

Flexural Strength of RC Beam Using Basalt Fiber Polymer

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ABSTRACT: The concrete construction field has shown a growing interest in the compensation 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 has a distinct fascination in executing another sort of strand named as basalt fibre reinforced polymer (BFRP), which has the dominating of being erosion safe, strong and cost effective that deliver a main outcome when applied in concrete organization. Besides, the accessible code provision and aids does not give any suggestions to the make use of 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 compared with that of steel fiber RC beam using BFRP rods.

I. INTRODUCTION

A now a day major problem that is currently facing the building and construction industry is the deterioration of concrete structures over time. In addition, many civil structures are no longer considered safe due to increased load specifications in the design codes, the overloading or under design of existing structures, or a lack of quality control. To maintain efficient serviceability, older structures must be repaired or strengthened so that they meet the same requirements demand of the structures being built today and in the future. It is both economically and environmentally acceptable to upgrade structure rather than rebuild them if this can be done using simple, effective, in addition to rapid methods. Pasting steel plates onto the soffits of beams was the first adopted and investigated method. Although the capacities, stiffness and cracking performance of the beams strengthened in this way are better the steel plate pasting method also has a number of disadvantages, such as the corrosion of the steel plates and the complicatedness of handling in addition to transporting long plates.

Furthermore, a steel plate is difficult to adapt to the profile of a concrete surface. To solve the problems with steel plates, the fibre-reinforced polymer (FRP) was introduced. The use of FRP for strengthening beams has paying attention considerable concentration worldwide due to the excellent toughness and high strength-to-weight ratio of this material. FRP laminates can be installed quickly and can conform to curved surfaces well. However, they encompass no marked effect on the stiffness of RC beams because of the limit on the thickness of FRP laminates. Furthermore, intensification with bonded FRP laminates requires the extra use of epoxy adhesive, an organic material with unqualified fire confrontation. In addition, the high cost of FRP is also an issue to consider. Industry is always trying to find new, better and economical material to manufacture new product, which is very beneficial to the industry. Today a significant growth is observed in the manufacture of composite material. With this in mind energy conservation, corrosion risk, the sustainability and environment are important when a product is changed or new product is manufactures.

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.

1.2 Currently Used Fiber Types

✓ Carbon Fibers

Carbon fibers are extremely thin fibers which are only 0.005-0.010 mm in diameter and are generally used in shorter lengths. The density of carbon fibers is very low when compared to steel, (one-fifth that of steel) thus making it a lightweight material. Apart from the low density, carbon fibers have high tensile strength, low thermal expansion, good abrasion resistance and stability at high temperatures with relatively high stiffness which makes it a popular material in the industries like aerospace, civil engineering, military, etc. However, the carbon fibers are relatively costly when compared to materials like fiberglass and synthetic fiber.

✓ Glass Fibers

Short length glass fiber is formed from the extremely thin fibers of glass. The types of glass fibers include E-glass, A-glass, E-CR-glass, C-glass, D-glass, R-glass and S-glass. The elastic modulus of glass fiber is found to be approximately one third of steel but when compared to carbon fiber, it elongates much more before failure. But the main disadvantage of glass fibers is that small diameter fibers have large surface area which makes it additional sensitive towards alkali environment. In recent years, attempts have been made to improve the alkali resistance properties of fiberglass.

✓ Steel Fibers

Steel fibers are commonly used in concrete to increase the toughness of concrete. Initially, steel fibers were used primarily for crack control and to replace the secondary reinforcements in pavements and tunnel lining. Today, while steel fibers are still used extensively for repair applications, they are also used increasingly to partially replace conventional steel reinforcements. The introduction of steel fibers in concrete can increase the resistance to fatigue, impact, blast or seismic events but the strength development is very little for low fiber volumes. The main advantage of using steel fibers in concrete is to increase the post-peak load carrying capacity of concrete after initial cracking. Types of steel fibers used in concrete are:

- Smooth cold-drawn wire;
- Deformed cold-drawn wire;
- Smooth or deformed cut sheet;
- Melt-extracted fibers;
- Mill-cut or modified cold-drawn wire.

