

Mechanical Characteristics of Silica Fume Enhanced Basalt Fiber Reinforced Concrete

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Abstract - The advancement of the building industry is associated with continuous research, development and design of new and improved materials and construction of structures. The construction of mega structures requires materials with increasingly improved properties, particularly strength, stiffness, toughness, ductility, durability & chemical resistance to various aggressive media. The conventional plain concrete possesses high compressive strength, low tensile strength, poor impact strength, ductility and little resistance to cracking and poor resistance to chemical attack. So it is necessary to overcome these drawbacks of concrete. Continuous research by concrete technologist to understand, improve, and develop a property of concrete has resulted in a new type of concrete known as fiber reinforced concrete. FRC is a relatively new composite material in which fibers are introduced in the matrix as micro reinforcement, so as to improve the tensile, cracking and other properties of concrete. In this project we used Basalt Fiber Reinforced Concrete (0.5% to 1.5%) & Silica Fume (10%) in concrete to check mechanical properties.

Key Words: Basalt Fiber Reinforced Concrete, Silica Fume, Mechanical Properties.

1. INTRODUCTION: -

Concrete is the most commonly used construction material in world, and it is very difficult to find another material of construction as versatile as concrete. Concrete is one of the most widely used construction material all over the world in view of its strength, high mould ability, structural stability and relative low cost. Rapid advances in Construction materials technology have enabled civil and structural engineers to achieve impressive gains in the safety, economy, and functionality of structure built to serve the common needs of society. The use of high strength, high stiffness structural fibers in concrete resulted in composite materials with substantial improvement in the mechanical properties and durability of concrete structures. There are clear indications that the use of fibers in concrete will increasingly continue to be the preferred choice for many repair and rehabilitation projects involving construction of bridges, Industrial floors,

airport pavements, overlays, high rise buildings, TV towers, parking garages, offshore structures and other structures. It is widely used as construction material in world, and it is very difficult to find another material of construction as versatile as concrete.

In recent years the demand of high-quality cements concrete and mortars have greatly increased. This is due to problem with the durability of concrete structures. Environmental conditions play a major role in deterioration of buildings. Many pollutants present in environment promote concrete deterioration and steel corrosion in concrete structures. Concrete made with Ordinary Portland Cement (OPC) possesses certain inherent drawbacks such as poor tensile strength, poor chemical and corrosion resistance, poor bonding with old concrete of new concrete, etc. The development of new materials having very high mechanical and durability performances is given considerable attention at Fiber Reinforced Concrete (FRC). Fiber reinforced concrete is gaining acceptance in the construction industry. Although every type of fiber has been tried out in cement and concrete, not all of them can be effectively and economically used. Each type of fiber has its characteristic properties and limitations. Some of the fiber that could be used is basalt fiber, polypropylene, nylons, asbestos, coir, glass, basalt and carbon. For present work Basalt fiber are used.

Objectives: -

This investigation deals with the behavior of Basalt fiber reinforced concrete (BFRC) composite with various volume fractions. The aim of this study is to investigate following properties:

- Strength properties of Basalt Fiber Reinforced Concrete (BFRC) such as compressive strength, split tensile strength, flexural strength, and flexural shear strength, pull out/ bond strength.
- To compare the results between plain concrete and fiber reinforced concrete
- Elastic constants such as Modulus of elasticity, Poisson's ratio and Modulus of rigidity.

2. Methodology: -

Experimental work was done to study the effect of basalt fibers on various properties of concrete and its feasibility in the actual field of construction, especially compressive strength, flexural strength, split-tensile strength, Pull-out test, workability, modulus of elasticity, etc of modified basalt fiber concrete after some preliminary trials.

Table 1: Physical Properties of Basalt Fibers.

