

Assessment of Compression strength of Concrete Columns Confined with Basalt Fibre Reinforced Polymer

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Abstract. Columns are the main load bearing element of a structure. Therefore, columns have an important function in many structures and can be vulnerable to exceptional loads. As structures age, the columns often have a lack of transverse reinforcement, which is unable to provide sufficient confinement to the concrete core or to prevent buckling of the longitudinal reinforcement which causes premature strength degradation of the column. The primary objectives of this research are to investigate the behaviour of axially loaded concrete columns confined with an obscure material in civil engineer for strengthening, basalt fibre reinforced polymer jacket (BFRP). This paper presents a test program that was done on concrete blocks confined with basalt fibre reinforced polymer (BFRP) and examination of its compression strength. The test results show that the strength enhancement of the concrete blocks consists of more ductile behaviour.

1. Introduction

The wrapping of basalt grids/mesh (BFRP) (Figure 1) around concrete columns is a promising method for structural strengthening and repair for their unique properties in terms of strength, lightness, chemical resistance and ease of application. This strengthening technique is of practical interest for their fast application and low labour cost. The sheets provide a passive confinement to the concrete core and react against the lateral dilation of the column under compression, which delays the weakening of the concrete and has shown to enhance both strength, ductility and ability to resist harsh environmental hazards like earthquakes, fire outbreak, etc of the column [1]. Great work has been done in the experimental and analytical areas on concrete specimens of circular columns since the development of fibre reinforced polymer (FRP) wrapping started in the 1980s and later on, columns of square and rectangular cross sections [2, 4, 5]. Experimental work have mostly focused on the common fibre reinforced polymer materials on the market which are carbon (CFRP), glass (GFRP) and aramid (AFRP) fibre. Basalt fibre reinforced polymer (BFRP) is a new material in civil engineering compared to carbon, glass and aramid and has shown/proved to a large extent to be a promising material for infrastructure strengthening. BFRP is made from basalt rocks through melting process and contain no other additives in the producing process which makes advantages in cost. Basalt fibres when compared to glass fibre show comparable mechanical properties at lower

cost and exhibit good resistance to chemical and high temperature exposure [5]. The ultimate strain of BFRP is higher compared to other common FRP materials based on this, it is interesting to use this advantage in column strengthening to enhance the seismic performance. Though the invent of basalt materials has been long, there is little research concerning the application of basalt fibre in civil engineering and its strengthening efficiency on concrete elements.



Figure 1. Basalt grids/mesh (BFRP).

To prepare the grid/mesh (Figure 1), quality basalt fiber is used, which is prescribed by the appropriate polymer compositions in the process. Figure 1 is ecostroy-sbs basalt grid 25x25mm.

Technical characteristics of the construction grid Ecostroy.

- Tensile strength: longitudinal direction - 50 kN / m, transverse - 50 kN / m.

- The relative elongation (longitudinal, transverse direction) is about 4%.
- The surface density is 200 g / m².
- Characteristics of the roll: width - 36cm, length 50m.
- Cell parameters: 25x25 mm.

There are ways to use basalt materials in increasing the mechanical performance of concrete. Basalt fiber reinforced concrete (BFRC) is constructed by adding certain proportions of chopped basalt fiber into the mixture for concrete. There are already many researches on the mechanical performance of basalt fiber reinforced concrete (BFRC) which have been reported. The slumps, workability, liquidity, and early cracking behavior of concrete structures with different contents of basalt fiber were explained in [6]. The authors of [6] found that the concrete structure with 0.5% (volume fraction) of basalt fiber maintain good workability. The early shrinkage of concrete structures can be significantly reduced by Basalt fiber. Adding a certain amount of basalt fiber can reduce concrete cracks by as high as 98% as basalt fibre is highly resistance to cracks. According to the studies of Borhan et al. [7], concrete compression strength with different contents of basalt fiber. Further on, [7] discovered that concrete compression strength increases when basalt fiber content (volume fraction) increases from 0% to 0.3%, but decreases by 12% when basalt fiber content (volume fraction) further increases to 0.5%. According to [8], Kabay studied the cracking resistance and wear resistance of concrete structures with different contents of basalt fiber, concluding that even low basalt fiber content can increase the intensity of toughness, crack resistance, and wear resistance of concrete structures. Based on a quasi-static flexural experiment, [9] pointed out that basalt fiber can enhance the toughness of mortar. Mortar with basalt fiber presents stronger toughness and higher sensitivity to strain rate compared to plain mortar. These research results have demonstrated that a reasonable content of basalt fiber can enhance mechanical properties of the concrete structure. They have laid the groundwork for studying effects of basalt fiber on enhancement of compression members of RC. The application of basalt fiber in RC columns has been reported by a few studies. The influence of basalt fiber content ws tested on the compression failure of concrete structures, the buckling of steel sections, and the debonding performance of the steel-concrete interface section of composite steel-concrete columns [10]. The results demonstrated that the structural behavior and strength of BFRC columns could be improved significantly by increasing the basalt fiber content (%). According to [11] the effects of basalt fiber content on the physical and mechanical parameters of three recycled concrete structures with different recycled aggregate replacement ratios (0%, 50%, and 100%), and then carried out a contrastive analysis about mechanical properties of short recycled concrete axial compression columns with different basalt fiber contents were discussed and the results showed that basalt fiber is superior to common concrete in term of enhancement of recycled concrete structures. Furthermore, basalt fiber can be used to enhance the mechanical properties of

recycled concrete structures and corresponding short columns.

