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Experimental Analysis of Concrete Beams Reinforced With Basalt Fiber Reinforced Polymer Composite Rebars by ANSYS

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ABSTRACT

The use of Basalt Fiber Reinforced Polymer Rebar (BFRP) in place of steel rods in concrete structures plays a significant role due to non-corrosive nature. These materials have higher strength than steel but exhibit linear stress-strain response up to failure. Furthermore, the modulus of elasticity of Basalt Fiber Reinforced Polymer is significantly lower than that of steel. The present study focuses on gaining an insight into behavior of the concrete beams reinforced with Basalt Fiber Reinforced Polymer bars subjected to two point loading system by varying the grade of the concrete and diameter of the bar. Experiment will be undertaken until failure to fully understand the influence of parameters on the flexural behavior of concrete beams reinforced with Basalt Fiber Reinforced Polymer rebars and the experimental observation includes failure mode, crack pattern, ultimate failure load, load deflection behaviour and ductility. The comparisons between the flexural capacity of Basalt Fiber Reinforced beam and steel beams from theoretical and experimental analysis are done. The structural behavior of Basalt Fiber Reinforced Polymer beam is validated by developing finite element models using ANSYS Software.

Keywords: Concrete beams, BFRP bars, Deflection, Crack pattern, Load Vs Deflection, ANSYS

1 Introduction

The use of basalt fiber reinforced polymer rebar in place of steel rods in concrete structures plays a significant role due to non-corrosive nature. Compared to steel reinforcement, the BFRP has higher tensile strength, lower density, higher fatigue resistance, better insulation. The chemical composition of basalts, which are made BFRP basalt is somewhat different. In addition to chemical composition, mechanical properties of basalt fibers originating from different sources are probably due to the different chemical components and processing conditions such as the temperature of the fiber production. Basalt fiber tensile strength tends to increase from 1.5 to 2.9 Gpa as the production temperature increase within the range of 1200 to 1375⁰ C. A basalt FRP bar is a composite material consisting of rigid polymer resin bounding



Article Title: Experimental Analysis of Concrete Beams Reinforced With Basalt Fiber Reinforced Polymer Composite Rebars by ANSYS

unidirectional basalt fibers. BFRP bars may be 2.3 times stronger or more, in terms of ultimate strength, than traditional steel reinforcing. Basalt FRP reinforcing bars offers numerous favourable properties over traditional reinforcing steel bars, including, but not limited to, high tensile strength, corrosion resistance and nonmagnetic nature. The basalt fiber rebar has higher mechanical strength than steel rebar with lower initial cost. In addition, it also has better alkali resistance and good cost effectiveness.

2 Recent works

Zhang, Xueyi, Zou, Guangping “Experimental research on continuous basalt fiber and basalt fiber reinforced polymer (2008), Salvatore Carisciano, Igor Maria De Rosa “Basalt woven fiber reinforced vinyl ester composites: Flexural and electrical properties”(2011), Pandian . A, Veerasimman A.P, Vairavan “A study on crushing behaviour of basalt reinforced composite structure” (2016), Abeer M. Erfan, Yasser A. Algash, Taha A. El-Sayed (2019) “Experimental and Analytical Flexural Behavior of Concrete Beams Reinforced Polymer Bars” (2019). Dawid Powlowski, Maciej Szumigala, “Flexural behaviour of full scale basalt FRP RC beams experimental and numerical studies” (2015). Mohamed A. El-Shaer “Structural Analysis of Concrete Beams Reinforced with Basalt FRP” (2016). Shisheven, Farzin Azimpour, Hamid, “Low Velocity Impact Behavior of Basalt Fiber Reinforced Polymer Composites” (2017). Ovitigala, Thilan “Structural Behaviour of Concrete Beams Reinforced with basalt Fiber Reinforced Polymer Bars” (2012). Lobanov. D.S, Slovikov. S.V, “Mechanical Properties of a Unidirectional Basalt - Fiber Reinforced Plastic under a loading Simulating Operation Conditions” (2017).

