Investigation on Mechanical Properties of Concrete Specimens Wrapped With Uni-Directional Basalt Fibre Reinforced Polymer Composites

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Abstract: The continual deterioration of concrete structures have heightened awareness of the need for effective structural repair and rehabilitation methods. In addition, the structures designed using old code provision must be retrofitted to meet the latest code provision. This paper presents the results of experimental studies on mechanical properties of concrete cylinders, Cubes and flexural beams confined with Uni-directional basalt fibre-reinforced polymer composite with one layer to up-to four layers.To study, the specimens are cast using M30 grade nominal mix concrete and tested for compressive strength, split tensile strength and modulus of rupture after a curing period of 28 days.The results showed that significant enhancement in the compressive strength,split tensile strength, and flexural strength of the BFRP-wrapped concrete specimens as compared to unconfined concrete specimens.

Keywords: Basalt fibre, modulus of rupture, split tensile strength, compressive strength, polymer composites

I. INTRODUCTION

Concrete is the one of the most commonly used composite materials for construction both on-shore and off-shore. The two main problems that are of interest in the durability and life of reinforced concrete structures are deterioration of concrete itself due to the aggressive salts in marine environment and the corrosion of steel reinforcement in concrete. The deterioration of concrete in itself is a factor that contributes to the corrosion of reinforcement, which in turn leads to distress in concrete structures. Other causes of distress include cracks due to drying shrinkage, temperature stresses, chemical reactions etc., continued exposure to aggressive environment and neglect of timely maintenance can lead to failure of structures - necessitating unforeseen and expensive repairs. The economic loss should also include the costs relating to non-functioning of any facility during repairs.

The repair or rehabilitation of concrete structures has been achieved by bonding steel plates to the structure [1]. Although this technique has proven to be reasonably effective, it has several distinct disadvantages like susceptibility of steel plates to corrosion and/or de-bonding and the weight of the steel plate may be excessive for long-span beams. In recent years, however, fibre reinforced plastic (FRP) plates have shown great promise as an alternative to steel plates for concrete beam repair/rehabilitation. FRP offer excellent corrosion resistance to environmental agents as well as the advantages of high stiffness-to-weight and strength-to-weight ratios when compared to conventional construction materials. Perhaps the biggest advantage of FRP is tailorability[2].Fibre may be eitherglass fibre[3] or carbon fibre or aramid fibre. Depending upon the type of fiber used, product isknown as Glass Fibre Reinforced Plastic (GFRP), in case glass fibre is used,Carbon Fibre Reinforced Plastic (CFRP)[4], in case Carbon fibre is used and AramidFibre Reinforced Plastic (AFRP), in case aramid fibre is used[5]. The main advantages of FRP materials are their lightweight,high strength and stiffness, resistance to corrosion and flexibility. Recently the retrofitting of concrete specimens and reinforced concrete piles using basalt fibres are used[7],[8]. The study explains the behaviour of cubes, cylinders, prisms and reinforced piles retrofitted using basalt fibres. The result shows that the specimen with double wrapping of basalt further gives better performance when compared too with conventional and single wrapped specimen. The experimental investigation on the Flexural Behaviour of Damaged RC Beams Strengthened in Bending Moment Region with Basalt Fibre Reinforced Polymer (BFRP) Sheets results in high load carrying capacity [9]. In this research paper, the BFRP laminates are wrapped to the concrete specimens with epoxy as bonding materials. The investigation has been carried out on the behaviour of strengthened beams with number of layers.

II. EXPERIMENTAL PROGRAMME

Materials properties

Cement:

The cement used in this experimental study is 53 grade PortlandCement conforming to IS 12269-1987. All properties of cement are tested The properties of cement are given in table 1.

Table 1 Properties of Cement

Sl no	property	values
1	Specific gravity	3.15
2	Fineness	98.5
3	Initial setting time	50min
4	Final setting time	480 min
5	Standard consistency	32%
6	Finess modulus	7%

Fine aggregate:

Fine aggregates are the aggregates whose size is less than 4.75mm. Sand is generally considered to have a lower size limit of about 0.07mm. Material between 0.06 and 0.002mm is classified as silt, and still smaller particles are called clay. In this project, clean and dry river sand available locally is used.The properties of fine aggregate are given in table 2

Coarse aggregate:

The aggregates most of which are retained on the 4.75mm IS sieve are termed as coarse aggregates. In this project, coarse aggregates of maximum 20mm size are used.The properties of coarse aggregate are given in table 3

Water:

Portable tapwater available in the laboratory with PH value of 7.0+1 and conforming to there requirement of IS456-2000 was used for mixing and curing the specimen .

