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Original Article

Experimental Studies on Shear Performance of Beams Reinforced with Basalt Rebars for Different Shear Configurations

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Abstract - *Essential elements of it are important to acknowledge the variations as well as drawbacks between the application of Basalt Fiber Reinforced Polymer (BFRP) bars and traditional steel reinforcement in structures made of concrete. Emphasis has been placed on expanding and creating new, more well-organized, sustainable materials to displace conventional steel rebar (rebar) utilized in concrete structural components. Additionally, having been deployed because of their excellent resistance to corrosion and low electrical resistance, characteristic steel rebars inside buildings made of concrete are the primary catalyst of this degradatioSn. Considering steel and basalt have densities of 7850 kg/m^3 and 2600 kg/m^{3,} respectively, which is around 3 times smaller than steel. As an outcome, the BFRP rebar is an environmentally conscious, lightweight alternative to the steel rebar used in construction. The article presents the current investigation on a sequence of beams maintained in bending, steel-clad with blocks in BFRP, in comparison with the location rays by blade support.*

Keywords - *Basalt rebar, Steel rebar, Shear behavior, Reinforced concrete, Beams.*

1. Introduction

Investigating the extent to which BFRP bars work as reinforcement in concrete constructions. There have been limited studies; several studies have reported their mechanical and durability characteristics [3], and experimental evaluations of the tensile load-carrying ability of BFRP properties and structure of the bond with concrete have been conducted. After conducting a number of research studies, they were able to establish the strength, flexibility, and very good bond strength with concrete compared to GFRP rebars. Additionally, they documented the outstanding durability characteristics of BFRP, including excellent thermal resistance and resistance to various acids [15], and BFRP exhibited excellent resistance to the freeze-thaw cycles [14]. However, the strength properties of BFRP underwent a significant reduction after exposure to the accelerated form of alkaline tests.

Experiments on reinforced concrete behaviour and shear strength of BFRP structures are still rare, considering the absence of research on their bending capabilities [1, 2, 4, 8, 10, 11, 15, 16, 17]. The results of research on bending effectiveness have revealed that RC beams furnished with FRP exhibit enhanced ultimate strength in comparison to those with Grade 60 steel, owing to the exceptional tensile capacity of FRP materials. However, due to discrepancies in shear transferring mechanisms through the response of the interlocking dowel and aggregate, the shear load-bearing aptitude of FRP RC exhibits lesser strength than traditional steel-RC beams, in contrast to the bending.

In contrast with steel, Fiber-Reinforced Polymers (FRP) possess less axial stiffness, resulting in the diagonal cracks forming that are bigger in width and depth. Consequently, shear is transferred by aggregate interlocking and concrete uncracking in the compression zone [21]. In addition, irrespective of the FRP reinforcement's exceptionally poor transverse strength attributes, the effect of shear through the action of the dowel is zero [9]. By summarizing the contributions of transverse reinforcement, shear, and concrete shear, shear strength in RC members will be determined. Reinforced materials of GFRP, CFRP, and AFRP, concrete practical test results, and numerous research studies and design requirements have offered methods utilized to determine the total shear capacity of RC elements with FRPs for different cases, with shear reinforcement and without shear reinforcement [4-8, 12, 13].

A substantial portion of the equations of shear recommended for RC-based FRP members were designed to modify equations from pre-existing steel RC member design codes. These improvements are designed to clarify the differences in material characteristics, such as a decrease in the material's tensile capacity, the shear capacity in the direction of the length, and the flexural capacity of the material, and the behaviour of non-yielding FRP [14]. However, it proved problematic to forecast the capacity of shear-bearing FRP-based elements of RC due to substantial variations in strength and elastic distinctive across different types of FRP.

Currently, a single investigation [2, 9, 12, 13] considers the behaviour of a concrete shear beam with fibrous reinforcement, particularly when a microscopic bar member occurs, which is made of BFRP (circular rod of 10 mm and 12 mm), has been published in the literature. Thus, the present investigation intends to examine the capability of the shear Beam of concrete containing longitudinal bars of BFRP strengthening with and without web reinforcements of BFRP. Various types of shear configurations have been utilised to estimate the carrying volume of RC shear force beams. By evaluating experimental data, prediction schemes, and equations from design codes, the anticipated shear capacity of BFRP RC beams by these methods is put to the test for their accuracy.

BFRP possesses excellent durability and mechanical characteristics, but most of the existing research has mainly considered flexural performance, bond strength, and part of durability, while the study of shear has been poorly addressed for BFRP-reinforced beams under different shear setups. For example, most of the existing design provisions derive from steel RC codes, thus creating designs that do not entirely take into consideration BFRP's reduced modulus of elasticity and its different shear transfer mechanism. Thus, a recognizably important gap in research exists in furthering our understanding and prediction of the shear capacity in BFRP-RC beams.

The project examines the shear behavior of basalt-reinforced material beams in ANSYS finite element modeling, validated against standard steel beams. The results showed opportunities for using BFRP rebars as a sustainable corrosion-resistant replacement for steel in concrete constructions that are subject to shear stress. The research examined the shear behaviour of RC beams retrofitted with BFRP bars in different shear conditions.

Vertical, inclined, and bent-up basalt shear reinforcements were evaluated, together with comparing basalt and traditional steel reinforcement, crack patterns, deflection, and maximum capacity for bearing loads, ultimate load-carrying capacity under shear, thus indicating the promise of basalt rebar as a sustainable, lightweight, and corrosion-resistant substitute for steel. This will further the understanding of shear performance in BFRP RC beams.

1.1. Objectives

- To evaluate the deformation of an RC beam reinforced with transverse reinforcement fabricated with basalt rebar subjected to the highest gravity force.
- Research on reinforced cement-basalite rods, which are used for the consolidation of concrete beams, for the crack pattern using basalt shear reinforcement within the concrete or mortar matrix.
- Comparison study of shear behavior by reinforcing the Beam for shear with basalt and steel.

2. Literature Review

In 2021, Kar & Biswal [27] investigated the RC beams and their increase in capacity due to the use of basalt and glass fiber materials. Around four-point experimental load testing, wherein parameters of interest included fiber width, orientation, and strengthening patterns; these methods offered improvement in shear capacity and ductility, while their limitations included sensitivity to prior loading and variation in effectiveness based on fiber type and configuration.