The tensile strengths of steel fibers are in the range of 345-2100 MPa and the ultimate elongations of 0.5-35%. The main disadvantage of high strength fibers is that it causes severe spalling approximately the fiber ends. Straight and smooth fibers have poor bond with the matrix. Thus the surface of fibers was modified in the recent years to provide measures to supplement the bond with matrix. These take in hooked end, crimped, deformed and enlarged end fibers. Round fibers are shaped by cutting or chopping wires, with diameters typically in the range of 0.25-1.0 mm in addition to flat fibers are produced by shearing sheets or flattening wire. The dimensions of flat fibers are in the range of 0.15-0.40 mm thick and 0.25-0.90 mm wide. Fibers are also produced by the hot melt extraction process.

Synthetic Fibers

The synthetic polymeric fibers in use in the construction industry include acrylic, aramid, carbon, nylon, polyester, polyethylene, and polypropylene fibers. The concept of using polymeric fibers was tried in 1965. In 1970s, the large scale use of polymeric fibers in concrete had started. All these fibers have a very high tensile strength, but most of these fibers have a moderately low modulus of elasticity. As the diameter of the polymeric fibers is in the order of micrometers, their very high length-to-diameter ratios are useful in fiber reinforced concrete. The major disadvantage of polymeric fibers is low modulus of elasticity, poor bond with cement matrix, and low melting point. Their bond to the cement matrix is improved by twisting several fibers together or by treating the fiber surface.

✓ Polypropylene

Polypropylene has been the most successful commercial application so far among the synthetic polymeric fibers discussed above. Polypropylene fibers are used mainly to control cracking in the initial setting stages. These fibers are produced on or after homopolymer polypropylene resin in a variety of shapes and sizes, and with different properties. The main advantages of polypropylene fibers are their alkali resistance, relatively high melting point (165°C) and the low cost of the material. Their disadvantages are poor fire resistance, sensitivity to sunlight and oxygen, a low modulus of

elasticity (1-8 GPa) and poor bond with matrix. These apparent disadvantages are not of necessity critical. Embedment in the matrix provides a protective cover, helping to minimize sensitivity to fire and other environmental effects.

✓ **Basalt Fibre**

Basalt is a natural material that is found in volcanic rocks. It is mainly used (as crushed rock) in construction, industrial and high way engineering. One can also melt basalt (1300-1700°C) and spin it into fine fibres. When used as (continuous) fibres, basalt knows how to strengthen a new range of (plastic and concrete matrix) composites. Basalt fiber is a material made from extremely fine fibers of basalt, which is collected of the minerals plagioclase, pyroxene, and olivine. It is alike to fiberglass, having better physic mechanical properties than fiberglass, but life form considerably cheaper than carbon fiber.

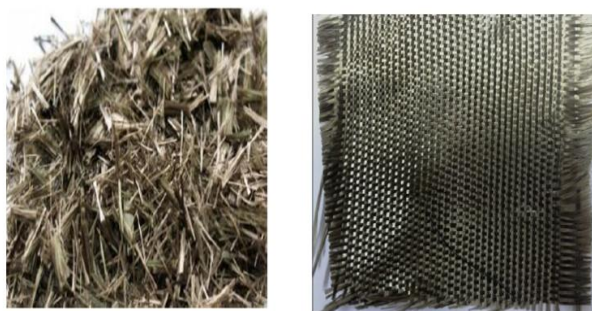


Figure 1 Basalt Fibre

II.LITERATURE REVIEW

1. Fiber-Reinforced Polymer Composites In Strengthening Reinforced Concrete Structures (2019)

Fiber-reinforced polymer (FRP) composites continue to provide designers with the ability to deliver innovative and intelligent solutions to overcome the ever-growing aging issues in infrastructure. Since it has been more than 50 years to the introduction of FRP materials to the construction industry, this paper presents a state-of-the-art review on historic and recent developments of FRP in strengthening and rehabilitation of civil engineering applications. This review highlights some of the classic and modern experimental, numerical, and analytical studies associated with the integration of FRPs into buildings, among other structures. The discussion presented herein aims at covering application of FRP systems in reinforced concrete structural members and also highlights the performance of FRPs (including bonding agents) under extreme conditions such as elevated temperature, saline environment, and cycles of freezing and thawing. This paper also presents a collective perspective on number of limitations, challenges and research needs associated with successful, sustainable, and durable implementation of FRPs in civil infrastructure.

