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Research paper

Behaviour of Basalt Fiber Reinforced Concrete Filled Mild Steel Tube

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Abstract

The present study is an attempt to understand the behavior of concrete filled steel tubular column under uniaxial load. A concrete-filled steel tubular (CFST) column is formed by filling a steel tube with concrete. It is well known that concrete- filled steel tubular (CFST) columns are currently being used in the construction of buildings, due to their excellent static and earthquake-resistant properties, such as high strength, high ductility, large energy absorption capacity, bending stiffness etc. The external strengthening of using basalt fiber reinforced concrete material is emerging as a new trend in enhancing the structural performance concrete filled steel tubular members to counteract the drawbacks of the past rehabilitation work. In this project we are going to study about strength of the steel and concrete by doing compression strength, flexural strength, push out and uniaxial compression test. The tests are carried out with the help of universal testing machine. The readings are recorded and graphs are plotted.

Keywords: *Concrete Filled Steel Columns (CFST), Basalt Fiber Reinforced Concrete (BRFC), uniaxial load., Compression Strength, Split Tensile Strength, Flexure Strength, RCPT, WPT*

1. Introduction

Concrete-Filled Steel Tube (CFST) column comprises steel hollow section of circular shape filled with plain or reinforced concrete. Steel columns have high tensile strength and ductility. Concrete columns have high compressive strength and stiffness. Composite columns combine steel and concrete, resulting in a column that has the beneficial qualities of both materials. Steel tube provided as confinements for concrete acts as a longitudinal and lateral reinforcement for the concrete core. Also it performs most effectively in tension and in resisting bending moment and also used as permanent formwork. CFSTs are used in buildings to avoid large size columns, supporting platform of offshore structures, roofs of storage tanks, bridge piers, and column in seismic zones.

Basalt CFST is widely used in high-rise and multistory buildings as columns and beam-columns, and as beams in low-rise industrial buildings where a robust and efficient structural system is required.

Furthermore, the distribution of materials in the cross section also makes the system very efficient in term of its structural performance. The steel lies at the outer perimeter where it performs most effectively in tension and bending. It also provides the greatest stiffness as the material lies furthest from the centroid. This, combined with the steel's much greater modulus elasticity, provides the greatest contribution to the moment of inertia.

The hollow tubes were designed in such a way that they are capable of supporting the floor load up to three or four storey height. Once the upper floors were completed, the concrete was pumped in to the tubes from the bottom. To facilitate easy pumping the tubes were continuous at the floor level. Due to the simplicity of the construction sequence, the project can be completed in great pace. The inherent buckling problem related to thin-walled steel tubes is either prevented or delayed due to presence of the concrete core. CFST columns have a high load-bearing capacity and high seismic resistance. CFST columns have an attractive as appearance and a reduced cross-section. The steel casing prevents spalling of the concrete, which remains protected against fire.

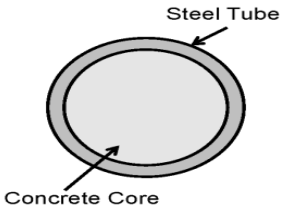

Fig 1: Schematic representation of concrete filled tube column

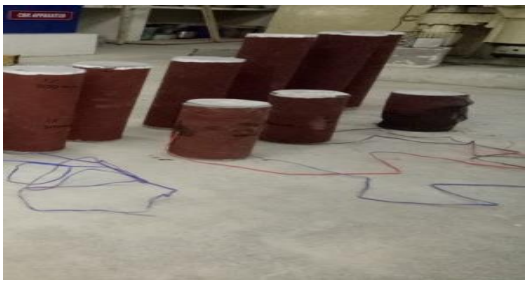

Fig 2: Mild Steel Steel specimens

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2. Objective

- To study the behavior of mild steel tube filled with basalt fiber reinforced concrete under uniaxial compression.
- To analyze the various properties of basalt fiber reinforced concrete.
- To determine the strength of mild steel tube filled with basalt fiber reinforced concrete.

