Behavior of RC Beam Using Basalt Fiber Polymer as Reinforcement

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Abstract –In the last few decades, the use of fiber-reinforced polymer (FRP) bars as internal reinforcement for concrete structures was driven by their anti-corrosive properties, lightweight, and high tensile strength. Their wide-spread was backed up by numerous studies that reported on their effectiveness in reinforcing reinforced concrete (RC) structures.The concrete construction field has shown a growing interest in the advantages of introduction of fiber reinforcement in structural elements. Among the different fibers available, e.g. steel, synthetic, glass, and natural fibers, the steel fiber is probably the most investigated and most commonly used. The advancement in fibre-reinforced polymer (FRP) innovation have a distinct fascination in executing another sort of strands named as basalt fibre reinforced polymer (BFRP), which has the dominating of being erosion safe, strong and cost effective that deliver a predominant outcome when applied in concrete structure. Besides, the accessible codal provision and aides does not give any suggestions to the use of Basalt bars since basic investigations and significant applications are as yet restricted. This project deals with the experimental investigation for enhancing the flexural strength capacities of fiber reinforced concrete (RC) beams using BFRP rods. A control specimen is prepared without adding fiber and BFRP rod. RC beam reinforced with BFRP rod alone is then casted and cured, after that three beam specimens with different lengths of steel fibers is casted. The ultimate loads, load-deflection curves, cracking and crushing patterns of BFRP reinforced concrete beam have been compare with that of steel fiber RC beam using BFRP rods. The objective of our investigation was examining the properties on BFRP and STEEL bars & these properties were evaluated and compared with the codal provision. The FE analysis of steel reinforcement and FRP bars beams are carried out in finite element method ABAQUS software. Additionally, the test outcomes prove that the basalt bars have a great mechanical behaviour over concrete structures and it can be set as a substitution of STEEL bars for light, temporary structures.

Keywords: Flexural Strengthening, FRP Bars, BFRP Reinforced Concrete Beam, ABAQUS Software

1. *INTRODUCTION*

Basalt fiber is a high presentation non-metallic fiber made from basalt rock melted at high temperature. Basalt rock can also make basalt rock, chopped basalt fiber, basalt fabrics and continuous filament wire. Basalt fiber originates from volcanic magma and volcanoes, a very hot fluid or semi fluid fabric under the earth's crust, solidified in the open air. Basalt is a common term used for a variety of volcanic rock, which are gray dark in colour. The molten rock is then extruded through diminutive nozzles to produce continuous filaments of basalt fiber. The basalt fibers do not contain any other additives in a single producing process, which gives additional advantage in cost. Basalt rock fibers have no toxic reaction with air or water, are noncombustible and explosion proof. When in contact with other chemicals they produce no chemical reaction that may damage health or the environment. Basalt fiber has good hardness and thermal properties. Basalt fibers have been successfully second-hand for foundation such as slabs on ground concrete. As an substitute, the use of wielded wire mesh in the form of Ferro-cement laminates has proven to have many advantages. Ferro-cement possesses good hardiness, ductility and durability. In addition, Ferro-cement can easily be cast into any form to fit the contours of the elements to be repaired. Epoxy is used to ensure the full composite behaviour of RC beams and laminate under loading.

1.1 Flexural Behavior of RCC Beam

RCC beam are effectively used as structural members in various constructions. RCC is a homogeneous material which is having various properties. RCC beams are classified as under reinforced, balanced and over reinforced sections on the analysis basis. In RCC both concrete and steels will reaches the stress and corresponding strains due to external subjected loads simultaneously. When in an RCC beam, if the steel tends to fail before the stress in concrete reaches the maximum permissible stress such beams are known as under reinforced sections. If both concrete and steel reaches the permissible stress values simultaneously such beams are considered as balanced sections. If the concrete tends to fail before the stress in steel reaches the maximum permissible stress such beams are considered as over reinforced sections. In the study based on the laboratory experimental analysis the flexure behaviour beam with basalt fiber polymer reinforcement of various sections are observed by destructive methods.