In 2022, Jianbing et al. [28] explained that reinforcing 4 point flexure tests and numerical simulations were subjected on the concrete beams reinforced with basalt fiber approaches to evaluate shear performance, cracking lLoad and ductility; this improved ductility, where actual prediction of beam behavior was concerned, although their downside was a lesser ultimate capacity in composite beams Causes attributed to the interface compatibility of post-tensioned-concrete with the fiber-reinforced resins.

In 2018, Duic et al. [29] explained a full-scale shear and flexure experiment on BFRP reinforced concrete beams rebars were performed in earlier work, analyzing cracking moments and deformability; this highlighted the reasonable ductility of BFRP and its environmental advantages but revealed a higher cracking pattern and lower shear capacity than steel, with useful structural design codes showing varying accuracy in their predictions.

In 2023, Adam et al. [30] investigations have scrutinized the bending characteristics of high-performance BFRP-RC beams, bars, and PVA fibers through a bending test with four points, while analytical prediction carried out by the strain compatibility method revealed that these beams demonstrated increased load-bearing capability and better utilization of BFRP tensile capacity; however, to optimize performance, careful selection of fiber and reinforcement ratio would be required.

In 2022, Refai et al. [31] examined the concrete bB-bbbeam's properties made up of basalt fibers. Four-point longitudinal loading tests were performed on BFRP bars, taking into consideration fiber volume ratio, reinforcement ratio, and shear span-to-depth ratio, and different effects; this improved shear capacity and provided good predictive power, but led researchers to conclude that existing models tended to overestimate strength and stressed the need for hybrid-specific design approaches.

3. Methodology

3.1. Experimental

3.1.1. Construction Material

The study's materials included cement, river sand, coarse aggregate, basalt rebar, regular steel, and water.

Cement

As per the IS 12269-1987, cement is used in project experimentation. Ordinary Portland cement grading 53 is utilized throughout the project experimentation [24].

Various laboratory investigations are done on cement; the output is displayed below in Table 1.

Table 1. The physical characteristics of cement

SL. No	Physical Characteristics	Outcome of Experiment	IS code recommendation IS:12269-1987
1	Specific gravity	3.16	3.0-3.15
2	Consistency of normal	34%	30
3	Time Setting (Initial)	60 min	30 minutes (min)
4	Time Setting (Final)	240 min	600 minutes (max)
5	Fineness	2%	0-10%

Fine Aggregate

Natural sand: In the current project movement, sand from local rivers in zone II of the Indian Standard version 383-1970 has been exploited.

The material properties of fine-grade aggregates and the conclusions of the sieve analysis are summarized in Table 2, as may be observed below.

Table 2. Particle size analysis test data & physical features for sand particles

SI No	IS Sieve size	Cumulative % passing	%Passing by weight (ISO 383-1970 for zone-II)
01	4.750 mm	97.67	090-100
02	2.360 mm	94.23	075-100
03	1.180 mm	80.0	055-090
04	600.00 microns	54.55	035-059
05	300 microns	6.07	008-030
06	150 microns	0.616	000-010
Physical Characteristics			
07	Specific gravity	2.634	02.6-02.8
08	Bulk density	1.687 gm/cc	1520kg/m^3
09	Fineness modulus	3.663	02.6-04

Coarse Aggregate

Basalt crushed stones of 20 mm size are used as per Indian Standard 383-1970. The data analysis of sieving and physical features aggregates with a 20 mm size is represented in Table 3.

Table 3. Sieve data analysis & material characteristics for 20 mm aggregate

SI No	IS Size of Sieve	Percentage of Cumulative passing	Weight% passing as per Indian Standard 383-1970
1	40 mm	100	100
2	20 mm	98.59	100
3	16 mm	95	90-100
4	12.5 mm	51.55	90-100
5	10 mm	30.33	40-85
6	4.75 mm	0.012	0-10
Physical Characteristics			
7	Specific gravity		2.8
8	Density of bulk		1.51 g/cc
9	Absorption of water		2.04%

Basalt Rebar

A majority of nations around the world have components of basalt rebar, a composite material. Basalt rebar is obtained by a manufacturing process that uses constant basalt winding. This transporter rod has continuous spiral ribs on the outside that are created by winding an oiled basalt strip in extremely resilient polymer composites. Basalt rebar resists a corrosive environment. However, typical corrosion occurs in steel materials. Acids, rust, and alkalis are all naturally hostile to basalt rebar. Concrete that has moisture in it does not crumble. It does not require any special coating. The ratio of the constant of thermal expansion of rebar basalt is equal to that of a normal beam. Common cutting equipment can readily be used to cut basalt rebar. Figure 1 represents the basalt rebars.

Fig. 1 Basalt rebars

3.1.2. Mechanical Properties of Basalt Rebar

- Tensile capacity having $2.9 GPa$.
- Modulus of elasticity having 90 GPa.
- High thermal stability – Properties of insulating, electrical, and sound effectiveness.
- Lightweight: approximately 25% smaller than a steel bar of the corresponding dimension, delivering considerable placement and usage savings.
- Minimal elastic moduli of other polymers that contain fibers and traditional steel.

- Basalt rebar is said to be three times stronger than steel rebar (for this comparison, it is assumed that the quoted tensile capacity of the basalt rebar is $800 - 1400\ MPa$ based on the diameter, while the reinforcing steel is considered to have a lower strength of $360 - 400MPa$).
- Corrosion-resistance: It cannot form rust and is impervious to chemicals, salt ions, and presumed alkalinity of concrete.

Conventional Steel

Fe 500 with a yield strength of around 500 $\frac{N}{mm^2}$ Steel (12mm and 10mm dia bars) complying with Indian Standard 1786-1985 is used to reinforce cement concrete beams for a few samples.

Water

Water standards complying with IS 456-2000 are used in the experimentation for all cases, that is, for casting and curing concrete specimens.

3.1.3. Selection of Proportion for Concrete Grade M20

The RC beams are established employing M20 quality concrete. Using the specifications established by the IS 10262-2009 code, the mix design was completed to make concrete of M20 grade. Appendix A comprises the blended design calculation. The enhanced hardening method was implemented to estimate the load-bearing capacity under compression, which enabled the establishment of the mix proportion for concrete that needed to be researched subsequently. Three test combinations have been used. The combined proportions are indicated in Table 4.

