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# STRENGTHENING OF REINFORCED CONCRETE BEAMUSING CARBON FIBER REINFORCED POLYMER LAMINATES

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**ABSTRACT**

*Worldwide, A great deals of research is currently being constructed concerning the view use of fiber reinforce polymer warps laminates and sheets in the repair and strengthening of reinforced concrete member. The rehabilitation of existing reinforce concrete (RC) Bridges & Building becomes necessary due to ageing, corrosion of steel reinforcement, defect in construction designed demand in the increased service load & damaged in case of seismic events & improvement in the design guidelines. Fiber reinforced polymer (FRP) application is very effective way to repair &strengthen structure that have become structurally weak over their life span. Previous experimental studies conducted to discuss strengthen schemes of RC beam best on the failure mechanism of RC beam.*

***Keyword: Carbon Fiber Reinforce Polymer, Reinforce Concrete Beam***

## 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. With increase in research and introduction of new materials and technology there are new ways of retrofitting the structure with many added advantages. Introduction of Fiber Reinforced Polymer (FRP) Composite is one of them.FRP composites comprise fibers of high tensile strength embedded within a thermosetting matrix such as epoxy, polymer or vinyl ester. The most widely used matrix is epoxy.

FRP was originally developed for aircraft, helicopters, space-craft, satellites, ships, submarines, high speed trains because of its light weight. The application of FRP in the civil engineering structures has started in 1980s. Then, the use of FRP for strengthening of existing or new reinforced concrete (RC) structures against normal and seismic loads increases at a rapid pace.Strengthening using FRP compositeFRP are available in many forms and are used as a structural reinforcement for the concrete structures. Some of these forms are bars, plates and sheets. The FRP sheets are more commonly used to strengthen the existing structures because of greater flexibility compared to other forms. The first application of FRP strengthening was made to reinforce the concrete beams. The beams are load bearing structural elements that are designed to carry both vertical gravity loads and horizontal loads due to seismic or wind. The structurally deficient beams fail during such events. There are mainly two types of failure of beams i.e., flexural and shear.Hence, the strengthening of such beams is needed in flexure or shear or both zones and the use of external FRP strengthening to beams may be classified as:

- Flexural strengthening
- Shear strengthening

The main objectives of the present work are:

1 To study the structural behavior of reinforced concrete (RC) beam..
2 To study the contribution of externally bonded Fiber Reinforced Polymer (FRP) sheets on the flexural behavior of RC beams.
3 To know the suitability of the FRP composites as repair materials for deteriorated RC Structures.
4 To study the deflection behavior of RC beam.
5 To study the flexural behavior of RC beams with different wrapping condition.

## II. MATERIALS AND METHODS

2.1 Materials

2.1.1 Cement:Portland cement concrete is made with coarse aggregate, fine aggregate (sand), Portland cement, water and, in some cases, selected admixtures such as fly ash, air-entraining agents, water-reducing agents, retarders, etc.

2.1.2 Fine aggregate:Specifications for the fine aggregate fraction of concrete have been developed almost exclusively on the basis of experience with natural sand for many years, since it was virtually the only type utilized.

2.1.3 Coarse aggregate:The aggregate property-testing program was the second stage. The basic aggregate characteristic tests were conducted to select the aggregates that are to be tested.

2.1.4 Water:Water is an important ingredient of concrete as it actively participates in the mix design consideration. It is generally stated in the concrete codes and also in the literature that the water chemically reacts with cement.

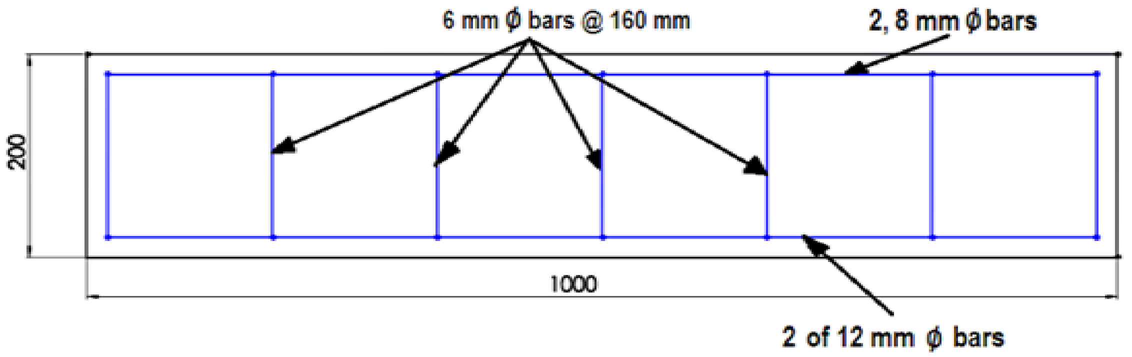
2.1.5 Concrete:There are various methods of mix design. In the present work, Indian Standard method (IS 10262-2009) is used for mix design.

