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Experimental Studies on Flexural Behaviour of RC Beams Reinforced with Basalt Rebars

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Abstract- The Paper covers utilization of Basalt rebar for concrete reinforcing, its comparatively new element, which seems a potential material for infrastructural reinforcing. Superior temperature endurance and low weight are only some of the advantages it offers above other composites and steel. Because it is non-corrosive, basalt rebar is an excellent option for reinforcing concrete constructions that are located near sea. The work describes several experimental studies, like a tensile strength testing of basalt rebar with standard steel as well as flexure strength test of beams reinforced both by basalt rebar and traditional steel, also work is being done for identifying material qualities, mixture ratio of M20 grade concrete as well as standard cubes were tested in compression as well as prisms are examined for flexural strength. There are 12 samples of 1500×150/230mm×1500 mm that have been cast and monitored under a 1000kN capacity load frame. Six of the specimens have standard steel reinforcement, while the other six have basalt reinforcement. Rebar with diameters of 10mm and 12mm is often utilized.

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EXPERIMENTALSTUDIESONFLEXURALBEHAVIOUROFRCBEAMSREINFORCEDWITHBASALTREBARS

Strictly as per the compliance and regulations of:

Experimental Studies on Flexural Behaviour of RC Beams Reinforced with Basalt Rebars

R. Ashutosh V. Kulkarni [α], Santosh Rathod [σ], Praveen Talwar [ρ], John Wesley [Ѡ], Sujeet Patil [¥] & Dr. Aravindkumar B. Harwalkar [§]

Abstract- The Paper covers utilization of Basalt rebar for concrete reinforcing, its comparatively new element, which seems a potential material for infrastructural reinforcing. Superior temperature endurance and low weight are only some of the advantages it offers above other composites and steel. Because it is non-corrosive, basalt rebar is an excellent option for reinforcing concrete constructions that are located near sea. The work describes several experimental studies, like a tensile strength testing of basalt rebar with standard steel as well as flexure strength test of beams reinforced both by basalt rebar and traditional steel, also work is being done for identifying material qualities, mixture ratio of M20 grade concrete as well as standard cubes were tested in compression as well as prisms are examined for flexural strength. There are 12 samples of 1500×150/230mm×1500 mm that have been cast and monitored under a 1000kN capacity load frame. Six of the specimens have standard steel reinforcement, while the other six have basalt reinforcement. Rebar with diameters of 10mm and 12mm is often utilized. The patterns of crack development with load deflection are being studied in this research project. Tensile strength of basalt rebar is double that of standard steel, according to results of experiments. When comparing basalt-reinforced beams with steel-reinforced beams, the load–deflection curve, the first crack load, the maximal load, as well as deflections are all taken into consideration. Conventional beams with basalt-reinforced beams have similar ultimate load-carrying capability. Deflection in basalt reinforced beams is 66.66 percent lower than in normal beams, according to the research. Failure of conventional RC beams was determined to be based on flexure criteria, but the failure of basalt reinforced RC beams was based on the expansion of shear crack.

Keywords: basalt rebar, steel, flexural behavior, reinforced concrete beams.

I. Introduction

New and better materials are being sought for by construction industry in an effort to develop product which is both lucrative to business as well as useful to building projects. These days, many new composite materials are being created upon large scale in industry and are being employed in routine building projects all over world. New, environmentally friendly materials must be used in lieu of older ones that are no longer sustainable or worthy of use because of their weakness, corrosion risk, or environmental effect.