Table 4. M20 grade concrete's trial mixtures.

S. No	Materials	Mix (kg/m³)
1	Cement	350
2	Aggregate of fine	721.04
3	Aggregate of course	1153.33
4	Water	191.58

Load-bearing capacity under compression of the selected mix was obtained at the close of 28 days of standard curing.

Specimen Details

Details involving the test specimen are shown in Table 6, along with data regarding reinforcement, which is displayed in Table 5.

Table 5. Data regarding reinforcement

Sn. No	Details	No. Of Specimens	Size Of Specimens (Mm)
1)	Cubes	06	150x150x150
2)	Ferro concrete beam specimens with no shear reinforcing bars	02	1350x230x150
3)	Ferro concrete beams with conventional rebar shear reinforcing bars	02	1350x230x150
4)	Ferro concrete beam specimen with basalt rebar shear reinforcement for two shear spans (Flexural reinforcement will be conventional steel)	02x03=06	1350x230x150

Table 6. Details of reinforcement

Series	Beam	Beam Size mm	Reinforcement Details
Reinforced concrete shear testing on reinforced concrete beams with traditional steel reinforcing bars	SS11	1350X150X230	2#10@ linkages @150mm c/c, top and bottom, 2LVS-6mm
	SS12	1350X150X230	2#10@ linkages @150mm c/c, top and bottom, 2LVS-6mm
Reinforced concrete basalt-reinforced beam specimen as vertical shear reinforcing bars for two shear spans (Flexural reinforcement will be conventional steel)	SB21	1350X150X230	2#10@ linkages @150mm c/c, top and bottom, 2LVS-6mm
	SB22	1350X150X230	2#10@ linkages @150mm c/c, top and bottom, 2LVS-6mm
Reinforced concrete basalt-reinforced beam specimen as inclined shear reinforcing bars for two shear spans (Flexural reinforcement will be conventional steel)	ISB31	1350X150X230	2#10@ linkages @150mm c/c, top and bottom, 2LVS-6mm
	ISB32	1350X150X230	2#10@ top and bottom,2LIS-6mm links @150mm c/c

Reinforced concrete basalt-reinforced beam specimen bent up bars.	BUB41	1350X150X230	2#10@ top as well as bottom
	BUB42	1350X150X230	2#10@ top as well as bottom
Reinforced concrete beam shear-free specimen reinforcing bars.	SN51	1350X150X230	2#10@ top as well as bottom
	SN52	1350X150X230	2#10@ top as well as bottom

Beam Details

The longitudinal and Beam cross-sections are represented in Figure 3, respectively.

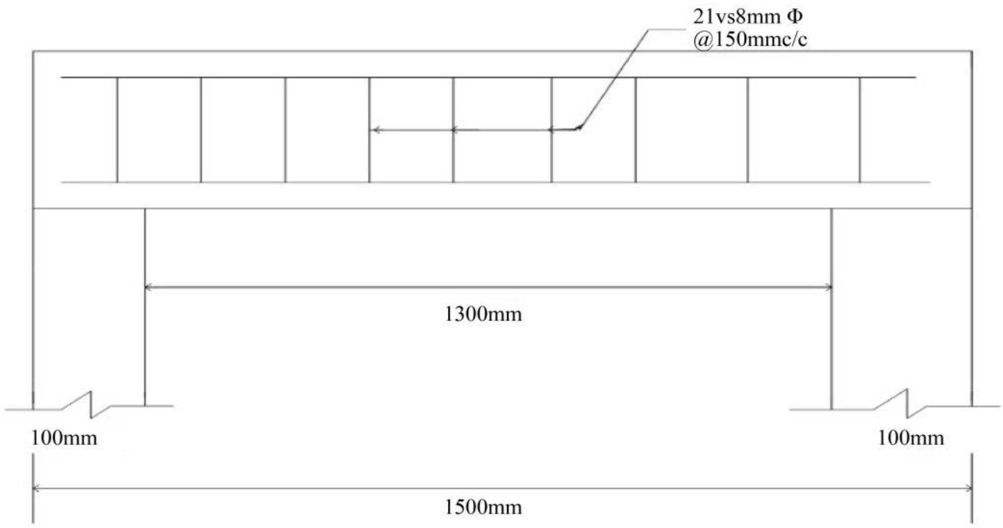


Fig. 2 L/S of RCC beam

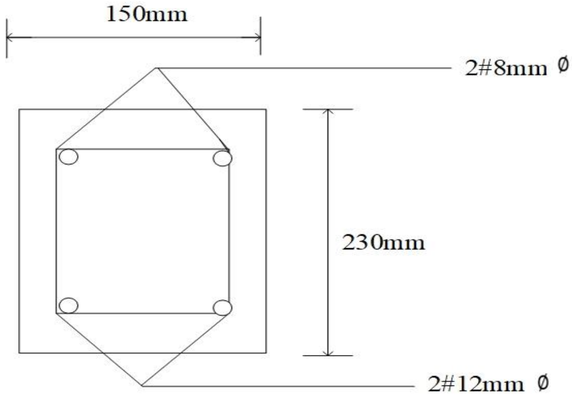


Fig. 3 C/S of RCC beam

4. Findings and Discussion

4.1. Compaction Factor Test

The results concerning the beam compaction factor" flowability are shown in Table 7.

Table 7. Compaction factor test

S. no	Partially compacted concrete weight(W2) kg	Fully compacted Concrete weight (W3) kg	Partially compacted concrete weight (W2-W1) kg	Fully compacted Concrete weight (W3-W1) kg	Compaction factor (W2-W1)/(W3-W1)
1	26.2	27.2	13.7	14.7	0.93
2	27.3	28.1	14.8	15.6	0.95
3	28.1	29.3	16	16.8	0.95

The compaction factor is 0.94 on average. The compaction factor estimations were good; however, they deviated from the flowability standard that the mix design had predicted.

