ANALYSIS OF MECHANICAL PROPERTIES OF BAMBOO AND FIBER REINFORCED FOAM CONCRETE

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ABSTRACT

An experimental investigation on bamboo and fiber reinforced foam concrete was carried out in this project. The foam concrete is the introduction of foam in the cement mortar. Cement, M Sand passing through 600μm, water and foaming agent (SLES) were materials for foam concrete. The mix ratio of foam concrete of density 1500 kg/m3 and 1600 kg/m3 and concrete without foam was Cement: M sand of 1:1 and water to cement ratio of 0.5 % of weight of cement. The polypropylene fibers were used in foam concrete of 0.5% of weight of cement. The cubes were cast to measure compressive strength for 7, 14 and 28 days of curing. The cylinders and prisms were cast to measure the tensile and flexural strength for 28 days of curing respectively. The results showed increase of compressive strength, tensile strength and flexural strength when the density increased. Based on the results, three bamboo and fiber reinforced foam concrete of density 1600 kg/m3 and steel and fiber reinforced concrete without foam beams of size 115 x 225 x 1200 mm were cast and cured for 28 days. The bamboo was treated with araldite epoxy resin and the bamboo reinforcement cage were wrapped with hexagonal oven mesh. The hexagonal oven mesh wrapped around bamboo reinforcement cage reduced slippage of bamboo from foam concrete.

Keywords: foam concrete, polypropylene fibers, bamboo, flexural strength.

Introduction

Foam concrete (FC) is a cellular lightweight concrete obtained by introducing foam into cementations matrix. The FC contains voids filled with air that are trapped in mix by a foaming agent. Cement, fine aggregate, and foaming agent are the materials of FC without the inclusion of coarse aggregate. Foam Concrete are high flow ability, low dead weight, excellent heat insulation, and high acoustic resistance. Foam concrete may be used for non-structural elements. Density of foam concrete in the range from 300kg/m^3-1850kg/m^3[17]. FC can be used as insulation from heat and sound and for load-bearing and non- load-bearing members. The constituent materials used are cement, M sand, and foaming agent. Cement is used as binding material which binds fine aggregate and admixtures together. Fine aggregate can be river sand, M sand, fly ash, silica fume, bottom ash, etc. Protein-based and synthetic- based foaming agents has two categories of foaming agents. First one is pre-foaming method and second is the mixed foaming method is the two methods of foam concrete producing. The foaming agents produce air bubbles in the cement matrix, making it lightweight. The different foaming agent creates different air void intensity and shapes, which influence foam concrete's density and strength. A protein-based foaming agent is naturally occurring hydrolyzed proteins and a synthetic- based foaming agent is a chemical agent which contains sodium lauryl ether sulfate. The influence of a foaming agent effect the stability and uniform distribution of air bubbles in foam concrete. The FC has low tensile strength and high shrinkage. Cracks are formed and hence durability of FC is decreased. Therefore, Fibers are mixed to the cement matrix to increase the strength, durability. There are different types of Metallic and Non–Metallic fibers are used in foam concrete. The metallic fibers are steel fibers that may lead to corrosion when used in foam concrete and Non- Metallic fibers are natural, synthetic, glass, and carbon fibers. In synthetic fibers, polypropylene fibers are used to reduce cracks and enhance the ductility of FC. Polypropylene fibers are lightweight, high strength, as well as corrosion-resistant material.

The bamboo is globally renewable and fast-growing grass. Bamboo is increasingly utilized as a substitute for steel in rebars. Researchers are studying the effect of bamboos as a rebars. Because bamboo is a biodegradable material, it must be treated to maintain its durability in the building sector. Bamboo reinforcement is used in foam concrete structure to lower the weight of the structure and as an optional to steel because it is ecofriendly to the environment.

1.1 Foam concrete advantages

To decrease the stress on the foundation because the FC has low density and self-weight. It has high thermal resistance and freeze and thaw resistance. Because it has high flow ability it can compact itself, therefore, there is no need for compaction while placing. Foam concrete is low-density concrete varying from 300kg/m3- 1850kg/m3[17] which is having high strength by weight ratio compared concrete, therefore, high strength with low density obtained in foam concrete. The air voids in foam concrete enable soundproofing in walls. Because of the lightweight nature of FC, it is used to reduce the weight of the structure on the substructure. Because of lightweight properties Foam concrete is used specifically in seismic zones. FC is highly flow able; it can be easily pumped over long distances.