Basalt is a common rock found all over world, and it's used to make basalt fibre. Concrete may be reinforced using Basalt Rebar, which is a great product. The tensile strength is three times greater and it is four times lighter over steel rebar. Basalt fibres are pultruded into rebar using pultrusion technology. Massive volumes of basalt rebar can be mass-produced. When exposed to heat, basalt rebar does not emit hazardous fumes or combust, and it does not cause an explosion. They will not generate a product that is toxic or detrimental to the environment when they are in close touch with chemicals. Corrosion damage to reinforced structures does have negative effect upon its endurance and ultimate strength. Basalt bars used as reinforcing in concrete projects are non-corrosive, according to Saravanan S and Rohith N S [1]. Flexural behavior and load bearing capacity were both improved by 23% and 11%, respectively, when M30 grade beam specimens were reinforced with Basalt bars, according to the findings of the experiments. Because to its lower density, basalt bar weighs less than steel bar. Basalt bar has the benefit of being resistant to chemical assaults like alkali, rust, as well as acids in its natural state. A volcanic igneous rock, basalt is created with cooling of molten lava hundreds of kilometers below surface. Researchers led by Marek Urbanski et al. [2] investigated the stress-strain behavior of material that turned out as linear besides quite dissimilar compared with steel. Jibin.c bright and Preetha Prabhakaran [3] studied the effects of prolonged stress and exposed with alkaline solution at extreme heat on concrete deformation and compared findings to acceptable standard levels defined by codal criteria. As in comparison with steel bars, Basalt rebar's creep rupture strength is much lower than steel bars' tensile strength. Rebars made of basalt are characterized by their intrinsic qualities, resin as well as adhesion with one another, all of which influence their creep properties.

II. Objectives

1. Studying ductility as well as mechanical characteristics of Basalt Rebar with Conventional steel Rebar.

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2. Regarding RC beams having basalt reinforcement, to establish preliminary cracking load, ultimate load, and load-deflection pattern; and to compare findings with conventional RC beams.
3. In order to determine how RC beams having basalt reinforcement and standard RC beams behave when subjected to flexure.

III. Methodology

a) Material used

In the experiment, materials included are cement, river sand, coarse aggregates, Basalt rebar, regular steel, and water.

A single batch of OPC53 graded cement, manufactured with compliance to specifications of IS 12269-1987, is utilized throughout the project. The project uses river sand from zone II of IS 383-1970, which is occurs naturally as well as locally accessible. According to IS 383-1970, crushed basalt stones are a depth of 20 mm. Basalt rebar is a cutting-edge composite material that has ardent proponents across the world. Rebar produced from basalt roving is known as basalt rebar. Spiral-ribbing carrier rods are made from twisted basalt strip, oiled on exterior, and enclosed in very durable polymeric compound. Corrosive conditions are no match for basalt rebar. In contrast, steel is vulnerable to regular corrosion. Alkalis, rust, and acids can't penetrate basalt rebar since it is inherently resistant. There's no need for a particular finish on this piece. Cutting basalt rebar to length is simple and may be done using standard tools. The basalt rebars are shown in Figure 1.

Fe 500 grade steel should be used for typical RC beams that meet IS 1786-1985 standards. Reinforcement is provided by 12mm as well as 10mm diameter bars.

In compliance with IS 456-2000, water that is fit for human consumption is used for both the casting as well as curing of concrete in this study.

Fig. 1: Basalt Rebars

b) Mix Proportion

M20 graded concrete had ben utilized for casting RC beams. Utilizing code requirements of IS-10262- In 2009, a concrete mix design for M20 grade was completed. The accelerated curing technique was used to assess concrete's compressive strength in order to determine the mix percentage for future investigation. 3 trial mix proportions are used in total. Table I shows the mix ratios.

Table I: Sample mixtures of M20 grade concrete

Sl.No.	Material	MIX1	MIX2	MIX3
I.	1Cement	380kg/m3	370kg/m3	360kg/m3
II.	Fine2 Aggregate	667.05kg/m3	676.01kg/m3	677kg/m3
III.	Coarse 3 Aggregate	1163.12kg/m3	1178.74kg/m3	1180.48kg/m3
IV.	4 Water	209kg/m3	199.8kg/m3	194.4kg/m3

Concrete mix 3 was chosen for casting RC beams based upon preceding findings of compressive strength, and selected mix's compressive strength were determined after 28 days of traditional curing.

c) Specimen Details

All these conventional as well as basalt-reinforced beams are included in Table III, which details specimens utilised in investigation and specifications for reinforcements.