Sr. No.	Property	Value
1.	Diameter	6 μ m
2.	Length of fiber	12mm
3.	Appearance	Golden Brown
4.	Deformation	-
5.	Tensile strength	4.84 GPa (4840 Mpa)
6.	Modulus of elasticity	89GPa (8900 Mpa)
7.	Specific gravity	2.8 to 3.0



Fig 1: Basalt Fiber

Table 2: Chemical and Physical Properties of Silica Fume

Chemical properties	Value
CaO	0.1-0.6%
SiO ₂	86-96%
Al ₂ O ₃	0.2-0.6%
Fe ₂ O ₃	0.3-1.0%
MgO	0.3-3.5%
SO ₃	0.1-0.4%
K ₂ O	1.5-3.5%
Na ₂ O	0.8-1.8%
Physical properties	
Specific gravity	2.1
Specific surface (cm ² /g)	15000-20000

Mix Proportion:

Mix proportion of concrete was decided by mix design. Mix design of concrete for grade M50 and M60 was done by using Indian Standard Method (IS-10262-2009). The mix proportion of concrete for grade M50 was 1: 1.44: 1.34: 0.89: 0.38 (C: FA: CA 20mm: CA10mm: w/c) and for M60 1: 1.19: 1.42: 0.95: 0.35 (C: FA: CA 20mm: CA10mm: w/c).

Table 3: Schedule of Preparation of BFRC Specimen for grade M50

Sr. No.	Mix Designation	Fiber Content (Vf) %	Compression Test	Split Tensile Test	Flexure Test	Pull Out Test	Total Specimen
1	M ₀	0.0	6	6	6	6	6
2	M ₁	0.5	6	6	6	6	6
3	M ₂	1.0	6	6	6	6	6
4	M ₃	1.5	6	6	6	6	6
5	M ₄	2.0	6	6	6	6	6
6	M ₅	2.5	6	6	6	6	6

In all 360 specimens were cast in laboratory for grade M50 and M60.

Test & Result:

Table 4: Slump, Slump Loss and Fiber Factor of BFRC Grade M50

Sr. No.	Mix Designation	Fiber Content (Vf) %	Workability by Slump Test (mm)	Slump Loss (%) From Eq ⁿ . (1)
1	M ₀	0.0	80	0.00
2	M ₁	0.5	72	10.00
3	M ₂	1.0	68	15.00
4	M ₃	1.5	64	20.00
5	M ₄	2.0	58	27.50
6	M ₅	2.5	54	32.50

Table 5: Slump, Slump Loss and Fiber Factor of BFRC Grade M60

Sr. No.	Mix Designation	Fiber Content (Vf) %	Workability by Slump Test (mm)	Slump Loss (%) From Eq ⁿ . (1)
1	M ₀	0.0	85	0.00
2	M ₁	0.5	76	10.59
3	M ₂	1.0	70	17.65
4	M ₃	1.5	68	20.00
5	M ₄	2.0	54	36.47
6	M ₅	2.5	50	41.18

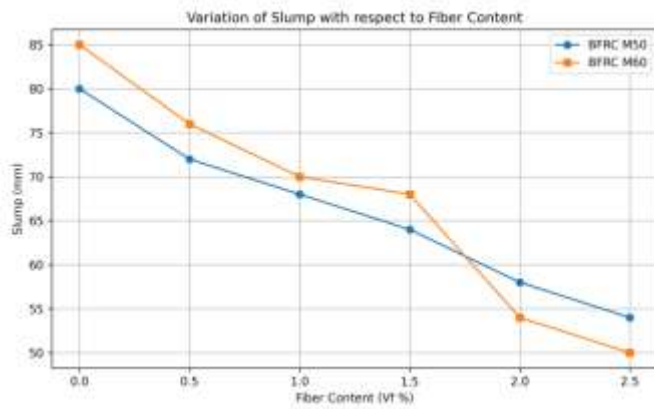


Fig.1: Variation of Slump with respect to Fiber Content (Vf%)

