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# Strengthening of a RC Beam using Synthetic FRP Laminates

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## Abstract

**Objectives:** The present research paper summarizes the study of use of synthetic polyester fiber for the strengthening of the reinforced concrete beams. **Methods:** In this experimental study, ten reinforced concrete beams were casted. They were externally strengthened with the help of synthetic polyester fiber using epoxy resin and hardener. The application of Polyester Fibre Reinforced Polymer sheets for strengthening of RC beams was done in u-wrap and bottom wrap. The effect of this on ultimate load carrying capacity and flexural strength was examined. **Findings:** The reinforced concrete beams were tested to failure using symmetrical two point concentrated static loading system. The results were found experimentally on load, deflection and failure types of each of the beams. The effect of various positions of wrapping of Polyester Fiber Reinforced Polymer on ultimate load carrying capacity was investigated. The results obtained showed increase in the ultimate load carrying capacity and flexural strength of the beams as compared with the control beam. The ultimate load obtained with polyester fibre reinforced beam was, however less compared to Carbon/Glass/Aramid as recorded in the literature. But the results obtained were encouraging and useful. **Applications:** Defects occur in reinforced concrete due to many factors like-age, corrosion of steel reinforcement, defective structural design etc. Fibre reinforced polymers can be successfully utilized for rehabilitation of these RC structures.

**Keywords:** Fiber Reinforced Polymer (FRP), Flexural Strength, Polyester Fiber, Strengthening of Beam, Ultimate Load

## 1. Introduction

There is immense need to rehabilitate the existing old structures in many parts of the world. Strengthening or rehabilitation of the concrete structures is required due to design flaws of construction, structural degradation of the structure, deterioration of steel due to corrosion and ageing of the reinforced concrete members. Many new techniques have been developed in order to strengthen the deteriorating structures, out of which the external strengthening utilizing the FRP is the most widely used method. FRP is a complex material commonly consisting of carbon, aramid or glass fibres in resin matrix. The first FRP system was used in 1940 in aerospace industry. The main components of FRP are the fibres and the resin. There are two different types of externally bonded FRP system (a) Prefab system (b) Wet lay-up. Prefab system are pre-manufactured cured laminates which are installed using adhesives. Wet lay-up are FRP wrapping system in which dry uni-directional fibres sheets are directly applied into the resin that has been applied to the concrete surface. FRP wrapping techniques using synthetic fibres such as carbon fibres, aramid fibres and glass fibres enhances the tensile stresses. The various synthetic fibers such as acrylic, aramid, carbon, glass are costlier and cannot be used by a common man living in rural areas. Thus for over a long period of time many researches are being carried out on the natural available fibres such as wood, flax, hemp, jute, straw, wood fibres, rice husks, wheat, barley, oats, rye, cane. In this experiment investigation is being carried out using the polyester fibre. Polyester is a type of polymers that contain the ester functional group in their main chain. Polyesters consists of naturally occurring chemicals, such as cutin of plant cuticles, and also synthetics through step-growth polymerization such as polybutyrate.

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## 2. Previous Researches on FRP

Campione[1] used the wrapping technique of CFRP and found out the relation between the strength reduction and the increase in the length of the CFRP wrapped specimen[2] studied the behavior of beams reinforced with GFRP and found an increase in ultimate load[3] studied the effect of width of the GFRP strips on the deflection of the RC beam and observed that increasing the GFRP area controlled the cracking of concrete in flexur[4] studied the strengthening of reinforced concrete beams using Prestressed GFRP and there was reduction in spalling in concrete beam reinforced with Prestressed GFRP[5] studied experimentally the flexural strengthening of reinforced concrete beams by the Carbon Fibre Reinforced Polymer Composite (CFRPC) and found out that the stiffness and first crack load increased significantly[6] studied the fatigue behavior of Reinforced Concrete Beams strengthened with Carbon Fibre Reinforced Plastic Laminates and concluded that the increase in stresses were not severe for the CFRP wrapped beams[7] investigated the use of Ultra High Strength Cementious Composite and found out that pre-loaded fatigue beam had higher load carrying capacity Compared to control beam.

## 3. Experimental Work

Reinforced Concrete beams of cross-sectional dimension 150mm x 150mm x 700 mm were used for experimental study. Reinforcement of 8 mm diameter were used as tension reinforcement at bottom and 6mm diameter shear reinforcement as stirrups were used at 125 mm spacing were used. Details of the reinforcement is shown in Figure 1.

