glass fibers have been commonly used for **50** years in the aeronautical industry given their very high strength to weight ratio. They also commonly find applications for wind turbines blades or in the field of naval engineering.

### *C. The Matrix*

Fiber reinforced polymer (FRP) composites are progressively more used in civil substructure for various applications ranging from reinforcing rods to tendons. Sometimes FRP is using for seismic retrofitting for columns and reinforcement for strengthening of walls, beams and slabs, to all-composite bridge decks, and even mixture (FRP composites in combinations with conventional materials) and all composite structural systems[2]. Ashik et al concluded that the usage of available natural fiber as reinforcement in polymer composites was reviewed from the expectations of natural fibers & position for fabrication and characterization [6]. In this matrix composite fibers play the major role of reinforcement bars (rebar) in concrete, they actually increase the strength of the material in which they are surrounded with resin is called the matrix. This matrix can be prepared of thermoplastics (material that melt when heated) or thermosets (material that cannot become liquid again). The matrix is commonly made of polyester, vinyl ester or epoxy in the case of aeronautical and structural applications. Fiber reinforced polymer (FRP) composites consist of carbon (c), glass (g) or aramid (a) fibers bonded together in a matrix of epoxy, vinyl ester or polyester. The fibers are the basic load carrying component in FRP whereas the matrix material transfers shear. FRP products commonly used for structural rehabilitation can take the form of strips, sheets and laminates [58].

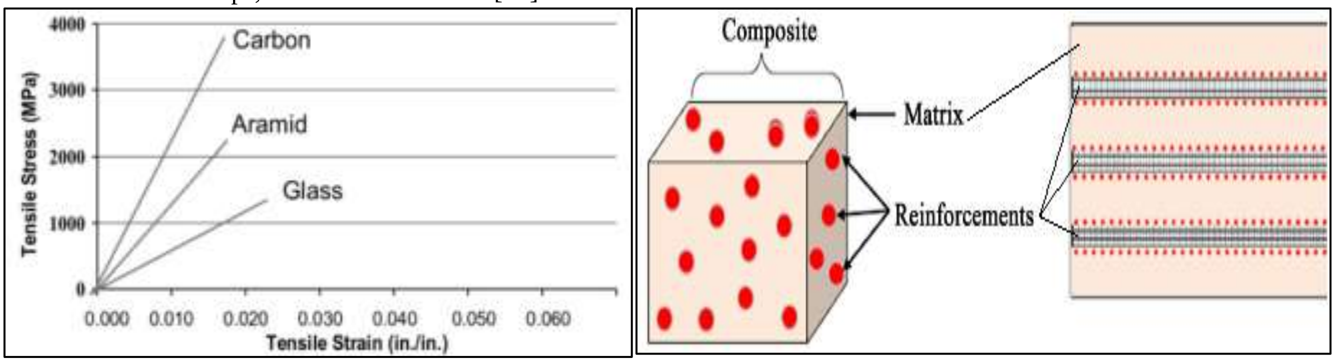


Fig. 2: The Matrix

### *D. Fibers in the Matrix*

The main purpose of the matrix is to transmission the stress between the different layers of fibers and to protect them from destructive environment. They act as a screen from the exterior layer of concrete and another important property of this material is that it behaves as a linear elastic material until failure as can be seen on the figure below for different types of fibers. In FRP there is no such plastic zone for steel or concrete and this is very important issue as respects to failure of this material which is very brittle. It raises safety matters. However given the rising demand for this type of innovative material the earliest FRP materials used glass fibers embedded in polymeric resins that were made available by the petrochemical industry because glass fiber is the combination of high-strength, high-stiffness structural fibers with low-cost, lightweight, environmentally resistant polymers [68].The CFRP was formed from unidirectional carbon fiber tow sheets and epoxy resin. The carbon fiber sheets had a nominal thickness of 0.165 mm. The GFRP was formed from a woven fabric and epoxy resin [72].