3. Raw Materials

The cement used was OPC53 grade cement and was tested for its physical properties as per IS: 40316. The manufactured sand (M-sand) from a local quarry was used as a fine aggregate. Similarly from the same source coarse aggregates were obtained and used in the experiment. Both fine aggregate and coarse aggregate were tested for its properties as per IS: 3837. The fibers used were chopped basalt fiber. Basalt is fine-grained, extrusive, igneous rock composed of plagioclase, feldspar, pyroxene and magnetite, with or without olivine and containing not more than 53 weight % SiO2 and less than 5 weight% total alkalis. Basalt fiber is a multi-performance fiber. The physical properties of cement, manufactured sand, natural aggregate and basalt fiber are given in table 1 to 3.

Table 1: Physical Properties of Cement

S.No	Characteristics	Value
1.	Standard consistency	32
2.	Fineness of cement	0.5%
3.	Initial setting time	35min
4.	Final setting time	4hrs 15mins
5.	Specific gravity	3.19

Table 2: Physical Properties of M-sand

S.No	Description	Test results
1.	Water absorption ,%	2.80%
2.	Specific gravity	2.62
3.	Fineness modulus	3.20

Table 3: Physical Properties of Natural Aggregate

S.No	Description	Natural aggregate
1.	Specific Gravity	2.76
2.	Water absorption, %	0.5
3.	Bulk density, kg/m^3	1450

Table 4: Physical Properties of Basalt fiber

S.No	Characteristics	Value
1.	Tensile Strength	2.8-3% GPa
2.	Elastic Modulus	85-87 GPa
3.	Elongation at Break	3.15%
4.	Density	2.67 g/cm3
5.	Length	12mm

4. Mix Design

A concrete mix can be designed by any rational method. However a most common method is by absolute volume method which is specified in IS10262:20009. While proportioning the mix certain stipulations are considered. They are the cement content, maximum water cement ratio, workability, exposure condition and degree of supervision. Further certain physical properties such as specific gravity, water absorption; moisture content, particle size etc are needed. Similar method is followed for designing concrete mixes. A typical mix proportion of normal concrete is shown in table 4.

Table 5: Mix proportion

Description	Conventional concrete
	Quantity, Kg/m^3
Cement, OPC 53 Grade	394
Fine aggregate	732
Coarse aggregate	1139
Water	197
w/c ratio	0.45

4.1 Fresh Concrete

The fresh concrete was prepared similar to conventional concrete. The time of mixing was about 2mts in order to absorb water by the basalt fiber reinforced concrete. In fresh concrete density, slump was determined. The slump was kept in the range of 80-100mm for both types of concrete. The mix was cohesive.

4.2 Preparation of Test Specimens

Test cubes of size 100*100*100mm were cast for determining the compressive strength of concrete. Similarly cylinders of size 100*200mm and beams of dimensions 100*100*500mm were cast for split tensile strength and flexural strength respectively. The steel tubes of height 400mm, 300mm and 200mm are chosen such that the slenderness of the ratio can be varied for the specimens and the concrete mix with basalt fiber is the infill used in the steel tubes. All the specimens were cured after 24hrs from the time of casting under constant temperature of 27 ± 2^{0}C and relative humidity of 90-100%.



Fig 3: Specimens of Concrete In-filled Mild Steel tube of height 200mm, 300mm and 400mm

5. Test Results and Discussion

5.1 Compressive Strength Test

The compressive strength is conducted on cubes at the age of 3, 14, 28 days, confirming to IS 516:1959.The test results are shown below in the table 3.1, 3.2, 3.3. After the results are computed and analyzed it was found that 66.6% of compressive strength has been increased after adding 0.5% of basalt fiber to the concrete mix. The compressive strength results are given in the tables.