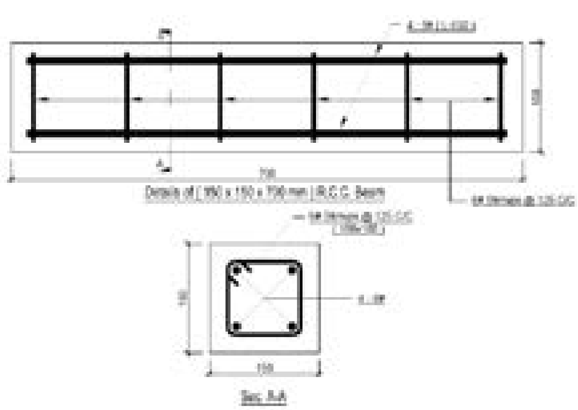

**Figure 1.** Beam Details.

### 3.1 Material Properties

The Concrete Mix proportion were done according to IS 10262:2009. The Water / Cement ratio of 0.5 was used for design of M20 grade of concrete. The design mix proportioning of concrete are given in table 1.

**Table 1.** Concrete Mix Design quantities

| Description | Cement | Sand (Fine Aggregate) | Coarse Aggregate | Water |
|---|---|---|---|---|
| Mix Proportion (by weight) | 1 | 1.85 | 3.05 | 0.5 |
| Quantities of material for one specimen(Kg) | 6.73 | 12.44 | 20.53 | 3.36 |

### 3.2 Coarse Aggregate

The stone chips used in the experimental study were were brought from Chutupali, for preparing concrete. The stone chips used were well graded 20 mm and down size were used. The results of physical tests conducted on coarse aggregate are tabulated in table 2.

**Table 2.** Properties of Coarse aggregate

| SL No. | Properties | Value |
|---|---|---|
| 1. | Specific Gravity | 2.63 |
| 2. | Fineness Modulus | 4.08 |
| 3. | Water Absorption (24 hours) | 0.26 |
| 4. | Bulk Density | 1.61 |

### 3.3 Fine Aggregates

The sand used in the experiment were as per the provisions of IS 383:1970.The Fine aggregates that passed through 4.75 mm sieve were used. The results of physical tests conducted on fine aggregate are tabulated in table 3.

**Table 3.** Properties of Fine aggregate

| SL. No. | Properties | Value |
|---|---|---|
| 1. | Specific Gravity | 2.60 |
| 2. | Fineness Modulus | 2.602 |
| 3. | Water Absorption (24 hours) | 1.0 |
| 4. | Bulk Density | 1.479 |

### 3.4 Cement

The cement used in the experiment was Portland Slag Cement conforming to IS 455:1989.Cement's properties were tested in accordance with Indian Standard specifications (IS: 4031-1968) to know its appropriateness. The results of various tests conducted on cement are given in tabulated in table 4.

**Table 4.** Physical Tests on cement

| SL No. | Properties | Results |
|---|---|---|
| 1 | Fineness of Cement (%) | 3.48 % |
| 2 | Standard Consistency (%) | 32 |
| 3 | Initial Setting Time (minutes) | 50 |
| 4 | Final Setting Time (minutes) | 327 |
| 5 | Specific gravity | 3.14 |
| 6. | Soundness Test(cm) | 1 |

### 3.5 Reinforcement Steel

The reinforcement steel used in the experiment were HYSD bars of Fe-500 of 8 mm diameter bars and 6 mm Fe-250 as shear reinforcement. The tensile testing of 8 mm diameter bars were done by Instron universal testing machine as shown in figure 2. The result of tensile test conducted on 8 mm diameter bars are tabulated in table 5.

**Figure 2.** Instron machine.

**Table 5.** Tensile test of 8 mm bars

| Sample | Ultimate Tensile Strength(MPa) | Modulus of Elasticity ($kN/mm^2$) |
|---|---|---|
| 1 | 599.518 | 57.938 |
| 2 | 629.239 | 61.66 |

## 4. Experimental Procedure

In this experimental study, 10 numbers of reinforced concrete beams were casted. They were cured for a period of 7 days and 28 days according to IS 516:1959. The specimens were dried after taking them out of the water. Then the sand paper was used to clean the surface of the beam. Then polyester fibre sheet was externally applied to the beam by using araldite epoxy resin and hardener and was tested after 24 hours.

### 4.1 Experimental Setup

The casted specimen reinforced with fibre were tested in the flexural testing machine using two point loading system. The load was being applied at the top of the beam. As the load was applied few visible cracks were seen; these were first crack load and the loading was noted. The loading continued till we got the ultimate crack. The flexural strength was calculated. Two point loading set-up is shown in the figures 3 to 6.

**Figure 3.** Flexural Testing machine.

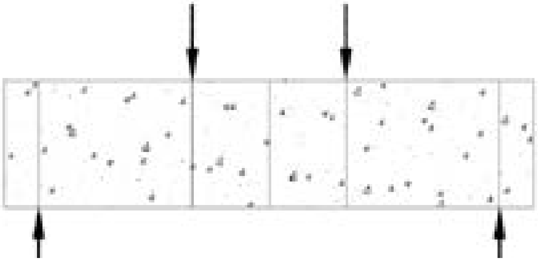

**Figure 4.** Two point loading beam.

**Figure 5.** Shear Force Diagram.

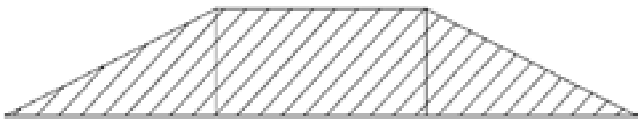

**Figure 6.** Bending moment diagram.

## 5. Test Results

The results of the test conducted on beams are tabulated in tables 6 to 8. The load vs. deflection graph are represented in figures 7 and 8.