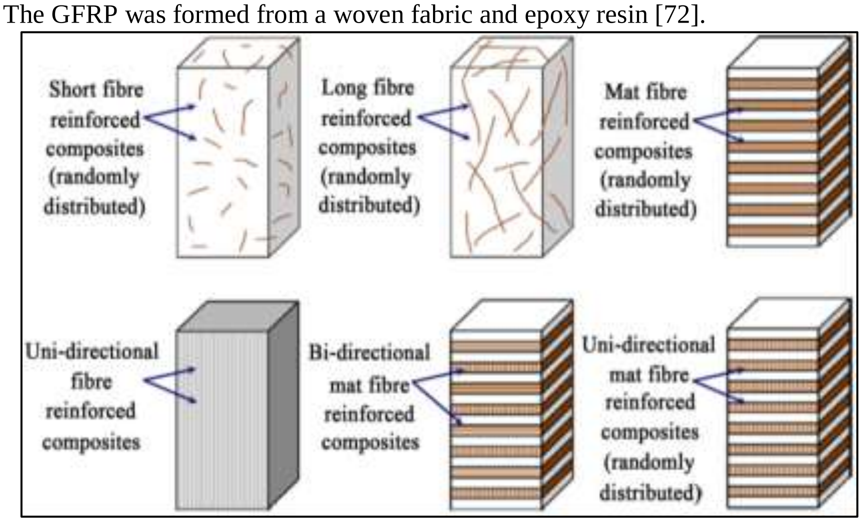


Fig. 3: Fibers in the Matrix

## VI. FIELD APPLICATION OF FRP

### *A. Seismic Retrofitting*

Seismic retrofitting is the modification of existing structures to make them more resistant in seismic activity, ground motion and soil failure. Seismic retrofitting is the failure mode which will be consider for cycle loading effect and particular stress will be made on brittle failure so that the structure is safe in case of any exciting earthquake event. We can also use two different kinds of FRP applications that can be designated as seismic retrofitting. The first case is when a structure has been spoiled by an earthquake it has to be renovated. As said before, FRP retrofitting is an alternate and economical solution. The second application is the improvement of the structure for earthquakes which might appear in the future. One of the weakness part of structure is columns. The lateral movement due to earthquakes creates an important shear stress in the columns. The shear failure will mostly occurred in the column where plastic hinges developed. Fiber reinforced polymer Composites are gradually being used in civil infrastructure from reinforcing rods to tendons, warping for seismic retrofit of columns, beams, and slabs etc [70]. In seismic retrofit of rectangular columns, by using FRP composites the technique of shape modification combined with FRP imprisonment is also attractive for the strengthening of columns subjected to static load which induce either axial compression or combined axial compression and bending in the column [66].

### B. *Retrofitting of Column by using FRP*

In recent years, the repair of un-strengthened and damaged reinforced concrete member by externally bonding of FRP laminates has established considerable attention [38]. Use of fiber reinforced polymer has increasing popularity in structural retrofitting field due to advantages such as lightweight, high strength and simplicity of application. One of the most attractive applications of FRP is wrapping existing reinforced concrete (RC) columns [39] or bridge piers to enhance their deformation capacity especially at the potential plastic hinge regions [37] and the retrofit of existing concrete columns by the provision of FRP jackets [42]. Such jackets are commonly formed in a wet layup process, with the fibers being present only or predominantly in the hoop direction [72]. Column is the most vulnerable load carrying element of structure but due to Minimum cross section size and lack of steel reinforcement in under designed columns leads to a weak column construction. It is very important to strengthen the columns so that the plastic hinges [43] are formed in the beams [58]. The role of FRP for strengthening of existing or new reinforced concrete structures is growing an extremely rapid speed of construction and the possibility of application without disturbing the existing functionality of the structure [45]. During an earthquake, three modes of RC column failures [57] that can take place due to cyclic axial [44] and lateral loads are shear failure [58]. Hybrid construction with FRP and concrete combine mass, stiffness [38], damper and low cost of concrete with the speed of construction, light weight, strength and durability of FRP [63]. CFRP & GFRP wrapping can enhance the strength of concrete columns under axial loading Compressive Strength of the Concrete Columns increases with increase in the number of layer of GFRP Confinement by GFRP enhances the performance of rectangular concrete columns [46].

### C. *Retrofitting of RC Beam by using FRP*

The use of steel and fiber reinforced polymers (FRPs) for strengthening RC beams can significantly improve the flexural strength, fatigue life and the serviceability of the beams compared to un-strengthened beams [27]. Strengthening and retrofitting activity by using synthetic fibers such as glass/carbon/aramid is becoming popular all over the world [55]. The most commonly used strengthening systems are glass or carbon fiber reinforced polymer (FRP) composite materials for low weight and their high tensile strength [29]. The shear strengthening parametric evaluation of reinforced concrete beams retrofitting using two different wrapping techniques using bio based woven jute fibers, and artificial carbon fibers and glass fibers, by full wrapping and strip wrapping techniques [74]. Glass fiber reinforced polymers sheets are being increasingly used in generally high strength-to-weight ratio, corrosion resistance and fatigue resistance [28]. The flexural strength[32] and ultimate load capacity of the beams improved due to external strengthening of beams using carbon fiber sheets is found to be more effective[62]. The reliability for this material application depends on how well they are bonded and can transfer stress from the concrete component to CFRP laminate and the strengthening system provides an economical [34] , load carrying capacity (35) and versatile solution for extending the service life of reinforced concrete structures [33].Glass fiber reinforced polymer laminates are increasingly being applied for the rehabilitation and strengthening of infrastructure in traditional repair techniques such as steel plates bonding [37]. Two primary types of fiber systems are used when the hand mixing method is used for FRP strengthening which is unidirectional tow sheets and multidirectional woven or fixed fabrics [36]. The current method used to strengthen reinforced concrete beams is to adhesively bond strips of thin composite laminates, typically these strips are attached to the soffits to increase the flexural capacity of the reinforced concrete element [65].FRP bars caused by their lower elastic modulus and lower transverse strength and stiffness than the conventional steel bars [30, 31].

