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An Experimental Study on Bamboo Fibre Reinforced Hollow Concrete Block

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Abstract

The Concrete hollow blocks play a vital role in the construction of various load-bearing and non-load-bearing structures. Bamboo fibre is reinforced in the block to control the failure at shell and face end of the block. Alccofine is used as SCM in block to control the failure due to shrinkage and heat of hydration. Therefore, Bamboo Fibre Reinforces Hollow Concrete block will be eco-friendly lightweight block compared to existing blocks; it also provides the aesthetic appearance and increases the load-bearing capacity of the masonry walls. The bamboo fibre used in the block increases the compressive strength and load-bearing capacity of blocks. It also enhances the bonding strength of concrete by reducing the cracks that occur due to plastic shrinkage and dry shrinkage. The block is cast in M5 grade of concrete using processed bamboo fibre at 0.5%, 1.0%, 1.5% of cement weight as additional reinforcement, 10% of Alccofine as replacement of fine aggregate. The study shows that block reinforced with bamboo fibre and Alccofine has a mild improvement in compressive strength when compared to conventional hollow concrete block.

Keywords — *Bamboo fibre, Alccofine, Fibre reinforcement, Compressive strength, Low-cost construction, Eco-friendly.*

I. INTRODUCTION

Hollow concrete masonry units reduce the duration and cost of the construction. These hollow blocks are mostly used in the construction of residential, multi-storied and industrial buildings. The hollow blocks are lightweight, which paves the way to ease of ventilation. The hollow blocks are made out of a mixture of cement, fine aggregate and coarse aggregate. These hollow blocks are found to be superior to traditional red bricks with various advantages such as economical, acoustic, resistance to fire, small dead load, thermal insulation, and architectural features.

In this experimental study, Bamboo fibres used in the hollow block increases the compressive strength and load-carrying capacity of blocks. It also enhances the bonding strength of concrete, reducing the development of cracks due to plastic shrinkage and dry shrinkage. Alccofine - 1203 is a supplementary cementitious material (SCM) used as partial replacement of cement in the blocks to reduce the Heat of hydration, and improve the workability of concrete.

II. LITERATURE REVIEW

M.K. Maroliyain their paper "Load Carrying Capacity Of Hollow Concrete Block Masonry Wall" has reported that the crack patterns developed in the structural components such as wall and the strength of wall constructed with hollow concrete block give the less strength when compared to traditional brick masonry. Still, cost of construction is comparatively less in hollow block masonry.

Shakeel Ahmad and authors in their paper "Mechanical Properties of Bamboo Fibre" revealed that Modulus of elasticity of concrete increases by the addition of bamboo fibres in such a way that bamboo reinforced concrete could be used in low-cost buildings.

Nikhil A. Gadge and Prof. S. S. Vidhale in their paper "Mix Design of Fiber Reinforced Concrete (FRC) Using Slag & Steel Fiber" has concluded that the optimum percentage for partial replacement of cement by any supplementary cementitious material (SCM)in concrete is permissible up to 20% and the optimum percentage for the addition of any natural fibre is tolerable up to 1.5%

Manisha M. Magdum and Dr V. V. Karjinniin, their paper "Properties of Hybrid Fiber Reinforced Concrete", recommended utilizing Alccofine - 1203 as a replacement for cement in concrete if possible, as the results showed that the use of hybrid fibres with Alccofine-1203 enhance the mechanical properties of concrete.

Siddharth P. UpadhyayandM. A. Jammu in their paper "Effect on Compressive strength of High-Performance Concrete Incorporating Alccofine and Fly Ash" stated that the cost of Alccofine is cheaper than cement; hence it is also economic with higher strength.

III. MATERIALS AND METHODOLOGY

A. *MATERIALS*

The physical properties of cement, fine aggregates, coarse aggregates, bamboo fibre, Alccofine and Water used for mix design of M5 grade of concrete were tested and properties of the above materials are given below.

a) *CEMENT*

Cement is a binding element that sets and hardens and can bind other materials together. Ordinary Portland cement of 53 grade of Deccan brand is using in this experiment throughout the whole programme. The physical properties of cement obtained and used are given in Table 1.

