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Research paper

Experimental Study on Strengthening of RC Short Columns with BFRP Sheets

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Abstract.

Earlier the methods adopted for the repair and rehabilitation were the external bonding of the damaged component with steel fibers and steel jackets. But the major problem that caused due to this steel components is corrosion. Fiber Reinforced Polymer (FRP) composite materials used for strengthening of components in the form of confinement is of considerable importance in civil engineering. This paper presents the results of axially loaded RC short columns which are strengthened by providing confinement with new material BFRP. The primary objective of this work is to examine the load carrying capacity of concrete columns confined with basalt fiber reinforced polymer jacket (BFRP) which is considered as an abstruse material for strengthening. BFRP materials are non-corrosive, non-magnetic, and chemical resistant and they are progressively being used for repair, rehabilitation, and strengthening of structures that are not stable enough to carry loads. The parameters considered in the study are full and partial wrapping and the number of layers of confinement. The results obtained from the experimental studies and the analytical models precisely shows that the BFRP confinements will upgrade the compressive strength of columns under the given load condition.

1. Introduction

Concrete structures are strengthened due to the deterioration of existing structure and failure of existing structure attributable to alterations made in the structure. The strengthening of reinforced concrete structures by providing lateral confinement has been under research until near past. Earlier methods adopted for enhancement and repair were external bonding with steel plates and steel jackets. But the major problem which occurs by using steel components is corrosion. The common problems associated with reinforced concrete structures are corrosion and structural deterioration. These problems propelled many researchers to venture into the use of alternative techniques and materials for concrete confinement.

Fibre Reinforced Polymer (FRP) have been used in the form of external wrapping such that it will strengthen the existing structure. Significant researches are being carried out in this field for the past few decades, as the need for strengthening has been grown rapidly, and many design guidelines have been published for FRP reinforcements including column confinement. The method of application of these fibers is of great importance. From the application point of view, the FRP products are placed, according to various techniques, such that the in case of discrete fibers they are dispersed in the matrix and fiber sheets they are wrapped around the structures. When the load is applied axially to a concrete column, there will be the lateral expansion, and it can be restrained by the effect of confinement provided by the FRP laminates. A lateral confinement pressure will be provided by FRP which delays the softening of the column under the various loading conditions and has shown to enhance the strength and ductility of the column [1].

The commonly used FRP materials are the carbon fiber reinforced polymer(CFRP), glass fiber reinforced polymer (GFRP), and aramid fiber reinforced polymer (AFRP), etc. The widely used material is CFRP.In spite of its high cost, it has been used for major repair works due to its exceptional mechanical properties compared to other fibers. Basalt fiber (BFRP) is a new material compared to carbon, aramid, jute, and glass. They are made from basalt rocks through the process of melting and contains no other additives in the process of manufacturing, which makes them advantages in cost compared to the carbon fibers [3]. The scope of the project work is to study the compressive strength of RC columns confined with Basalt fiber reinforced polymer sheets subjected to constant axial loads and comparing it with concrete columns without any external reinforcement. Comparison of failure pattern, ultimate load carrying capacity is studied.

2. Literature Review

Jin et al. research on the mechanical properties of columns retrofitted with glass fiber composite. [4]. The results showed that wrapping of existing concrete columns with glass fiber composite straps greatly increases the deformation capability and shear failure resistance. The failures happened due to brittle shear failure mode has been turned to ductile failure modes after the column was retrofitted. Watanabe et al. (1997) examined the effect of confinement of retrofitting of fiber reinforced polymer sheets on the ductility and strength properties of the cylinders subjected to uniaxial compression. It was found that the increase in confinement thickness proportionally increases the compressive strength of the concrete [5]. Shi Zhang et al. (2000) conducted experiments on increasing efficiency in the concrete columns with

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external reinforcements. It was noted that the fiber reinforced in hoop direction provides high strengthening to the columns. For best usage, the carbon fiber hybridized with glass fiber reinforcement can be used which tends to increase the mechanical properties [6]. M.N.S. Hadi" (2007) conducted some studies on the Behavior of eccentrically loaded concrete columns strengthened with CFRP. Based on tests results he concluded that the strength gain and ductility are obtained when columns are reinforced with CFRP laminates. [7]. Akshay P. Mote, H. S. Jadhav (2014) conducted a study on BFRP wrapped circular columns under axial loading. From the experimental results, it can be concluded that the columns strengthened with BFRP show high ductility index and load carrying capacity [8]. "Saravanan S, Sakthieswaran N, Shiny Brintha G (2016) conducted a study on axially loaded RC capsule columns wrapped with hybrid fibers like Glass, Basalt and Jute fibers. After experimental studies, the columns covered with hybrid fibers has got more axial compressive strength compared to unconfined column [9].