Table 8. Strength of Compressive results at 28 days for M20 grade

Mix design ation	Identity of the sample	Load (tons)	Accelerated curing compressive test of strength in N/mm²	Strength of Compressive +12.63N/mm²	Average strength of compressive N/mm²
MIX	C1	50	21.79	34.44	34
	C2	53	23.10	35.74	
	C3	44	19.17	31.82	

4.1.1. Concrete Ability to Bear Compressive Loads Test Results

The results obtained from the accelerated hardening method compressive-strength evaluations are shown in Table 7. Three cubes are molded using the MIX test and retained for conventional curing. The presented data is the result of the compression test on 28 28-day cubes of M20 grade concrete, as shown in Table 8.

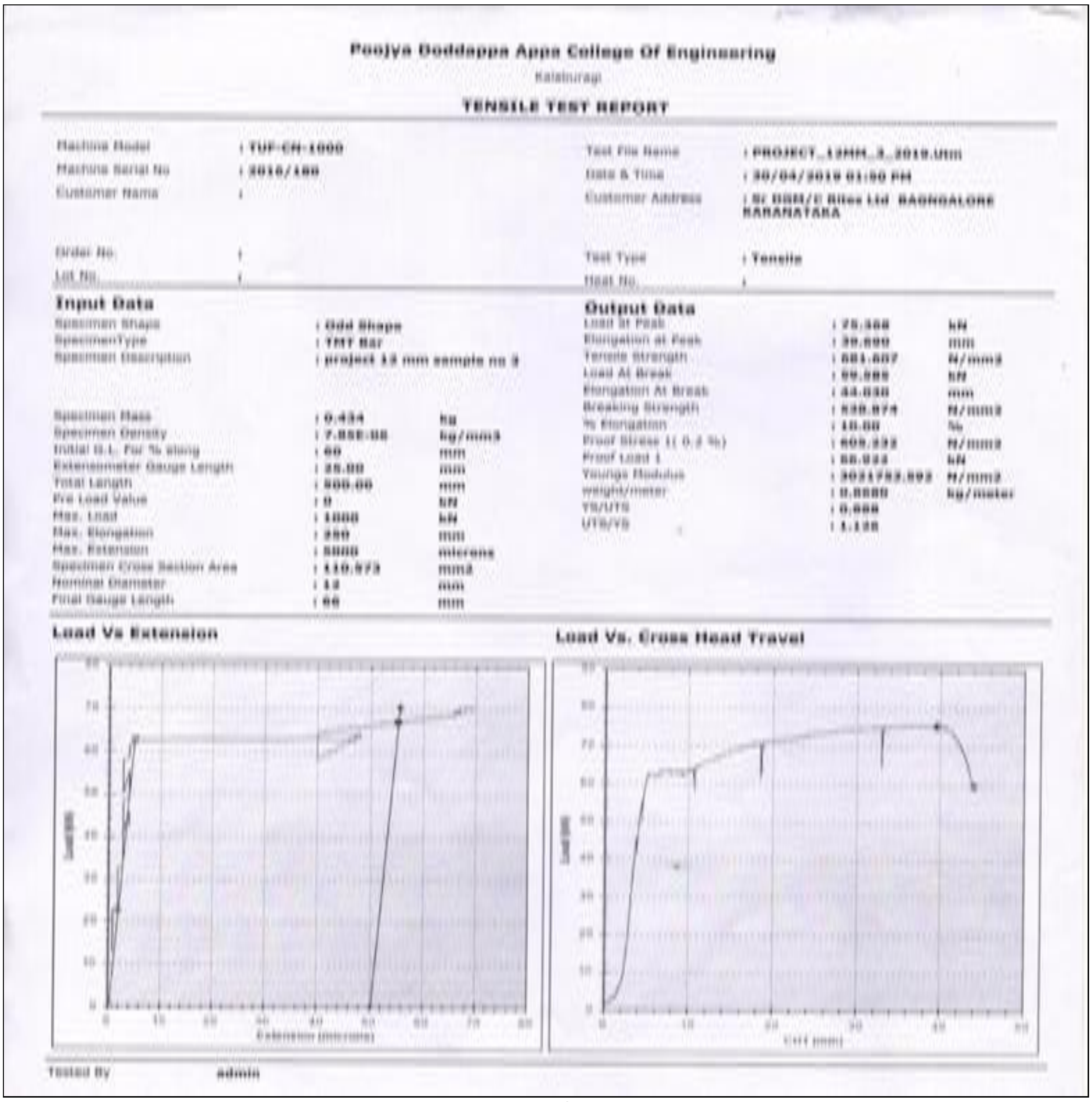


Fig. 4 Tensile test report for conventional steel

4.1.2. Rebar Tension Test

Traditional Steel Tensile Capacity Test

Figure 4 shows the conservative steel's labelling during the period of challenge and the outcome of the experimental test. The test of tensile capacity was executed by IS 1608 recommendations on a servo-controlled digital universal test apparatus with a 500 KN capacity, as shown in Figure 6.

Fig. 5 Labelling on traditional steel reinforcing bars during testing

The 12 mm circular steel was found to have failed by generating a shape of a cup and a cone at the gauge length premises, resulting in an elongation percentage of 10% and a tensile capacity of $681.607 \frac{N}{mm^2}$. As indicated in Figure 5.

Figure 6 illustrates how it makes basalt rebars at the exact moment of testing, and Figure 7 shows the test report. The tensile capacity test had been performed.

4.1.3. Tensile Capacity Test on Basalt Bars

Examination of the tensile capacity of basalt rebar for 12 mm bars demonstrated the contrary; contrary to providing a cup and cone fracture, the bar fractured at the end point by fracturing its surface. The deformation proportion was 3.33%, and the tensile capacity was $1449.96 \frac{N}{mm^2}$. It has been observed that basalt reinforcing bars have approximately twice the tensile capacity of traditional steel.

4.1.4. Ductility Test on Reinforcing Bars

In spite of the stretching value, bending and bending tests are carried out to evaluate ductility; the test was performed according to IS1786-2008. The basalt rebar in the bending test and reflection test has developed broken, losing its ductility characteristics, which are inferior to conventional steel. The conventional steel performed the test. The biggest disadvantage of basalt rebar is flexibility.

4.2. Rebars Properties

4.2.1. Rebars at Weight per Meter Length

Table 9 describes the average weight of the conventional rebar per meter as well as the rebar of basalt.