This paper presents results and their comparisons from the tests that were performed on BFRP tensile coupon specimens and concrete rectangular confined with BFRP under concentric compression loading.

2. Experimental procedure

2.1 Tensile tests

Tensile tests were made on six specimens to determine the actual material strength of the basalt fibre reinforced polymer (BFRP) composite. The BFRP was formed from unidirectional basalt grid/mesh. The basalt grid/mesh had a nominal thickness of 0,65 mm, which was used for the calculation of material properties.

A single layer of BFRP tensile specimen was prepared and tested of 30 mm width and 300 mm length. Each end had an additional layer on each side for more strength at the gripping zone. The preparation started with the usual wet layup process involving the impregnation of each basalt sheet with epoxy resin, followed by the application of an additional layer of sheet at each end.

All the specimens were stayed for seven days at room temperature before undergoing the testing. All specimens were tested in a testing machine with an applied load capacity of 100 kN at a head displacement rate of 2 mm/min based on the recommendation of ASTM [12]. The longitudinal strains were measured simultaneously using two strain gages at opposite sides of the specimens with an active gage length of 6 mm. In the results, the strains are the average from the two strain gages. Two computers were used for data reading, one for the load reading and one for the strain reading.

2.2 Compression tests on BFRP confined rectangular columns

Total of 11 columns, comprising of rectangular concrete columns of 100mm x 100mm x 400mm were casted with a concrete of 25 MPa compressive strength done in the laboratory of civil engineering, academy of engineering in Peoples Friendship University of Russia (RUDN University). To check the confinement stiffness variation, the specimens were wrapped with one layer of basalt grids/mesh which is referred to as layer of BFRP jacket (Figure 2). Five rectangular columns were without jackets for examining the unconfined concrete strength. Six identical rectangular specimens were made with of BFRP confinement.



Figure 2. Lying of Basalt grids/mesh (BFRP) for confinement.

Before casting, the basalt grids/mesh of Figure 1 were cut to size the rectangular form then, laid inside rectangular forms. The basalt fibre mesh was cut with lengths of 39.5cm and the three side to a length of 30cm. The 5mm gap provided for the length of the column was to prevent axial load on the BFRP jacket. As the sheets were wrapped in a continuous way, these lengths allowed for an overlap of 2cm. All specimens were axially loaded in a universal testing machine with a compressive capacity of 2500 kN under displacement control mode with a constant speed of 0,5 MPa/s. Axial load was recorded from an output signal from the test machine and the axial deformation was measured as the displacement of the loading base plate. Figure 3 shows the pictures of the rectangular columns in the forms.



Figure 3. Rectangular columns in the forms.

3. Test results

3.1 Tensile test specimens

All the experimental specimens showed a good linear response up to first failure at peak load. From the results, the applied stress decreased when the fibre at the edge ruptured and then started to increase again until the whole section ruptured. Table 1 below shows the test results from each specimen where;

- F is the applied tensile force,
- σ is the tensile stress obtained from the tensile force and the cross section area,
- ϵ is the longitudinal strain measured by the strain gauges,
- E is the elastic modulus calculated according to ASTM [12].

Table 1. Tensile test results.

Specimen	f(KN)	σ (Mpa)	ϵ (%)	E (MPa)
TB1	11.97	1330	23.3	5708
TB2	11.64	1293	15.3	8451
TB3	11.09	1232	7	17600
TB4	11.32	1257	10.6	11858
TB5	12.22	1357	24.3	5584
TB6	11.44	1271	13	9777
Average	11.63	1290	15.6	9830