3. Experimental Studies

The experimental studies include testing of Basalt fiber reinforced polymer confined reinforced concrete columns of square cross-section. The main objective of the tests was to conduct experimental analysis on the load carrying capacity and to study the failure patterns of BFRP confined columns. In this experimental work, the columns were cast and wrapped with BFRP sheets and the tests were being conducted and material properties of relevant material reviewed.

Materials

Ordinary Portland Cement Grade 53 was used. All the physical properties were tested, and the results were obtained as per the standard specifications. The specific gravity of cement was 3.15 and the initial setting time was found to be 30 minutes. The river sand was used as the fine aggregate with a specific gravity of 2.604. The aggregates were of grading Zone II. The coarse aggregate of maximum size 20 mm was used, and its specific gravity was 2.6. For mixing and curing purpose Ordinary potable water which frees from chemical substances and suspended particles was used. Mix proportion adopted was M25 that is nominal mix proportion to get the 28th-day compressive strength as 25 N/mm2. The w/c (water cement) ratio of 0.5 was used. For determining the compressive strength, three cube specimens were cast and were tested for 7th, 14th and 28th day. The average compressive strength obtained at the 28th day of concrete was 26.373 N/mm2.

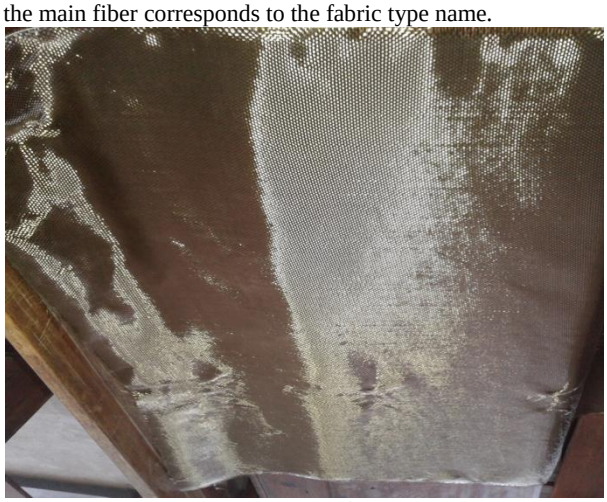


Reinforcement Details of Column

Basalt fibre

Unidirectional fabric sheet, GSM 300

The basalt roving was used to make the woven fabric sheet and was provided in 1000mmwide rolls. Thetotal material weight is 327 g/m^2 but the weight of the longitudinal fiber is 300g/m^2 which is the main fiber corresponds to the fabric type name.



Basalt unidirectional fabric sheet

Table 1: Properties of basalt fabric

Tensile strength (Mpa)	Tensile modulus of Elasticity(Mpa)	Elongation (%)	Thickness (mm)	Polyester Yarn density (tex)	Area weight (g/m2)
2100	105	2.6	0.115	5.25	300

Epoxy Resin

The epoxy resins used are Masterbrace 3500 (primer) and Masterbrace 4500 (Saturant).MasterBrace 4500 is a blue pigmented rein with long pot life and is 100% solid it is part of the MasterBrace resin systems for the creation of composite strengthening. Master brace 3500 is a primer which is applied over the concrete surface prior to the application of saturant.it is a mixer of two components that are a primer and a hardener.

4. Fabrication Procedure

Column specimens were constructed in the laboratory. The process of application of basalt sheets over the concrete surface consist of the following steps:

1. Surface preparation and application of primer.
2. Cutting of fabric according to the specifications.
3. Wrapping with the sheets and applying epoxy

The method adopted for retrofitting was the full wrapping of the concrete columns around all the four sides. The first step was the surface preparation that the surface of the column which is to be wrapped is to be cleaned and made rough with the help of a wire brush and then all the dirt and debris are to be washed with water. The columns are dried for 24 hours. After that, according to the instructions provided by the manufacturer the epoxy resin primer is to be mixed. Next, in a plastic container combine the epoxy matrix according to manufacturer's instructions to produce a uniform mix. First, a coat was applied over the concrete surface, and then the fiber sheet was wrapped over that surface, then second coating was applied over the sheet including the overlapping such a way that the resin is squeezed through the roving of the fabric. Basalt fiber wrapped concrete columns were cured for seven days at room temperature before testing.

Testing of columns

All short column specimens were tested on UTM (1000kN) as shown in the figure. The test procedure of all the columns was same. The surface of control columns was cleaned, and white cement was applied for the clear visibility of cracks. The load was applied until the failure took place. Then ultimate load and

corresponding deformation were noted down. First, the control specimen was placed inside the UTM, and the load was applied. Hydraulic jack did the loading. The ultimate load or fracture load was calculated.