1.2 Disadvantages of foam concrete

FC takes a long time for mixing and the setting time takes greater than 24 hours, so it takes a more time to demould. The major disadvantage in FC is drying shrinkage because coarse aggregate is not used. As compare to the normal concrete Because of the low density, the compressive strength and flexural strength decreases. Difficulty occurs in mixing and finishing foam concrete. Specialized laborers and equipment are required for generating foam and mixing foam concrete.

1. Materials and Methodology

2.1 Materials

2.1.1 Cement

Cement is a ingredient which binds the other materials utilized in foam concrete. In this project Cement, I is utilized Ordinary Portland Cement (OPC) of 53 grades conforming to IS 12269 -1987. Cement properties are verified by according to IS 4031 part - 1, 4,5,11. Table I represents physical properties of cement.

TABLE 1.PROPERTIES OF CEMENT

Property	Units	Value Obtained	Limiting value as per IS:12269: 2013 specifications
Specific Gravity	-	3.16	3.15
Standard Consistency	%	33	-
Fineness	%	4	10
Initial setting time	minutes	45	30(min)
Final setting time	minutes	150	600(max)

2.1.2 Manufactured sand (M Sand)

M sand is a good substituent for river sand and has fewer impurities which provide better quality of concrete. M Sand tests were performed as per IS: 383-1970. M Sand passing through 600µm was used in this project to minimize the breakage of air voids in foam concrete. Table II shows the properties of Manufactured Sand.

TABLE 2. PROPERTIES OF MANUFACTURED SAND

Tests conducted	Test result	Method of test	Permissible limit
Fineness of M Sand	2.32	IS 2386 Part-1 (1963)	2.2-2.6
Specific Gravity	2.6	IS 2386 Part-3 (1963)	-

2.1.3 Foaming agent

Foaming agents were used to produce air pockets in the cement matrix to produce lightweight foam concrete. Sodium Lauryl Ether Sulfate (SLES) foaming agent was used

2.1.4 Polypropylene Fibers

Polypropylene fibers (PPF) are a polymer material with high strength, lightweight, and corrosion resistance. PPF has a low density (0.9–0.95 g/cm3) and the fibers are ideal for foam concrete. By adding PPF crack resistance of FC can be improved and make it ductile.

TABLE 3. FOAMING AGENT PORPERTIES

Sr. No	Specification	Values/Details
1	Name	Sodium Lauryl Ether Sulfate Solution
2	Molar mass	288.38 g/mol
3	Physical state	Liquid
4	Appearance	Colorless to Pale yellow
5	pH	6.5-8.5
6	Brand	Godrej SLES L24-230

Fig.1. Polypropylene fibers

TABLE 4. PROPERTIES OF POLYPROPYLENE FIBERS

Properties	Values/Details
Material	Polypropylene fibers
Length	12+/- 0.25mm
Melting point	1640C
Specific Gravity	0.91
Thermal Conductivity	Low
Alkali Resistance	Alkali Proof
Color	White
Electric Conductivity	Low
Water Absorption	Negligible
Acid and chemical resistance	Very high

3 Mixes and Proportions

TABLE 5. MIXES AND PROPRORTIONS

Sr. No	Mixes	Mix 1	Mix 2	Mix 3
1	Cement : Sand (C:S)	1:1	1:1	1:1
2	Water/cement (W/C)	0.5	0.5	0.5
3	M Sand size	< 600µm	< 600µm	< 600µm
4	Target density	1500 kg/m3	1600 kg/m3	Without foam
5	Fiber content	0.50% weight of cement	0.50% weight of cement	0.50% weight of cement

4 Experimental work

Cubes were cast and cured for 7, 14, and 28 days. Cylinders and prisms were cast and cured for 28days to test indirect tensile and flexural strength, respectively, foam concrete (1500 kg/m3, 1600 kg/m3) and concrete without foam. A foam generator is a machine that produces foam. SLES: Water of 1:15 used to the bucket and mixed thoroughly. Priming was performed in order to remove entrapped air in the pipe. The air compressor, water, and foaming agent (SLES) produce foam in the outlet pipe. The quantity of foam added depends on the density of FC.

