Experimental study on properties of concrete reinforced with basalt bars

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Abstract - *Conventional steel bars used in the construction industry are susceptible to various attack such as corrosion and other environmental attacks. Basalt bar is made from basalt rock which can be used as an alternative to steel bars of reinforced concrete structures. In this paper, the properties such as flexural strength of concrete beams and axial load of concrete columns reinforced with steel as well as basalt reinforced concrete are studied. A total of 12 beam specimens and 6 column specimen are cast and tested. In beams, number of tension bars is varied as two and three where as in columns, a single type of specimen with four numbers of longitudinal bars is used. Result shows that flexural strength of beams is improved largely whereas axial load carrying capacity of columns for basalt reinforced specimen is less than that of steel reinforced specimen.*

***Key Words*: Axial load, basalt bars, concrete beams, concrete columns, flexural test, steel bars …**

1. INTRODUCTION

Concrete structures made up of steel reinforced bars are normally used in construction industry. But steel reinforced structures are susceptible to corrosion attack which affect its durability and strength parameters. Non corrosive fiber bars as reinforcement of concrete structures is an alternative solution to this.

Basalt bar is a type of polymer reinforced bar which can be used as an alternative to steel up to an extent. Basalt bar is lighter than steel bar as its density is much lower. The main advantage of basalt bar are that it is naturally resistant to chemical attack such as alkali, rust and acids. Basalt bars are obtained from basalt rocks which is the most common type of rock in earth crusts. Basalt rocks are volcanic igneous rocks which are located at a depth of hundreds of kilometers beneath the surface by the cooling of molten lava.

In 2012, Enrico Qugliarini studied and confirm that BFRP rods and BF ropes shows better tensile strength than GFRP products [1]. BFRP bars shows good mechanical property as it could be considered as same category of GFRP bars [2].One of the main advantage of basalt bar is that its durability performance is high [3]. Basalt rebars which are non-corrosive can be considered as an alternative for steel reinforcement of concrete structures [4]. In the case of reinforced columns, the axial load carrying capacity increases from rectangular to square and then square to circular [5].

2. EXPERIMENTAL PROGRAM

2.1 Materials

The compressive strength of hardened concrete was found to be 34.9 N/mm2 at 28th day when tested for concrete cubes of 150mmx150mmx150mm size. Slump obtained was 105 mm after conducting slump tests. In the experimental study Ordinary Portland Cement 53 grade is used. Specific gravity of the cement is obtained as 3.15 and standard consistency is 38%.Cement is having an initial setting time of 30 minutes and fineness of 2%. Locally available M sand is used as fine aggregate and 20 mm nominal size aggregates are used as coarse aggregate. Specific gravity of fine aggregate and coarse aggregate are 2.7 and 2.81 respectively. Masterglenium sky 8233 is used as admixture for concrete.

Table -1: Mix proportion

Cement	Fine aggregate	Coarse aggregate	Admixture	Water Cement ratio
1	1.44	2.66	0.5% of cement	0.43

2.2 Beam specimen

Twelve rectangular concrete beams were cast and tested for this experimental study to find out the flexural strength of beams. The beams were 1000 mm long, with rectangular cross section of 150 x 200 mm. Basalt bars of 8 mm in diameter and steel bars of 8 mm in diameter were used as the longitudinal main bars. Two steel bars of 8 mm in diameter are used as compression reinforcement of all the beams. Basalt bars of 8mm diameter with two and three numbers are respectively used as tension reinforcement. To compare it with control specimen, steel bars of 8mm diameter with two and three numbers are also used as tension reinforcement. Steel bars with 6 mm in diameter and 172 mm spacing are used as shear reinforcement in all the specimen. M30 graded concrete with a water cement ratio of 0.43 is used in this experimental study. Thickness of cover selected in all the beam specimens are 25 mm. The reinforcement detailing for beam specimen are given as shown in Fig-1 and Table-2