Test setup

Table 2: Details of the columns tested

specimen	Column sizes (mm)	Fully/partially wrapped	No of layers
Control specimen C1	150x150	Nil	0
Control specimen C2	150x150	Nil	0
Test specimen F1	150x150	Fully	1
Test specimen F2	150x 150	Fully	2
Test specimen F3	150x 150	Partially	1
Test specimen F4	150x 150	Partially	2



Control specimens

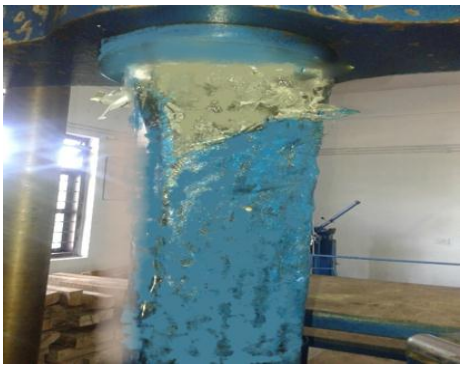
5. Results and Discussions

Failure Pattern

Test was continued until the failure of the specimen occurs. Total a number of 6 specimens were tested. It was found that the specimens with partially wrapped Basalt Fibre Reinforced Polymer specimens (F3 and F4) showed higher resistance compared with the fully wrapped and control specimens (C1,C2,F1 and F2).



Failure pattern of control specimen







Failure pattern of F1 , F2 and F3

Failure of the specimens could be divided into three types first mode is compression failure mode .The compression failure mode that is this is a brittle failure mode this type of failure occurs mainly in ordinary reinforced concrete components. In this study we can see this type of failure in the control specimens (figure 6.1).The second type of failure is the rupture of the laminates that is here we can see in some specimens there is rupture of BFRP laminates with sudden failure, this type of failure occurs for specimens which are wrapped with one layer of laminates. During the loading of these specimens a clicking sound could be heard, signifying the straining of the BFRP laminates and the cracking of the epoxy resins. This type of failure can be seen in specimen's f1 and f3. The third mode of failure is ductile failure it occurs with

the rupture of BFRP laminates .these type of failure occurs mainly because of the problems associated with the corner radius. In order to avoid such failure the columns can be provided with sufficient corner radius that is rounded corners with more than 20mm.
From the failure patterns of the control specimens it is clear that the failure occurs mainly due to crushing.as long as it is a short columns there is no chance of buckling. Due to crushing failure the cracks are mainly seen at the top and bottom of the column specimen. In order to avoid such failure economically some specimens are partially wrapped with BFRP laminates and some specimens are fully wrapped with BFRP laminates. The ultimate load carrying capacities of each specimens are graphically plotted and compared with the control specimens.

Table 3: Ultimate load values

Column marks	Description	Ultimate load	Percentage of increase in ultimate load
C1	Short control column	**370kN**	-
F1	Fully wrapped(1 layer)	**420 kN**	**11.90%**
F2	Fully Wrapped (2 Layer)	**485 kN**	**23.71%**
F3	Partially wrapped (1 layer)	**410kN**	**9.75 %**
F4	Partially wrapped (2 layer)	**440kN**	**14.89%**

6. Numerical Analysis with Models

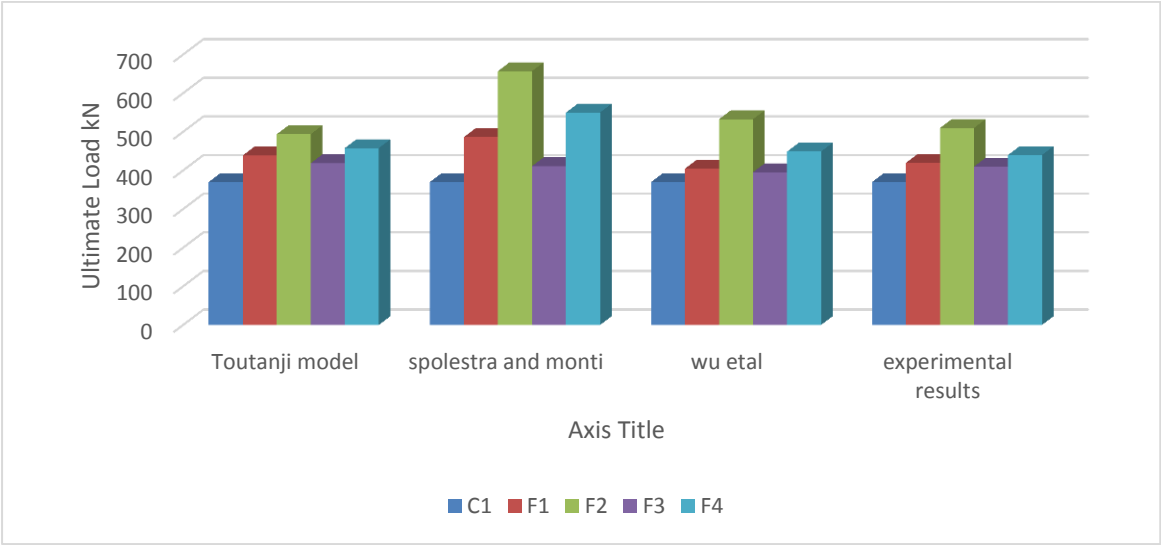
An analytical inference on the compressive strength of FRP confined concrete columns was obtained with the help of literature, To determine the ultimate load the ultimate stress that $f_{cu}$is to be calculated for that some of the available expressions from the previous studies are reported in Table 4.The other symbols in the table are: $-f_{co}$- peak stress in the unconfined concrete; f_{cc}– peak stress in the concrete; $-f_{lu}$- ultimate confinement pressure, and ρ_f– geometric reinforcement ratio,f_{ju}-Tensile strength of fibre,E_f- elastic modulus of fibers; t_{eq}– the equivalent thickness of fibers; b_f– strip depth ;p_f- strip spacing; n- number of FRP layers; D– diameter.