2. Flexural Behavior Of Basalt Fiber-Reinforced Concrete Slab Strips Reinforced With BFRP And GFRP Bars (2019)

This research investigates experimentally and analytically a novel one-way slab system reinforced with either basalt fiber-reinforced polymer (BFRP) or glass fiber-reinforced polymer (GFRP) longitudinal bars embedded in fiber-reinforced concrete (FRC) incorporating basalt macro-fibers (BMF). Twelve one-way concrete slab strips were prepared and tested to failure under four-point loading configuration. The investigated parameters included the type of fiber-reinforced polymer bars (BFRP and GFRP), the longitudinal reinforcement ratio ρ_f (1.4 and 2.8 ρ_{bf} , where ρ_{bf} is the balanced reinforcement ratio), and the volume fraction of the fibers added (0, 0.5, 1, and 2% per volume). The test results demonstrated the promise of BMF to enhance the flexural performance of the tested slab strips in terms of ductility and load-carrying capacities. The formulations of different available codes and design guidelines were used to predict the test results. Comparison between the experimental and predicted results showed the adequacy of the models to predict the flexural performance of the tested slab strips. The findings of this study demonstrated the potential of using the BMF as alternatives to conventional fibers in flexural concrete members.

3. 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.

4. 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

5. 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.

6. Comparison Of Basalt Fibre Reinforced Polymer (BFRP) Rebar And Steel Rebar In Concrete Beams (2017)

This paper compares holistically the mechanical and environmental performance of basalt fibre reinforced polymer (BFRP) rebar against conventional steel rebar in concrete beams. This assessment involves material testing and life cycle assessment (LCA). The results show that BFRP tendons in reinforced concrete beams are stronger and lighter than steel with a better environmental profile and fewer embodied emissions, as fewer material and energy resources are required during production. The future market is expected to be within the precast industry, rather than in on-site construction, as precast BFRP concrete beams have approximately half the emissions of steel reinforced concrete beams.

III.METHODOLOGY

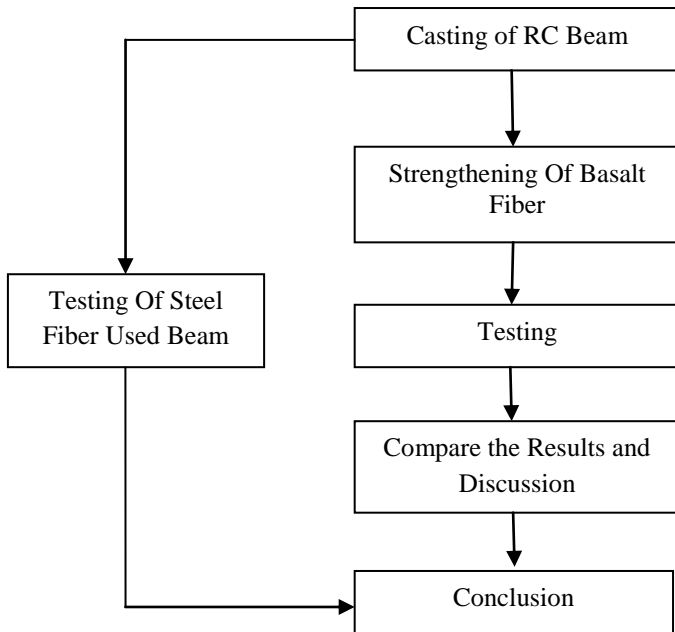


Figure. 1: Flowchart of Methodology

1. MATERIAL PROPERTIES

The materials used in the study are ordinary Portland cement of M 20 the average yield stress of main steel bars used in the experiment is 500 MPa and an elastic modulus of 200 GPa. Fine aggregate used is M sand, coarse aggregate used is of size 20mm, basalt fiber of 36mm length and 18µm diameter, closely spaced welded wire mesh with square opening having wire spacing of 12.5mm and wire diameter of 1.35mm, two-part epoxy impregnation resin, superplasticizer.