**Table 6.** Ultimate load and first crack load values for 7 days

| SL No. | Beam Designation | First Crack load(KN) | Ultimate Load(KN) |
|---|---|---|---|
| 1 | SD-1 [Control] | 27 | 61.8 |
| 2 | SD-2 [Control] | 29.9 | 60.8 |
| 3 | SD-3 [Single Bottom wrap] | 34.3 | 67.7 |
| 4 | SD-4 [Single Bottom wrap] | 29.4 | 68.6 |
| 5. | SD-5 [Single u-wrap ] | 45.1 | 71.0 |
| 6. | SD-6 [Single u-wrap ] | 42.2 | 70.6 |

**Table 7.** Ultimate load and first crack load values for 28 days

| SL No. | Beam Designation | First Crack load(KN) | Ultimate Load(KN) |
|---|---|---|---|
| 1 | SD7-[Control] | 49.0 | 81.4 |
| 2 | SD-8[Control] | 44.1 | 83.4 |
| 3 | SD-9[Single Bottom wrap ] | 58.8 | 93.2 |
| 4 | SD-10[Single Bottom wrap ] | 49.0 | 94.1 |

**Table 8.** Flexural Strength results for 7 days and 28 days

| SL No. | Beam Designation | Flexural Strength (Mpa) | Increase in Flexural Strength (%) |
|---|---|---|---|
| 1 | SD-1-[Control] | 18.81 | |
| 2 | SD-2[Control] | 18.51 | |
| 3 | SD-3[Single Bottom wrap ] | 20.61 | 11.17 |
| 4 | SD-4[Single Bottom wrap ] | 20.84 | |
| 5. | SD-5[Single u-wrap ] | 21.49 | 15.48 |
| 6. | SD-6 [Single u-wrap ] | 21.62 | |
| 7 | SD7-[Control] | 24.78 | |
| 8 | SD-8[Control] | 25.39 | |
| 9 | SD-9[Single Bottom wrap ] | 28.37 | 13.65 |
| 10 | SD-10[Single Bottom wrap ] | 28.64 | |

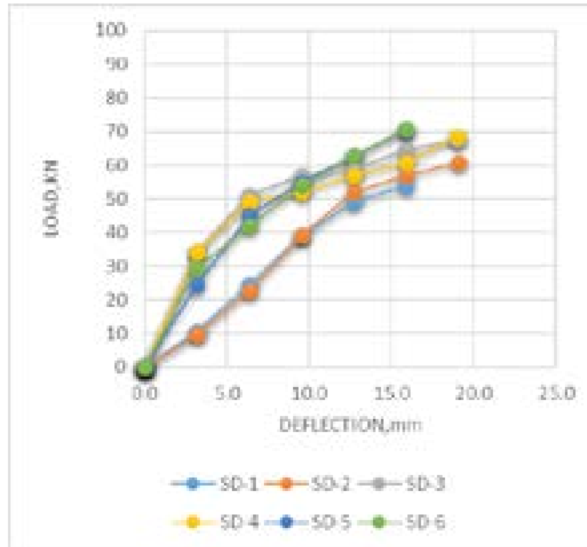


**Figure 7.** Load vs Deflection graph for 7 days ultimate loads.

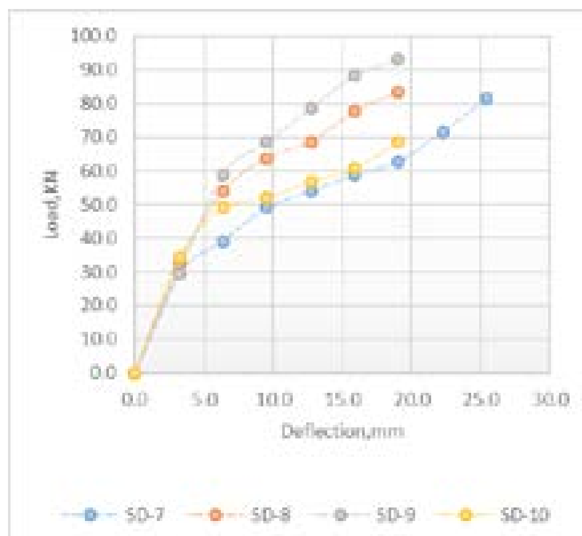


**Figure 8.** Load vs. Deflection graph for 28 days ultimate loads.

## 6. Conclusion

- In the experimental work reinforced concrete beams were strengthened using the FRP which resulted in increase of initial crack load and ultimate load.
- The flexure strength of the concrete increased 11.17 % for the single layer wrapping, 15.48 % for U-wrap for 7 days and 13.65% for single layers 28 days compared to the control beam.

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