3	M ₂	1.0	36.98	33.22	35.11
4	M ₃	1.5	37.28	33.45	35.46
5	M ₄	2.0	37.47	33.84	35.71
6	M ₅	2.5	37.67	34.04	36.05

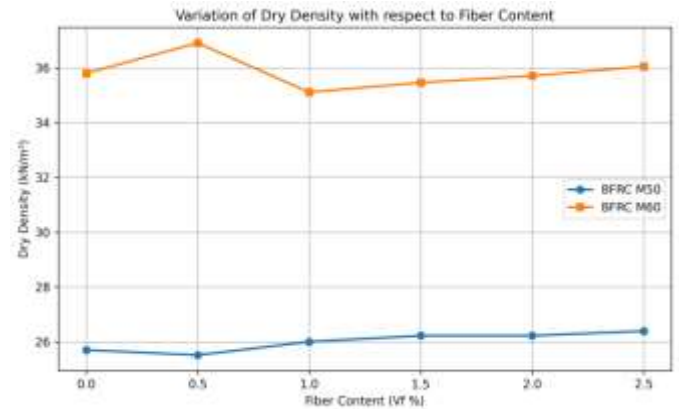


Fig.3: Variation of Dry Density (ρ) with respect to Fiber Content (Vf%)

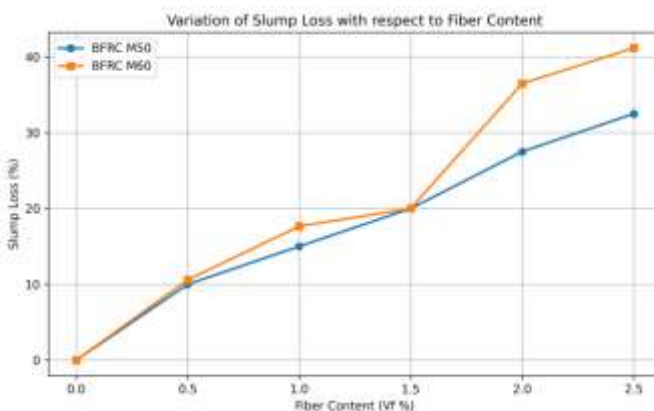


Fig.2: Variation of Slump Loss with respect to Fiber Content (Vf%)

Table 1: Wet and Dry Density of BFRC Grade M50

Sr. No.	Mix Designation	Fiber Content (Vf) %	Wet Density at Casting kN/m³	Dry Density at 7 Days kN/m³	Dry Density at 28 Days kN/m³
1	M ₀	0.0	26.49	25.54	25.70
2	M ₁	0.5	26.59	25.41	25.51
3	M ₂	1.0	26.66	25.66	26.00
4	M ₃	1.5	26.68	25.70	26.22
5	M ₄	2.0	26.71	25.73	26.22
6	M ₅	2.5	26.78	25.93	26.39

Table 2: Wet and Dry Density of BFRC Grade M60

Sr. No.	Mix Designation	Fiber Content (Vf) %	Wet Density at Casting kN/m³	Dry Density at 7 Days kN/m³	Dry Density at 28 Days kN/m³
1	M ₀	0.0	36.49	33.68	35.80
2	M ₁	0.5	36.74	34.41	36.91

Table.3: Compressive load (P_c), Compressive Strength (f_{cu}) and Percentage increase in Compressive Strength over Normal mix of BFRC7 days

Sr. No.	Mix Designation	Fiber Content (Vf) %	Comp. Load (P_c) (kN)	Comp. Strength (f_{cu}) (MPa)	Percentage increase in Comp. over Normal Mix	Comp. Load (P_c) (kN)	Comp. Strength (f_{cu}) (MPa)	Percentage increase in Comp. Strength over Normal Mix
			M50			M60		
1	M ₀	0.0	300.00	30.00	0.00	350.00	35.00	0.00
2	M ₁	0.5	333.33	33.33	11.10	393.33	39.33	12.37
3	M ₂	1.0	366.66	36.66	22.20	430.00	43.00	22.86
4	M ₃	1.5	386.50	38.65	28.83	450.00	45.00	28.57
5	M ₄	2.0	353.33	35.33	17.77	420.00	42.00	20.00
6	M ₅	2.5	336.66	33.66	12.20	405.55	40.50	15.71