3.1. Physical Properties Of Basalt Fibre

Basalt fibres used in the experimental investigations was monofilament with a dark brown appearance and shiny surface. The physical properties of basalt fibres are given in Table

Table 1: Physical Properties Of Basalt Fiber

Properties	Values
Length (mm)	24 ± 2
Diameter (mm)	16 ± 0.5
Aspect ratio (L/D)	1500
Specific Gravity	2.63
Melting Temperature (0C)	1400
Tensile Strength (MPa)	3200
Elastic Modulus (GPa)	110
Elongation at break (%)	3.5

3.2. Types Of FRP Strengthening Systems And Products

FRP materials are manufactured in a variety of products and are mainly categorized into two groups, constant cross-sectioned and pultruded sectioned. Constant cross-sectioned FRP composite structural shapes are often produced for use in construction industry, specifically in buildings and bridge applications, while pultruded sections are mainly used in highway bridge decks and pedestrians passes. In addition, FRP products can be further classified as those developed for use in new structures and those used for strengthening and retrofitting of existing structures. FRP reinforcements for new structures can be divided into three primary products:

- ✓ FRP bars for use as internal reinforcement,
- ✓ FRP tendons for prestressed concrete (PC) members,
- ✓ stay-in-place FRP formwork for reinforced concrete members

The use of FRP materials to strengthen and/or repair load-bearing structural elements in existing structures is referred to as “retrofitting”. Retrofitting applications can be broadly classified into two types. The first type is called “strengthening”, where structure’s initial strength or ductility need to be upgraded to account for new services or levels of loading. This increase may be necessitated by the desire to make the structure compatible with existing building regulations or may be desired due to changes in intended use of the structure. The other type of FRP retrofitting can be classified as “rep airing”.

In the latter case, FRPs are used to repair an existing and deteriorated structure to bring its load-carrying capacity, ductility or stability back to the level for which it was designed for. In any way, the most commonly used FRP products are manufactured as prefabricated plates, bars, sheets and anchorages.

3.3. 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.

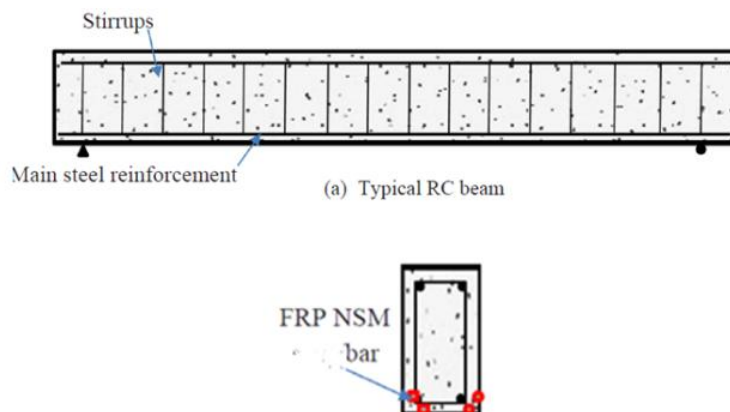


Figure. 2: Use Of FRP For Flexural Strengthening In RC Beams

IV.RESULT AND DISCUSSION

1 Analytical Flexural Strength of RC Beam

Table 1 Load Carrying Capacity Of Steel Strengthened Concrete Beam

Sr. No	Size of Beam mm	Type of Fiber		Load Carrying Capacity of Steel Fiber	Load Carrying Capacity of BFR Fiber	% Difference Between Steel Fiber	% Difference Between BFR Fiber
		Steel	BSF	KN	KN	-	-
1	150X150	2Ø12	2Ø12	38.65	29.45	-	-
2	150X150	3Ø12	3Ø12	45.63	32.87	15.30	10.40
3	150X150	4Ø12	4Ø12	54.6	34.69	16.43	5.25
4	150X150	2Ø16	2Ø16	57.84	36.41	5.60	4.72
5	150X150	3Ø16	3Ø16	60.86	39.87	4.96	8.68
6	150X150	4Ø16	4Ø16	63.54	42.59	4.22	6.39
7	150X150	2Ø20	2Ø20	67.96	45.89	6.50	7.19
8	150X150	3Ø20	3Ø20	70.98	48.75	4.25	5.87
9	150X150	4Ø20	4Ø20	79.45	53.987	10.66	9.70