2.1.6 Steel Reinforcement:The Fe500 grade TMT bars were used as steel reinforcement for casting the section. The bars were bent and fixed in accordance with procedure specified in IS 2502.

2.2 Epoxy resin:Epoxy resins are relatively low molecular weight pre-polymers capable of being processed under a variety of conditions. 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.

## III. METHODOLOGY

3.1 Casting of Beams:The experimental programmed consists of the testing sixteen reinforced concrete beams had a cross section of 150 mm x 200 mm with an overall length of 1000 mm.




| SR.NO. | BEAM NO. | NO. Of BEAMS | STRENGTHEN TYPE |
|---|---|---|---|
| 1 | SP1, SP2, SP3 | 3 | ORDINARY |
| 2 | SP4, SP5, SP6 | 3 | FULLY WRAPPED |
| 3 | SP7, SP8, SP9 | 3 | U-SHAPED WRAPPED |
| 4 | SP10, SP11, SP12 | 3 | INCLINE STRIP |
| 5 | SP13, SP14, SP15 | 3 | PARALLEL STRIP |

Table No.3.1.1: Strengthening Type with Respect to Beam

3.2 Procedure of CFRP Wrapping

1. Grinding the surface from joint up to 150 mm and to get an even surface. All projections are grounded off.
2. Apply mix of Epoxy resin and hardened be prepared concrete surface area. Work site must be thoroughly ventilated during the application of chemicals.
3. The fiber sheet must be cut before application of mix into prescribed sizes using scissors or cutters.

3.3 Testing of beam

The specimens were fixed on universal testing machine such that the both end 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

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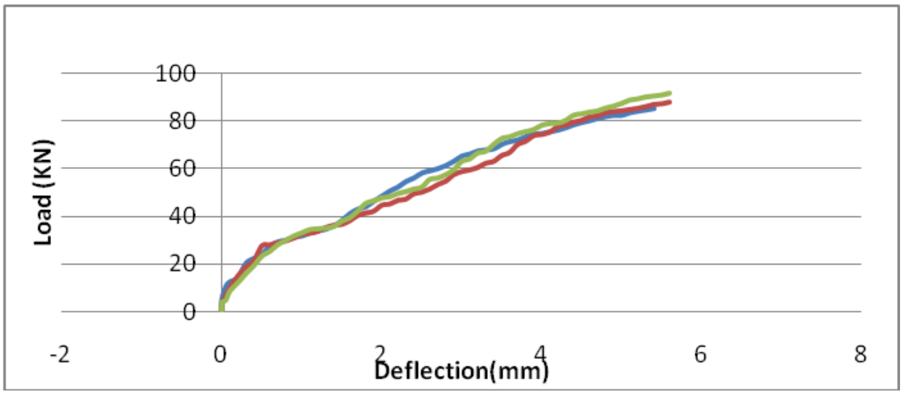
placed on top of the application of load on the beam for measuring deflections. Theleast count of dial gauge is 0.01mm.

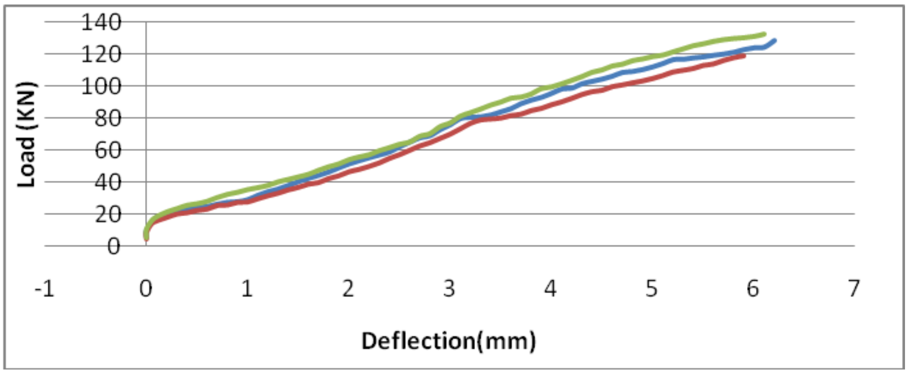
## IV. RESULT ANALYSIS4.1.Ordinary specimen




Graph4.1: Comparative Load (KN) $V_{s.}$ Deflection (mm) for SP1, SP2, SP3

As per above graph shows that the total average taken ordinary specimen is 86.76 KN and deflection 5.3 mm .