4.2.2. Shear Performance of RC Beams under Load

(Figures 8 to 12 are given below)

Table 9. Weight of average for conventional rebar per meter length

Rebar Category	Diameter (mm)	Weight per unit length (kg/m)
Conventional Steel	12	0.863
	10	0.585
	8	0.382
Basalt Rebar	12	0.236
	10	0.165
	8	0.109

It was observed that the average weight of rebar basalt is 72.5% lower in comparison to conventional steel.

Fig. 6 Casting of beams

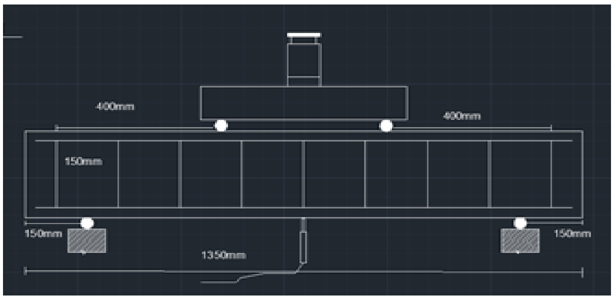


Fig. 7 Loading frame

Fig. 8 RC beam with steel reinforcement

Fig. 9 RC beam with steel and basalt reinforcement

(a) **(b)**

Fig. 10 RC beam with steel and no stirrups

(a)

(b)

Fig. 11 RC beam specimen with basalt rebar inclined shear reinforcement for two shear spans (Flexural reinforcement will be conventional steel)

(a) **(b)**

Fig. 12 RC beam specimen with basalt rebar bent up bars

5. Analytical

ANSYS is used according to the Finite Element Method; The software analysis essentially aims to study shear capacity effects on an RC beam and establish its model for computer analysis of frames of this type.

ANSYS modelling of a beam consists of five stages,

1. Selection of element type.
2. Modelling the geometry.
3. Assigning material properties.
4. Loading and support.
5. Meshing the geometry.

In this study, 5 beam models of different shear configurations were studied. These beams are modelled in ANSYS software. The details of the model are given below, step by step. These beams are to be validated with experimental results from the base paper of the literature study.

5.1. Modeling in ANSYS Software

5.1.1. Selection of Element Type

The model consists of 2 types of elements: concrete and rebar. For concrete, select a solid element, which is known as solid 65; for rebar, select a line element, which is known as link180.

Table 10. ANSYS element

Material	Element type
Rebar	Link element (Link 180)
Concrete	Solid element (Solid65)

5.1.2. Line Element (Link 180)

Line element, also known as link 180, is utilised to simulate the reinforcement. According to the application, that component is capable of being used as a bolt, reinforcement bar, cable element, or truss element. The two nodes that together make up the three-dimensional element each have three translation variables of freedom. The element might be seen in Figure 13.

5.1.3. Solid Element - Concrete

SOLID65, commonly referred to as three-dimensional solid modeling, has been used under or upon concrete footings that do not have reinforcing bars in the solid body. The solid can crush when compacted and crack when tensioned.

In this case, in a concrete application, the rebar's capability can be utilized to represent reinforcing behavior, while the property of a solid element can be employed to mimic the structure of concrete. As displayed in Figure 14, this element comprises 8 nodes. Each node has three degrees of freedom along the x, y, and z directions.

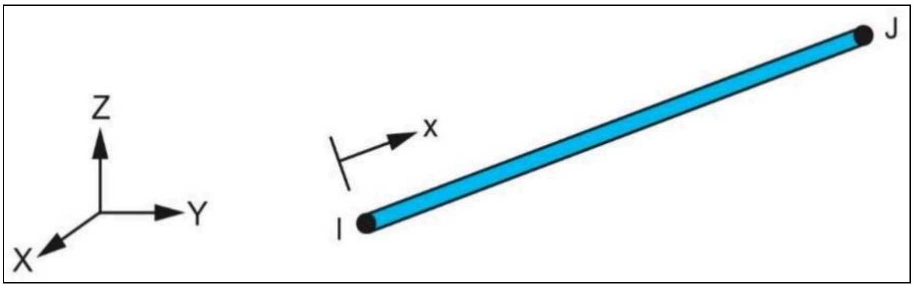


Fig. 13 Line element (link 180)

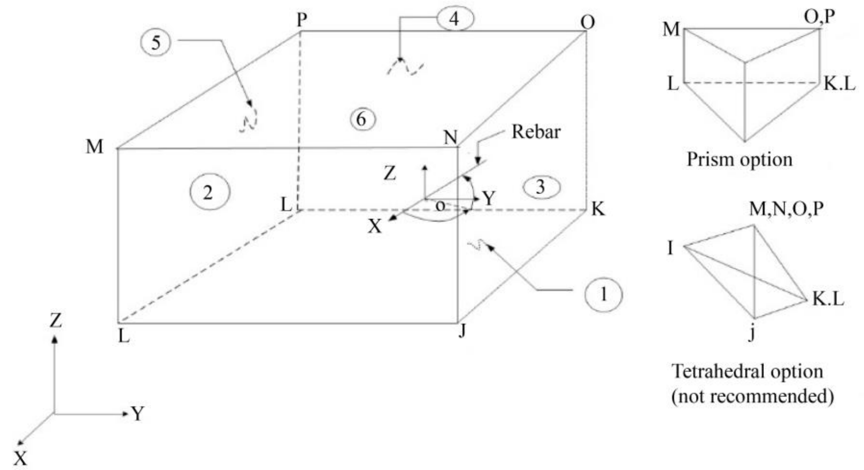
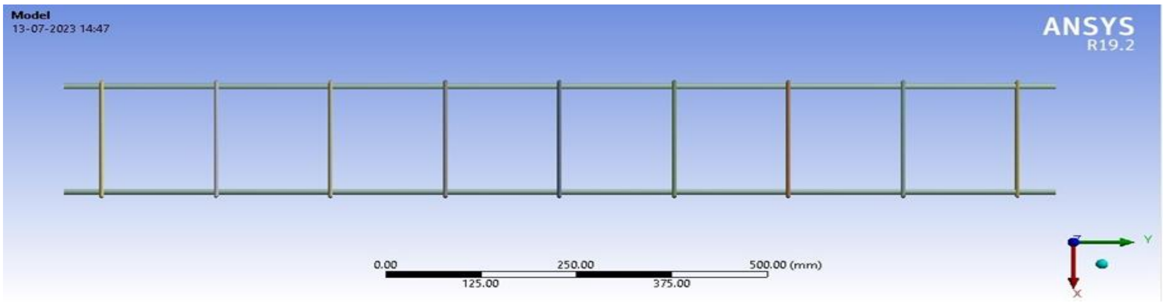


