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Retrofitting Of The Structure Using Composite Material

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Abstract: 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 we are working on the properties of composite materials and uses in retrofitting process to improve strength and durability of the structure and studying the behavior of reinforced concrete structure strengthened (retrofitted) using composite materials. The mechanical properties of the composite materials analysis of the structure with the help of ETABS software. We will focus on comparative analysis between steel retrofitting and composites materials (FRP) retrofitting of the existing structure.

1. Introduction:

The durability and performance of a concrete structure can be improved with the help of retrofitting. The construction industry has been using traditional materials for hundreds of years to build and rehabilitate concrete structures. However, the introduction of composite materials (FRP) in civil engineering has completely reshaped the way the construction industry builds and upgrades concrete structures. When it comes to retrofitting or rehabilitation, composite materials are superior to traditional materials both in terms of ductility and strength. Failure of bonding, deteriorations, rust, and construction errors are some of the factors that make it necessary for structures to be retrofitted. 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.

2. 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

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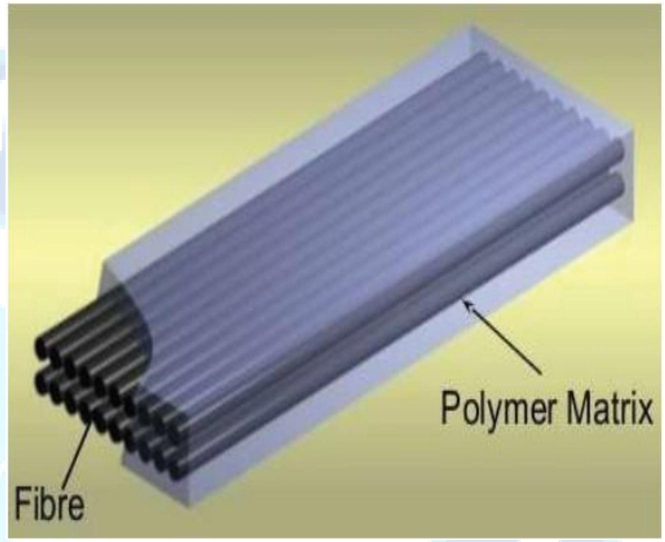
required for those structures which is not being fitted with the newest criteria of earthquake engineering or have experienced significant damages due to earthquakes. In times of economical limitations and decreasing state budget, replacing old infrastructures is too costly. Over past few years, the 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.

3. 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].



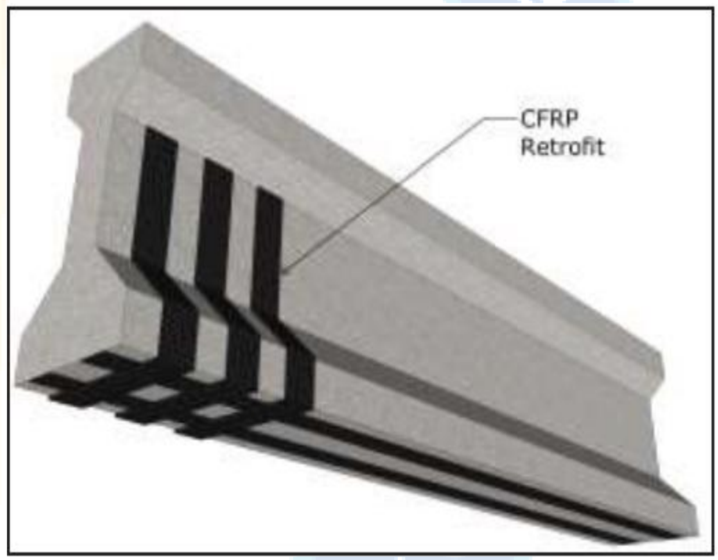


Fig. 1: Fiber Reinforced Polymer (FRP)