2. *METHODOLOGY*

In research methodology investigate the normal flexural strength concrete sample with different amount of added basalt fiber in concrete beam. In this study RC beam analyze with basalt and steel fiber reinforcement for the strengthening material for concrete composite. All the results are compared with the steel and basalt fiber reinforcement using various parameters.

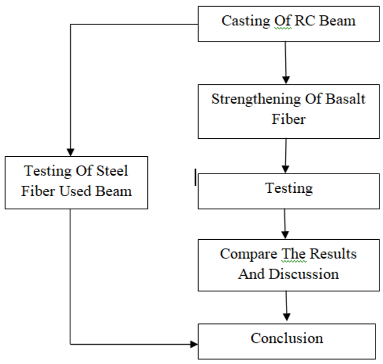

Figure 1 Flowchart Of Methodology

3. *LITERATURE REVIEW*

1. **Flexural Behavior of Basalt Fiber Reinforced Polymer Tube Confined Coconut Fiber Reinforced Concrete (2019)**

Basalt fiber has arisen new perspectives due to the potential low cost and excellent mechanical performance, together with the use of environmental friendly coir can be beneficial to the development of sustainable construction. In this study, a new composite structure called basalt fiber reinforced polymer (BFRP) tube encased coconut fiber reinforced concrete (CFRC) is developed. The 28-day compression strength of the plain concrete is about 15 MPa, which represents the low-strength poor-quality concrete widely existing in many old buildings and developing countries. Three types of BFRP tubes, i.e., 2-layer, 4-layer, and 6-layer, with the inner diameter of 100mm and a length of 520 mm, were prepared. The plain concrete (PC) and CFRC were poured and cured in these tubes to fabricated BFRP tube confined long cylindrical beams. Three PC cylindrical beams and 3 CFRC cylindrical beams were prepared to be the control group. The four-point bending tests of these specimens were carried out to investigate the enhancement due to the BFRP tube and coir reinforcement. The load-carrying capacity, force-displacement relationship, failure mode, and the cracking moment were analyzed. Results show that both BFRP tube confined plain concrete (PC) and BFRP tube confined CFRC have excellent flexural strength and ductility, and the inclusion of the coir can further enhance the ductility of the concrete.

2. **Experimental And Analytical Flexural Performances Of Reinforced Concrete Beams Strengthened With Post-Tensioned Near Surface Mounted Basalt Composite Laminates (2018)**

Near surface mounted (NSM) is a technique that improves the strengthening capacity of composite laminates. The use of a post-tensioning technique modifies the performance of the strengthening because it is active bearing loads from the very beginning. This study compares the performances of three beams: one without strengthening, one with passive NSM laminate, and a third with post-tensioned NSM laminate. The experimental approach compares the precracking and post-cracking performance until failures, showing that the post-tensioned solution withstands larger loads in pre-cracking and presents less deformation in post-cracking. Moreover, post-tensioning is an effective technique that can prevent loss of stiffness even after cracking. Finally, simple analytical equations based on the plane cross-section for precracking and failure analysis are proposed, showing good agreement with the experimental results

3. **Experimental Study Of Concrete Beams Prestressed With Basalt Fiber Reinforced Polymers (2017)**

Current research presents a comparative experimental investigation and introduces a new prestressing system for concrete members considering composite materials such as basalt fiber reinforced polymers (hereinafter–BFRP) in lieu conventional steel reinforcement. Certain three groups of total large–scale beams and one non–prestressed control beam were tested depending on the degree of prestressing of the reinforcement. This paper summarizes a study undertaken to analyze flexural behavior in particular to deflection, cracking growth and stiffness. Further research of prestressed BFRP concrete is introduced in order to expand potential application of basalt composite materials in the industry.