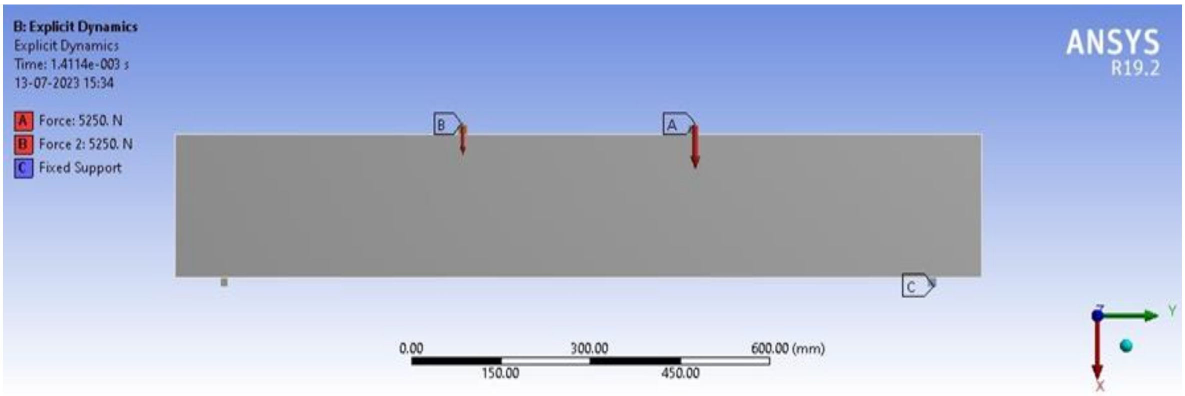
Fig. 14 Mimic structure of concrete

5.1.4. Modeling the Geometry

The modeling of geometry has been carried out in ANSYS 19.2. The Beam has a dimension of 230x150x1350 mm for different shear reinforcement. The Beam consists of two different materials: concrete and rebar. The concrete part is modeled with a solid element, which is also known as solid65 in ANSYS, and the reinforcing bar is modeled with a line element, which is also known as link 180. The modeling of the geometry is carried out in the design modeler. The model consists of a simply supported beam of dimensions 1350 x 150 x 230 mm with a two-point loading setup (Figure 15).



(a)



(b)

Fig 15 Loading and support

6. Average Results of Specimens

6.1. Results of RC Beam Specimens with Conventional Rebar Shear Reinforcement are Shown in Table 11

Table 11. Results for RC beam, then becomes shear reinforcement with normal steel rebar

Sl No	Name	First-crack lLoad(kN)	Deflection (mm)	Ultimate Load (kN)
1	SS11	43.3	2.17	106.2
2	SS12	67	4.01	101.8
AVG		55.15	3.09	104

Results of RC beam specimen with basalt rebar vertical shear reinforcement for two shear spans (Flexural reinforcement will be conventional steel) are shown below in Table 12.

Table 12. RC beam specimen with basalt rebar vertical shear reinforcement for two shear spans

Sl No	Name	First -crack load(kN)	Deflection (mm)	Ultimate Load (kN)
1	SB21	61.6	5.05	100.4
2	SB22	50.5	1.28	75.9
AVG		56.05	3.46	88.15

Results of the RC beam specimen with no shear reinforcement are represented in Table 13.

Table 13. Results of RC beam specimen with no shear reinforcement

Sl No	Name	First-crack load(kN)	Deflection (mm)	Ultimate Load (kN)
1	SN51	57.7	3.02	97.4
2	SN52	61.9	2.27	94.3
AVG		59.8	2.65	95.8

Results of RC beam specimen with basalt rebar inclined shear reinforcement for two shear spans (Flexural reinforcement will be conventional steel) are represented in Table 14 below.

Table 14. Results of RC beam specimen with basalt rebar

Sl No	Name	First-crack lLoad(kN)	Deflection (mm)	Ultimate Load (kN)
1	ISB31	71.7	3.5	112.8
2	ISB32	64.8	2.79	107
AVG		68.25	3.09	109.55

Results of the RC beam specimen with basalt rebar bent-up bars are represented in Table 15.

Table 15. Results of RC beam specimen with basalt rebar bent up bars

Sl No	Name	First-crack Load(kN)	Deflection (mm)	Ultimate Load (kN)
1	BUB41	47.5	2.35	79.8
2	BUB42	45	2.15	-
AVG		46.25	2.20	79.8

6.2. Comparison Between SS11 and 12, SB21 &22, SN51 & 52

The bBeam with steel reinforcement in both flexural and shear reinforcement has a high capacity compared to steel and basalt reinforcement, i.e., SS11 and SS12 beams have failed at 106.2 and 101.8KN, respectively or the ultimate Load, whereas the bBeam with steel in flexure and basalt in shear has failed at 88.15KN, which is less compared to the above bBeam

Another type of specimen with codes SN51 and SN52 is where steel is provided in longitudinal reinforcement without stirrups. Only two stirrups are provided at the support to hold the main bars in position. The mean strength of I-section beams was found to average 95.8 kN for the ultimate Load, which is better than that of the Beam with steel and basalt reinforcement (SB21 and SB22).

6.3. Comparison Between ISB31 & 32:SN51 & 52

ISB 31 and ISB 32 beam is a type in which flexural reinforcement is of conventional steel, and shear reinforcement of basalt bars and stirrups in an inclined manner. These types of beams failed at an average ultimate load of 104.5 kN.

As mentioned above, a beam type with steel in both flexure and shear reinforcement without stirrups failed at the mean axial Load of 95.8 KN. Compared to these types of beams, a beam with inclined stirrups has a higher load capacity.