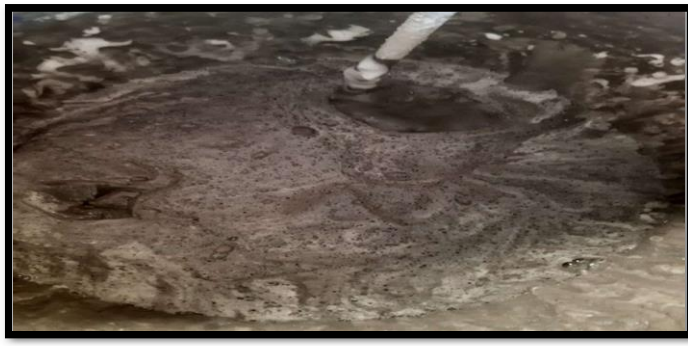

Fig. 2. Foam concrete mix

Compressive strength test was performed on 150 x150 x 150mm cubes, and cubes were placed such that the load applied to opposite face as cast in the CT machine (CTM) of capacity of 2000 kN. The tests were performed as per IS 516: 1959 and the rate of loading for FC concrete specimen was 0.1 kN/sec. The maximum load that the specimen can resist across the c/s area is compressive strength of the concrete.

A cylinder of dimensions of 300 mm X 150 mm in diameter and 300 mm in length cylinder were tested to determine tensile strength according to IS 516: 1959. The cylinders were placed along the length in CTM at 0.1 kN/sec. Load was applied to the cylinder and tensile strength of specimen was indirectly reported.

Flexural strength was evaluated in a flexural testing machine of 100 kN capacity. Prisms were subjected to a two- point loading test with IS 516: 1959. The capacity of concrete to bending forces known as flexural strength.

Three bamboo and fiber-reinforced foam concrete beams are made using a 115 x 225 x 1200 mm beam mould. From the results test, the density of foam concrete considered in beam was 1600 kg/m3. Bamboo strips are used a reinforcement in this project. Two bamboo strips of 20 x 20 x 1150 mm were provid ed as tensile reinforcement.

Fig. 3. Treated Bamboo reinforcement

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The percentage of steel reinforcement was maintained at 3.58% of area of reinforcement. Two hanger bars of 20mm in diameter of bamboo strips are provided hold the steel stirrups. The bamboo strips are applied with Araldite epoxy resin and sand sprinkled, dried, and steel wire was wound around the strips to provide grip to the rebars. Bamboo rebars were prepared, and 8 mm stirrups were provided at 150 reinforcement was wrapped with hexagonal wire mesh to avoid slippage of bamboo from the concrete. Bamboos are treated and hexagonal wire mesh was wrapped around the reinforcement cage to minimize the slippage of bamboo from foam concrete. Curing of beams for 28 days was done.

Three steel and fiber-reinforced concrete beams were cast using a 115 x 225 x 1200 mm beam mould. The concrete beam with steel reinforcement was cast, and the concrete beam's flexural strength was determined. The components employed in concrete beam include OPC 53 cement, 600μm sand, polypropylene fibers, and water. Foam was not included to the concrete. 2 - # 12 as tensile reinforcement and 2 - #8 as hanger rebars and # 8 mm diameter @ 150mm c/c as shear reinforcement was provided.

Fig. 4. Two-point load test setup

The two-point load testing of the cast bamboo and fiber reinforced foam concrete beams and steel and fiber reinforced concrete (FRC) without foam beams was conducted in the loading frame. The clear span of beam was 1000 mm. At 333.33 mm the steel load points were placed. Linear Variable Differential Transformer (LVDT) was kept at mid span of beam to measure deflection. Applied load through the load cell and the failure load as well as deflections were measured. Three bamboo and fiber reinforced foam concrete beams namely F1, F2, F3 tested under flexure. Three steel and FRC without foam beams namely C1, C2, C3 tested under flexure. The crack patterns were observed shown in the Fig. 11.

5 RESULTS AND DISSCUSSIONS

I) Compressive strength test

1) The foam concrete of density 1625kg/m3, compressive strength increased compared to 1514kg/m3. The percentage increase for density of 1625kg/m3 compared to density of 1514kg/m3 for 7, 14, as well as 28 days were 19.40 %, 24.92%, and 44.41% respectively.
2) Density of 2094kg/m3 the concrete without foam has higher strength compressive compared to foam concrete.
3) The strength compressive of foam concrete of density 1514kg/m3 for 7, 14 and 28 days showed decrease of 68.15% ,60.40%, 64.96% respectively compared to concrete without foam of density 2094kg/m3.
4) The strength compressive foam concrete of density 1625kg/m3 for 7, 14 & 28 days showed decrease of 61.97% ,50.53%, 49.40% respectively compared to concrete without foam of density 2094kg/m3.