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Table II: Details on the test specimen

Specimen kind	Specimen dimension (mm)	Tests	Specimens quantity
Cube	150×150×150	Testing of compressive strength for typical concrete.	09 (3 trials)
Plain concrete Beam (prism)	100×100×500	Flexural strength of traditional concrete.	03
RC Beam	1500×150×230	Two-point loading flexural strength test. 1. Traditional beam/ reference beam. 2. Beam strengthened with basalt rebars.	06 06

Fig. 2: Basalt Reinforcing

Fig. 3: Laying Reinforcement into wooden mould

Table III: Reinforcement specifics of beam specimen

Series	Beam identification	Whole length	Clear span	Beam dimension in mm	Reinforcing particulars
Traditional beam	CB11	1500	1300	1500×150×230	2 of 8mm at top and 2 of 10mm at bottom, 2 Legged Vertical Stirrups of 6mm at 125 c/c
	CB12	1500	1300	1500×150×230	2 of 8mm at top and 2 of 10mm at bottom, 2 Legged Vertical Stirrups of 6mm at 125 c/c
	CB13	1500	1300	1500×150×230	2 of 8mm at top and 2 of 10mm at bottom, 2 Legged Vertical Stirrups of 6mm at 125 c/c
Traditional beam	CB21	1500	1300	1500×150×230	2 of 8mm at top and 2 of 12mm at bottom, 2 Legged Vertical Stirrups of 6mm at 125 c/c
	CB22	1500	1300	1500×150×230	2 of 8mm at top and 2 of 12mm at bottom, 2 Legged Vertical Stirrups of 6mm at 125 c/c
	CB23	1500	1300	1500×150×230	2 of 8mm at top and 2 of 12mm at bottom, 2 Legged Vertical Stirrups of 6mm at 125 c/c

Series	Beam identification	Whole length	Clear span	Beam dimension in mm	Reinforcement particulars
Basalt reinforce Beam	BB11	1500	1300	1500×150×230	2 of 8mm at top and 2 of 10mm at bottom, 2 Legged Vertical Stirrups of 6mm at 125 c/c
	BB12	1500	1300	1500×150×230	2 of 8mm at top and 2 of 10mm at bottom, 2 Legged Vertical Stirrups of 6mm at 125 c/c
	BB13	1500	1300	1500×150×230	2 of 8mm at top and 2 of 10mm at bottom, 2 Legged Vertical Stirrups of 6mm at 125 c/c
Basalt reinforce Beam	BB21	1500	1300	1500×150×230	2 of 8mm at top and 2 of 12mm at bottom, 2 Legged Vertical Stirrups of 6mm at 125 c/c
	BB22	1500	1300	1500×150×230	2 of 8mm at top and 2 of 12mm at bottom, 2 Legged Vertical Stirrups of 6mm at 125 c/c
	BB23	1500	1300	1500×150×230	2 of 8mm at top and 2 of 12mm at bottom, 2 Legged Vertical Stirrups of 6mm at 125 c/c

d) Determining Mechanical Characteristics

i. *Tensile strength testing for rebar's*

Tensile strength testing is often used steel tests. An attempt is made to break the sample until it cracks in order to measure its tensile strength, yield strength, plasticity, and decrease in surface area using a bending test. For testing, this has been put into its paces using 500-kN digital servo-driven universal equipment.

ii. *Compressive Strength*

Compressive strength may be determined experimentally in accordance with codal criteria. Compressive strength of cube may be calculated using below equation.

