FLEXURAL BEHAVIOUR OF RC BEAM STRENGTHENED WITH BASALT FIBER REINFORCED POLYMER

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Abstract –

The performance of the concrete is generally determined from its mechanical properties are conducted on hardened concrete specimens. The mechanical properties depends on the quality of raw materials used, curing techniques adopted and the atmospheric conditions maintained throughout the test. These properties is more important for the design of concrete structures and it is purely depends on these result values.The present study enumerates the mechanical properties and flexural behavior of reinforced concrete beams strengthened with Basalt Fiber Reinforced Polymers (BFRP). Two reinforced concrete beams are cast and tested for investigate the flexural behavior. One beam served as reference beam and other beams are strengthened with 2layered BFRP laminates. All the beams are tested under four point bending and the results are compared with control concrete beam and presented. The experimental results concluded that reinforced concrete beam strengthened with 2 layered BFRP laminates at the tension zone exhibit an increase in load carrying capacity than the control concrete beam.

Keywords – fiber-reinforced, basalt, strengthened, flexural, laminates.

1. Introduction

The performance of the concrete is generally determined from its mechanical properties are conducted on hardened concrete specimens. The mechanical properties includes compressive strength, tensile strength, flexural strength, impact strength, thermal strength, modulus of elasticity, etc. The mechanical properties depends on the quality of raw materials used, curing techniques adopted and the atmospheric conditions maintained throughout the test. These properties is of much importance as the design of concrete structures purely depends on these result values.In last few decades, many researchers conducted experimental study on Reinforced concrete (RC) beams strengthened with different types Fibre Reinforced Polymers (FRP) having different configurations. Practical application of external strengthening fiber reinforced polymer laminates or sheets to concrete may not be as perfect as carried out in the laboratory. The

bonding defects cannot be avoided. An experimental program including two-point loading test on reinforced concrete (RC) beams strengthened with and without FRP was conducted.The present study is planned to investigate the mechanical properties of concrete and flexural response of reinforced concrete beams strengthened using natural basalt fiber laminates.

2 Materials and Mix proportion

2.1 Materials Used

Concrete mix of M20 grade, with Ordinary Portland Cement (OPC) of 53 grade satisfying the requirements of IS12269-1987, Fine Aggregate (FA) confirming to zone II, Coarse Aggregate (CA) of maximum size 20mm and potable water was used in this study. Fe500 grade steel confirming IS1786-2008 was used as reinforcement. The basalt fibers of diameter 1.2mm are fabricated together to form 1-layered BFRP laminate of thickness 0.41mm. The epoxy resin (1kg of Corocreteresin)mixed up with 200gms of hardener was used to bond the BFRP laminate at the soffit of the beam specimens

2.2 Mix Proportioning

Mix proportioning is the process of preparing batch of concrete by selecting and arriving at relative proportion of materials used in concrete mix for attaining its target mechanical properties. A good concrete mix should be homogeneous, free from porous, free from harmful organic substances. The material proportioning is normally based on ratio of cement: sand: gravel used for concrete mix which can be modified based on aggregates chosen to obtain the right workability. Generally, there exists two types of mix namely nominal mix and design mix. In nominal mix, all the ingredients and their proportions are specified whereas the design mix is a performance based mix design in which the material proportioning are decided by the designer. This research adopts design mix and the ratio for M20 grade concrete mix is 1:1.89:3.5 to achieve the target strength of 27MPa. The proportioning of mix for $1m^3$ concrete is tabulated in Table 1.

Table 1 Mix Proportion for 1m^3 of Concrete

W/C	Cement (kg/m^3)	Coarse Aggregate (kg/m^3)	Fine Aggregate (kg/m^3)	Water (kg/m^3)
0.55	349.02	1222.22	662.22	192.00

Steel mould with cube of 150mm^3, cylinder of 150mm diameter 300mm long and prism of 100 wide 100 deep 700 long is used for compressive, tensile and flexural strength test respectively. All the moulds are applied with sufficient amount of oil or grease for ease during de-moulding of sample. Table 2 shows the mixture proportion for mechanical properties of concrete per specimen.