4. *METHODOLOGY*

4.1. Basalt Material as Strengthening Method

There are several types of basalt fiber strengthening methods used to strengthen concrete. Here three types are mentioned: External strengthening, , fiber matrixes, and rod type material.

✓ **The External Strengthening**

A fiber sheet layer is applied to the lower part (tension side) of the concrete beam as seen on fig.3.1. This method increases the strength considerably since it holds the concrete together.

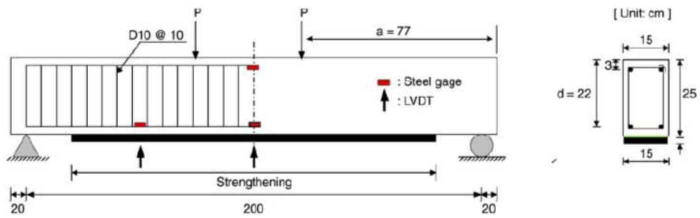

Figure 2 Fiber Strengthening Under the Beam

✓ **Fiber Matrixes**

Fiber matrixes are put in the concrete to increase strength in typical steel reinforced beams. The matrixes are placed in the concrete beam in such a way as to maximize the shear strength and prevent cracks. Shear cracks usually form 45° cracks from the foundation and to the direction of the force. The fiber matrixes are placed in such a way that they try to prevent shear cracking, which is the fibers are placed perpendicular to the possible crack. This will give extra strength to this area of the beam and prevent the shear cracking.

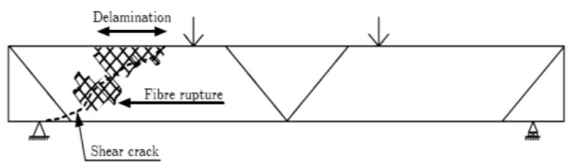

Figure. 1: Fiber Matrix Set in the Concrete

✓ **The Rod/Bar Type**

In this study the rod type is of the most interest. Basalt fiber rod can be considered a good choice for reinforcement of concrete where for example weather

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 04 Issue: 08 | August -2020 ISSN: 2582-3930

conditions are such that corrosion is likely. The danger is usually to structures close to the sea or salty environment, houses and bridges are in that category. When using typical rebar close to salty environment special consideration of the concrete cover needs to be kept in mind, but with FRP rebar too little concrete cover is of no danger to the strength of the structure.

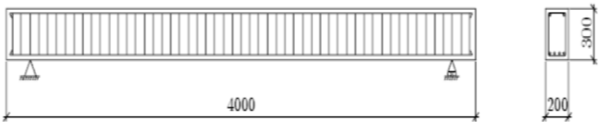

Figure. 2: Typical Concrete Beam Reinforced with Bars

✓ **Basalt Fiber Bar**

Basalt composite bars are made by utilizing basalt fibers and a resin epoxy binder. They are non-corrosive, consist of 80% fibers and have a tensile strength three times that of the steel bar normally used in building construction. Wherever corrosion problems exist, basalt fiber composite bars have the potential to replace steel in reinforced concrete. Currently there are many FRP bar manufacturing companies which market their products. Most of these bars are made of E-glass fiber and thermosetting resin. However FRP bars lack sufficient durability under extreme conditions. These bars are costly and are also non-resistant to alkalis. Basalt bars do not possess these disadvantages and can be effectively used in various applications such as highway barriers, offshore structures, and bridge decks.

The above mentioned advantages alone could warrant a sufficient argument for substitution of steel bars with basalt bars on a large scale. Other advantages of the basalt bar are that its weight is one-third of the weight of steel and the thermal expansion coefficient is very close to that of concrete. The high mechanical performance/price ratio of basalt fiber composite bar, combined with corrosion resistance to alkaline attack, are further reasons for replacing steel in concrete with basalt fiber composite bars.

4.2. Types of FRP strengthening applications in reinforced concrete structures

In the last three decades, the integration of FRP strengthening systems has been increased due to the superior characteristics of these composites. This has been duly noted in the open literature by the amount of research and published work. This section aims at highlighting some of the notable experimental, numerical and analytical investigations carried out in recent years. In particular, studies related to flexural, shear, torsional, axial and seismic strengthening are presented.