Table 4 : Expressions for ultimate strength

Reference	f_{cu}	f_{lu}
Toutanji [10]	$f_{co}(1+\left(\frac{f_{lu}}{f_{co}}\right)^{0.85})$	Fully wrapped=.$\frac{2n.teq.f_{ij}}{D}$ Partially wrapped=$\frac{2n.teq.b_f f_{ij}}{D.p_f}$
Spoelstra and Monti[11]	$f_{co}(0.2+3\sqrt{\overline{f_{lu}}}), \overline{f_{lu}} = \frac{f_{lu}}{f_{co}}$	
Wu et al.[12]	$0.75+2.5\frac{f_{lu}}{f_{co}}$	

Table 5: Comparison of the Experimental Results with Models

Column Marks	Experimental results	Toutanji model	Spoelstra and Monti model	Wu et al model
C1	370 kN	370 kN	370 kN	370kN
F1	420 kN	438.63 kN	486.33 kN	405 kN
F2	510 kN	493.79 kN	657.133 kN	532 8 kN
F3	410 kN	418.69 kN	411.07 kN	395.56 kN
F4	440 kN	457.85 kN	550 kN	448.8 kN



comparison chart

7. Conclusion

Axial strength of the columns can be increased efficiently by providing wrapping in the form of confinement using fibers. Columns fully wrapped with BFRP sheets shows better performance compared to the partially wrapped columns. The number of BFRP layers is one of the significant parameters that influence the behavior of concrete columns. To increase the confinement pressure, additional layers can be added so that the stiffness will also get increased. Various analytical models were analyzed and results obtained were compared with the experimental results.The results obtained were similar to the experimental results other than in Spoelstra and Monti model. Spoelstra model overestimates the ultimate load capacity of confined specimens.

References

[1] A.de Diegoa,Arteagaa, J. Fernándezb, R. Pererab, D. Cisnerosa, Materials de Construction, 65 320 (2015).
[2] A. Nanni and N. M. Bradford, Construction and Building Materials, 9 115-124(1995),
[3] J. Sim,Composites Part B: Engineering, 36 504-512 (2005).
[4] L.Jin, H.Saadatmanesh, and M.R Ehsani, Infrastructure Repair Methods-Infrastructure: New Materials and Methods of Repair, Proceedings of the Materials Engineering Conference, 758–764 (1994),
[5] K.Watanabe, Non-metallic (FRP) Reinforcement for Concrete Structures, Proceedings of the Third International Symposium, 233-238 (1994).
[6] Shi Zhang, Lin Ye and Yiu-Wing Mai, Applied Composite Materials 7 125–138(2000).
[7] Muhammad and N. S Hadi, Composite Structures 77 (1) 92-96(2007).
[8] Akshay P. Mote and H. S. Jadhav, Int. Journal of Engineering Research and Applications, 4 89-92 (2014).
[9] S.Saravanan,N.Sakthieswaran, ShinyBrintha, Journal of Research in Advent Technology, 3 6 (2015).
[10] H.A. Toutanji, ACI Materials Journal, 96 (3) 397-404 (1999).
[11] M.R. Spoelstra and G. Monti, Journal for Composite Construction, 3 (3) 143-150 (1999).
[12] G. Wu, Z.T. Lu, Z.S.Wu, Construction and Building Materials, 20 (3) 134-148 (2006).
[13] J.G. Teng, T. Jiang, L. Lam, Y. Luo, ASCE Journal Composite Construction, 13 (4) 269-278 (2009).