Table 2 Mixture Proportion for Mechanical Properties of Concrete per Specimen

Specimen	W/C	Cement (kg/m^3)	Coarse Aggregate (kg/m^3)	Fine Aggregate (kg/m^3)	Water (kg/m^3)
Cube	0.55	1.18	4.13	2.23	0.65
Cylinder	0.55	1.85	6.47	3.3	1.2
Prism	0.55	1.74	6.11	3.31	0.96

The preparation of mix for concrete specimen is made machine mixed for the test which consist of batching and mixing of materials, placing of concrete mix, de-moulding of specimen, curing and then testing. The batching process includes weighing the raw materials for M20 grade concrete in right proportion as per the standard mix design. First, the cement and fine aggregate is fed into the machine for mixing, later coarse aggregates are added and blended thoroughly in dry state. The required amount of water is added at regular interval of time for uniform mixing. Proper mixing of concrete is of utmost important to obtain good quality of concrete mix. The mix is placed in mould with three layers of mix providing 25 tamping's in each layer for uniform compaction of concrete. The specimens are placed in a vibrator to remove active pores or voids present in concrete mix. Vibration is stopped as soon as the cement slurry appeared on the top surface of the mould. The specimens are allowed to remain in the steel mould for the first 24 hours at ambient condition. The specimens are de-moulded after 24 hours of casting and are transferred to curing tank for 7, 14 and 28 days at ambient temperature based on testing age of the concrete specimen.

3. Mechanical Properties

In this study, the major mechanical properties such as compressive, tensile and flexural strength test is carried out. Each test consists minimum of average of three specimens designated as CC-1, CC-2 and CC-3. The results should not exceed 5% the result of other specimens and if it exceeds it represents the poor mix of concrete. The dimensions of the specimen are as per Indian Standard

3.1 Compressive Strength

Compressive strength is a strength of concrete in hardened state and is an important parameter in design of reinforced concrete structures as concrete is employed to carry the compressive stresses. It is the resistance of concrete when it is compressed. The compressive strength is a characteristic compressive strength of 150mm^3 cube specimen over a curing period of 28 days. The characteristics compressive strength is a strength in which the 95% of cubes should not have the value less than that. The test specimen to be tested are removed from curing tank and the excess water are wiped off. The testing is carried out as per IS 516:1959 in compressive testing machine which consists of two parallel bearing plate ends made with steel. One plate fixed to the top for load application and other plate is fixed at its base. The bearing surfaces are cleaned and the specimen is placed, aligned central to the plate. Load is applied normal to the specimen's cross section and increased gradually at a rate of 14N/mm^2/min till the specimen fails. The load at which the cube fails is noted with the failure pattern. Similar testing procedure is carried out for the remaining specimens. The characteristic compressive strength of cube is obtained by dividing the maximum load carried to the cross sectional area of the cube. The average of all the cubes tested gives the characteristics compressive strength of the cube specimen and are tabulated in Table 3

Table 3 Compressive Strength Test Results

Specimen ID	Compressive Strength (MPa)					
	7 Days		14 Days`		28 Days	
CC-1	17.62	17.85	24.96	25.12	28.42	27.84
CC-2	17.49		24.87		27.33	
CC-3	18.45		25.54		27.76	