➢ **Flexural Applications**

Alternatively, near-surface mounted rods with fiber direction parallel to the member longitudinal axis can also be utilized. This use of FRP rods to strengthen RC beams in flexure has been well studied are highlighted herein. In an early study by Ritchi et al. in 1991, strengthened RC beams with adhesively bonded GFRP and CFRP plates were tested to failure. The tested beams were 2.75m long and were subjected to dominant flexural effects. Results of this investigation revealed that strengthened beams achieved 17 to 95% increase in stiffness, and 40–97% increase of ultimate strength when compared to similar unstrengthened control beams.

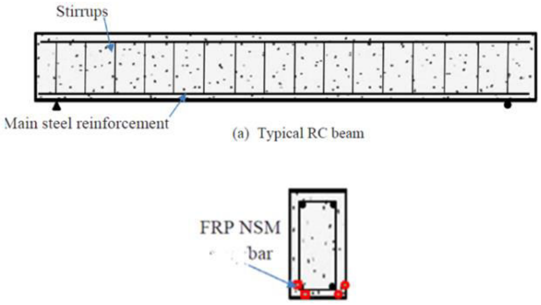

Figure. 3: Use Of FRP For Flexural Strengthening In RC Beams

➢ **Shear Application**

FRP, as a strengthening material, has also been used to enhance shear capacity of RC beams. In such application, FRP strengthening systems can be used in variety of techniques including side bonding of FRP sheets and/or plates in addition to use of NSM technique. In the case of side bonding of FRP, individual and relatively narrow sheets/plate are bonded and spaced at external sides of the RC beam to act in parallel in resisting shear forces, similar to internal steel stirrups. One of the early studies that investigated shear response of FRP-sided bonded RC beams

➢ **Torsion Applications**

FRP as external reinforcing materials and systems are often extensively used to enhance the strength requirement related to flexure and shear in RC beams and column. But strengthening of members subjected to torsion is the least researched area as can be seen by the limited number of published studies. This is due to the fact that beams mare mainly subjected to flexural and shears effects and most codal provisions tend to neglect effects of torsion when beams have sufficient shear reinforcement. Further, the complicated test set-up required to carry out torsional tests is another challenge that hinder such research efforts. In general, torsional strengthening of beams follows that of flexure and shear strengthening, in which beams continue to be strengthened with conventional FRP sheets, plates and/or NSM strips. The use of hybrid strengthening systems or use of ductile FRP material in torsional application is not fully investigated yet. Typical strengthening schemes used in torsional application are very similar to those used in shear strengthening

➢ **Axial Applications**

One of the early uses of FRP materials was to strengthen bridge piers and columns post-earthquake events. In such application, FRP sheets are commonly used, although some recent studies have proposed the use of NSM reinforcement as well. Lateral confinement of concrete columns by means of spirally FRP bars composites, as shown in Fig., onto the concrete surface can increase compressive strength and inhibit longitudinal steel reinforcement buckling.

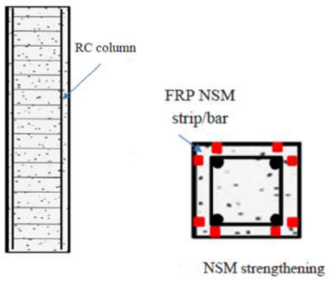

Figure. 4: Use Of FRP For Axial Strengthening In RC Columns

- **Seismic Applications**

While the most studies focused on the static and monotonic behavior of FRP-strengthened structures, the seismic response of such strengthening systems has also been a focal point of investigation. The cyclic behavior of FRP-strengthened structures was thoroughly investigated due to the fact that FRP was mainly developed as an efficient retrofitting tool, especially in the case of seismically damaged buildings and bridges. The strengthened beams in this study achieved moderately higher failure loads, of about 10–30%, over that of the unstrengthened beam specimen. Other similar studies on the FRP composites in seismic applications are provided

