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Comparative Study on Strengthening of Concrete Structures using Natural and Artificial fibers

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Abstract. In India, most of the existing buildings, bridges and historical monuments are more than 50 years old. Demolition of the entire structure and construction of new structure is not a feasible solution as it involves lot of investment, time, and effort. So there is a drastic increase in the demand for low cost and most sustainable fiber composites for strengthening/retrofitting of the existing buildings and bridges. In the present paper, the possibility of using basalt fiber as a strengthening material for retrofitting of the reinforced concrete structures is explored. Normal strength concrete cylinders were cast and wrapped with Basalt fiber fabric. The results are compared with specimens wrapped with one layer of carbon fiber and control specimen. Test results showed an improvement in compressive strength of cylinders as the number of layers of wrapping of basalt fibre fabric is increased. The load deflection performance of wrapped specimens is also found promising in terms of stiffness and ductility.

Keywords: Retrofitting; Basalt fiber; Carbon fiber; Compressive strength; Ductility

1. Introduction

A survey conducted by the Union Ministry of Surface Transport reveals that out of 6500 bridges in India 5600 needs to be retrofitted or strengthened. So there is a drastic increase in the demand for a sustainable method for strengthening/retrofitting of the existing buildings and bridges. At present, the construction industry is fixating on the development of sustainable and eco-friendly fiber composites for the strengthening of concrete structures. Various researches are going on to find out a low cost eco-friendly retrofitting fiber composites. Many research works are focused on the use of natural fiber which can give better performance compared to the artificial fibers. The retrofitting of existing reinforced and pre-stressed concrete structures has always been a concern in the current industrial scenario. Besides the natural ageing and damage of structures and materials, there are many other reasons that urge for the structural rectification. These include a change in utility of the structure, insufficiency in design and construction, environmental factors, lack of maintenance and unexpected or other impact loadings. Effective renovation and rehabilitation of structures seek new materials which are economical and convenient. Although there are different types of fibers available in the market, it is difficult to identify a single fiber which can provide high strength and low cost. Usage of Carbon fiber in retrofitting not only leads to environmental pollution but also causes different health issues. Current research focuses on the development of a sustainable fiber which is pollution free, user-friendly, strong and economical.

Many research works are carried out in past on the usage of fibre reinforced composite like glass, carbon , basalt etc. for strengthening of concrete structures (K.M. Mini et.al^[1] (2014), Jikai Zhou et.al^[2] (2016), I. S. T. Liu et.al^[3] (2006), Akhila Padanattil et.al^[4] (2014). But the application of natural fibers like basalt as a strengthening materials is not gained much popularity as that of artificial



fibers (Vivek Dhand et.al^[5] (2015), I.D.G. Ary Subagia et.al^[6] (2014), Ahmed El Refai ^[7] (2013), Ahmet B. Kizilkanat et.al^[8] (2015), V. Fiore et.al^[9] (2015), Cory High et.al^[10] (2015), Nayan Rathod et.al^[11] (2013))

G Campione et al. ^[12](2015) demonstrated the behaviour of concrete cylinders externally wrapped in compression with basalt and carbon fibres. The post-peak resistance and the axial strain of confined concrete corresponding to basalt fiber reinforced polymer failure have been found increased by a reduction in brittleness of unconfined concrete. Jongsung Sim et.al (2005)^[13] conducted various experiments to examine the durability and mechanical properties of basalt fiber and studied the application in structural concrete members as a strengthening material. Bin Wei et.al (2010)^[14,15] observed a reduction in the tensile strength of fibres with an increase in treatment time. Also, the variation in strength with treatment time is found similar for both basalt and glass fibers in alkali environment. However, basalt fibers are found better than glass fiber in terms of acid resistance and chemical stability. The basalt fiber reinforced composite is used in a chemical environment for long-term operations.

The present paper reports the comparison of performance of Basalt fiber vis-à-vis of carbon fiber for strengthening applications. This paper contrasts the wrapping effect on the compressive strength of the structure wrapped with varied number of basalt layers and one layer of carbon fiber. Basalt fibers have a noticeable potential to replace the conventional carbon fiber in terms of cost, design, environmental friendliness and high strength. The focus of this research work is to suggest an alternative to carbon fiber (artificial fiber) in terms of strength and sustainability.

2. Experimental setup

2.1 Concrete and Mix proportions

The concrete test specimens are prepared based on the mix design conforming to IS 10262-2009^[16]. Target design level of concrete mix is set as 30 MPa. 53 grade Dalmia brand ordinary Portland cement according to IS 12269-2013^[17] with water -cement ratio of 0.5 are used. The fine aggregates with a specific gravity of 2.67 (river sand) and coarse aggregate passing through 20 mm are used. The quantity of consumables used for performing the test are listed in Table 1.

Table.1. Quantity of Materials used

Sl.No	Particulars of item	Quantity per m ³
1.	Cement	312 kg
2.	Fine Aggregate (River sand)	565 kg
3.	Coarse aggregate (20 mm nominal size)	758 kg
4.	Water	156 litres

2.2 Adhesives/chemicals and Fibers

Adhesive used as a bonding layer between concrete and fibers is a mixture of 100 parts by weight of LY 556 Epoxy resin to 15 parts by weight of HY 991 hardener. A characteristic tensile strength of 85 MPa and modulus of elasticity of 3.8 GPa for epoxy resin is observed. Basalt fiber fabric and carbon fiber fabric having a size of 300 gsm are used in the experiment.