4. The Different Types Of Fibers

Carbon Fibers

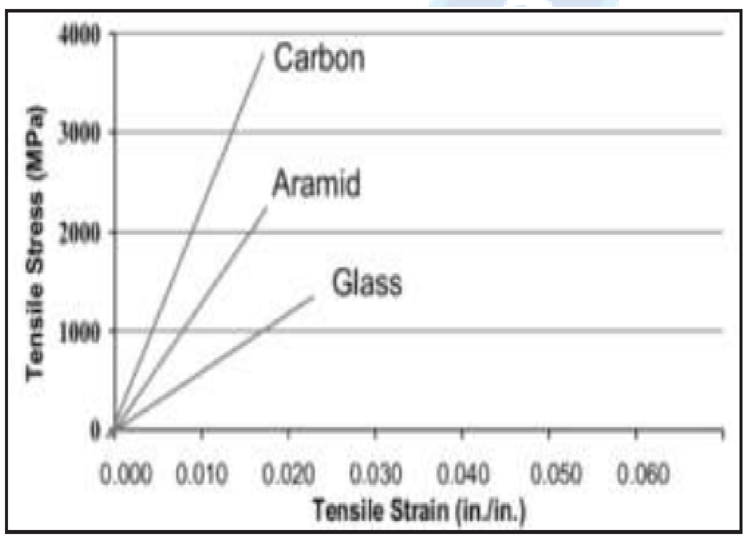
Fiber reinforced composites are reviewed to replace metallic components in many industries for past several years. Because, compared to conventional metals component fiber reinforced composites have low density, higher corrosion resistance, high specific strength and stiffness, and improved fatigue performance. 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].

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.

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.



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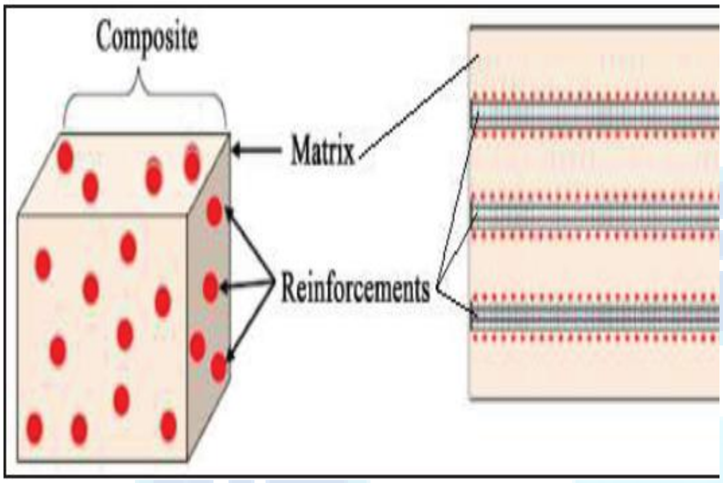

Fig. 2: The Matrix

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.

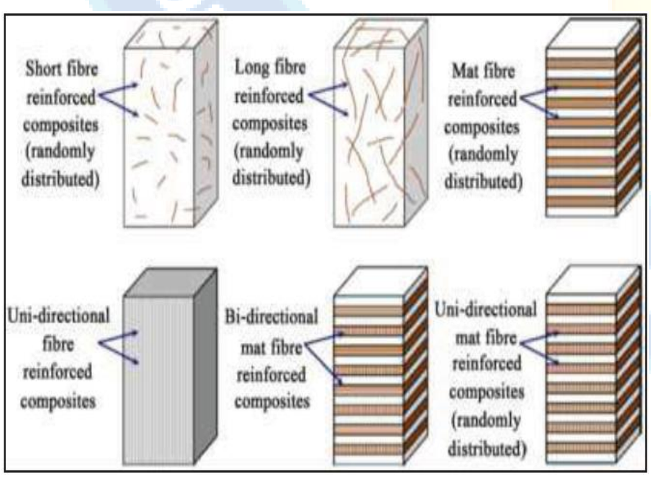

Fig. 3: Fibers in the Matrix

5. Methodology:

The different type of options available that can be used to retrofit or repair members of existing reinforced concrete structures. Following are the most commonly used options for retrofitting-

1. Steel jacketing,
2. Active confinement by wire Pre-stressing
3. Jacketing with reinforced concrete
4. Use of advanced composite material.

Steps in Reterofitting Process:

- To 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.
- To inspect the existing structure to be retrofitted.
- Based on the results of the inspection, evaluate the performance of the structure and verify that it fulfills performance requirements.
- If the structure does not fulfill performance requirements, and if continued use of the structure through retrofitting is desired, proceed with design of the retrofitting structure.
- Select an appropriate retrofitting method and establish the materials to be used, structural specifications and construction method.
- Evaluate the performance of the structure after retrofitting and verify that it will fulfill performance requirements.
- 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.

FRP jacketing of the structure [IS code - 15988 : 2013]

Dimensions of FRP jacket is determined assuming composite action between fiber and existing concrete. The rupture strength of FRP is used as its limiting strength. Limit state moment capacity of FRP retrofitted member is given by:

Ultimate flexure strength is determined based on the assumption that compressive concrete reaches a strain of 0.003 5 and FRP reaches its maximum strain.