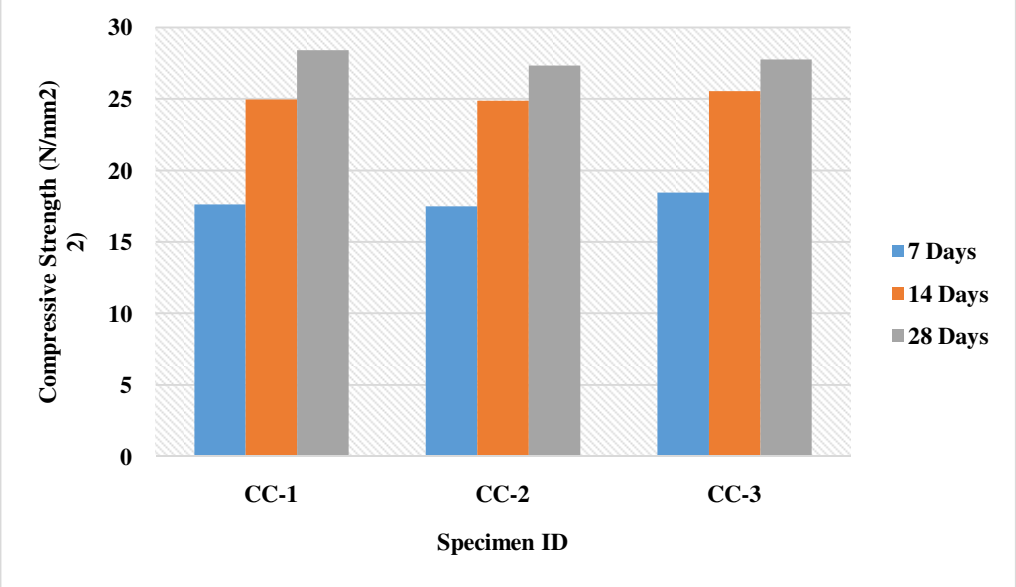

Figure 1 Compressive strength

From Figure 1, it is observed that the average compressive strength of tested cube specimen is 17.85MPa, 25.12MPa and 27.84MPa at 7 days, 14 days and 28 days respectively. It is to be noted that the casted cube specimen attains the target strength of concrete 26.6MPa at 28 days. The 7 days and 14 days average compressive strength is 64.11% and 90.23% the 28 days average compressive strength.

3.2 Split Tensile Strength

Tensile strength is an significant parameter as the reinforced concrete structures are more vulnerable to crack due to tensile force as concrete is weak in carrying the tensile stresses. Applying uni-axial tensile force onto concrete is difficult and hence the load can be applied indirectly by using split tensile strength test or flexure tensile strength test. The standard method to determine tensile strength is split tensile strength test and is adopted in this study. It is the strength carried by concrete when diameter of cylinder splits across the cross section. The cylindrical specimen of 150mm diameter and 300mm long is taken from the curing process and are allowed to dry. The test is carried out in accordance with IS 5816:1970 on compressive testing machine. The specimen is positioned inside a jig and placed horizontally between the bearing plates. The compressive load is applied diametrically and uniformly over the specimen and effect's about $1/6^{th}$ the depth of the cylinder whereas the remaining $5/6^{th}$ of depth is subjected to tensile loading. Concrete is assumed elastic to carry the lateral tensile load

throughout the vertical plane. The load is gradually increased at a rate of 1.2 to 2.4N/mm^2/min till the specimen fails and failure load is noted. The testing is done for all the specimen and the average of all gives the split tensile strength for the concrete specimen. The strength is reported as failure load to the cross sectional area of the cylinder and are tabulated in Table 4.

Table 4 Split Tensile Strength Test Results

Specimen ID	**Spilt Tensile Strength (MPa)**					
	7 Days		**14 Days`**		**28 Days**	
CC-1	1.87	1.93	2.77	2.84	3.01	3.10
CC-2	2.03		2.84		3.12	
CC-3	1.91		2.93		3.18	

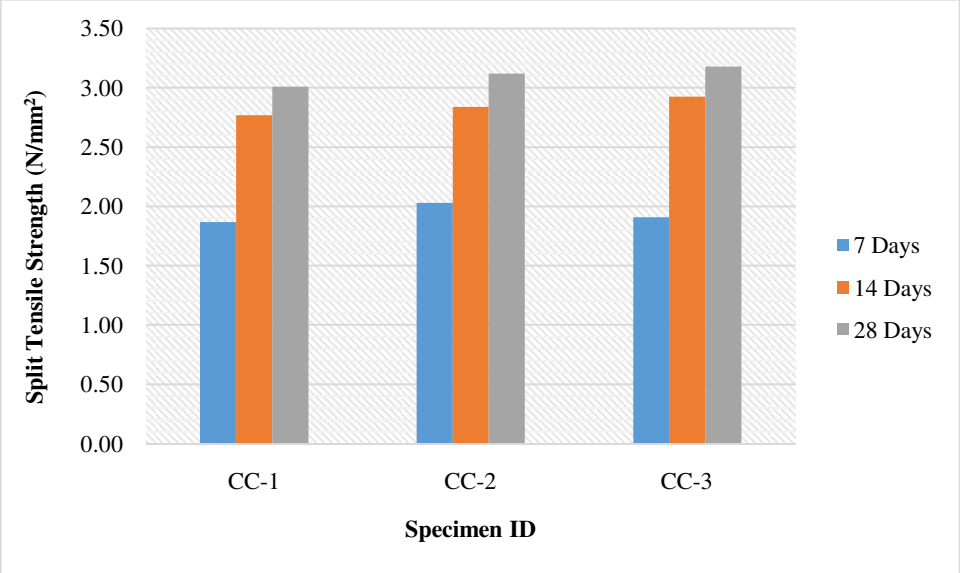

Figure 2 Split tensile strength

From figure 2, The average split tensile strength of cylindrical specimen is 1.93MPa, 2.84MPa and 3.10MPa at 7 days, 14 days and 28 days respectively. The 7 days and 14 days average split tensile strength is 62.25% and 91.61% the 28 days average split tensile strength. As per Indian Standard IS: 456:2000, it is reported that the tensile strength of concrete is 10% to 15% the compressive strength of concrete. Adhering this, the average split tensile strength at 28 days is 3.10MPa which is 11.13% the 28 days average compressive strength of cube specimen.