Cube Compressive strength=load at failure/ cross sectional area in N/mm^2.

iii. *Bending Strength*

According to codal criteria, bending strength of a normal concrete prism is deliberated. Equation is used to determine bending strength is as shown below:

Bending strength=PL/bd2 in N/mm^2.

iv. *Analysis of RC Beams*

After 28 days of curing, reinforced concrete beams were prepared to be tested. For making it easy for mounting upon testing machines and reinforced concrete beams are capable for testing. Marking lines were used to indicate placement of point loads, supports, as well as beam's mid-span on the testing machine. In order to conduct the test, the specimen was placed horizontally in a loading setup. In such 1000KN capacity loading frame, the beams are put to the test. The beams are held in place by circular steel supports on each of their two sides. There was only one-third point loading on all of the beams since they were designed to break in flexure instead of shear. During this test, the beam was equipped with an LVDT to measure deflection at the mid-span. The beam's mid-span point was fitted with a load cell. Repetition of the jacking process until beam's maximum load capacity was attained was necessary for applying load. The two-point loading system was chosen. The pace of loading remained constant throughout. The data gathering technology automatically acquired information. Figure 4 depicts testing apparatus.

Fig. 4: Flexural Failure of beam

IV. Results and Discussions

a) Rebars Characteristics

i. Weight / Meter Rebar Length

As shown in Table IV, conventional as well as basalt reinforcing bars have an average weight per meter.

Table IV: Average weight/meter length of rebars

Rebar type	Diameter	Average weight / meter length in kg
Traditional Rebar	12	0.86
	10	0.58
	8	0.38
Basalt rebar	12	0.23
	10	0.16
	8	0.10

When compared to standard steel, basalt rebars are 72.5 percent lighter in weight.

b) Tensile Strength Test for Conventional and Basalt Rebars

A 500 kN digital universal servo-controlled tensile strength testing equipment was used to perform test in accordance with requirements of IS 1608, as indicated in Figures 5 and 6. Figures 7 and 8 illustrate results of tests.

Fig. 5: Marking upon Conventional rebars

Fig. 6: Marking upon Basalt rebars while testing while testing

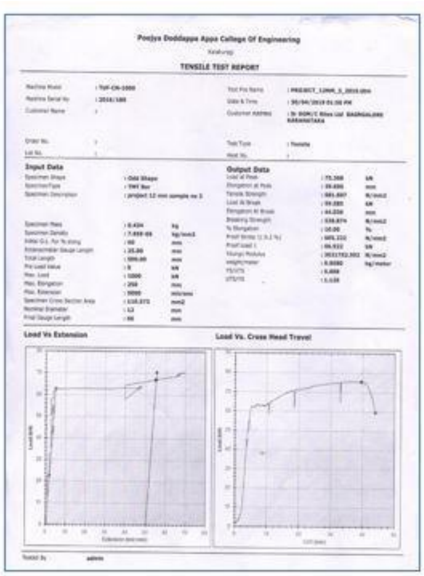

Fig. 6: Tensile testing report for Conventional

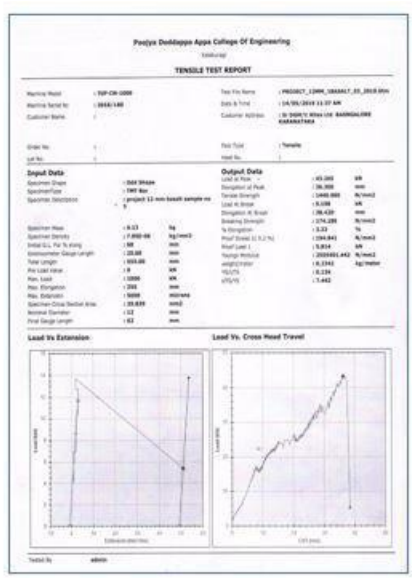

Fig. 7: Tensile testing report for Basalt Steel Rebar

c) Ductility Testing upon Rebars

In addition to elongation value, Bend and Re-bend test was utilized to determine ductility, and test was carried out in accordance with IS1786-2008. basalt rebar failed bend and rebend test, but standard steel did, demonstrating that basalt rebar has a lower ductility value than steel. The basalt rebar's biggest drawback is this.

d) Compressive Strength Test

Using the accelerated curing technique, compressive strength test results are shown in Table IV.