Fig.5. Compression Testing Machine

TABLE 6. COMPRESSIVE STRENGTH TEST RESULTS

Mix	Density (kg/m^3)	AchievedDensity (kg/m^3)	No. of Curing days	Average Compressivestrength (N/mm^2)
Mix 1	1500	1514	7	5.67
			14	8.99
			28	9.39
Mix 2	1600	1625	7	6.77
			14	11.23
			28	13.56
Mix 3	-	2094	7	17.8
			14	22.71
			28	26.8

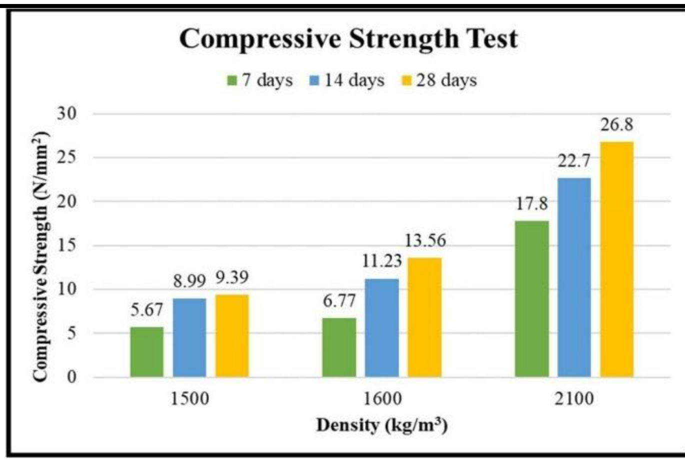

Fig. 6. Bar graph representing compressive strength

II) Split Tensile Strength Results

1) The split tensile strength after 28 days curing of FC of density 1512kg/m3, density 1634kg/m3 and concrete without foam of density 2012kg/m3 1.42 N/mm2,

   1.92 N/mm2 and 2.77 N/mm2 respectively.

2) Increase of 28th day tensile strength of FC of density 1634kg/m3 was 35.21% compared to foam concrete of density of 1512kg/m3.
3) The observation was made for 28th day tensile strength of FC with density 1512kg/m3 decreased 48.74% compared to normal concrete of density 2012kg/m3.
4) The observation was made for 28th day tensile strength of FC with density 1634kg/m3 decreased 48.74% compared to the concrete of density 2012kg/m3.

TABLE 7. SPLIT TENSILE STRENGTH TEST RESULTS

Mix	Density (kg/m^3)	Achieved Density (kg/m^3)	No. of Curingdays	Average Tensile strength (N/mm^2)
Mix 1	1500	1512	28	1.42
Mix 2	1600	1634		1.92
Mix 3	-	2012		2.77

Fig.7. Split tensile strength test

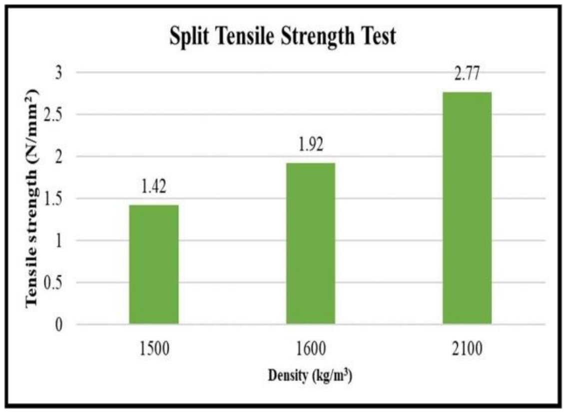

Fig. 8. Tensile strength test results

III) Flexural strength test

1) The flexural strength of foam concrete after 28 days of density 1539 kg/m3, density 1627 kg/m3 and concrete without foam of density 1981kg/m3 was 2.4 N/mm2, 2.8 N/mm2 and 6.27 N/mm2 respectively.
2) The observation was made for 28th day flexural strength of foam concrete with density 1539kg/m3 decreased 61.70% compared to the normal concrete of density 1981kg/m3.
3) The observation was made for 28th day flexural strength of FC with density 1627kg/m3 decreased 55.32% compared to the Normal concrete of density 1981kg/m3.
4) Experimental determination of flexural strength of Mix 2 (1625kg/m3) was 2.8N/mm2 and theoretical determination of flexural strength of M20 grade Normal concrete is 3.13N/mm2.
5) A target density of 1600kg/m3 was preferred over a target density of 1500kg/m3 for casting foam concrete beams with bamboo reinforcement.