Basalt Fibre:

Basalt fibre is a material made from extremely fine fibres of basalt, which is composed of the minerals plagioclase, pyroxene, and olivine. It is similar to carbon fibre and fibre glass, having betterphysical and mechanical properties than fibre glass, but being significantly cheaper than carbon fibre Basalt fibre is made from a single material, crushed basalt, from a carefully chosen quarry source and unlike other materials such as glass fibre, essentially no materials are added. The basalt is simply washed and then melted. The manufacture of basalt fibre requires the melting of the quarried basalt rock at about 1,400 °C (2,550 °F). The molten rock is then extruded through small nozzles to produce continuous filaments of basalt fibre. There are three main manufacturing techniques, which are centrifugal-blowing, centrifugal-multiroll and die-blowing. The fibres typically have a filament diameter of between 9 and 13 µm which is far enough above the respiratory limit of 5 µm to make basalt fibre a suitable replacement for asbestos.They also have a highelastic modulus, resulting in excellent specific strengththreetimesthatof steel.

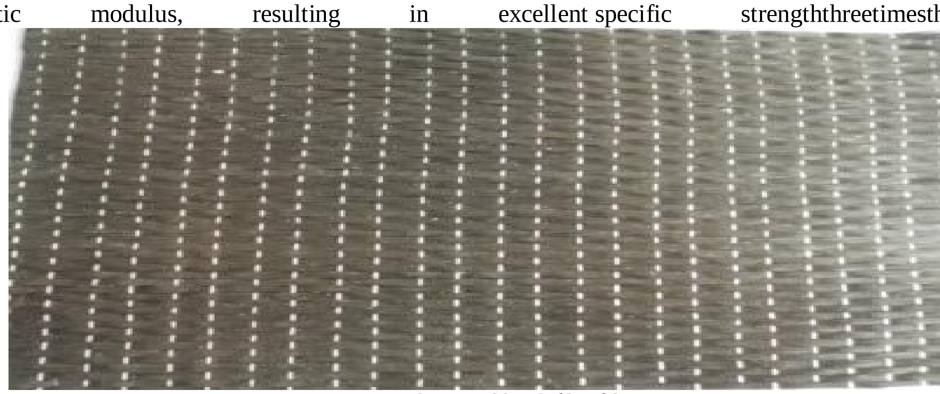


Figure 1.Unidirectional basalt fibre fabric

Gluing Material:

Epoxy resin is a solvent less, modified epoxy resin manufactured from Epichlorohydrine and Bisphenol-A and further modified with reactive diluents. It can be cured at room temperature with polyamide hardener for various coating applications. Hardener is selected suitable room temperature cure hardener for the above resin. The mix in general, is a slow curing and therefore it has long pot life. This enhance user to mix large quantity of materials and they can do the coating neatly. This hardeners are generally low viscous, which enables users to incorporate more fillers. Epoxy resin with hardener was used as a bonding material to basalt fibre cloth and in concrete extract. The proportion of resin: hardener is 1.0:0.5. The properties of resin and hardener are shown in Table 4.

Table 2Typical Property Of Epoxy Resin And Hardener (Values Given By Manufacturer)

Properties	Epoxy Resin	Hardener
Appearance	Clear low viscosity liquid	Pale yellow liquid
Viscosity at 30°C	550-650 cps	300-400 cps
Type	Room temp. Cure	Room temp. Cure
Epoxy equivalent	180-200	-
Amine value	-	380-420
Specific Gravity at 30°C	1.1-1.2	0.96-0.98

Mix proportion

Mix proportion for M_{30} grade is being designed by IS 10262-2007. Initial tests on all the ingredients of concrete were done and the results were tabulated.The proportion arrived is 1:1.76:2.3.The water cement ratio is 0.42.