2.3 Specimen preparation and test procedures

Concrete cylinders with 100 mm diameter and 200 mm height are cast (Table 1) and are water cured for 28 days. After curing, the cylinders are dried at room temperature. 100 parts by weight of epoxy resin to 15 parts by weight of hardener are thoroughly mixed in a steel container. A prime coat of adhesive is applied initially over the concrete cylinder in order to eliminate the surface

irregularities. The confinement used in the test concrete specimens are 1 layer carbon FRP (CFRP 1 Layer), 1,2 and 3 layers of Basalt FRP(BFRP 1 Layer, BFRP 2 Layer, BFRP 3 Layer) . The basalt/carbon fiber fabrics is tightly wrapped around the exterior of test cylinders and hold it for some time in order to make the confinement air tight. Additional layers of epoxy resin hardener are applied rapidly over the exposed surface of the fabric as the number of wrapping increases. The test cylinders after confinement are kept for air drying for 24 hours at room temperature. Tests are carried out after proper drying. A compression testing machine with a capacity of 2000 kN is used for the calculation of compressive strength of the test specimen.



Figure 1. Concrete test cylinders wrapped with Basalt Fibre



Figure 2. Testing of Basalt specimen in Compression Testing machine

3. Results and Discussion

3.1 Cylinder Compressive Strength

Table 2 presents the cylinder compressive strength values of various test specimens. From the results, it is observed that compressive strength increases with wrapping of fibre fabric. A comparable and increased compressive strength vis-à-vis single layer carbon fibre fabric wrapping is observed with basalt fibre from two layers wrapping onwards. There is a drastic improvement in the compressive strength of test specimen as number of layers of wrapping increases. Hence, an equivalent compressive strength can be achieved by increasing the number of wrapping of basalt fibre fabric. The strength corresponding to 2 Layer BFRP almost matches with that of 1 layers CFRP.

Table 2 Compressive strength of cylindrical specimens

Sl.no	Specimen	Cylinder Compressive Strength (MPa)
1	Control Mix	31.84
2	BFRP 1 Layer	35.96
3	BFRP 2 Layer	39.51
4	BFRP 3 Layer	46.15
5	CFRP 1 Layer	38.88

3.2 Load-Deflection Behaviour

Figure 2 shows the load-deflection behaviour of cylindrical specimens wrapped with fiber fabric. An increase in stiffness is clearly observed with the wrapping of specimens. A single layer wrapping of carbon fiber fabric proves to give larger stiffness vis-à-vis basalt fabric. However, a substantial increase in ductility and improvement in post-cracking behaviour is observed with

basalt fabric wrapping. A single layer of basalt fibre fabric shows a clear rise in stiffness even though no drastic change in ductility is observed compared to control specimen. The confinement caused by the fabric during Poisson effect of concrete may be the reason for the increase in stiffness. The increase in ductility can be interpreted as the mobilisation of the tensile strength of fabric after cracking of concrete. The possibility of a catastrophic failure in basalt fabric confined specimen is nominal due to improved ductility.

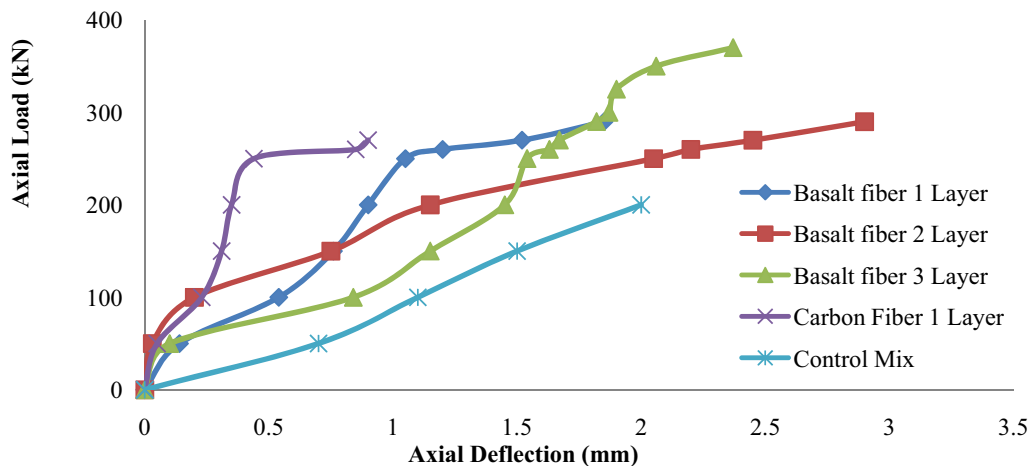


Figure.3. Comparison of Load v/s Deflection of Concrete with varied layers of Basalt and Carbon Fiber

4. Conclusions

The present study focuses on strengthening of plain concrete cylinder with varying layers of basalt and one layer of carbon fiber fabric wrapping. A comparison of compressive strength and load-deflection behaviour of basalt fibre with single layer wrapping of carbon fiber fabric is carried out. The results are compared with control specimens.

From the experiments conducted an increase in compressive strength is observed with fiber wrapping. The compressive strength increased with increase in number of layers of wrapping. Load-deflection behaviour also shows a noticeable improvement. A clear enhancement in stiffness is also observed by wrapping with fiber fabric. The ductility is found to increase for basalt wrapped specimens. Two layers of basalt fibre fabric wrapping can provide a similar and better performance than mono layer carbon fibre fabric wrapping. It is also observed that sudden and brittle failure is minimised by basalt fibre wrapping.

Basalt fibre fabric has been found promising in strengthening and retrofitting of old structures over carbon fibre fabric. Basalt is found competent in terms of compressive strength and ductility. As it reduces the chance of brittle failure, basalt fibre can be employed in earthquake strengthening applications. The cost of the entire retrofitting can be reduced by using basalt fiber as an alternative to costly and polluting carbon fibre fabric. Being a natural fibre, basalt provides a sustainable development in construction.

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