6.4. Comparison between SN51 and SN52 with BUB 41 and 42

BUB41 and 42 are beams with complete basalt rebars, and two rings are tied at ends at an angle of 45 degrees and tested for the Load at ultimate. The Beam tested failed at 79.8 load, whereas beams with conventional steel without stirrups failed at an average load of 95.8KN.

6.5. Comparison between SB11&12 with BUB 41 and 42

SB11&12 are the beams with steel as flexural reinforcements and basalt as shear reinforcements, and BUB41& 42 are the beams with basalt being both flexural and shear reinforcements. In this condition, the SB11 & 12 showed better ultimate load-carrying behavior than BUB41&42, where SB11 & 12 have a carrying volume of ultimate load 88 kN and BUB41 & 42 have a carrying volume of ultimate Load 79.8 kN.

6.6. Comparison between SB11&12 with: ISB31 and 32

SB11&12 are the beams with steel as flexural reinforcements and basalt as shear reinforcements, and ISB 31 and ISB 32 beams are a type in which flexural reinforcement is of conventional steel and shear reinforcement of basalt bars and stirrups in an inclined manner. In this comparison, the inclined stirrups ISB 31 and ISB 32 beam showed better load-carrying capacity of 104.5 KN than SB11 and SB12, whose load-carrying capacity is 88KN.

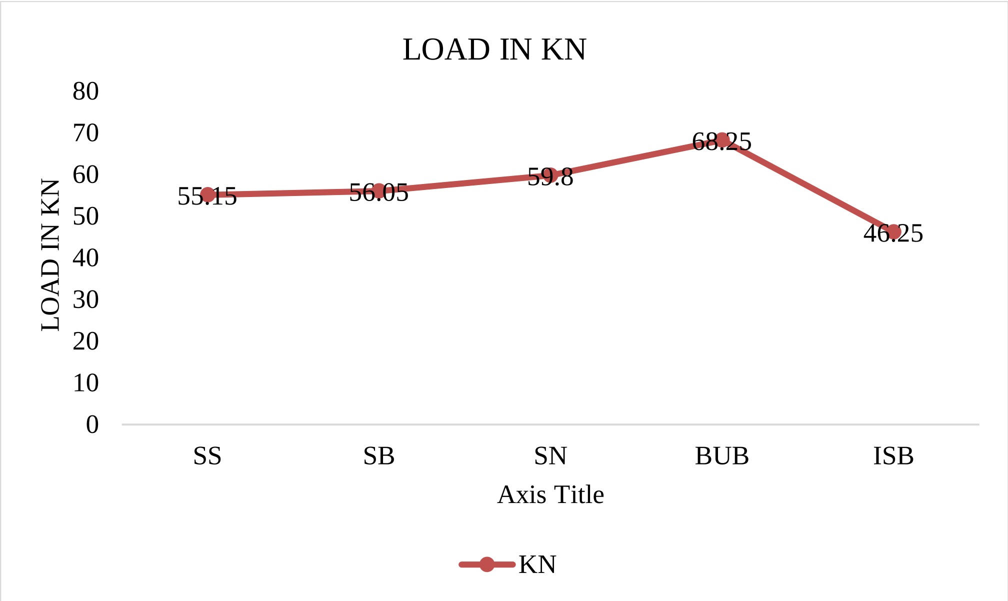


Fig. 16 Initial crack load-carrying capacity of all specimens

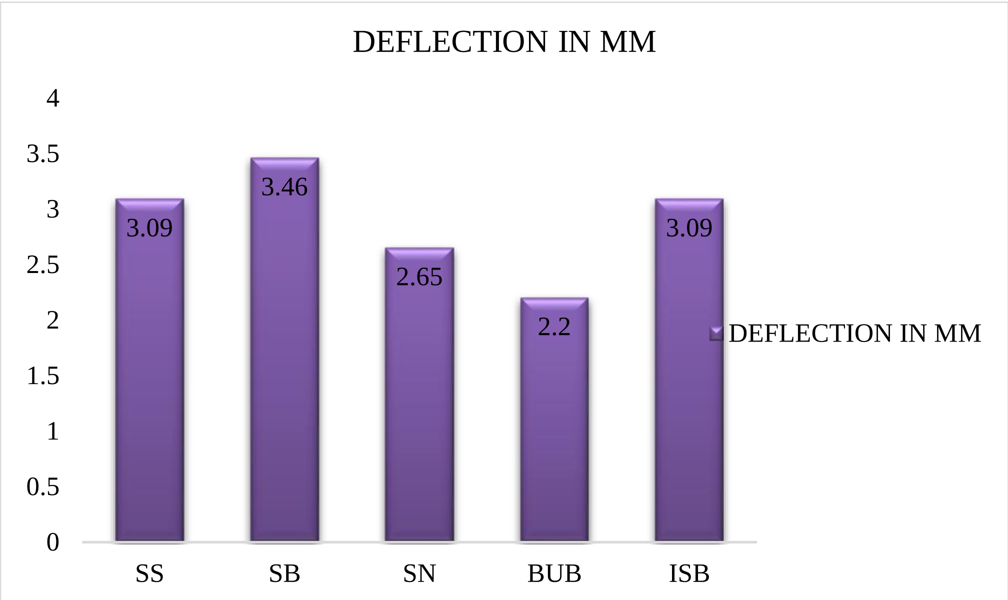


Fig. 17 Initial crack load deflection of all specimens

6.7. The Comparative Study is Founded on the Findings of Both Experimental and Analytical Studies

6.7.1. Experimental Study

5 beam specimens of different shear configurations have been experimentally tested, and results have been obtained. The required result is taken from the base paper of the literature survey.

6.7.2. Analytical Study

5 beams were modeled in ANSYS software and analyzed. The required data was collected from the base paper of the literature survey (Figure 18 is given below).