After testing trial mixes utilising an accelerated curing technique, it was determined that Trial MIX3 was strong enough for use in casting of RC beams. Table V shows results of compressive strength testing after 28 days. Trial MIX3 is used to make three cubes, which are then kept for conventional curing. Traditional curing yields compressive strength that is almost comparable to predicted strength attained with accelerated curing. Fig. 8 shows a cube specimen that has failed.

Table IV: Compressive strength testing result (Accelerated curing technique)

Mix identity	Specimen Name	Load (kN)	Compressive strength in N/mm² (accelerated curing test)	Compressive strength +12.65 N/mm²	Average compressive strength N/mm²
MIX.1	Cube 11	405.8	18.03	30.68	33.59
	Cube 12	458	20.35	33	
	Cube 13	550.4	24.46	37.11	
MIX.2	Cube 21	342.6	15.22	27.87	29.77
	Cube 22	481.9	21.41	34.06	
	Cube 23	331.9	14.75	27.40	
MIX.3	Cube 31	337.6	15.0	27.65	29.08
	Cube 32	451.2	20.05	32.70	
	Cube 33	320.4	14.24	26.89	

Table V: Compressive strength testing result at 28 days with M20 grade mix

Mix identity	Specimen Name	Load (KN)	Compressive strength N/mm²	Average compressive strength N/mm²
MIX.3	Cube 11	742	33	29.6
	Cube 12	659	29	
	Cube 13	602	26	

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Fig. 8: Compressive Strength Test Failure Pattern on a Cube

e) Flexural Strength Test upon Concrete

Table VI shows outcomes of flexural strength testing, and Fig 9 shows the prism's failure pattern. The prism fails slowly, with first sign of failure being development of flexural crack.

Table VI: Results of flexural strength testing with M20 grade mix at 28 days

Mix identity	Specimen Name	Load (kN)	Flexural strength N/mm²	Average flexural strength N/mm²
MIX.1	Prism 11	11.76	4.704	3.78
	Prism 12	8.82	3.52	
	Prism 13	7.84	3.13	

Fig. 9: For M20 grade concrete, prism failure patterns during flexural strength testing

After steady stress, prism fails gradually, with creation of flexural crack as precursor.

f) Behavior of RC Beams under Flexure

Every beam is attributed to 2kN/sec escalation in load, and resulting deflection is recorded.

i. *Conventional RC Beams*

a. *Conventional RC Beams (CB1 SEREIS)*

Figure 10 depicts usual crack pattern and load-deflection graphs depicting CB11, CB12, and CB13 beams.

Fig. 10: For conventional beams of CB1 series, crack patterns with load deflection graph CB11, CB12, and CB13

There are 110.4 kN for CB11, 111.2 kN for CB12, and 107.6 kN for CB13 in terms of first crack loads. The final loads are 135.7 kN, 127.2 kN, also 124.6 kN, respectively. These are equivalent deflections: 6.38mm, 7.07mm, and 7.54mm, respectively. Flexural failure was seen in CB12 and CB13. On the other side, CB11 indicated compression face extension of shear crack. Regardless of fact that first crack is flexural.

b. *Conventional RC Beams (CB2 Series)*

Fig. 11 depicts usual crack pattern for CB21, CB22, and CB23 beams, as well as a load vs. deflection graph for these three beams.