Shear strength of a beam after strengthening:

$$V = VCON + Vs + VFRP$$

where $VCON = Tc \times b \times D$

$$Vs = 0.87 \times fy \times ASV \times (d\ SV)$$

$$VFRP = ff\ Af(d/s)$$

VCON = shear contribution of concrete;
Vs = shear contribution of steel;
and VFRP = shear contribution of FRP sheet

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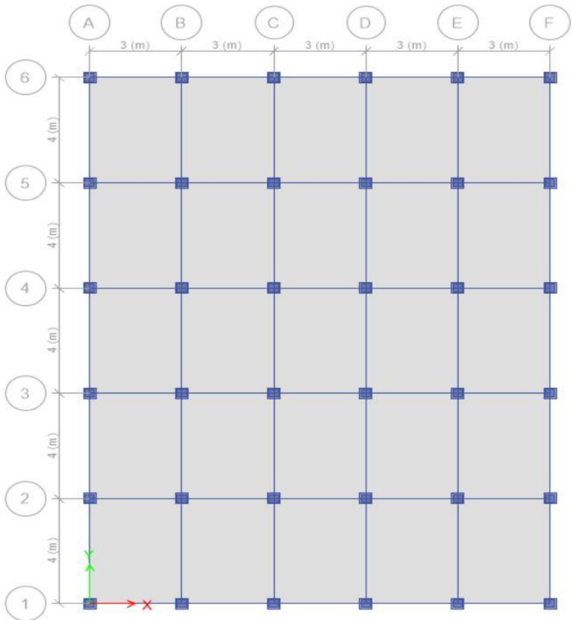

