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# STUDY OF FLEXURAL BEHAVIOR OF RC BEAM USING CARBON FIBRE REINFORCED POLYMER LAMINATE

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## ABSTRACT

*Carbon Fiber as an external reinforcement is used extensively to deal with the strength requirements related to flexure in structural systems. In the present work, the behavior and performance of rectangular reinforced concrete Beam strengthened with externally bonded Carbon Fiber subjected to flexure is studied experimentally.*

*Rectangular RC Beam externally bonded with Carbon Fiber. The result is usually 93–95% carbon. Lower-quality fiber can be manufactured using pitch or rayon as the precursor instead of PAN. The carbon can become further enhanced, as high modulus, or high strength carbon, by heat treatment processes. Carbon heated in the range of 1500–2000 °C (carbonization) exhibits the highest tensile strength( 5,650 MPa or N/mm²), while carbon fiber heated from 2500 to 3000 °C (graphitizing) exhibits a higher modulus of elasticity ( 531 GPa or 531 kN/mm²) .*

***Keywords: Carbon Fiber , Flexural Strength , Strengthening.***

## I. INTRODUCTION

The deterioration of civil engineering infrastructures such as buildings, bridge decks, girders, offshore structures, parking structures are mainly due to ageing, poor maintenance, corrosion, exposure to harmful environments. These deteriorated structures cannot take the load for which they are designed. A large number of structures constructed in the past using the older design codes in different parts of the globe are structurally unsafe according to the new design codes and hence need up gradation.The conventional retrofitting techniques available are concrete-jacketing and steel-jacketing. The concrete-jacketing makes the existing section large and thus improves the load carrying capacity of the structure. But these techniques have several demerits such as construction of new formworks, additional weight due to enlargement of section, high installation cost etc. The steel-jacketing has proven to be an effective technique to enhance the performance of structures, but this method requires difficult welding work in the field and have potential problem of corrosion which increases the cost of maintenance.

A lot of work have been carried out world-wide to evaluate the performance of Beam strengthened using various composites. The experimental programmers in the present investigation has been carried out to study the effect of various strengthening materials such as, AF,CF on the performance RC Beam under static as well as cyclic

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loading. A significant improvement in the moment carrying capacity, energy absorption, etc. was observed for all the strengthened specimens.

**1.1 Objective & scope**

The main objectives of the present work are: .

1. To know the suitability of the FRP composites as repair materials for deteriorated RC Structures.
2. To study the deflection behavior of RC beam.
3. To study the flexural behavior of RC beams with different wrapping condition.

This work can be further extended with different parameter. Following are the some of extensions-

1. To study flexural behavior of RC beam with different fibers like Aramid ( Kevlar) and glass fiber.
2. To study the torsional behavior of joints with glass fiber.
3. Experimental study of beam using FRP Sheet like Glass fiber and armid fiber.

**1.2 Flexural Strengthening of Reinforced Concrete (RC) Beam**

Beams are strengthened in flexure through the use of FRP composites bonded to their tension zone using epoxy. The direction of fibers is parallel to that of high tensile stresses. Both prefabricated FRP strips, as well as sheets are applied. Several studies have been conducted to examine the flexural strengthening of RC members with FRP composite; however, few researchers have addressed shear strengthening.

**1.3 Shear Strengthening of Reinforced Concrete (RC) Beam**

The shear failure of an RC beam is distinctly different from the flexural failure. The flexural failure of a beam is ductile in nature, whereas shear failure is brittle and catastrophic. When the RC beam is deficient in shear, or when its shear capacity is less than the flexural capacity after flexural strengthening, shear strengthening must be considered. It is critically important to examine the shear capacity of RC beams which are intended to be strengthened in flexure.

**1.4 Introduction to Carbon fiber**

In 1958, Roger Bacon created high-performance carbon fibers at the Union Carbide Parma Technical Center, now Graf Tech International Holdings, Inc. located outside of Cleveland, Ohio. Those fibers were manufactured by heating strands of rayon until they carbonized. This process proved to be inefficient, as the resulting fibers contained only about 20% carbon and had low strength and stiffness properties. In the early 1960s, a process was developed by Dr. Akio Shindo at Agency of Industrial Science and Technology of Japan, using polyacrylonitrile (PAN) as a raw material. This had produced a carbon fiber that contained about 55% carbon.

The high potential strength of carbon fiber was realized in 1963 in a process developed by W. Watt, L.N. Phillips, and W. Johnson at the Royal Aircraft Establishment at Farnborough, Hampshire. The process was patented by the UK Ministry of Defense then licensed by the National Research Development Corporation (NRDC) to three British companies: Rolls-Royce, already making carbon fiber, Morganite and Courtaulds.

.**Table No 1.4.1 Properties of CFRP**

| Properties | CFRP |
|---|---|
| Technical data of fiber | 430 gsm |
| Modulus of elasticity | 240kN/mm$^2$ |
| Tensile strength | 5650MPa to531GPa |

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| | |
|---|---|
| Total wt of sheet in main direction | 430 g/m$^2$ |
| Density | 1.7g/cm$^3$ |
| Ultimate strain % | 1.55 |
| Colour | Black |
| Thickness for static density wt/density | 0.117mm |

**1.5 Application**

They are used in repairing of RC beam structure. It can be applied to increase strengthening of slabs and column.