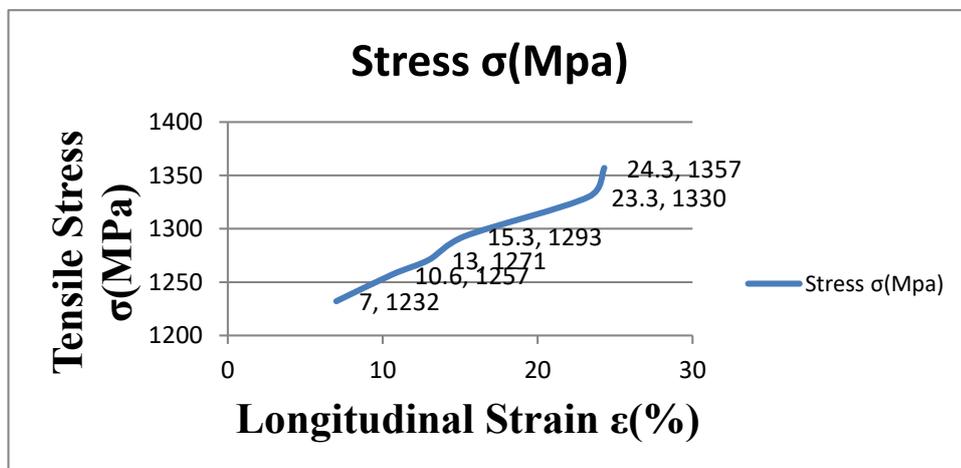


Figure 4. Stress-Strain diagram for BFRP

3.2 Rectangular specimens

In the results gotten from the experiments, diverse hardening response was observed in all specimens after reaching the unconfined concrete strength where the BFRP jacket activates. The failure observed in the specimens in the experiments can be divided into two modes:

- tensile rupture of the BFRP jacket and a combination of delamination at the overlap,
- tensile rupture of the BFRP jacket.

The average test results from each rectangular column series where;

- x is the number of days,
- f_c is the unconfined concrete strength obtained from the plain rectangular column,
- f_{cc} is the confined compressive strength,
- ϵ_{c1} is the axial strain corresponding to the unconfined concrete strength and
- ϵ_{cu} is the ultimate axial strain at failure.

Table 2. Compression test results.

Sample	x	f_c (Mpa)	f_{cc} (Mpa)	f_{cc}/f_c	ϵ_{cu} (%)
CD-1	14	35.8	79.4	2.22	15
CD-2	28	44.6	102.2	2.30	9

Figure 5 shows the results of the confined and unconfined rectangular after failure.



Figure 5. Rectangular columns after test

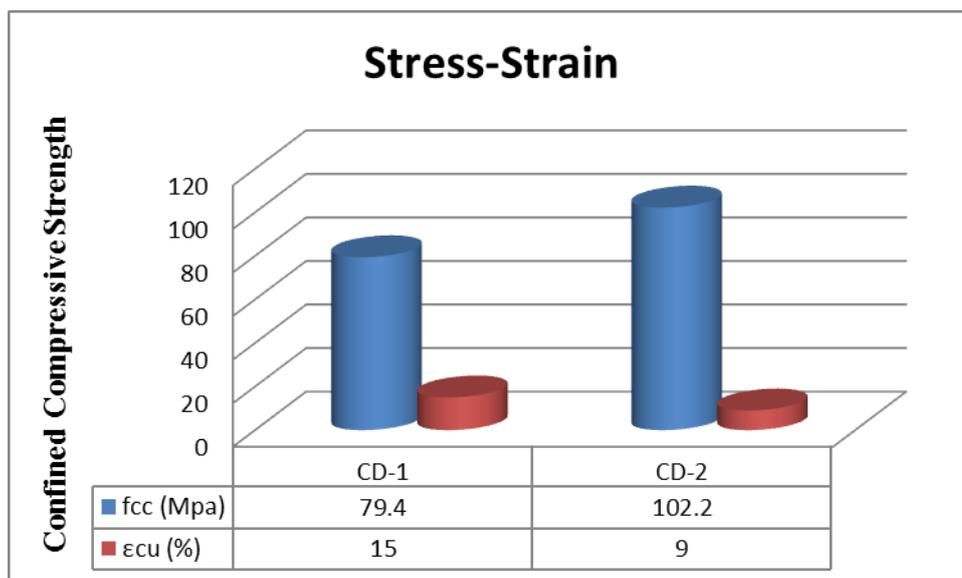


Figure 6. Stress-Strain chat for the confined columns

4 Conclusion

Where the fibres ruptured first at the edges on the tensile coupon specimens indicates that the orientation of the fibre to the applied tensile load was not perfectly parallel which however can be the case in structural strengthening. Therefore, the ultimate strength and strain were taken at the peak load which was considered to represent the material strength of the BFRP jacket.

Figure 4 and 6 show very well the increase in compressive strength and axial strain obtained by increase in the maturity days of the concrete columns adding BFRP (Basalt grids/mesh). The columns with basalt grids/mesh show a good ductile behaviour where the maximum gain in axial strain is 15% on the 14th day and 9% on the 28th day while the unconfined failed in the both days. These results review the efficiency of BFRP as a strengthening material for concrete columns but as this paper only presents tests on short rectangular concrete columns. Basalt reinforced concrete has capacity to resist cracks.

More researches are going on the mechanical properties and effectiveness of basalt materials on structures.

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