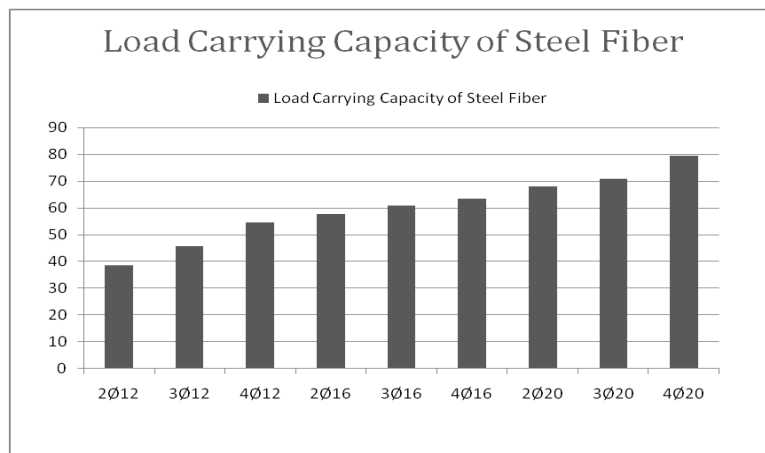


Figure. 3: Load Carrying Capacity Of Steel Strengthened Concrete Beam

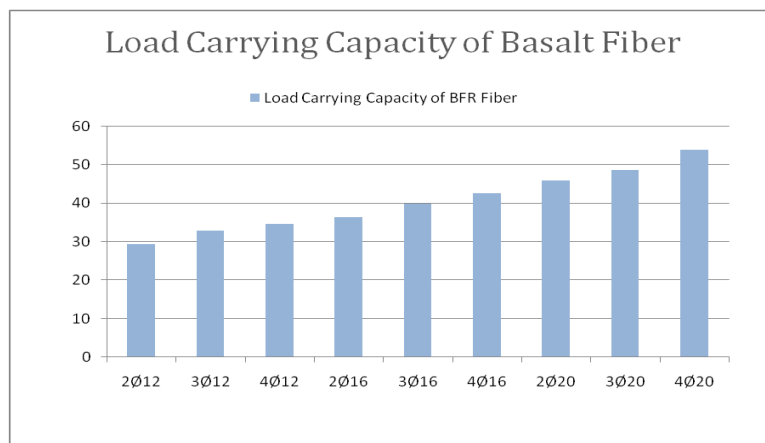


Figure. 4: Load Carrying Capacity Of Basalt Strengthened Concrete Beam

2 Increase in Load Carrying Capacity Steel and Basalt Fiber

Table 2 Increase In Load Carrying Capacity Of Steel and Basalt Fiber

Sr. No	Size of Beam mm	Type of Fiber		Load Carrying Capacity of Steel Fiber KN	Load Carrying Capacity of BFR Fiber KN	Increase in Load Of Steel Fiber KN	Increase in Load Of Basalt Fiber KN
		Steel	BSF				
1	150X150	2Ø12	2Ø12	38.65	29.450	–	–
2	150X150	3Ø12	3Ø12	45.63	32.870	6.980	3.420
3	150X150	4Ø12	4Ø12	54.6	34.690	8.970	1.820
4	150X150	2Ø16	2Ø16	57.84	36.410	3.240	1.720
5	150X150	3Ø16	3Ø16	60.86	39.870	3.020	3.460
6	150X150	4Ø16	4Ø16	63.54	42.590	2.680	2.720
7	150X150	2Ø20	2Ø20	67.96	45.890	4.420	3.300
8	150X150	3Ø20	3Ø20	70.98	48.750	3.020	2.860
9	150X150	4Ø20	4Ø20	79.45	53.987	8.470	5.237