5. *RESULT AND DISCUSSION*

1 Load Vs Deflection Curve

Table 1 Load Vs Deflection Curve For Steel

Sr. No	Load	12 mm			16 mm			20 mm		
		2	3	4	2	3	4	2	3	4
1	5	0	0	0	0	0	0	0	0	0
2	10	0.5	0	0	1.5	0	0	0	1.3	0
3	15	0.7	0.7	0	2.4	1.8	1.1	0	3.5	1.9
4	20	1	0.9	1	3.3	2.4	2.4	0.8	3.45	2.89
5	25	1.5	1.1	1.2	4.2	3	3.7	1.4	3.89	3.74
6	30		1.3	1.8	5.1	3.6	5	2	4.33	4.59
7	35		1.5	2.4	6	4.2	6.3	2.6	4.77	5.44
8	40		1.7	3	6.9	4.8	7.6	3.2	5.04	6.29
9	45		1.9	3.6	7.8	5.4	8.9	3.8	5.31	7.14
10	50		2.1	4.2	8.7	6	8.2	4.4	5.58	7.99
11	55				9.6	6.6	7.5	5	5.85	8.84
12	60				10.5	7.2	8.8	5.6	6.12	9.69
13	65				11.4	7.8	9.1	6.2	6.9	10.54
14	70				12.3	8.4	9.4	6.8	7.98	11.39
15	75					9	9.7	7.4	9.06	11.24
16	80						10	8	10.14	12.09
17	85							8.6	11.22	12.94
18	90							9.2		13.79
19	95									13.64
20	100									15.49
21	105									16.34
22	110									17.19
23	115									18.04

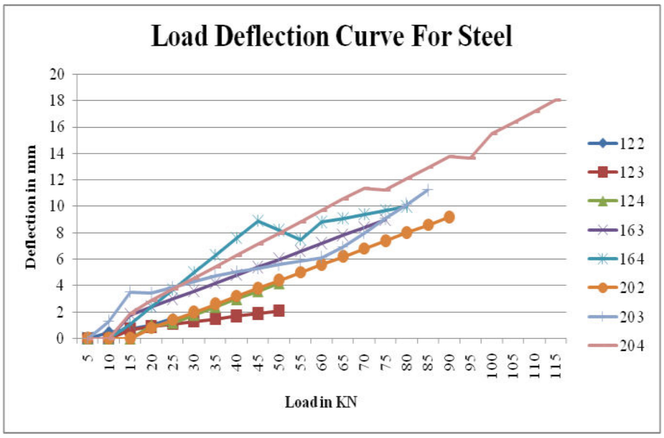

Figure 1 Load Vs Deflection Curve For Steel

Figure shows that load Vs deflection curve for steel. Result is obtained load carrying capacity increases deflection is also increases that are load carrying capacity is directly proportional to deflection.

Table 2 Load Vs Deflection Curve For BFR

Sr. No	Load	12 mm			16 mm			20 mm		
		2	3	4	2	3	4	2	3	4
1	5	0	0	0	1.8	0	0	0	0	0
2	10	0.5	0.98	1	2.8	1.3	0	0	0	0
3	15	1.1	0.89	1.2	2.4	1.8	0	0	0	0
4	20	1.8	0.9	2.3	3.3	2.9	0	0.8	1	1.89
5	25		1.1	3.4	5.2	4	1.7	1.4	2.34	2.74
6	30		2.5	4.5	7.1	5.1	5	2	3.68	5.59
7	35			5.6	9	6.2	6.3	2.6	4.02	3.44
8	40				10.9	7.3	7.6	3.2	4.36	4.97
9	45				12.8	8.4	8.9	3.8	5.7	6.5
10	50					9.5	8.2	4.4	7.04	8.03
11	55					10.6	7.5	5	8.38	9.56
12	60					11.7	8.8	5.6	9.72	11.09
13	65						9.1	7.2	11.06	12.62
14	70						9.4	8.8	12.4	14.15
15	75						9.7	10.4	13.74	15.68
16	80							12	15.08	17.57
17	85									19.46