Table 4: Compressive load (P_c), Compressive Strength (f_{cu}) and Percentage increase in Compressive Strength over Normal mix of BFRC 28 days

Sr	Designation	Fiber Content (Vf %)	Com p. Load (P_c) (kN)	Com p. Strength (f_{cu}) (MPa)	Percentage increase in Com p. over Normal Mix	Com p. Load (P_c) (kN)	Com p. Strength (f_{cu}) (MPa)	Percentage increase in Com p. Strength over Normal Mix
			M50			M60		
1	M ₀	0.0	503.33	50.33	0	613.33	61.33	0.00
2	M ₁	0.5	520.00	52.00	3.32	623.33	62.33	1.63
3	M ₂	1.0	540.00	54.00	7.29	646.66	64.66	5.43
4	M ₃	1.5	553.33	55.33	9.93	650.00	65.00	5.98
5	M ₄	2.0	533.33	53.33	5.96	630.00	63.00	2.72
6	M ₅	2.5	506.66	50.66	0.66	620.00	62.00	1.09

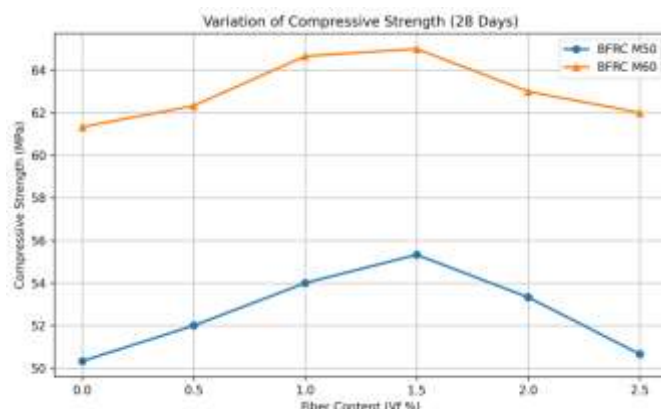


Fig 5: Variation of Compressive Strength (f_{cu}) with respect to Fiber Content (Vf) BFRC28 days

Table 5 Flexural load at failure (P), Flexural Strength (f_b) and Percentage Increase in Flexural Strength over Normal Mix BFRC 7 days

Sr	Designation	Fiber Content (Vf %)	Flex ural Load (P) (kN)	Flex ural Strength (f_b) (MPa)	Percentage increase in Flexu ral Stren gth over Normal Mix	Flex ural Load (P) (kN)	Flex ural Strength (f_b) (MPa)	Percentage increase in Flexu ral Stren gth over Normal Mix
			M50			M60		
1	M ₀	0.0	3.89	1.95	0.00	5.82	2.91	0.00
2	M ₁	0.5	4.28	2.14	9.74	5.89	2.94	1.03
3	M ₂	1.0	4.71	2.35	20.51	6.08	3.04	4.47
4	M ₃	1.5	6.20	3.10	58.97	8.44	4.22	45.02
5	M ₄	2.0	5.85	2.93	50.26	8.24	4.12	41.58
6	M ₅	2.5	5.40	2.70	38.46	7.33	3.65	25.43

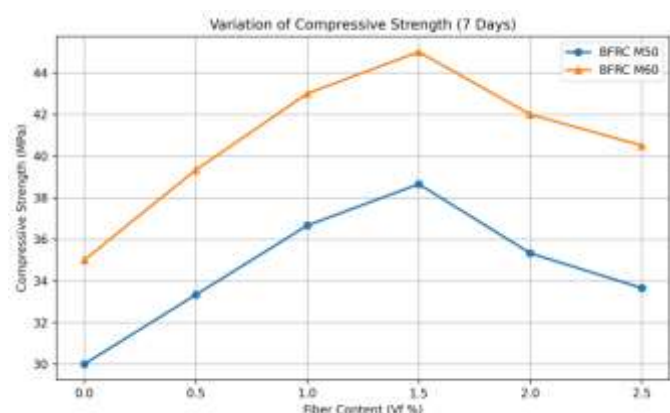


Fig 4: Variation of Compressive Strength (f_{cu}) with respect to Fiber Content (Vf) BFRC 7 days