Table1:Properties of Cement

S.No	Property	Results
1	Standard Consistency	29%
2	Initial setting time	58 minutes
3	Final setting time	600 minutes
4	Specific gravity	3.12

b) *COARSE AGGREGATE*

Coarse aggregates are a construction component made of rock quarried from ground deposits. Coarse aggregates are the particles that retain on 4.75 mm sieve. Graded coarse aggregate (crushed granite stones) of the maximum size of 10 mm is used. Table 2 shows the properties of the above CA.

Table2: Properties of Coarse Aggregate

S.No	Property	Results
1	Specific Gravity	2.84
2	Water absorption	0.55%
3	Particle shape	Angular

c) *FINE AGGREGATE*

Fine aggregate (FA) are the particles that pass through 4.75 mm sieve and retain on 0.075 mm sieve. Fine aggregates (River sand) grades conforming to IS: 383-1970 Zone – II and Zone III respectively are used in this project, and their properties are given in Table 3.

Table3: Properties of Fine Aggregate

S.No	Property	Results
1	Specific Gravity	2.61
2	Water absorption	1.04%
3	Fineness modulus	2.736

d) *BAMBOO FIBRE*

Bamboo fibre is a reproduced natural fibre processed from bamboo. Bamboo fibre is made up of bamboo stalk and pulp. The bamboo fibre used in this project is shown in Fig 1.

Fig 1: Bamboo fibre

It is distinguished by its good hygroscopicity, permeability and softness in nature. The physical properties of bamboo fibre obtained are given in Table 4.

Table 4: Properties of Bamboo fibre

S.No	Property	Results
1	Specific gravity	0.75
2	The diameter of the fibre	0.50 mm

e) *ALCCOFINE*

Admixtures are generally used to reduce the water content and to maintain the workability Alccofine – 1203 is used in our project to maintain both strength and workability. Alccofine used in this project is shown in Fig 2. The physical properties of Alccofine – 1203 obtained are given in Table5.

Fig 2: Alccofine - 1203

Table5: Properties of Alccofine - 1203

S.No	Property	Results
1	Specific Gravity	2.72
2	Fineness (cm^2/g)	2250
3	Bulk Density (kg/m^3)	1437

f) *WATER*

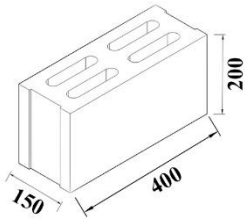
The potable water used in the manufacture of blocks shall be free from matter harmful to concrete.

B. METHODOLOGY

The objective of the present study was to study the effect of bamboo fibre and Alccofine – 1203 on compressive strength of hollow concrete block by additional reinforcement of cement with 0%, 0.50%, 1%,1.50% of bamboo fibre and partial replacement Of cement with 10%of Alccofine - 1203. Bamboo fibre is processed from the bamboo waste collected from the furniture industry. Processed bamboo fibres are chopped down to a length of 30 mm with an aspect ratio of 60. Design and dimensions for the block are determined, and the concrete mix of M5 grade was adopted with a nominal design ratio of 1:5:10 and water-cement ratio of 0.5. To carry out the experimental investigation, totally 40 blocks of size 400mm x 150mm x 200mm were cast. From these 40 blocks, 12 blocks were used to determine the compressive strength of concrete after 7days of Curing and another set of 12 blocks were used to determine the compressive strength of concrete at 28 days. Universal Testing Machine of 1000 KN capacity was used to determine the total compressive load taken by concrete blocks at different ages. Apart from the compressive strength test, 8 blocks are used for performing both Block density and Water absorption test. Rest of the blocks are preserved for future reference.