Table 6: 3 days curing test for compressive strength

CUBE	FIBER %(N/mm2)			
	0	0.5	0.75	1
1	18.94	20.32	15.2	11.49
2	16.9	20.50	17.4	14.50
3	13.7	17.40	16.8	12.56
Average	17.94	18.94	16.46	12.8

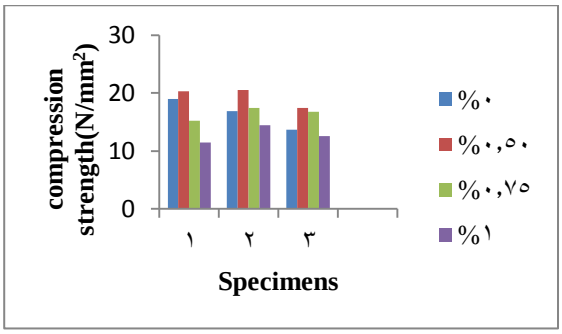


Fig 4: Bar chart representation of 3 days curing test for compressive strength

Table 7: 14 days curing test for compressive strength

CUBE	FIIBER %(N/mm2)			
	0%	0.5%	0.75%	1%
1	28.6	42.6	31.4	26
2	29.9	47	34.2	16
3	28.25	44	33.8	22
Average	28.92	44.53	33.27	21.33

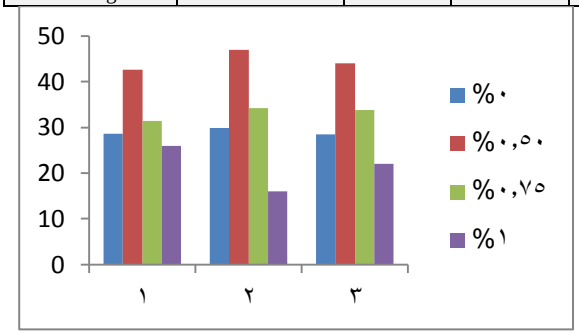


Fig 5: Bar chart representation of 14 days curing test for compressive strength

Table 8: 28 days curing test for compressive strength

UBE	FIBER % (N/mm2)			
	0%	0.5%	0.75%	1%
1	30.2	52	31.8	32.1
2	36.6	46.05	33.8	28.2
3	32.2	52.85	35.6	29.0
Average	33	50.3	33.7	29.77

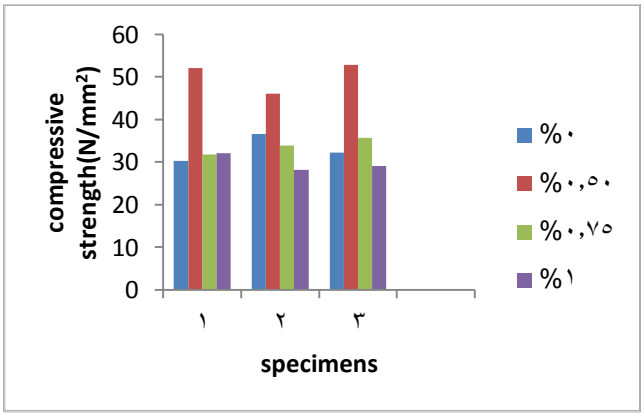


Fig 6: Bar chart representation of 28 days curing test for Compression Strength



Fig 7: 28 days Compression Test

5.2 Split Tensile Strength Test

The concrete mix were casted and cured, these specimens were cured for time period of 28 days. Testing to determine the tensile strength of all specimens was carried out as per IS: 516-1959.

Table 9: 28 days curing test for Split Tensile Strength

Cylinder	Fibre % (N/mm2)			
	0%	0.5%	0.75%	1%
1	3.47	4.8	4.026	2.43
2	4.92	4.31	3.98	2.426
3	3.57	4.54	3.83	2.413
Average	3.99	4.55	3.95	2.423

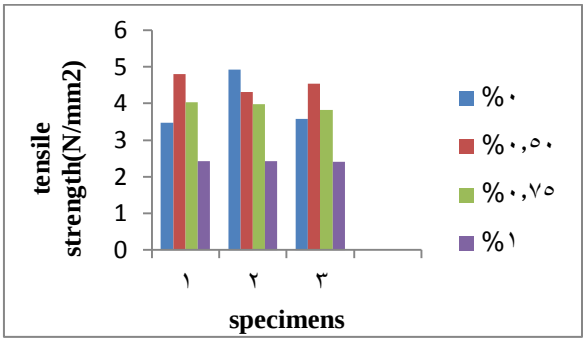


Fig 9: Bar chart representation of Split Tensile Strength



Fig 10: 28 days Split Tensile Test

5.3 Flexural Strength Test

The test has been carried out as per the specified guidelines. The beam size of 100*100*500 mm was casted and cured for 28 days and tested under the point load under flexure.