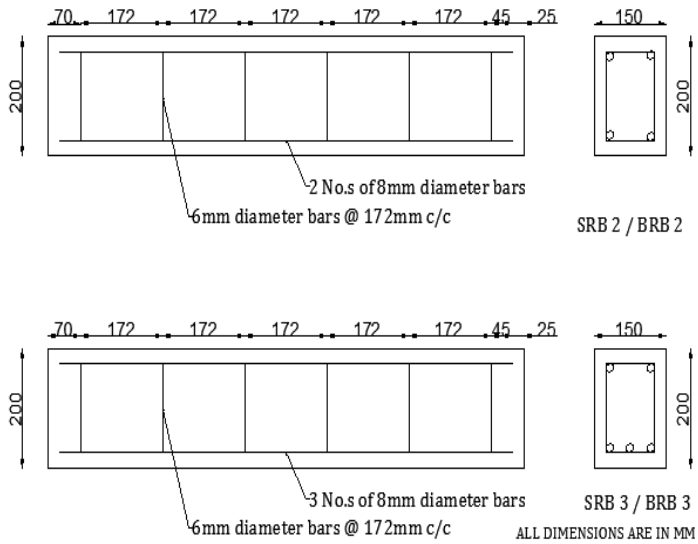

Fig -1: Reinforcement of beam specimens with steel and basalt

Table -2: Test specimen for beams

Sl No:	Specimen	Mix	No. of bars in tension zone	Main bar diameter (mm)	Stirrup diameter (mm)	Material
1	SRB21	M30	2	8	6	Steel
2	SRB22	M30	2	8	6	Steel
3	SRB23	M30	2	8	6	Steel
4	BRB21	M30	2	8	6	Basalt
5	BRB22	M30	2	8	6	Basalt
6	BRB23	M30	2	8	6	Basalt
7	SRB31	M30	3	8	6	Steel
8	SRB32	M30	3	8	6	Steel
9	SRB33	M30	3	8	6	Steel
10	BRB31	M30	3	8	6	Basalt
11	BRB32	M30	3	8	6	Basalt
12	BRB33	M30	3	8	6	Basalt

Where, SRB – Steel Reinforced Beam
BRB – Basalt Reinforced Beam

2.3 Column specimen

Six columns were cast and tested in this experimental study to find out the axial load. The columns were 600 mm long with diameter of the cross section is 150 mm. Basalt bars of 8 mm in diameter with four numbers were used as main bars and steel bar with 8mm diameter of four numbers were also used as control specimen. Lateral ties of 6 mm in diameter and 150 mm spacing were used as lateral ties in all the column specimen. M30 graded concrete with water cement ratio of 0.43 is used in this experimental study. 30 mm thickness cover is used in all the column specimen. The reinforcement detailing for beam specimen are given as shown in Fig-2 and Table-3

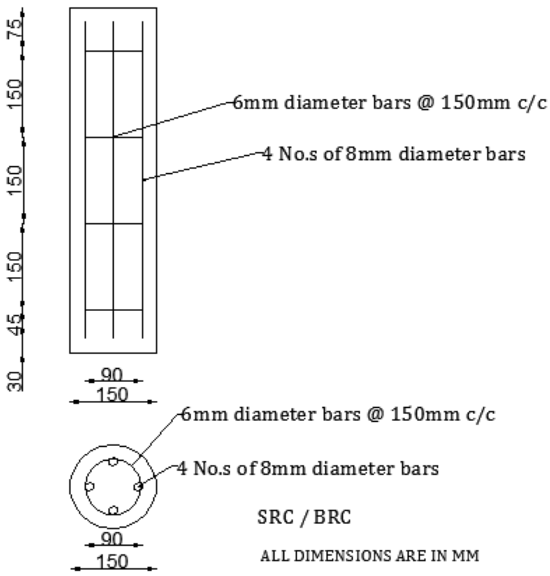

Fig -2: Reinforcement of column specimens with steel and basalt.

Table -3:.Test specimen for columns

Sl No:	Specimen	Mix	Main bar diameter (mm)	Lateral ties diameter (mm)	Material
1	SRC1	M30	8	6	Steel
2	SRC2	M30	8	6	Steel
3	SRC3	M30	8	6	Steel
4	BRC1	M30	8	6	Basalt
5	BRC2	M30	8	6	Basalt
6	BRC2	M30	8	6	Basalt

Where, SRC – Steel Reinforced Column
BRC – Basalt Reinforced Column

2.4 Preparation of test specimen

The concrete was batched in the laboratory, mixed manually, placed by hand in steel moulds and compacted using tamping rods.