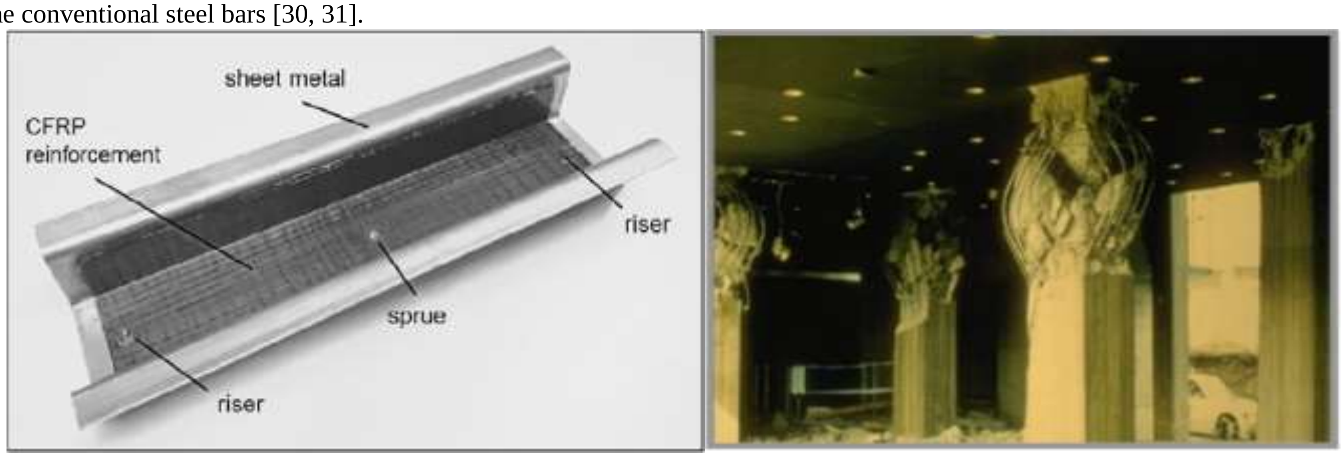


Fig. 4: Retrofitting of RC Beam by using FRP

### D. Retrofitting of RC slabs by using FRP

The rehabilitation and strengthening of structural members with composite materials has recently received great attention. Reduced material costs, coupled with labor savings inherent with its lightweight and comparatively simple installation, its high tensile strength, low relaxation, and immunity to corrosion, have made FRP an attractive alternative to traditional retrofitting techniques [50]. One of the most attractive applications of FRP materials is their use as confining devices for concrete slabs [69]. CFRP laminate shear reinforcement demonstrated a substantial increase in shear strength, ductility, and energy dissipation capacity [50]. The use of corrosion free fiber reinforced polymer (FRP) composites as reinforcement to concrete is currently being seen as a promising option to generate durable concrete structures. However, there exists very little credible information about its field application and performance [49]. Extensive applications of the fiber-reinforced polymer (FRP) materials as new construction materials have been recently accomplished. Different types of FRP materials, carbon fiber-reinforced polymers (CFRPs) and glass fiber-reinforced polymers (GFRPs) are used extensively in the structural engineering field [48]. The use of glass-fiber reinforced polymer (GFRP) bars as internal reinforcement is a possible solution to corrosion of steel bars. In addition to their noncorrosive properties, GFRP bars have higher strength than steel bars and are light and easy to handle, which makes them attractive as reinforcement for certain concrete elements, such as slabs [53]. Fiber reinforced-polymer (FRP) bars in construction industry as a replacement to steel bars provides a superior material which is capable to overcome corrosion problems larger deflections and wider crack widths in concrete [52].The ultimate load carrying capacity of GFRP reinforced slabs is increased, the corresponding deflections, strains and crack width are reduced by increasing the thickness, grade of concrete, reinforcement ratio of the slabs. GFRP reinforced concrete slabs experiences better performance under repeated loading than those slabs reinforced with steel.(51) Basalt fibers show comparable mechanical properties to glass fibers at lower cost and exhibit good resistance to chemical and high temperature exposure [54].

## VII. CONCLUSION

In this paper an understanding of the properties and performances of fiber reinforced polymers (FRP) has been developed through the study of their different applications for structural retrofitting. Design guidelines and recommendations should be made more readily available to ensure more rapid and effective applications of FRP as a seismic material. This innovative technique shows a great potential when disruption of traffic or activity of the building is not possible or only for a limited time. Indeed, applying fiber reinforced polymers (FRP) layers is very quick and does not require specialized equipment’s (crane, etc). With increasing acceptance by the industry over the past years, FRP have become commonly used in different types of structural retrofitting. The standard comparison highlights the limitations of the use of fiber reinforced polymers as most of the differences in the calculation come from security coefficient related to the adherence of the fiber reinforced plates to the concrete.

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