Table 10: 28 days curing test for Flexural test for 28 days

Beam	Fibre % (N/mm2)			
	0%	0.5%	0.75%	1%
1	7.72	7.6	7.8	5.7
2	6.48	7.51	6.9	5.15
3	6.28	7.33	6.67	5.49
Average	6.83	7.48	7.12	5.45

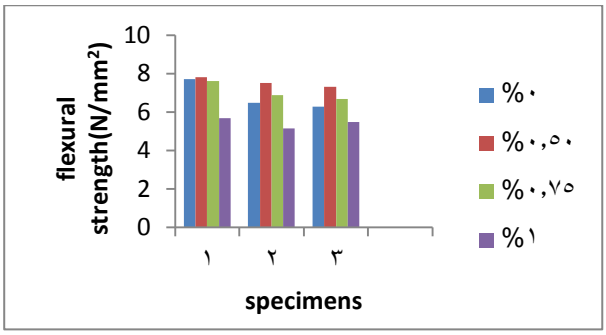


Fig 11: Bar chart representation of flexural strength

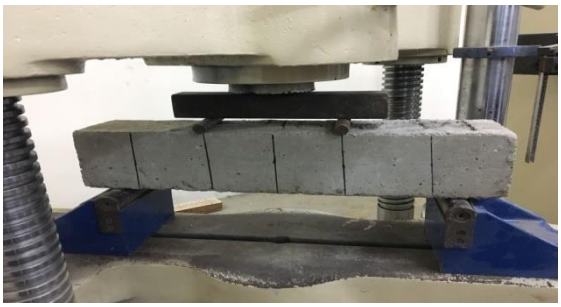


Fig 12: 28 days Flexural Strength Test

5.4 Preparation of Test Specimen and Test Setup

The steel tubes of height 400mm, 300mm and 200mm are chosen such that the slenderness of the ratio can be varied for the specimens. Three specimens of each height and diameter of 100mm was taken and a total of thirteen specimens were casted. The concrete mix with fiber (FRC) is the infill used in the steel tubes. The process includes the mixing of the concrete mixes at a proper ratio. The test set up involves the UTM machine which has a capacity of 1000kN and CTM which has capacity of 2000kN were used. Two strain gauges are fixed onto the specimen, perpendicular to each other. One gauge was fixed in the horizontal direction indicating the horizontal (lateral) deformation strain and another gauge fixed in the vertical direction to measure the vertical strain.



Fig 13: Test setup of mild steel tube

5.5 Load - Deflection Result of the Mild Steel Tube

The load deflection behavior of the column is studied by recording the amount of the deflection at the distinct intervals of compression loading. The deflection at the heights of column of 200mm, 300mm and 400mm are recorded and graphs are plotted.