2.5 Curing condition

The casted specimens are allowed to set for 24 hours of the mould. Thereafter it is demoulded and placed in water filled tank for 28 days.

2.6 Flexural test setup

The beam flexural tests under three point loading were performed in a universal testing machine with 1000 kN capacity. The load was applied at midpoint of the beam specimen, increased at a uniform rate till the ultimate failure occurs. The specimens were arranged with simply supported conditions with an effective span of 780 mm. Deflection of the beam was measured using a dial gauge of least count .01mm at center of the specimen. The experimental test set up for beam specimen is as shown in Fig-3.

Fig -3: Experimental setup for beam specimen

2.7 Axial load test setup

All the column specimens were tested for a universal testing machine with 1000 kN capacity. The load was applied to one end of the column specimen, increased at a uniform rate till the ultimate failure. Axial deformation of the column was measured using a dial gauge of least count .01mm. The experimental test set up for column specimen is as shown in Fig-4.

Fig -4: Experimental setup for column specimen

3. RESULTS AND DISCUSSION

3.1 Flexural test

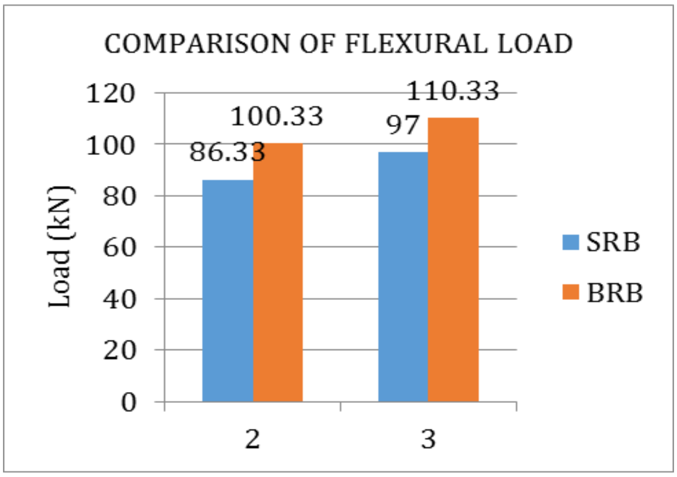

Chart -1: Comparison of flexural load

Steel reinforced beam with two numbers of tension bars shows an average ultimate load of 86.33 kN whereas basalt reinforced beam with two numbers of tension bars shows an average ultimate load of 100.33 kN. An improvement on flexural load carrying capacity of 16.22% can be observed here. In the case of three numbers of tension bar reinforced beam specimen, steel reinforced beam have an average flexural load of 97 kN whereas basalt reinforced beam has an average flexural load of 110.33 kN. An increase in 13.74% flexural load is observed. The increase in flexural load may due to improved tensile characteristics of basalt bars.