4.2. Fully wrapped specimen




Graph4.2: Comparative Load (KN) $V_{s.}$ Deflection (mm) for SP4, SP5, SP6

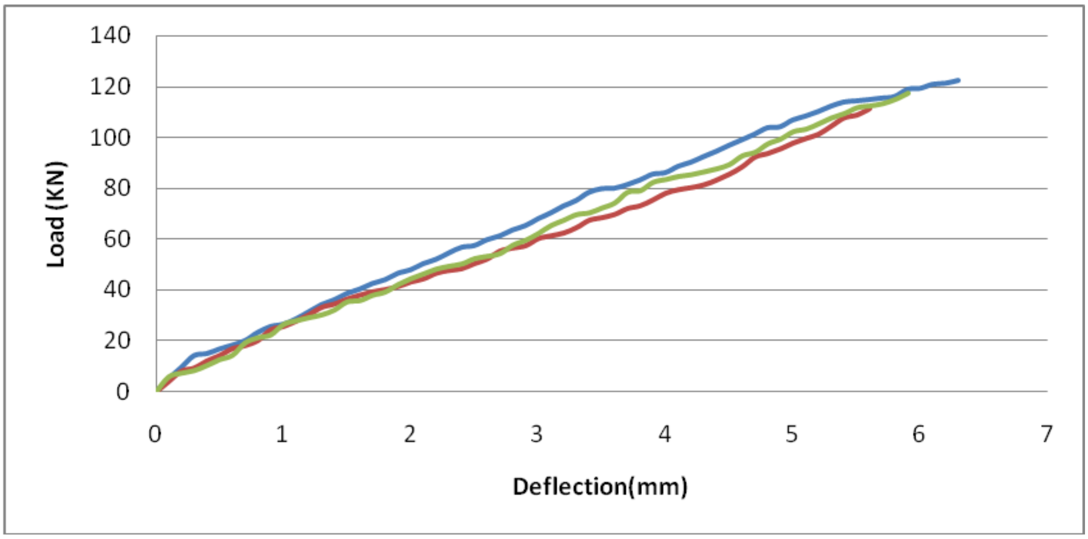
As per above test result it shows that the total average load of ordinary specimen 86.76 KN and carbon fiber specimen 126.53 KN .deflection for 5.76 mm will be taken by ordinary and carbon fiber specimen 6.05mm .It mean load carrying capacity increase of carbon specimen and increases deflection compare to ordinary specimen.

Load Study:With reference to the test results, the loads on ordinary specimens at first crack stage are compared to the loads on carbon fiber specimens at first crack stage. It is observed that the load carrying capacity of carbon fiber specimens are increased when compared to the ordinary specimens. From these values the percentage of increase in load carrying capacity of carbon fiber specimens over ordinary specimens.

| No of layers | Load (KN) | | Percentage increase in strength |
|---|---|---|---|
| | Ordinary Specimen | carbon Fiber Specimen | |
| 1 | 86.76 | 126.6 | 68.53 |

Table 4.1: Comparison of load taken by ordinary and CFRP specimen**.**

4.3. Specimen with U-shape layer CFRP:




Graph4.3: Comparative Load (KN) $V_{s.}$ Deflection (mm) for SP7, SP8, SP9

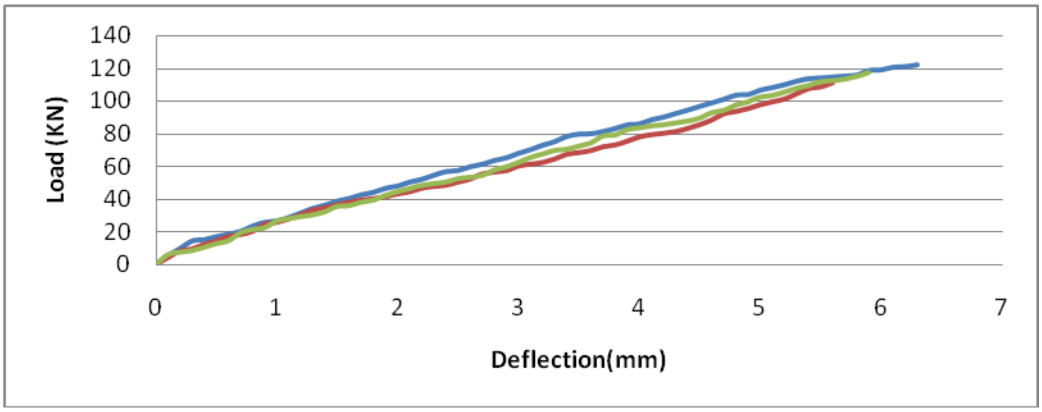
As per above test result it shows that the total average load of ordinary specimen 86.76 KN and carbon fiber specimen 119.2 KN .deflection for 5.76 mm will be taken by ordinary and carbon fiber specimen 5.9 mm .It mean load carrying capacity increase of carbon specimen and increase deflection compare to ordinary specimen.