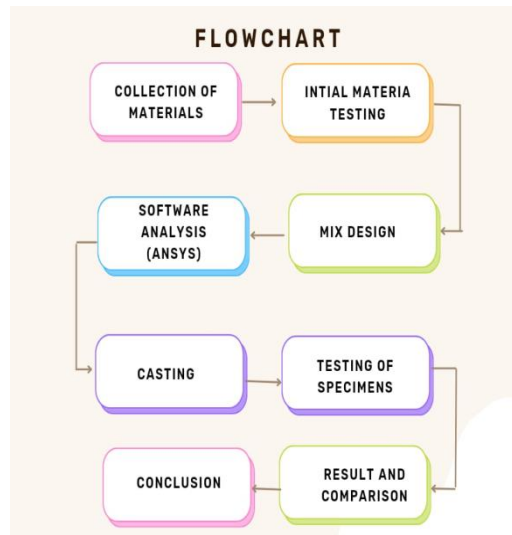
3 Materials and methods

This part briefly explains the methodology adopted in this experimental work. It also includes material collection, initial material testing, casting of conventional test specimen, testing of conventional specimen, casting of beam element, testing of beam element, analysis of test results, analysis using ANSYS, comparison of experimental and analytical results. The materials that are used for the preparation of the beam specimen are cement, fine aggregate, coarse aggregate, water, Basalt fiber reinforced polymer composite rebar, steel rods.



Article Title: Experimental Analysis of Concrete Beams Reinforced With Basalt Fiber Reinforced Polymer Composite Rebars by ANSYS

4 Methodology



5 Proposed Work Explanation

The experimental work contains six RC beams with dimensions of 150mm x 150 mm in wide, depth and 750 mm at length were examined till failure. Three beams were reinforced with basalt bars and others were reinforced using steel bars, all beams are examined using 2000 KN capacity testing machine.

Series	Specimen Designation	Details of Reinforcement		
		Tension	Compression	Stirrups
BFRP	B30-1	2 ϕ 10	2 ϕ 8	ϕ 8@ 150
	B30-2	2 ϕ 12	2 ϕ 8	ϕ 8 @ 100
	B30-3	2 ϕ 16	2 ϕ 8	ϕ 8@ 80
STEEL	BS30-1	2 ϕ 10	2 ϕ 8	ϕ 8@ 150
	BS30-2	2 ϕ 12	2 ϕ 8	ϕ 8 @ 100
	BS30-3	2 ϕ 16	2 ϕ 8	ϕ 8@ 80

6 Results and Discussion

Through the experimental test, the tested beams were naked detected until first crack occurs till failure. The crack corresponding load was recorded and the midspan deflection at first crack. The mode of failure was varied between flexural failures especially for beams reinforced steel bars the failure was tension failure. For specimens B30-1, B30-2 the failure occurs suddenly which refer to failure mechanism of fiber bars, it is BF basalt bars failure. The failure mode of beam B30-3 was compression failure.



Article Title: Experimental Analysis of Concrete Beams Reinforced With Basalt Fiber Reinforced Polymer Composite Rebars by ANSYS

6.1 Flexural Strength

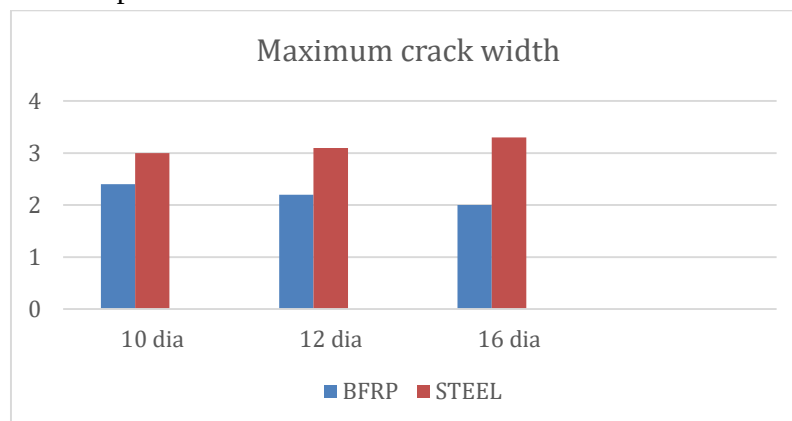
Beam mould of size 15 x 15x 70 cm (when size of aggregate is less than 38 mm) or of size 10 x 10 x 50 cm (when size of aggregate is less than 19 mm) Tamping bar (40 cm long, weighing 2 kg and tamping section having size of 25 mm x 25 mm). Prepare the test specimen by filling the concrete into the mould in 3 layers of approximately equal thickness. Tamp each layer 35 times using the tamping bar as specified above. Tamping should be distributed uniformly over the entire cross-section of the beam mould and throughout the depth of each layer.

Clean the bearing surfaces of the supporting and loading rollers, and remove any loose sand or other material from the surfaces of the specimen where they are to make contact with the rollers.