Table 16. Analytical and Expt. Result comparison

Beam	1st Crack Load in Ansys	Ansys Deflection (mm)	Experimental 1st Crack Load(mm)	Experimental Deflection values in mm
SS11&12	55.15	1.1	55.15	3.09
SB21&22	56.05	1.3	56.05	3.46
SN51&52	59.80	1.0	59.8	2.65
BUB41&42	68.25	0.8	68.25	2.20
ISB31&32	46.25	1.15	46.25	3.09

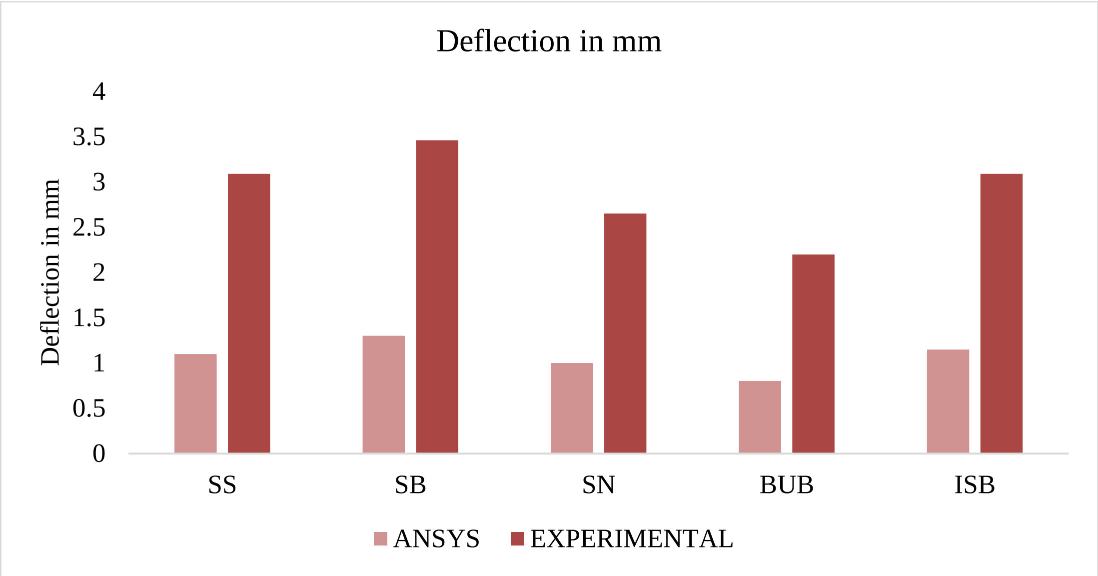


Fig. 18 Load deflection comparison graph

7. Discussion

From previous reports, it is evident from this study that RC beams with basalt rebar have been superior in shear characteristics, as these beams perform better in contrast with traditional steel-reinforced beams. The occurrence of inclined basalt stirrups in the beams has been responsible for higher first-crack loads and deflections before failure, which could imply better energy absorption and load-carrying. All these effects are contributed by the excellent tensile capacity of basalt rebar, its non-corrosive property, and its light weight. Different from previous studies, which mainly concern flexural performance, this research is oriented toward multiple shear configurations validated by ANSYS modeling for a broader understanding of BFRP shear performance with respect to RC beams.

8. Conclusion

Basalt rebar can sustain tensile capacity twice that of mild steel.

- The weight per basalt rebar per meter length is lower than conventional steel by 71.5%.
- Basalt bars rebound in nature, which means cracks appear on the beam and disappear after removing the Load, whereas steel does not have this property.
- As per test results, the initial Crack in basalt-glass-reinforced beams appears only at a later state compared to basalt-carbon reinforced steel beams.
- For inclined stirrups, the ultimate Load is high.
- The deflection of beams reinforced with basalt rebar was considerably more than that of the reference beam with steel reinforcement, where the Young's modulus difference was significant, with the basalt bar being lower than that of conventional steel.
- SS11/12 and SB11/12 are beams containing steel and basalt straps, respectively; the initial crack load for the beam specimens was similar, irrespective of the carrying capacity of the ultimate Load. Since the basalt rebar offers more carrying capacity under the ultimate Load than steel, its yield strength for carrying Load is lower than that of steel.
- When compared with specimens of basalt inclined stirrups and steel vertical stirrups, even without considering the yield strength of basalt rebar, the

inclined basalt rebar performs much better than the steel vertical stirrups by 23.5%.

- The initial crack load also occurs at a higher load in inclined basalt rebar compared to the steel stirrups.
- The specimens with basalt rebar as both the flexural and shear reinforcement carried considerably lesser loads than all other specimens.
- Since basalt rebar is more durable compared to steel, even though it may carry a lesser load, it can rely on basalt rebar as a better shear reinforcing material, because the stirrups are more prone to damage by corrosion, which will never occur in basalt rebar, and even if they are exposed to any chemicals.
- The Load that produced the first Crack in the steel-reinforced Beam BS10VS with vertical shear reinforcement was recorded at 43.3 KN, for which the model-calculated deflection was 1.0 mm in Ansys software for that beam.
- First-crack Load for Basalt-reinforced bBeamBB10VS with vertical shear is at 50.1 KN, with Ansys software giving a deflection value of 1.1 mm.
- It can be observed that a beam with basalt rebars outperforms steel rebars in terms of strength.
- The first fracture load for the Beam reinforced with basalt is 14.26% greater than the Load for a beam reinforced with steel rebar.
- Using Ansys software, the first crack load of the basalt rebar-reinforced beam with inclined stirrups was recorded at 64.8 KN with a 1.5 deflection.
- The Load vs Deflection graph for both the experimental result and analytical result from Ansys varies linearly.
- The deflection for bBeamBS0VS was observed to be 2.1 mm from experimental data, whereas the deflection for the same bBeam was 1.0 mm from the ANSYS software for the Load 43.3 KN.
- From beam BS10VS and bBeamBB10VS, observe that the 1st crack load is high and deflection is less for beam 2, i.e., Beam reinforced with basalt rebar, as compared to beam 1, i.e., Beam reinforced with steel rebar.

Data Availability Statement

All data were obtained from the simulation reports generated by the software and tools used by the authors. Work is being done to implement the same approach using real-world data with appropriate permissions.

Author’s Contributions Model

Author 1: Sujeet Patil, He contributed to the conceptualization, methodology, data collection, and preparation of the manuscript. Author 2: Dr. Rajendra Kumar Harsoor, He analyzed the paper and the supervisor of this paper.

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Declaration Of Interests

The authors declare that they have no competing financial interests or personal relationships that could have influenced the work reported in this paper.

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