Specimen preparation

The concrete was produced with a similar mixture design before casting in standard cylindrical, cube and beamsformworks. Totally twenty cubes, twenty cylinder and twenty beams were cast . After 28 days water curing, the surface of specimens were cleaned and prepared for wrapping. The Basalt fibre cloth was cut and impregnated with epoxy resin by the hand lay-up technique. The epoxy resinconsisted of two components, the main resin and the hardener. The mixing ratio of the components by weight was 2:1 and they were mixed for three minutes. The Basalt fibre cloths were configured in predefined orientations, and then were impregnated with the epoxy resin. Epoxy resin should be cured in laboratory temperature for a minimum of seven days.

III. TEST PROGRAMME

Compressive strength test:

The compressive test is carried out on specimens cubical in shape. The cube specimen is of the size 150 X 150 X 150 mm. The cubes are tested as per IS: 516-1979. The tests are done on an electro-hydraulically operated compression-testing machine and compressive load is applied on opposite faces axially, slowly at the rate of 800 kN/minute. The compressive load is noted for the ultimate failure. Twenty specimenswere tested to determine the compressive strength of conventional specimen (without wrapping) and wrapped specimens.The results are presented in table no:5

Figure 5.Compressive Strength Testing on U 4

Split tensile strength test:

Split tensile strength test is carried out on the 800KN capacity compressive testing machine. The 150mm diameter, 300mm length cylinders are used for this test according to IS516-1959. Twenty cylinders were tested to determine the split tensile strength of conventional specimen (without wrapping) and wrapped specimens.The tested values are tabulated in table no 6. The test set-up is also shown in figure

Figure 8. Split tensile strength on U 1 and Control

Flexural strength test:

The flexural strength test is carried out on Flexural testing machine. The 100X100X500 mm prisms are used for this tests according to IS: 516-1959. Totally twenty prisms were tested to determine the flexural strength of conventional (without wrapping)and Wrapped specimen for 7and 28 days.Flexural testing set up is shown in figure

IV. RESULTS AND DISCUSSIONS

a) *Compressive Strength*

The compressive strengths values for the control Specimen (without wrapping), one layer ,Two layers Three layers and Four layersWrapped specimens are shown in table 5.

Table 5. Results of Compressive Strength

Duration	Compressive strength (N/mm^2)				
	Control beam	One layer	Two layer	Three layer	Four layer
7th Day	22.80	26.60	31.55	36.88	40.67
28th Day	40.44	45.77	51.67	54.00	59.78

The percentage increase of compressive strengths for one layer up to four layers at 7 days and 28 days are shown in figures.

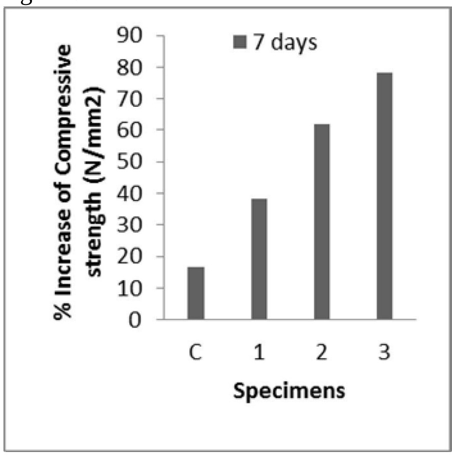


Figure 3 Comparision of compressive Strength of specimens at 7 days

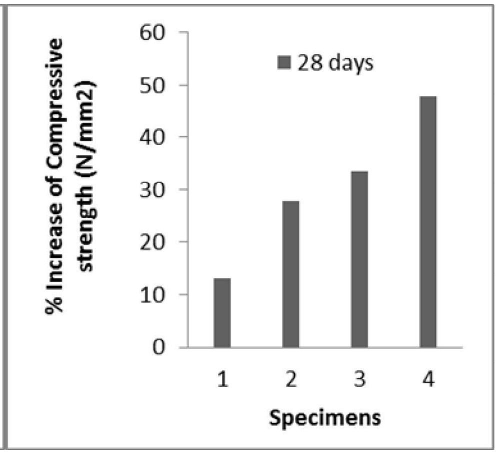


Figure 4Comparision of compressive Strength of specimens at 28 days

b) *Split tensile Strength*

The split tensile strengths values for the control (without wrapping), one layer ,Two layers Three layers and Four layers Wrapped specimens are shown in table6.The percentage increase in the split tensile strength of one layer,two layers ,three layers and four layers after 7 days and 28 days are shown in figures.