Load Study:With reference to the test results, the loads on ordinary specimens at first crack stage are compared to the loads on carbon fiber specimens at first crack stage. It is observed that the load carrying capacity of carbon fiber specimens are increased when compared to the ordinary specimens. From these values the percentage of increase in load carrying capacity of carbon fiber specimens over ordinary specimens

| No of layers | Load (KN) | | Percentage increase in strength |
|---|---|---|---|
| | Ordinary Specimen | Carbon Fiber Specimen | |
| 1 | 86.76 | 119.2 | 72.78 |

Table4.2: Comparison of load taken by ordinary and CFRP specimen**.**

4.4. Specimen with inclined layer CFRP:




Graph4.4: Comparative Load (KN) $V_{s.}$ Deflection(mm) for SP9,SP10,SP11

As per above test result it shows that the total average load of ordinary specimen 86.76 KN and carbon fiber specimen 115.2 KN .deflection for 5.76 mm will be taken by ordinary and carbon fiber specimen 6.1 mm .It mean load carrying capacity increase of carbon specimen and increase deflection compare to ordinary

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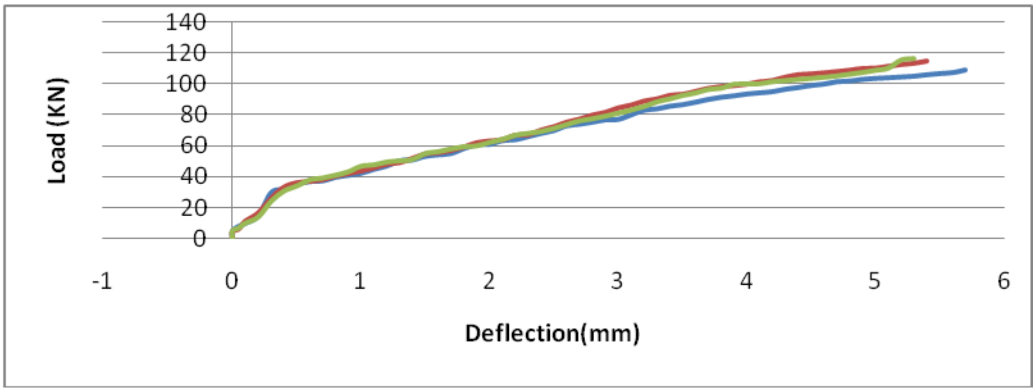
specimen.Load Study:With reference to the test results, the loads on ordinary specimens at first crack stage are compared to the loads on carbon fiber specimens at first crack stage. It is observed that the load carrying capacity of carbon fiber specimens are increased when compared to the ordinary specimens. From these values the percentage of increase in load carrying capacity of carbon fiber specimens over ordinary specimens

| No of layers | Load (KN) | | Percentage increase in strength |
|---|---|---|---|
| | Ordinary Specimen | Carbon Fiber Specimen | |
| 1 | 86.76 | 115.2 | 72.78 |

Table No 4.3: Comparison of load taken by ordinary and CFRP specimen.

4.5. Specimen with parallel strip CFRP:




Graph4.5: Comparative Load (KN) $V_{s.}$ Deflection (mm) for SP12, SP13, SP14

As per above test result it shows that the total average load of ordinary specimen 86.76 KN and carbon fiber specimen 113.2 KN .deflection for 5.76 mm will be taken by ordinary and carbon fiber specimen 5.5 mm .It mean load carrying capacity increase of carbon specimen and increase deflection compare to ordinary specimen. Load Study:With reference to the test results, the loads on ordinary specimens at first crack stage are compared to the loads on carbon fiber specimens at first crack stage. It is observed that the load carrying capacity of carbon fiber specimens are increased when compared to the ordinary specimens. From these values the percentage of increase in load carrying capacity of carbon fiber specimens over ordinary specimens

| No of layers | Load (KN) | | Percentage increase in strength |
|---|---|---|---|
| | Ordinary Specimen | Carbon Fiber Specimen | |
| 1 | 86.76 | 113.2 | 72.78 |

Table No 4.4: Comparison of load taken by ordinary and CFRP specimen.

## V. CONCLUSION

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

1. The strengthening techniques using wrapping system for the damaged R.C.C beam have proved to be effective.
2. The ultimate load carrying capacity of the strengthened beam was improved with decrease in deflections.
3. Carbon composite materials can be efficiently used for strengthening and rehabilitation of reinforced concrete joints.

4. Considerable increase in first crack load can be achieved by using Carbon reinforced polymers.
5. Considerable increase in yield load can be achieved by use of Carbon reinforced polymer materials.

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