Circular rollers manufactured out of steel having cross section with diameter 38 mm will be used for providing support and loading points to the specimens. The length of the rollers shall be at least 10 mm more than the width of the test specimen. A total of four rollers shall be used, three out of which shall be capable of rotating along their own axes. The distance between the outer rollers (i.e. span) shall be **3d** and the distance between the inner rollers shall be **d**. The load shall be applied at a rate of loading of 400 kg/min for the 15.0 cm specimens and at a rate of 180 kg/min for the 10.0 cm specimens.

6.2 Patterns of crack and width

First cracks occurred in all specimens approximately in the tension zone at the middle of the beams. All specimens showing tension failure for beam B30-1, B30-2 with different of its failure load but there was a sudden crushing in basalt bars due to its failure mechanism after tension cracks in concrete occurred. For specimen B30-3 the cracks occurred in the tension zone at the beginning of the loading but due to the increasing in reinforcement ratio, the concrete crushed at compression zone Failure.





Article Title: Experimental Analysis of Concrete Beams Reinforced With Basalt Fiber Reinforced Polymer Composite Rebars by ANSYS

BFRP	2.4	2.2	2.0
STEEL	3	3.1	3.3

6.3 Ultimate failure load – deflection

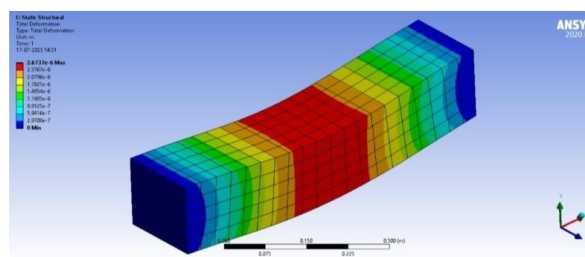
The experimental failure loads for two beam groups and its corresponding deflections were recorded. The deflections were recorded using LVDT at the mid span verse to corresponding loads.

Series	Specimen Designation	First crack load, kN	Ultimate failure load ,kN	Deflection at first crack load, mm	Deflection at ultimate load, mm
BFRP	B30-1	14	120	1.7	23.0
	B30-2	16.5	140	1.5	20.0
	B30-3	17	165	1.3	19.6
STEEL	BS30-1	8.5	25	2.5	33.1
	BS30-2	9.1	30	2.3	30.5
	BS30-3	10	45	2.0	29

6.4 Analysis of beam using ANSYS software

NLA was done to verify the BFRP beams with experimental results. The ANSYS software was used to verify this purpose. The failure load, deflection, first cracks, total cracks and ductility are the main parameters which will discussed in the finite element program. Therefore, an agreement and correlation between the obtained NLFEA results and experimental ones which verify the model ANSYS. The program for the beams which used which used in experimental test is the same for what in NLFEA.

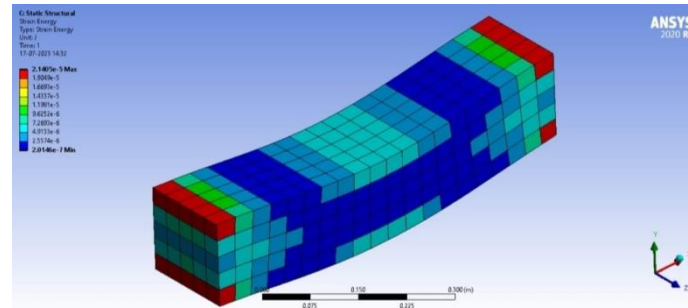
Total deformation



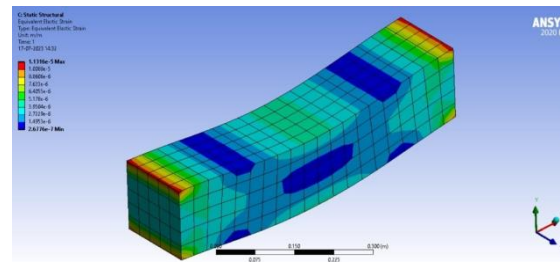


Article Title: Experimental Analysis of Concrete Beams Reinforced With Basalt Fiber Reinforced Polymer Composite Rebars by ANSYS