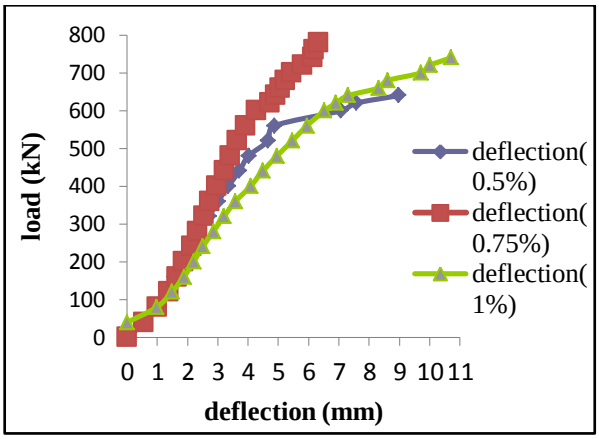


Fig 14: Load Deflection curve for the mild steel tube of height 200mm

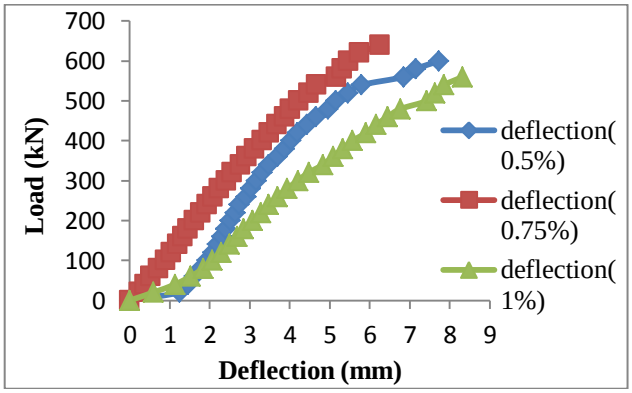


Fig 15: Load Deflection curve for the mild steel tube of height 300mm

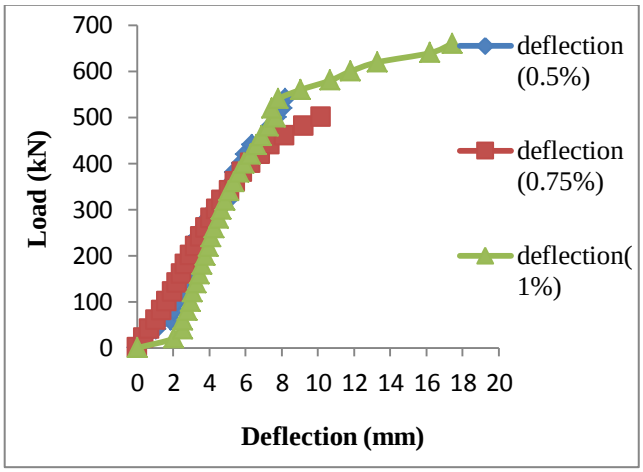
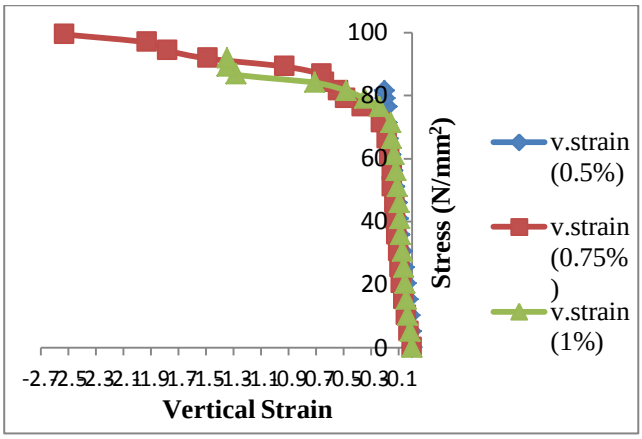


Fig 16: Load Deflection curve for the mild steel tube of height 400mm

5.6 Stress - Strain Result of the Mild Steel Tube

The stress- strain behavior of the columns is studied by recording the amount of deformation (strain) at distinct intervals of compressive loading (stress). The stress at the heights of column of 200mm, 300mm and 400mm are recorded and graphs are plotted.