3.2 Load vs deflection for SRB 2 and BRB 2

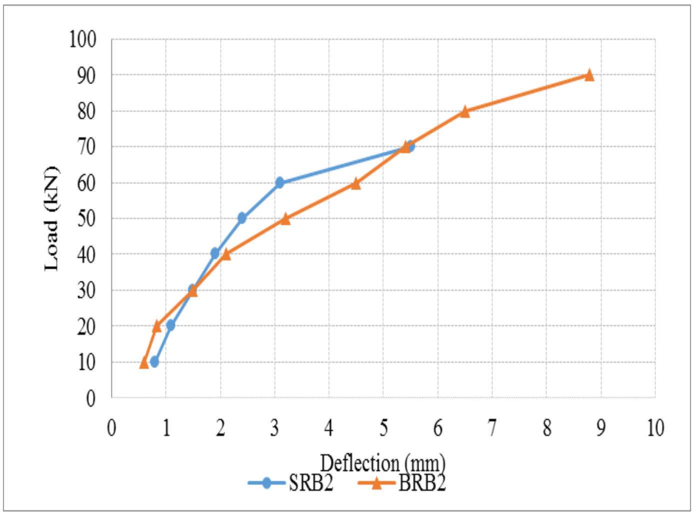

Chart -2: Load VS Deflection for SRB 2 and BRB 2

Load-deflection curves were plotted for each beam and the results were compared, based on the values obtained. In the case of steel reinforced beam load-deflection shows almost linear pattern up to yield value and after that it shows a nonlinear pattern. We can find out the yield load from the typical pattern of a load-deflection curve of steel reinforced beams loaded at midspan. But in the case of basalt reinforced beam, load deflection shows nonlinear pattern till failure. Due to the development of sudden and numerous cracks after the steel reinforcement as well as basalt reinforcement has reached its maximum yield stress, the dial gauge readings were taken only up to some point before the ultimate failure load of the specimen. Hence the midspan deflection corresponding to the ultimate failure load was not taken using the dial gauge. Yielding of steel reinforced bars are observed from 60 kN. Even though load carrying capacity of basalt reinforced beams are more, it also shows more deflection for a particular load. This is due to the lower modulus of elasticity of basalt bars than steel bars.

3.3 Load vs deflection for SRB 3 and BRB 3

In the load – deflection curve shown above, till the yield point, steel bars shows a linear pattern. Thereafter nonlinear patterns can be observed. Yielding of steel reinforced beam starts from 70 kN. In the case of basalt bars, the curve shows a nonlinear behavior till failure. Basalt reinforced beam with three numbers of tension bars shows more load carrying capacity than steel reinforced beam. But the deflection of basalt reinforced beams are more.

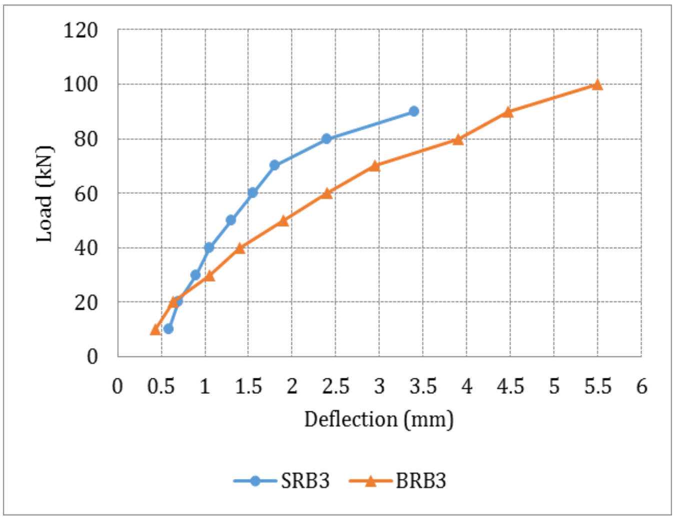

Chart -3: Load VS Deflection for SRB 3 and BRB 3

3.4 Crack pattern

The crack patterns observed from the steel reinforced and basalt reinforced beams are shown below.

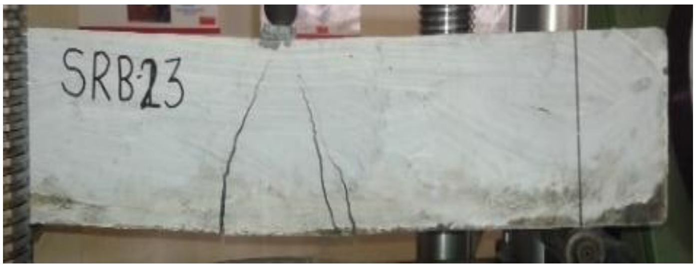

Fig -5: Crack pattern of beam SRB2-3

Fig -6: Crack pattern of beam BRB2-2

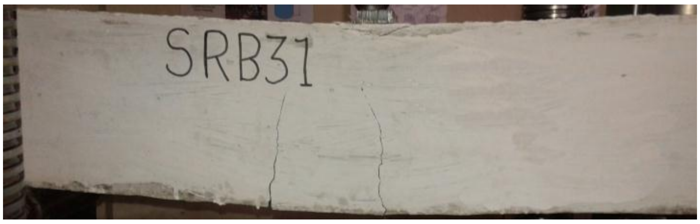

Fig -7: Crack pattern of beam SRB3-1

Fig -8: Crack pattern of beam BRB3-1

All the crack patterns were flexural crack patterns. The flexural cracks are originated as a result of increased stress in the tension zone of the beams which exceeds the bending strength of concrete.But the crack width of basalt bars are larger than that of steel bars.This is due to the improved tensile strength of basalt bars than steel bars.