Strain Energy



Stress



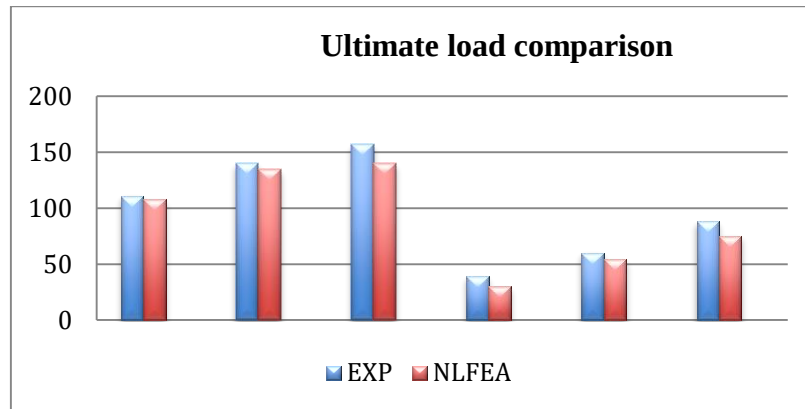
Comparison between experimental results and NLA

After obtained all available results from non-linear finite element analysis, a comparison between the experimental results and NLA results.

Series	Specimen Designation	Ultimate Failure load, Pult KN		Deflection at Ultimate load, mm	
		NLA	EXP	NLA	EXP
BFRP	B30-1	108	111.0	20.5	25.0
	B30-2	135	140.0	18.9	20.0
	B30-3	140	157.0	17.5	18.0
STEEL	BS30-1	30	39.0	26.8	33.0
	BS30-2	54	60.0	27.0	37.0
	BS30-3	75	88.0	30.8	39.0



Article Title: Experimental Analysis of Concrete Beams Reinforced With Basalt Fiber Reinforced Polymer Composite Rebars by ANSYS



	B30-1	B30-2	B30-3	BS30-1	BS30-2	BS30-3
EXP	111	140	157	39	60	88
NLFEA	108	135	140	30	54	75

7 Conclusion

The BFRP bars showed mechanical failure mechanism as FRP polymers which take the brittle failure mode if it reaches its ultimate capacity. It is noted that critical load for tested beams reinforced with BFRP bars was much greater than the carrying capacity of beams with conventional steel reinforcement, which arose from the different degrees of mechanical reinforcement in both types of beams. The failure of beams with BFRP reinforcement did not occur suddenly and this effect was a result of transformation of the beam into a tie system. Deflections of the beams with BFRP reinforcement were significantly higher than the reference beam deflection, due to the much lower modulus of BFRP bars compared to steel bars. Deformation of the reinforcement of concrete beams with basalt reinforcement were considerably higher than the beams with steel reinforcement.

References

1. Nanni A, Year: 2005, "Guide for the design and construction of concrete reinforced with FRP bars (ACI 440.1 R-03)", In Structures Congress 2005: Metropolis and Beyond, pp. 1-6.
2. Garbacz A; Lapko A; Urbanski M, Year: 2013, "Investigation on concrete beams reinforced with basalt rebars as an effective alternative of conventional RC structures", Proceedings of the 11th International Conference on Modern Building Materials, Structures and Techniques, Procedia Engineering.
3. Baorong Huo, Year: 2011, "Theoretical and Experimental study on BFRP Concrete Structures", Doctor Paper of Lianing Technical University.



Article Title: Experimental Analysis of Concrete Beams Reinforced With Basalt Fiber Reinforced Polymer Composite Rebars by ANSYS

4. Kelley Paul L; Michael L. Brainerd; Milan Vatovec, Year: 2000, "Design philosophy for structural strengthening with FRP," Concrete International, Vol: 22, no: 2, pp. 77-82.
5. El-Nemr Amr; Ahmed Ehab A; Benmokrane B, Year: 2013, "Flexural and serviceability of normal- and high strength concrete beams reinforced with glass fiber –reinforced polymer bars", ACI structural journal, Vol: 110, no: 6.
6. Jason Duic; Sara Kenno; Sreekanta Das, Year: 2018, "Performance of concrete beams reinforced with basalt fiber composite rebar", Construction and building Materials, Vol. 176, pp. 470-481.
7. El-Sayed; Taha A., Year: 2019, "Flexural Behaviour of RC beams containing recycled industrial waste as steel fibers", Construction and Building Materials, Vol: 212, pp. 27-38
8. Barris C; Torres L; Mias C; Vilnova I, Year: 2012, "Design of FRP reinforced concrete beams for serviceability requirements", Journal of Civil Engineering and Management, Vol: 18, no: 6, pp. 843-857.
9. Sarja A, Year: 2002, "Integrated life cycle design of structures", New York: Spoon Press 2002.