Fig 4: Plan

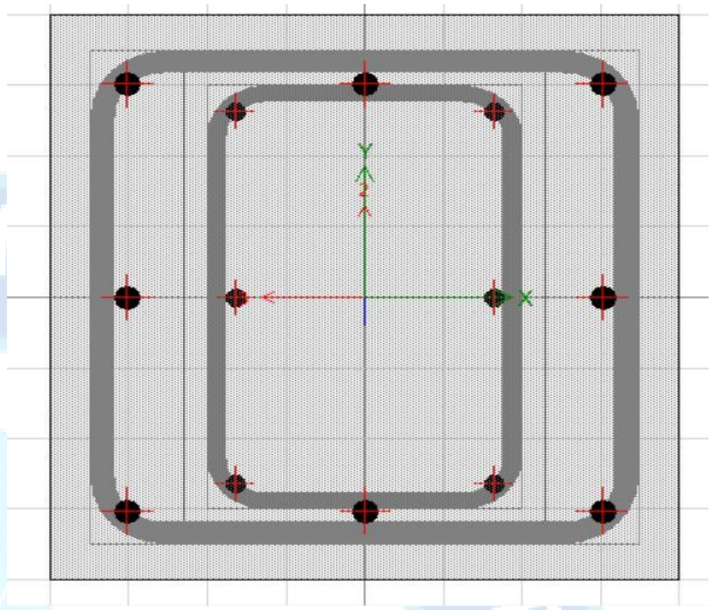

Fig 6: Beam Steel Retrofitting Size – 230 mm x 350 mm

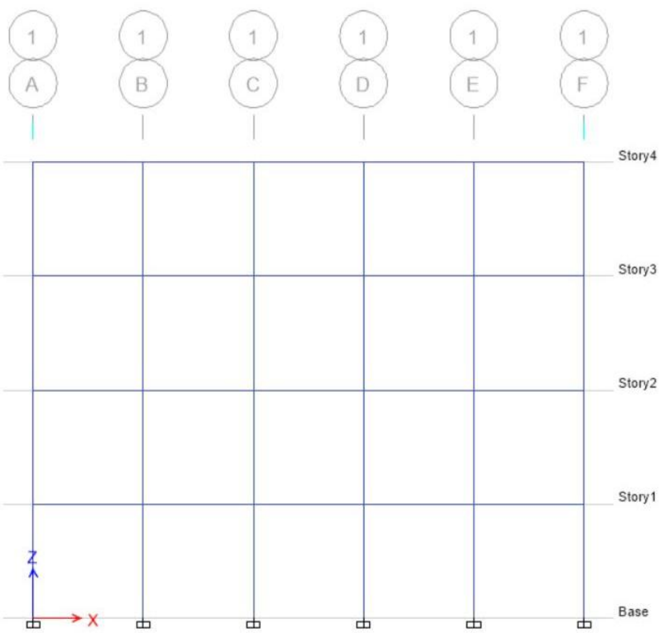

Fig 5: Elevation

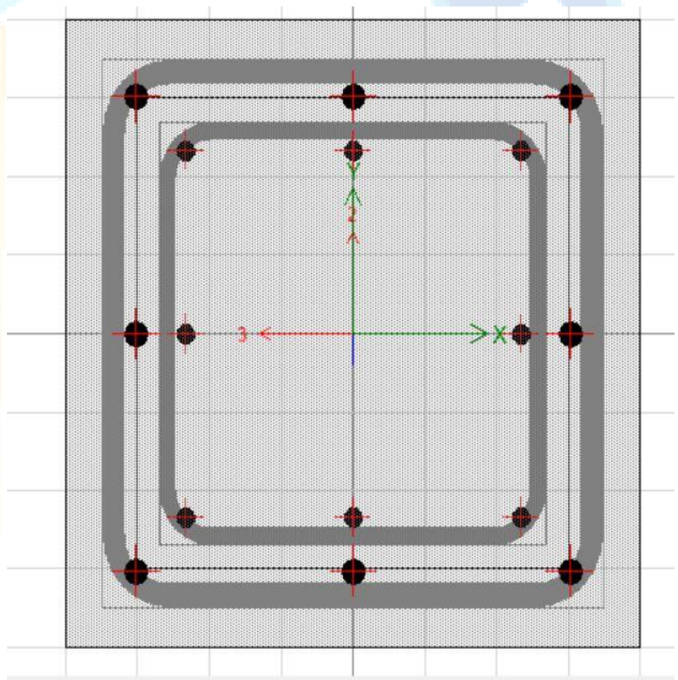

Fig 7: Column Steel Retrofitting Size – 300 mm x 300 mm

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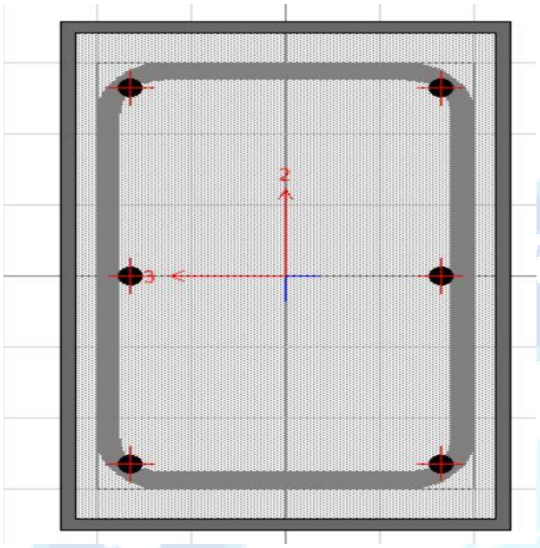