3.5 Axial load test

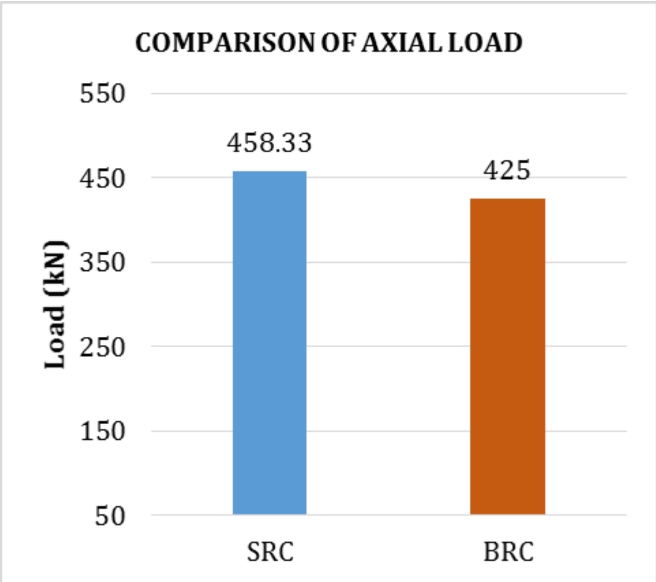

Chart -4: Comparison of axial load

Steel reinforced columns shows an average ultimate load of 455 kN and basalt reinforced column shows an average ultimate load of 420 kN. A decrease of axial load carrying capacity of 8.3 % can be observed in the case of basalt reinforced columns than steel reinforced columns.

3.6 Axial load test

Load-deformation curves were plotted for each column and the results were compared, based on the values obtained. From the above chart, both steel and basalt reinforced columns shows linear behavior till failure. Even though initial deformation for basalt reinforced columns are less thereafter it shows more deformation than steel reinforced columns for a particular load.

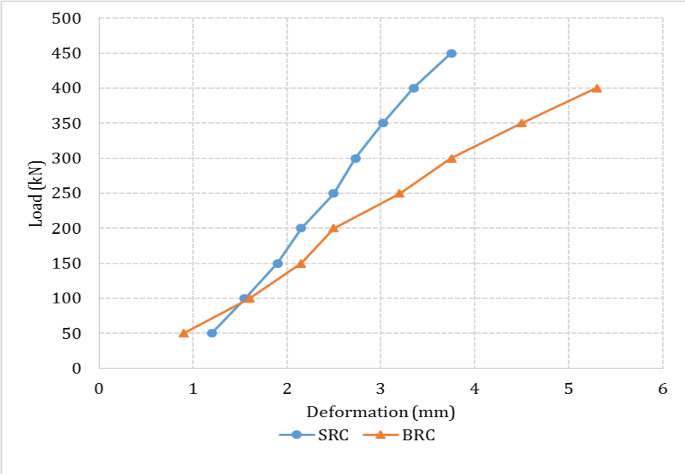

Chart -5: Load VS Deformation of SRC and BRC

3.7 Failure pattern

Fig -9: Failure pattern of column SRC1 and BRC 2

The failure patterns of columns are due to shearing and splitting of concrete as a result of high axial load. In the case of basalt reinforced columns a typical sound was heard of straining is observed at the failure load.

4. CONCLUSIONS

The major conclusions derived from this experimental study are as follows

1. The flexural load carrying capacity of the basalt reinforced beams are improved by 16.22% as that of steel beams with two numbers of tension bars whereas the load is improved by 13.74% in the case of reinforcement bars with three numbers of tension bars. This may be because of the improved tensile strength of basalt bars.

2. Deflection caused by flexural load is more in basalt reinforced beam than steel reinforced beam. This is due to the lower modulus of elasticity of basalt bars than steel bars.

3. The axial load carrying capacity of columns reinforced with steel bars are more, that is 8.3%. The axial load vs deformation curves are linear in the case of steel as well as basalt. The failure patterns of basalt as well as steel bars are also similar in nature.

4. Basalt bars can be used as a replacement of steel bars in construction industry as reinforcement of beams. In the case of columns further studies should be made.

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