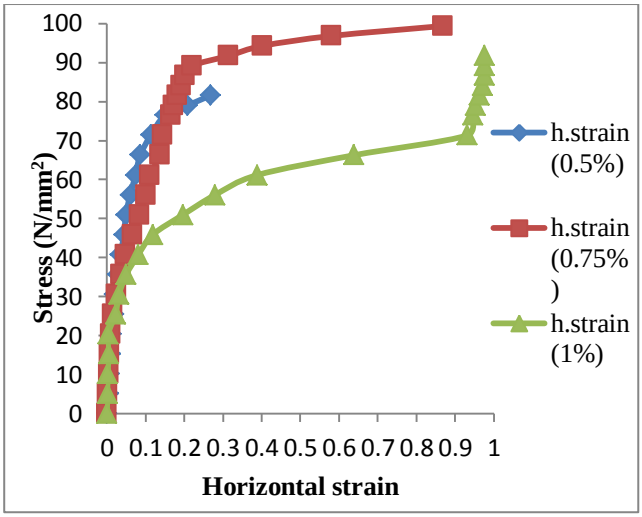


Fig 17: Stress - Strain curve for the mild steel tube of height 200mm

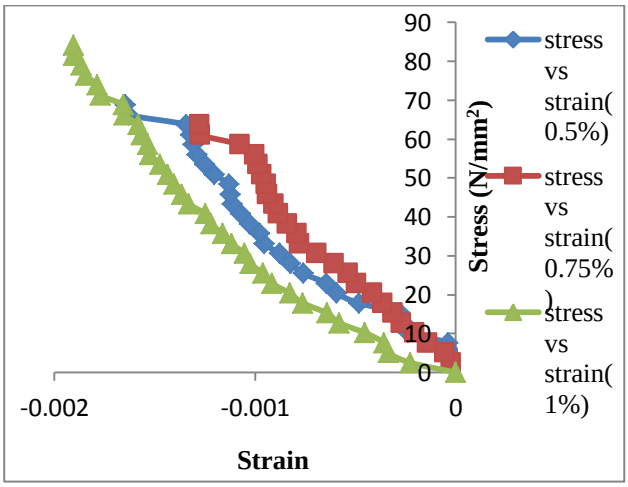


Fig 18: Stress - Strain curve for the mild steel tube of height 300mm

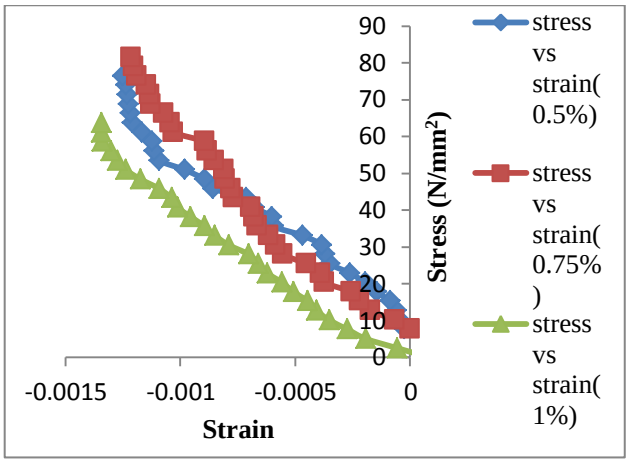


Fig 19: Stress - Strain curve for the mild steel tube of height 400mm

Table 11: The ultimate strength obtained for mild steel tube

Tube	Fiber		
	0.5%	0.75%	1%
200mm	622 kN	812 kN	800 kN
300mm	670 kN	680 kN	696 kN
400mm	698 kN	764 kN	716 kN



Fig 20: Failure pattern of mild steel tube

6. Conclusion

Based on the experiment studies carried out on the basalt fiber reinforced concrete filed stainless and mild steel tube, the following conclusions are made:

The compressive strength of the concrete has increased 52.42% in 0.5% of basalt fiber compared to the other mix proportion.

The tensile strength of the concrete has increased 14.04% in 0.5% of basalt fiber compared to the other mix proportion.

The flexural strength of the concrete has increased 9.52% in 0.5% of basalt fiber compared to the other mix proportion

The concrete filled steel tube columns have a higher load carrying capacity. By varying slenderness ratio, it is observed that the shorter column has higher load carrying capacity.

Mild steel tube of height 200mm having 0.75% of basalt fiber has higher strength and load carrying capacity compared to the height 300mm and 400mm.

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