Fig. 9. Flexural strength test

TABLE 8. FLEXURAL STRENGTH TEST RESULTS

Mix	Density (kg/m^3)	Achieved Density (kg/m^3)	No. of Curing days	Average Flexural strength (N/mm^2)
Mix 1	1500	1539	28	2.4
Mix 2	1600	1627		2.8
Mix 3	-	1981		6.27

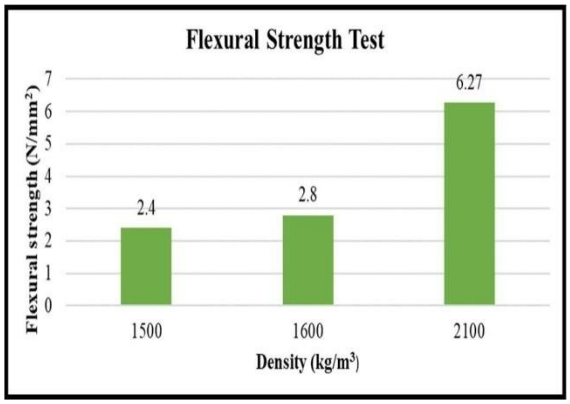

Fig.10. Flexural strength test results

TABLE 9. TABULATION OF EXPERIMENTAL AND THEORETICAL FLEXURAL STRENGTH

Mix	Experimental 28th day compressive strength, f_{ck} (N/mm^2)	Experimental flexural strength (N/mm^2)	Theoretical Flexural strength (N/mm^2) $=0.7\sqrt{fck}$
Mix 1	9.39	2.4	2.14
Mix 2	13.56	2.8	2.57
Mix 3	26.8	6.27	3.62
M20	20	-	3.13

IV) Two – point load test of beams

1) The average ultimate load of bamboo and fiber reinforced foam concrete beams was 23.22 kN and the deflection at middle of the beam was 5.01 mm.
2) The average ultimate load of steel and fiber reinforced concrete without foam beams was 62.94 kN the deflection at middle of the beam and was 7.19 mm.
3) About 63.18% decrease of load of bamboo and fiber reinforced foam concrete beams was observed when compared to steel and bamboo reinforced beams.
4) The flexural strength of foam concrete beams reinforced with bamboo was 0.368 times the flexural strength steel and fiber reinforced concrete without foam beams.

5) No delamination of bamboo reinforcement was observed in the beams as hexagonal woven mesh wrapped around bamboo rebar cage.

TABLE 10. FLEXURAL STRENGTH TEST RESULTS OF BEAMS

	Ultimate load (kN)	**Average Load (kN)**	**Moment (kN-m)**	**Flexural strength (N/mm^2)**	**Deflectionat midspan (mm)**
F1	24.17				
F2	22.27	23.22	3.87	3.98	5.01
F3	23.22				
C1	60.97				
C2	62.07	62.94	10.49	10.81	7.19
C3	65.77				

Fig. 11. Crack pattern

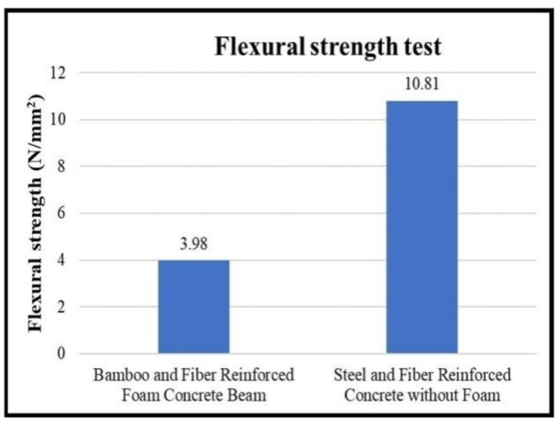

Fig.12. Results of flexural strength test on beams

6 CONCLUSIONS

1) The 28th day compressive strength of foam concrete of density 1625 kg/m3 was observed to be 44.41% higher compared to the foam concrete of density 1514 kg/m3. It can be concluded that as the density increases compressive strength increases.
   The 28th day split tensile strength of foam concrete of density 1634 kg/m3 was observed to be 35.21% higher compared to the foam concrete of density 1512 kg/m3.
2) The 28th day flexural strength of foam concrete of density 1627 kg/m3 was observed to be 16.67% higher compared to the foam concrete of density 1539 kg/m3.
3) The percentage decrease of flexural strength of foam concrete having density 1627 kg/m3 was found to be 10.54% compared to the theoretical value of flexural strength of conventional concrete of M20 grade.
4) The percentage decrease of flexural strength of foam concrete having density 1539 kg/m3 was found to be 23.32% compared to the theoretical value of flexural strength of conventional concrete of M20 grade.
5) The flexural strength of bamboo reinforced foam concrete beam was 0.368 times the flexural strength of steel reinforced concrete beams without foam.
6) As a result of the data acquired, foam concrete having density 1625 kg/m3 with cement: sand =1:1 and water/cement = 0.5 may be employed as lightly loaded structural members such as lintels.

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