Table 6. Split tensile Strength

Duration	Split tensile strength (N/mm^2)				
	Control beam	One layer	Two layer	Three layer	Four layer
7th Day	2.62	3.62	4.86	5.07	5.8
28 th Day	3.4	4.93	6.50	7.96	8.1

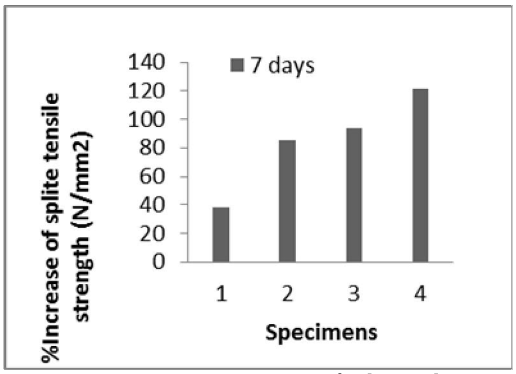


Figure 3 Comparision of split tensile Strength of specimens at 7 days

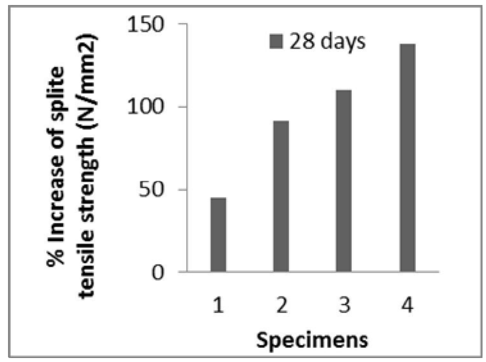


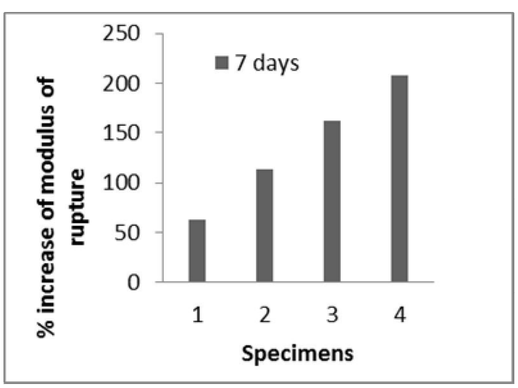
Figure 4Comparision of split tensile Strength of specimens at 28 days

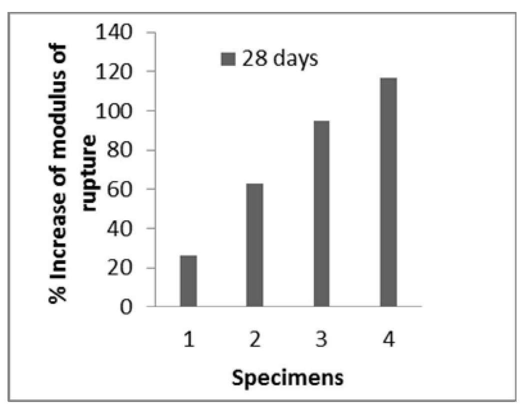
c) Modulus of rupture

The modulus of rupture values for the control (without wrapping), one layer ,Two layers Three layers and Four layers Wrapped specimens for 7 days and 28 daysare shown in table 7

Table 7.Flexure test results of specimens

Duration	Average Flexural strength (N/mm^2)				
	Control beam	One layer	Two layer	Three layer	Four layer
7th Day	2.4	3.90	5.13	6.28	7.40
28 th Day	5.1	6.90	8.30	9.95	11.05





V. CONCLUSION

1) The result of the experimental study indicates that externally bonded BFRP laminates can be used effectively to strengthen the reinforced concrete elements.

2) If the number of layers of fibre increases the compressive strength,flexural strength and split tensile strength are apparently increased.
3) The 28 th day compressive strength for four layers specimen gives higher value than the control specimen
4) The 28 th day split strength for four layers specimen gives higher value than the control specimen
5) The 28 th day flexural strength for four layers specimen gives higher value than the control specimen
6) Based on the observation, BFRPfibre can be used as repair and retrofitting materials.

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