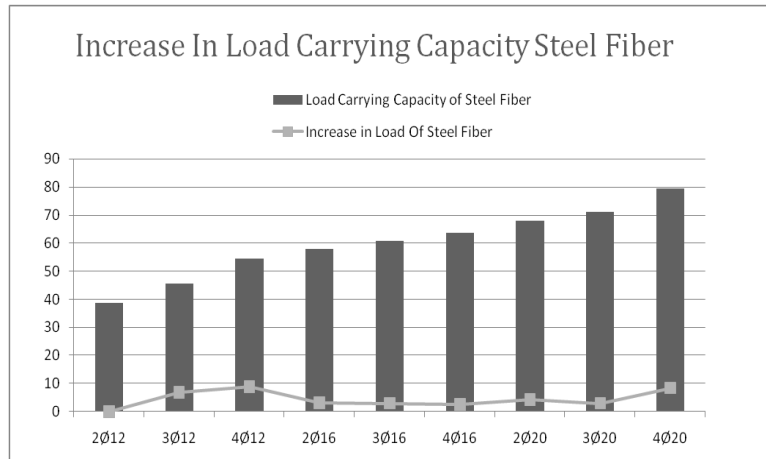


Figure. 5: Increase In Load Carrying Capacity Of Steel Fiber

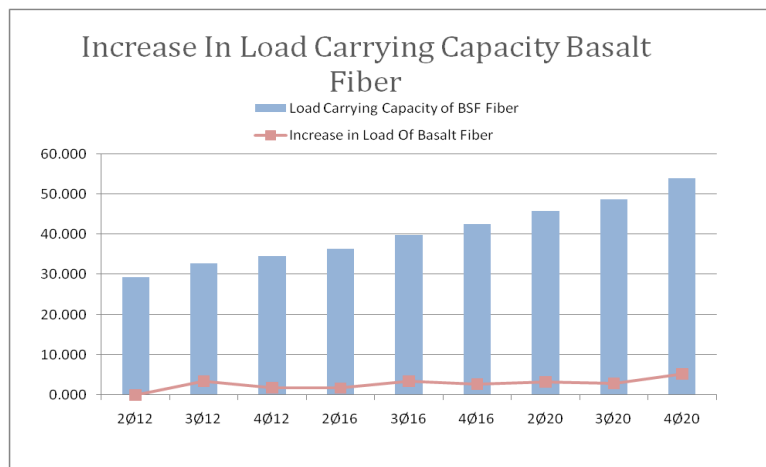


Figure. 6: Increase In Load Carrying Capacity Of Basalt Fiber

3 Comparison for Load Carrying Capacity With Steel Basalt Fiber

Table 3 Comparison Between Steel And Basalt Fiber

Sr. No	Size of Beam mm	Type of Fiber		Load Carrying Capacity of Steel Fiber KN	Load Carrying Capacity of BFR Fiber KN	% Difference between Steel & BFR Fiber
		Steel	BSF			
1	150X150	2Ø12	2Ø12	38.65	29.45	23.80
2	150X150	3Ø12	3Ø12	45.63	32.87	27.96
3	150X150	4Ø12	4Ø12	54.6	34.69	36.47
4	150X150	2Ø16	2Ø16	57.84	36.41	37.05
5	150X150	3Ø16	3Ø16	60.86	39.87	34.49
6	150X150	4Ø16	4Ø16	63.54	42.59	32.97
7	150X150	2Ø20	2Ø20	67.96	45.89	32.47
8	150X150	3Ø20	3Ø20	70.98	48.75	31.32
9	150X150	4Ø20	4Ø20	79.45	53.987	32.05

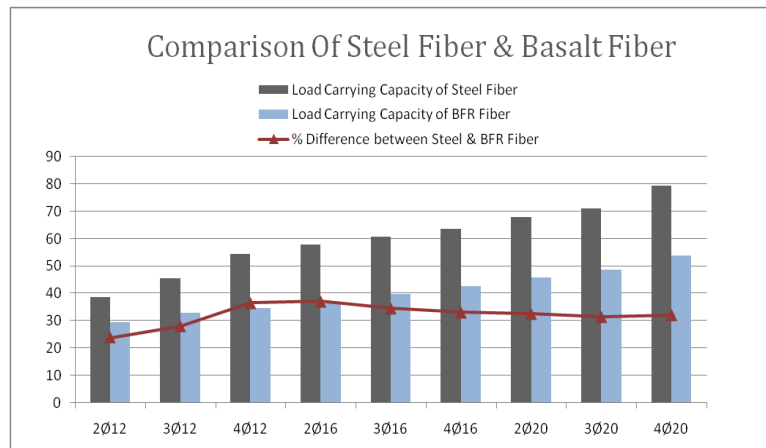


Figure. 7: Comparison of Load Carrying Capacity of Steel and Basalt Fiber

V.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.
- In this Analytical result sample no 6 beam size is 150X150 mm steel and basalt fiber reinforcement used. In which steel beam section carry more load carrying capacity such as 79.45KN than basalt fiber beam.
- In this sample compare load capacity to steel, the load is also increase 8.97 KN. The maximum strength carry 16.43 % than steel fiber used beam section.
- In this sample compare load capacity to basalt, the load is also increase 3.420 KN. The maximum strength carry 10.40 % than basalt fiber used beam section.
- Comparison steel and basalt fiber used strengthened beam concluded that steel fiber carry more load 37.05 % than basalt fiber.

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