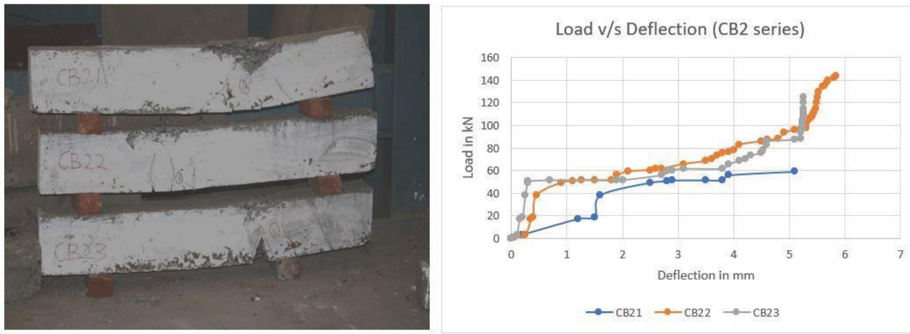

Fig. 11: Crack pattern along with typical beam load vs. deflection graph

Primary crack loading are determined as 59.2kN, 143.3kN as well as 124.2kN for CB21, CB22 also CB23 correspondingly. Equivalent ultimate load values were 121.7kN, 155.6kN and 157.5kN, as well as deflection readings are 5.21mm, 5.84mm, and 5.6mm, respectively. Flexural collapse was seen in all CB2 series specimens.

ii. *Beams with Basalt Reinforcement*

a. *Basalt Strengthened Beams (BB1 Series)*

Load-vs-deflection graphs for load-bearing beams illustrated in Figure 12 demonstrate typical crack patterns of BB11, BB12, and BB13.

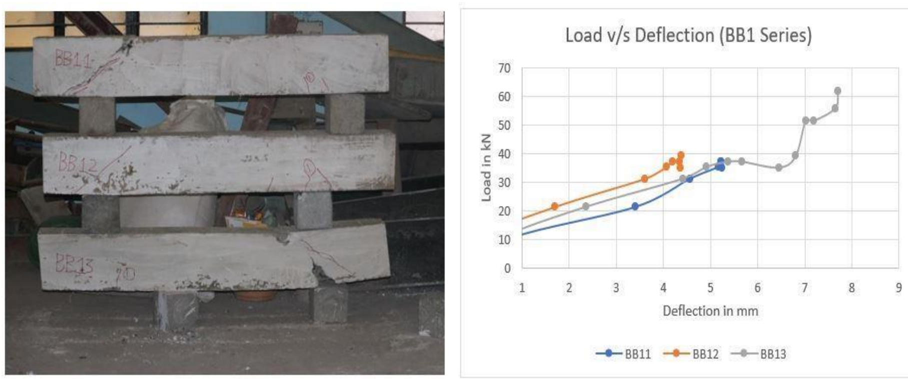

Fig. 12: Crack shape as well as Basalt-reinforced beams load-deflection graph

There are three primary crack loading for BB11, BB12, and BB13, respectively: 61.7kN, 37.2kN, and 35.1kN, correspondingly. Ultimate load values were 120.7kN, 124kN, as well as 121kN respectively. Also, deflection value was 5.24mm, 4.38mm, 7.7mm respectively. Every one of specimen exhibited shear crack which went all way through to compression face. The initial crack had been flexural crack.

b. *Basalt Reinforced Beams (BB2 Series)*

As shown in Figure 13, typical cracking formation of beam BB21, BB22, and BB23 and load vs. deflection graph is displayed.

Fig. 13: Crack pattern as well as Basalt reinforced beam load-deflection graph

For BB21, BB22, and BB23, first crack loads are 53.5kN, 37.2kN, and 47.5kN, correspondingly. There is a 107.5kN, 120.7kN, and 116.2kN ultimate load. That's 4.91mm, 4.38mm, and 3.63 millimetres of deflection in each case.

Every one of the specimens exhibited shear crack which went all way through to compression face. The initial crack had been flexural crack, in spite of fact that.

ii. *Assessment of First Crack as well as Ultimate Load of Several RC Beam*

Figures 14 and 15 show comparing with first crack as well as ultimate weight for standard RC beams with basalt strengthened beam (CB1&BB1) besides (CB2&BB2).