**1.6 Types of matrix material**

The matrix has a strong influence on a several mechanical properties of composite such as transverse modulus and strength, shear properties and properties in compression. Physical and chemical characteristics of the matrix such as melting or curing temperature, viscosity and reactivity with fiber influence the choice of fabrication process. The matrix material for a composite system is selected, keeping in view all these factor. Thermoset resin are the most commonly used matrices for production of Carbon fiber composite. They are usually available in partially polymerized state with fluid or pasty consistency at room temperature. When mix with proper reagent, they polymerized to become a solid, vitreous material.

The reaction can be accelerated by adjusting the temperature. Thermoset resin have several advantages, including low viscosity that allows for a relative easy fiber impregnation, good adhesive property, room temperature polymerization characteristics, good resistance to chemical agents, absence of melting temperature etc. disadvantage are limited range of operating temperature, with the upper bound limit given by the glass transition temperature, poor roughness with respect to fracture (brittle behavior) and sensitivity to moisture during field applications. The most common thermosetting resin for civil engineering are the epoxy resin. Polyester or vinyl ester resin are also used. Considering that the material is mixed directly at the construction site and obtains its final structural characteristics through a chemical reaction, it should always be handled by specialized personnel.

**1.7. Advantages and disadvantages**

**1.7.1. Advantages**

FRP is corrosion proof. When steel is in contact with water, oxygen, or other strong oxidants, or acids, it rusts. Easy in transportation can be easily rolled. High fatigue resistance. Light weight. Hence, very high strength to weight ratio. The lower weight makes handling and installation significantly easier than steel. This is particularly important when installing material in cramped Locations.Fiber composite materials are available in very long lengths while steel plate is generally limited to 6m. The availability of long length and the flexibility of the material also simplify installation and joints and laps are also not required.Very less period of time is required.Does not impact on detailing or form of historic structures Low unit weight (150-900 g /m2). Fiber composite strengthening materials have higher ultimate strength and lower density than steel. Low energy consumption during fabrication of raw material and structure, and the potential for real time monitoring

**1.7.2. Disadvantages**

The main disadvantage of externally strengthening structures with composite materials is the risk of fire, vandalism or accidental damage, unless the strengthening is protected. Below 5˚c temperature we cannot use

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FRP. The lack of experience of the techniques and suitably qualified staff to carry out the work. Lack of accepted design standards. FRP composites are sensitive to hydrothermal environment

## II. EXPERIMENTAL STUDY

### 2.1 Materials

#### 2.1.1 Concrete

Concrete is a composite construction material composed of aggregate, cement and water. There are many formulations that have varied properties. The aggregate is generally coarse gravel or crushed rocks such as limestone, or granite, along with a fine aggregate such as sand. The cement, commonly Portland cement, and other cementitious materials such as fly ash and slag cement, serve as a binder for the aggregate. Various chemical admixtures are also added to achieve varied properties. Water is then mixed with this dry composite which enables it to be shaped (typically poured) and then solidified and hardened into rock-hard strength through a chemical process known as hydration. The water reacts with the cement which bonds the other components together, eventually creating a robust stone-like material. Concrete has relatively high compressive strength, but much lower tensile strength. The ultimate strength of concrete is influenced by the water-cementitious ratio *(w/c)*, the design constituents, and the mixing, placement and curing methods employed.

#### 2.1.2 Cement

Cement is a material, generally in powder form, that can be made into a paste usually by the addition of water and, when moulded or poured, will set into a solid mass. Numerous organic compounds used for adhering, or fastening materials, are called cements, but these are classified as adhesives, and the term cement alone means a construction material. The most widely used of the construction cements is Portland cement. It is a bluish-gray powder obtained by finely grinding the clinker made by strongly heating an intimate mixture of calcareous and argillaceous minerals. The chief raw material is a mixture of high-calcium limestone, known as cement rock, and clay or shale. Blast-furnace slag may also be used in some cements and the cement is called Portland slag cement (PSC). The color of the cement is due chiefly to iron oxide. In the absence of impurities, the color would be white, but neither the color nor the specific gravity is a test of quality.

#### 2.1.3 Fine aggregate

Fine aggregate is natural sand which has been washed and sieved to remove particles larger than 5 mm and coarse aggregate is gravel which has been crushed, washed and sieved so that the particles vary from 5 up to 50 mm in size. The fine and coarse aggregate are delivered separately. Because they have to be sieved, a prepared mixture of fine and coarse aggregate is more expensive than natural all-in aggregate. Sand is used for making mortar and concrete and for polishing and sandblasting. Sands containing a little clay are used for making moulds in foundries.

Clear sands are employed for filtering water. Sand is sold by the cubic yard (0.76 m3) or ton (0.91 metric ton) but is always shipped by weight. The weight varies from 1,538 to 1,842 kg/m3, depending on the composition and size of grain. The fine aggregate is passing through 4.75 mm sieve and had a specific gravity of 2.67.