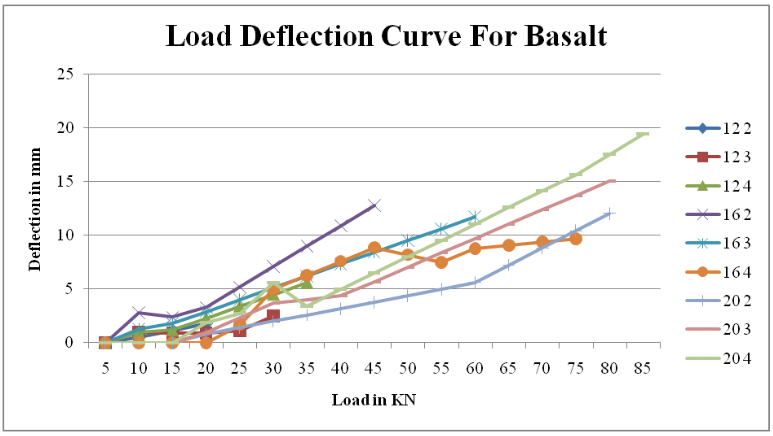

Figure 2 Load Vs Deflection Curve For Basalt

Figure shows that load Vs deflection curve for basalt. Result is obtained load carrying capacity increases deflection is also increases that are load carrying capacity is directly proportional to deflection.

2 Load Vs Area

Table 3 Load Vs Area Curve For Steel and BFR

Sr. No	Size of Beam	Type of Fiber		Load Carrying Capacity of Steel Fiber	Load Carrying Capacity of BSF Fiber	Area of Steel provided	Load vs Area in steel	Load vs Area in Basalt
	mm	Steel	BSF	KN	KN			
1	150X150	2Ø12	2Ø12	38.65	29.45	226.08	0.171	0.130
2	150X150	3Ø12	3Ø12	45.63	32.87	339.12	0.135	0.097
3	150X150	4Ø12	4Ø12	54.6	34.69	452.16	0.121	0.077
4	150X150	2Ø16	2Ø16	57.84	36.41	401.92	0.144	0.091
5	150X150	3Ø16	3Ø16	60.86	39.87	602.88	0.101	0.066
6	150X150	4Ø16	4Ø16	63.54	42.59	803.84	0.079	0.053
7	150X150	2Ø20	2Ø20	67.96	45.89	628	0.108	0.073
8	150X150	3Ø20	3Ø20	70.98	48.75	942	0.075	0.052
9	150X150	4Ø20	4Ø20	79.45	53.987	1256	0.063	0.043

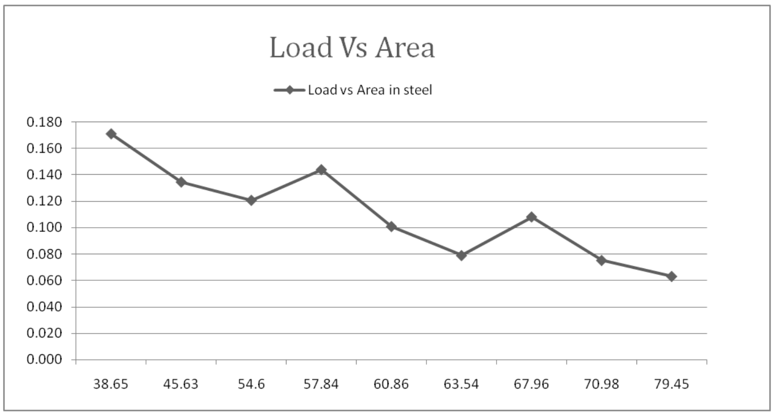

Figure 3 Load Vs Area Curve For Steel

Figure shows that load Vs area curve for steel. Result is obtained area of steel bar increased increases the load carrying capacity basalt fiber. Load carrying capacity is directly proportional to area of steel fiber.