3.3 Flexural Strength

Flexural strength is a measure of resistance to bending of concrete to determine its modulus of rupture. It is the highest stress experienced by the concrete specimen before yielding. The test procedure follows IS 516:1959 and is conducted on Universal Testing Machine which consist of two rollers over which the prism is placed such that its axis coincide with the axis of loading machine. The load is divided equally through these two rollers without causing any torsional effect. The load is then increased at a rate of 4kN/min till fracture propagates and the procedure is followed for all the prism specimens. The ratio of fracture load to the cross sectional area of prism results in flexural strength of concrete. The values obtained from the test are reported in Table 5.

Table 5 Flexural Strength Test Results

Specimen	**Flexural Strength (MPa)**					
	7 Days		**14 Days`**		**28 Days**	
CC-1	2.26	2.23	3.02	3.00	3.44	3.39
CC-2	2.32		3.03		3.51	
CC-3	2.12		2.94		3.23	

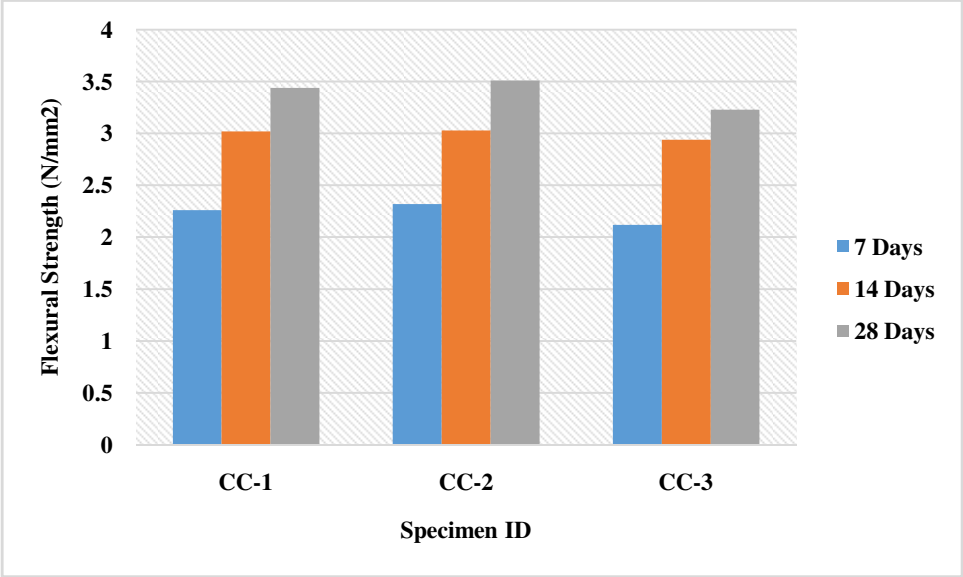

Figure 3 Flexural strength

From the figure 3, the average flexural strength of M20 grade concrete is 2.23MPa, 3.00MPa and 3.39MPa at 7 days, 14 days and 28 days respectively. The 7 days and 14 days average flexural strength is 66.78% and 88.5% the 28 days average flexural strength.

4. Flexural behavior of beam

4.1 Beam Casting and Detailing

Three reinforced concrete beams of width 150mm, depth 250mm and 3000mm length was cast with 2numbers of 12mm diameter bars as tension reinforcement and 2numbers of 10mm diameter bars as hanger bars with 8mm diameter bars as transverse reinforcement placed at 125mm center to center distance. All beams are cast with M20 grade concrete mix ratio1:1.5:3. The details of reinforced concrete beam is presented in Figure 4.