Fig 8: Beam FRP Retrofitting

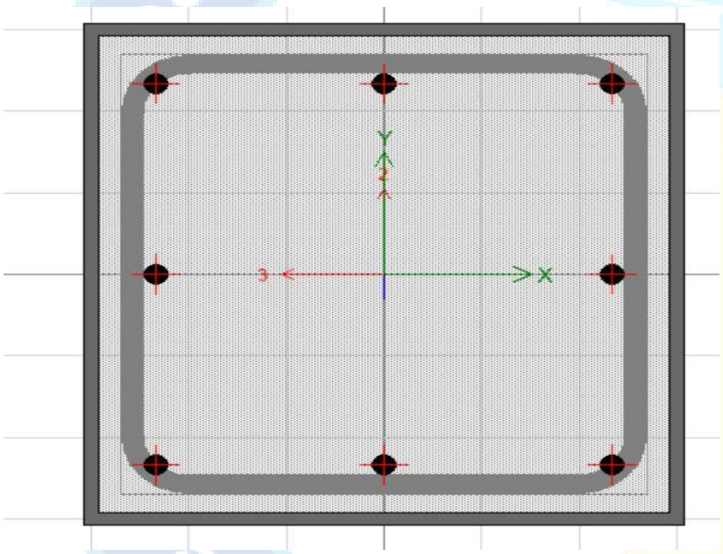


Fig 9: Column FRP Retrofitting

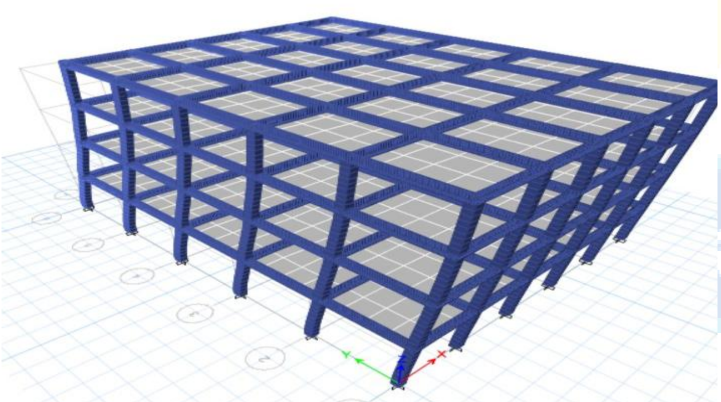


Fig 10: Deformed Model Using Response Spectrum Method

6. Analysis

Modelling and analysis of G + 3 building with normal , steel jacketing and composite material FRP retrofitting for seismic loads.

Comparison of results and graph of all models for the parameters storey displacement, storey drift, Storey stiffness, base shear and natural period.