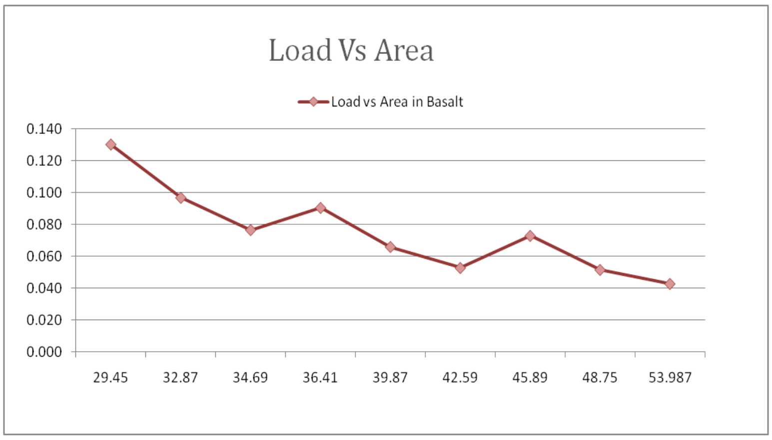

Figure 4 Load Vs Area Curve For Basalt

Figure shows that load Vs area curve for basalt. Result is obtained area of steel bar increased increases the load carrying capacity basalt fiber. Load carrying capacity is directly proportional to area of basalt fiber.

3 Failure Pattern of Beam

The RC beam specimens are tested under axial load to find out load carrying capacity. Local buckling of specimen is occurred close to mid height of specimens. Various failure modes of specimens are tabulated as below.

Table 4 Failure Pattern Of Beam

Sr. No	Steel Fiber	Deflection in Steel	Type of Failure	Basalt Fiber	Deflection in Basalt	Type of Failure
1	2Ø12	1.75	Steel yielding	2Ø12	2.2	Steel yielding
2	3Ø12	2.3	Concrete crushing	3Ø12	2.6	Steel yielding
3	4Ø12	2.54	Concrete crushing	4Ø12	2.75	Concrete crushing
4	2Ø16	2.65	Steel yielding	2Ø16	2.9	Concrete crushing
5	3Ø16	2.7	Concrete crushing	3Ø16	3.2	Concrete crushing
6	4Ø16	2.78	Concrete crushing	4Ø16	3.45	Shear compression
7	2Ø20	3.2	Shear compression	2Ø20	4.08	Concrete crushing and bar rupture
8	3Ø20	3.5	Concrete crushing and bar rupture	3Ø20	4.5	Concrete crushing and bar rupture
9	4Ø20	4.54	Concrete crushing and bar rupture	4Ø20	5.2	Concrete crushing and bar rupture

6. CONCLUSION

The conclusion can be listed below:

- FRP materials can be an integral part of modern design of structures due to superior properties of FRP composites and their potential in developing structural systems that exceed those constructed by traditional materials.
- The major contribution of FRP composites is its potential to extend service life of existing structures.
- FRP systems are very versatile and easy to install which come in handy in flexural, shear, torsional and axial retrofitting applications.
- Load deflection behavior of steel is maximum deflection for 20 mm diameter of 4 bars used beam section is 18.4mm and ultimate load such as 110.81KN. Minimum for 12 mm diameter of 2 bars used beam section is 1.5 mm and ultimate load for 25.05KN.
- Load deflection behavior of basalt is maximum deflection for 20 mm diameter of 4 bars used beam section is 19.46mm and ultimate load such as 84.94KN. Minimum for 12 mm diameter of 2 bars used beam section is 1.8 mm and ultimate load for 21.94KN
- Comparison steel and basalt fiber used strengthened beam load deflection behavior concluded that steel fiber carries more load and deflection basalt fiber.

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