Table 6 Flexural load at failure (P), Flexural Strength (f_b) and Percentage Increase in Flexural Strength over Normal Mix for BFRC 28 days

Sr. No	Mix Designation	Fiber Content (Vf) %	Flexural Load (P) (kN)	Flexural Strength (f_b) (MPa)	Percentage increase in Flexural Strength over Normal Mix	Flexural Load (P) (kN)	Flexural Strength (f_b) (MPa)	Percentage increase in Flexural Strength over Normal Mix
			M50			M60		
1	M ₀	0.0	6.41	3.20	0.00	8.04	4.01	0.00
2	M ₁	0.5	8.63	4.32	35.00	9.81	4.9	22.19
3	M ₂	1.0	9.81	4.91	53.44	11.58	5.78	44.14
4	M ₃	1.5	10.5	5.25	64.06	11.94	5.96	48.63
5	M ₄	2.0	8.34	4.17	30.31	10.73	5.19	29.43
6	M ₅	2.5	7.85	3.92	22.5	9.58	4.78	19.20

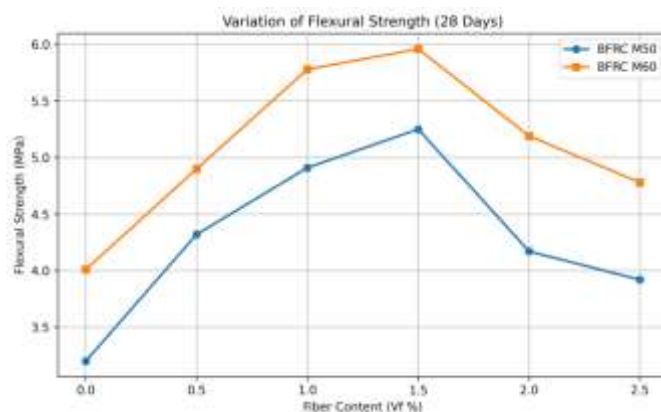


Fig.7 Variation of Flexural Strength (f_b) with respect Fiber Content (Vf) for BFRC 28 day

CONCLUSIONS:

1. The wet and dry density at 28 days has increased marginally for fiber reinforced concrete over normal concrete. This may be due to partial cement replacement by silica fume, which densifies the concrete because of its micro-filler effect due to the relatively finer particle size.
2. However, maximum gain in strength of concrete is found to depend upon the amount of fiber content. The optimum fiber content to impart maximum gain in various strengths varies with type of the strengths.
3. The optimum percentage fiber volume fraction for compressive strength, flexural strength and split tensile strength is 1.5% while for bond strength is 2.0%. Satisfactory workability was maintained with increasing volume fraction of fibers by using super-plasticizer.
4. With increasing fiber content, mode of failure was changed from brittle to ductile failure when subjected to compression and bending.
5. The strength models developed for BFRMC predicts the results of various strengths which are in good compliance with experimental results.

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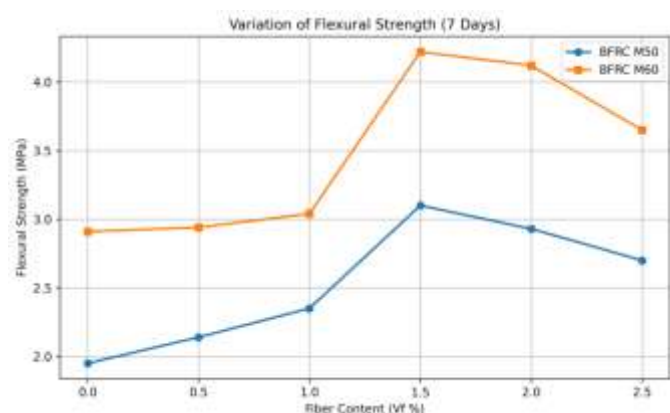


Fig.6 Variation of Flexural Strength (f_b) with respect Fiber Content (Vf) for BFRC 7 days

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