Seismic zone considered in this project is Zone III

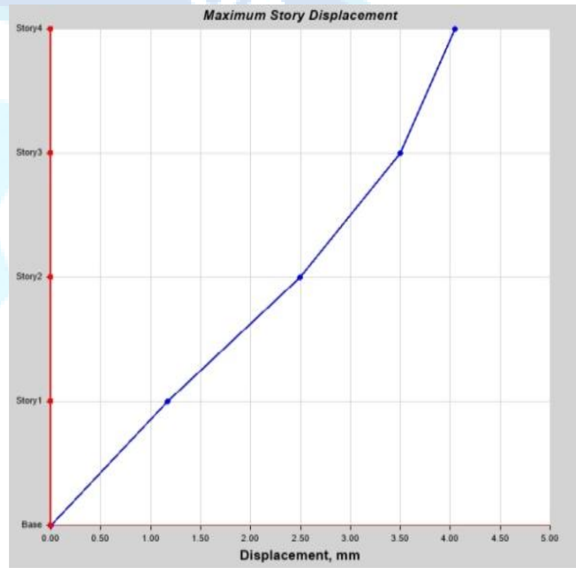


Fig 11: Story Displacement

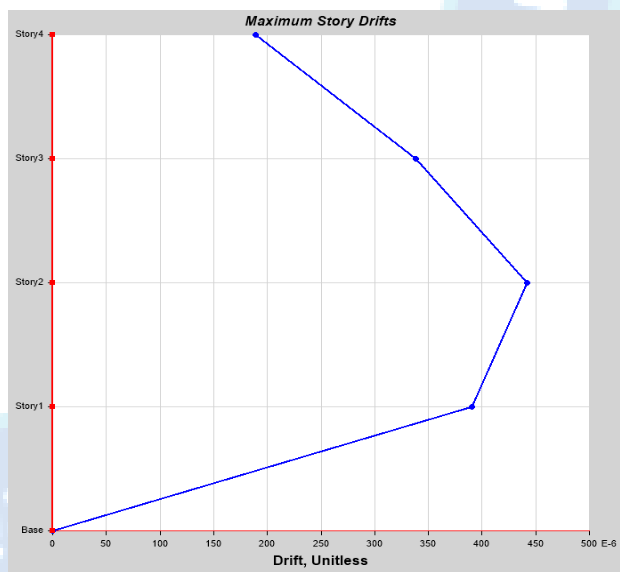


Fig 12: Maximum Story Drifts of Existing Building without retrofitting

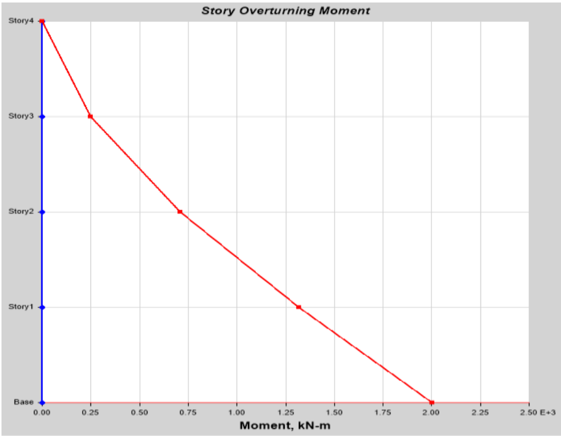


Fig 13: Story Overturning Moment of Existing Building without retrofitting

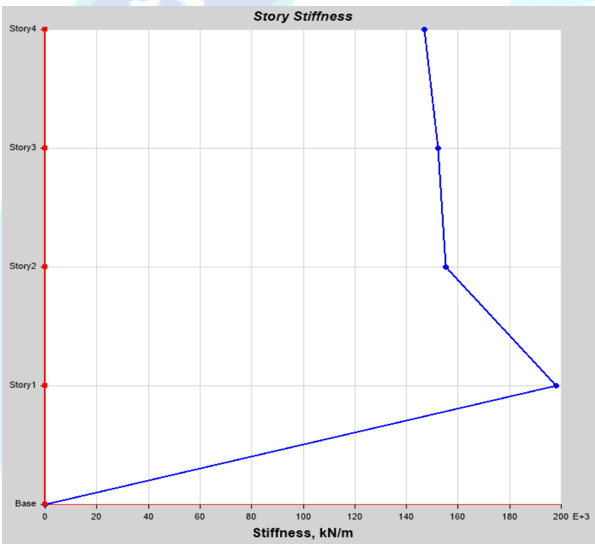


Fig 14: Story Stiffness of Existing Building without retrofitting

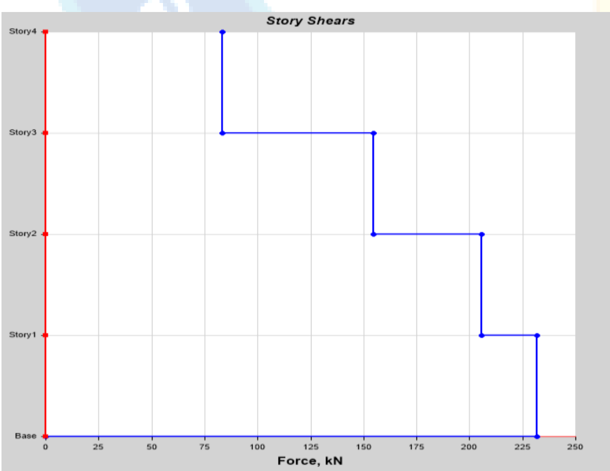
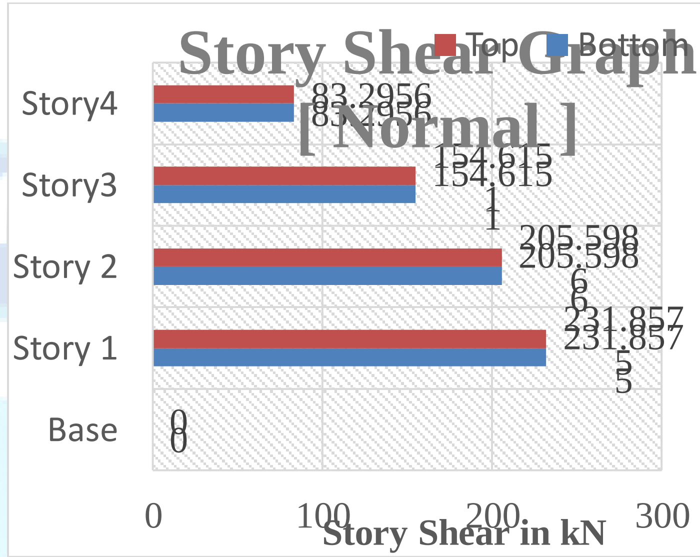


Fig 15: Story Shears of Existing Building without retrofitting



7. Conclusion:

We have considered and compared all results between steel reinforced and fiber reinforced composite material. According to comparative results, and analysis data we find out conclusion .

- The model with Fiber reinforced has very slightly greater time period as compared to the model with steel reinforced of time period . So we consider the fiber reinforced as compared with steel reinforced .
- The model of fiber reinforced polymer has least stiffness and model of steel reinforced has maximum stiffness than others , When we consider the stiffness criteria we tend to choose the model having the least stiffness so as to provide flexibility to the building model so that the building does not develop cracks in the event of an Earthquake.
- Fiber reinforced polymer composite material has slightly greater than steel reinforced on retrofitting conditions in some cases story displacements and story drifts
- Fiber reinforced polymer composite material has much greater than steel reinforcement retrofitting in some cases base shear lateral loads .

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