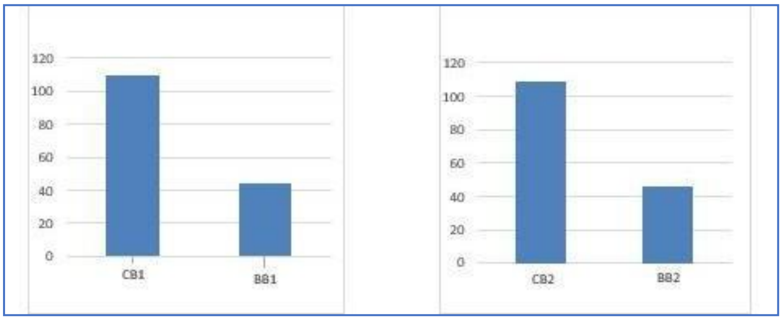

Fig. 14: Comparing first crack of (CB1 & BB1) and (CB2 & BB2)

Matched to ordinary RC beams of CB1 series, first crack weight of BB1 series' Basalt strengthened beams was reduced by 59.2 percent. As a result, ultimate loading for Basalt-reinforced BB1 series beams fell by 57.66 percent in comparison to standard RC beam of CB1 series.

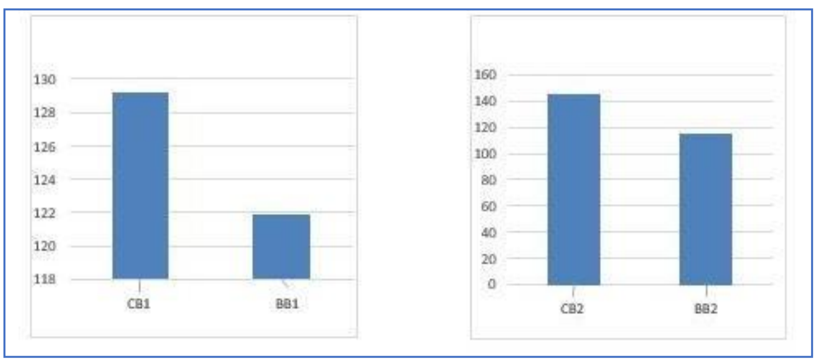

Fig. 15: Comparing ultimate load of (CB1 & BB1) and (CB2 & BB2)

When equated with conventional reinforced concrete (RC) beam of CB2 series, first crack load of Basalt reinforced BB2 series beam fell with 5.62 percent. In comparison to ordinary RC beam of CB2 series, maximum load for BB2 series' Basalt reinforced beam was reduced by 20.78 percent.

V. Conclusions and Further Scope

a) Conclusion

Established upon findings of an experimental investigation, the relevant conclusions are drawn:

1. Basalt rebar has a tensile strength double that of conventional steel.
2. This means that basalt rebar is 71.5 percent lighter per meter of length when compared to ordinary steel.
3. The basalt rebar's lack of ductility is a serious drawback. In contrast to slow collapse of ordinary rebar, failure of basalt rebars was instantaneous.
4. The failure of conventional RC beams occurred immediately after first crack formed, but failure of basalt-reinforced beams occurred after first crack formed.
5. Deflecting value for basalt reinforced beam is extraordinarily reduced by 66.66% in comparison with normal beam, basalt reinforced RC beams have a greater rigidity.
6. Conventional RC beam failure was flexural, but the failure of basalt reinforced beams was due to expansion of shear cracks, which may be linked to basalt reinforcing bars' increased tensile strength.
7. Basalt reinforced beams including a tension steel percentage of 0.5 percent had lower first crack load as well as ultimate load than conventionally reinforced beams, reducing by 59% and 5.62 percent, respectively.
8. For 0.73 percent tension steel reinforced Basalt beams, ultimate load as well as first crack load were reduced by 57.66 percent and 20.78%

correspondingly as compared to normal beams of the same size.

b) Scope for Further Study

1. Basalt rebars may be made more ductile by research on this topic.
2. RC beams having basalt reinforcement may be examined in terms of their shear behavior.
3. Studying RC beams having basalt reinforcement at impact as well as fatigue loads is possible.

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