#### 2.1.4 Coarse aggregate

Coarse aggregate are the crushed stone is used for making concrete. The commercial stone is quarried, crushed, and graded. Much of the crushed stone used is granite, limestone, and trap rock.. The sizes are from 0.25 to 2.5

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in (0.64 to 6.35 cm), although lager sizes may be used for massive concrete aggregate. Machine chorused granite broken stone angular in shape is use as coarse aggregate.

**2.1.5 Carbon fiber**

Carbon Fiber is a composite material made by combining two or more materials to give a new combination of properties. The lower weight makes handling and installation significantly easier than steel. This is particularly important when installing material in cramped Locations. Fiber composite materials are available in very long lengths while steel plate is generally limited to 6m However, Carbon fibers different from other composites in that its constituent materials are different at the molecular level and are mechanically separable. The mechanical and physical properties of Carbon fiber are controlled by its constituent properties and by structural configurations at micro level. Therefore, the design and analysis of any Carbon fiber structural member requires a good knowledge of the material properties, which are dependent on the manufacturing process and the properties of constituent materials.

**2.1.6 Epoxy resin**

Epoxy resins are relatively low molecular weight pre-polymers capable of being processed under a variety of onditions. Two important advantages of this resin are over unsaturated polyester resins are: first, they can be partially cured and store in that state and second they exhibit low shrinkage during cure. However, the viscosity of conventional epoxy resin is higher and they are more expensive compare to polyester resins. The cured resin has high chemical, corrosion resistance, good mechanical and thermal properties, outstanding adhesion to a variety of substrate and good electrical properties. Approximately 45% of the total amount of epoxy resin produced is used in protective coating while the remaining is used in structural application such as laminate and composites, tooling, casting, construction, adhesives etc.

**2.1.7 Reinforcement**

The Fe500 grade TMT bars were used as steel reinforcement for casting the section. All reinforcement was placed and maintained in the position by providing proper cover blocks. Reinforcement was placed and tied in such a way that concrete placement was possible without segregation of the mix and which allowed compaction by immersion vibrator

## III. RESULT

The specimens were fixed on universal testing machine such that the both ends of columnwere fixed by UTM. The projections of beam length 300 mm on either side of the column were fixed by proving ring attached with hydraulic jacks. Only one end beam was loaded by means of hydraulic jack and readings aretaken from proving ring. Other end of the beam also has same arrangement but only for supporting purpose. Packing plates were placed on either side of the column. The hydraulic jack and proving ring was seatedvertically. A dial gauge was placed on top of the application of load on the beam for measuring deflections. Theleast count of dial gauge is 0.01mm. The whole arrangement of test setup was shown

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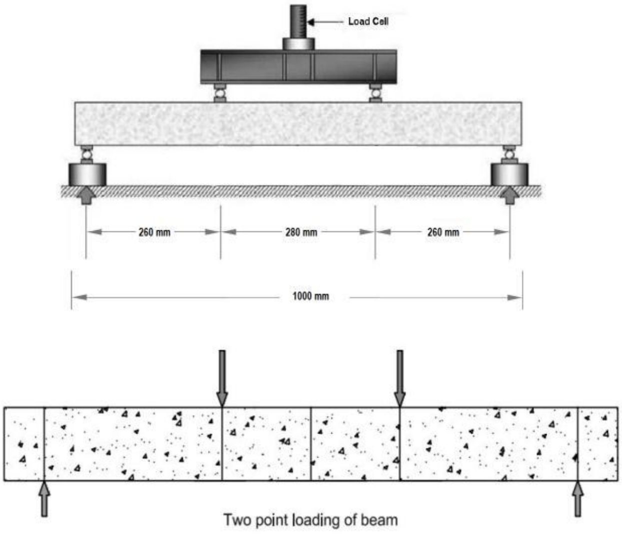


**Fig. 3.1: Experimental setup for testing of beams**

**Table No 3.1 Deflections and Loads**

| Types of wraping | Avg. deflection (mm) | Avg. Load (KN) |
|---|---|---|
| Ordinary Beam | 5.3 | 86.76 |
| Fully wrap Beam | 6.05 | 126.53 |
| Parallel strip Beam | 5.5 | 113.2 |
| Inclined strip Beam | 6.1 | 115.2 |
| U-shaped Beam | 5.9 | 119.2 |

## IV. CONCLUSION

Based on the experimental investigations carried out on the ordinary and strengthened beam specimens using different CFRP wrapping, the following conclusions were drawn.

The strengthening technique using wrapping system for the damaged R.C.C beam have proved to be effective. The ultimate load carrying capacity of the strengthened beam was improved with decrease in deflections. Considerable increase in first crack load can be achieved by using Carbon reinforced polymers. Considerable increase in yield load can be achieved by use of Carbon reinforced polymer materials.

**Table No 4.1 increase in strength**

| Types of wraping | Percentage increase in strength |
|---|---|
| Ordinary Beam | 0% |
| Fully wrap Beam | 31% |
| Parallel strip Beam | 23% |
| Inclined strip Beam | 25% |
| U-shaped Beam | 27% |

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