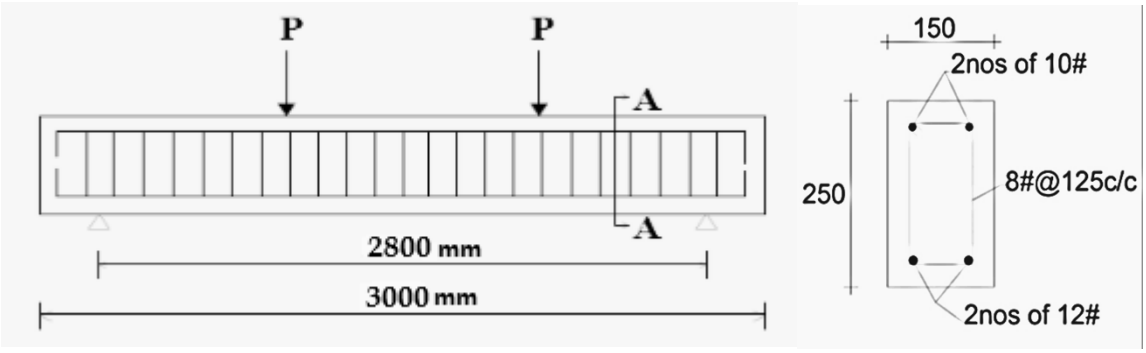

Figure 4 Beam detailing

The M20 grade concrete mix is prepared with a proportion of 1:1.89:3.56 of cement, fine aggregate and coarse aggregate.

4.2 Strengthening of Beams

One beam served as control concrete beam and the other beam as strengthened with 2-layered BFRP laminates at the soffit of the beams using epoxy resin and kept cured for 7days at room temperature. Two beams are tested under four-point bending until failure. The BFRP strengthening process is shown in figure 5.

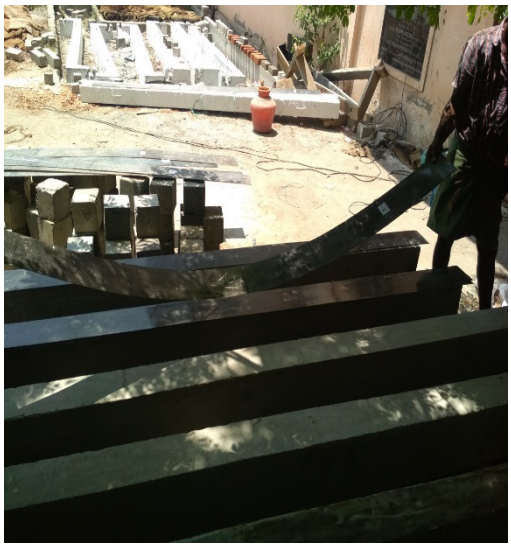

Figure 5 Strengthening of beam

4.3 Test Protocol

The beams prior to testing are white washed for better visibility of cracks while the testing is conducted. The beam to be tested is simply supported over the testing machine with a bearing of 100mm from both the ends. Hydraulic jack is used for two-point load application and the load cell measures the applied load. Steel plate is placed over the beam specimen for uniform load transmission. Strain gauges are fixed at top, middle and bottom of the beam to measure the compressive, neutral and tensile strain respectively. Deflection of the beam can be read from LVDT which is placed at the soffit of beam. The load cell is bought to 0kN and the whole experimental test setup is planned for cyclic distribution of load as shown in Figure 6.



Figure 6 Test protocol

4.4 Load-Deflection

Table 6 Load and deflection of beams

Sl. No	Beam ID	Load (kN)	Deflection (mm)
1	0BFRP	39	24.60
2	2BFRP	40	24.20

Fig.7 Load-Deflection for beams

TheFig.7 inferred that, the ultimate strength of 2-layered BFRP strengthened beams enhanced by 2.56% than compared to that of control concrete beam. Also,the control concrete beam has a deflection of 24.6mm and it got reduced by 1.63% by external strengthening of 2-layered BFRP laminates.The load-deflection behavior is found to be typical in the initial stage for control concrete beam and 2-layered BFRP beam.

4. Conclusion

4.1 Mechanical Properties

The average compressive, split tensile and flexural strength at 28 days of tested specimen is 17.85MPa, 1.93MPa and 2.23MPa respectively. It is to be noted that the casted cube specimen attains the target strength of concrete of 26.6MPa. The 7 days and 14 days average compressive strength is 64.11% and 90.23% the 28 days average compressive strength. The average split tensile strength of 7 days and 14 days is 62.25% and 91.61% the 28 days average split tensile strength. Also, the 7 days and 14 days average flexural strength is 66.78% and 88.5% the 28 days average flexural strength.

4.2 Flexural behavior of beam

The application of BFRP laminates at the soffit of the RC beams proved to be an effective strengthening to enhance the ultimate load carrying capacity of RC beams. Near surface mounted BFRP laminate strengthening techniques are found effective to enhance load carrying capacity

and controlled deflection of RC beams. The 2 layer of BFRP plates in strengthening of beams decreases the deflection and increases the load carrying capacity.

5.References

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