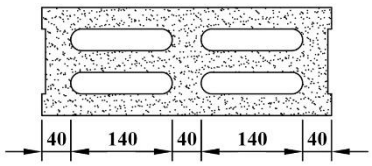
a) DESIGN OF THE BLOCK

The blocks are designed and manufactured as per the IS codal provisions 2185-1 (2005): Concrete masonry units, Part 1: Hollow and solid concrete blocks. The nominal dimensions of the units are so designed by taking account of the thickness of mortar joints, as they will produce wall lengths and heights. The dimensions of the BFRHC Block with their respective views are given in the following figures.



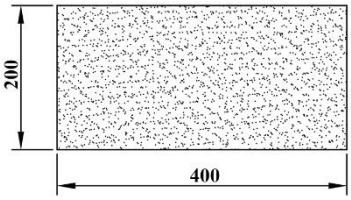
ALL DIMENSIONS ARE IN 'mm'

Fig 3: 3D view of the block



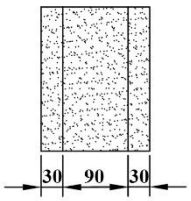
ALL DIMENSIONS ARE IN 'mm'

Fig 4: Top view of the block



ALL DIMENSIONS ARE IN 'mm'

Fig 5: Face view of the block



ALL DIMENSIONS ARE IN 'mm'

Fig 6: Side view of the block

b) CASTING AND CURING OF BLOCK

Batching of the ingredients should be done accurately, and concrete mixing shall be done in a mixer to achieve homogeneous mix. At first, the raw materials such as river sand, cement, bamboo fibre is batched and taken of specified below given quantity, at next stage the Alccofine - 1203 which is to be replaced with cement is added to cement and mixed thoroughly. The material quantities for casting M5 grade blocks are given in Table 6.

A third stage, the coarse aggregate is mixed thoroughly by adding the cementitious material and then potable water is added to it.

Fig 7: Batching and Mixing

Table6: Material Quantities for casting block

S. No	Materials	Percentage of Bamboo fibre			
		0%	0.50%	1%	1.5%
		Material Quantity per m^3			
1	Cement	138.24 Kg/m^3	138.24 Kg/m^3	138.24 Kg/m^3	138.24 Kg/m^3
2	Coarse Aggregate (CA)	1380 Kg/m^3	1380 Kg/m^3	1380 Kg/m^3	1380 Kg/m^3
3	Fine Aggregate (FA)	691.2 Kg/m^3	691.2 Kg/m^3	691.2 Kg/m^3	691.2 Kg/m^3
4	Bamboo fibre	---	0.70 Kg/m^3	1.38 Kg/m^3	2.00 Kg/m^3
5	Alccofine	---	13.82 Kg/m^3	13.82 Kg/m^3	13.82 Kg/m^3
6	Water	69 litres/m^3	69 litres/m^3	69 litres/m^3	69 litres/m^3

The block is compacted by Vibro-compaction machine to get a proper finish and size without broken edges. The blocks shall be handled carefully until they are sufficiently hardened before starting the curing process.

Fig 8: Casting of blocks

c) CURING PROCESS

The blocks hardened is cured as per 13.5 of IS456 or by pond curing. The strength of the concrete not only depends upon the mix proportions it also depends upon the hydration process thus to prevent the loss of moisture and to maintain the temperature, but Curing is also carried out on all the blocks that we have cast are demoulded and cured in curing tank for the period of 7 and 28 days.

Fig 9: Curing Process

IV. RESULTS AND DISCUSSION

a) COMPRESSIVE STRENGTH OF BLOCKS

The blocks are tested in Universal Testing Machine (UTM) as shown in Figure.10 after achieving 7, 28 days of curing. The results of compression strength for conventional block and blocks with bamboo fibre and Alccofine are tabulated in Table 7 & 8.

Fig 10: Compression test on blocks

Table7: Compressive Strength of BFRHC Blocks at 7 Days in (N/mm^2)

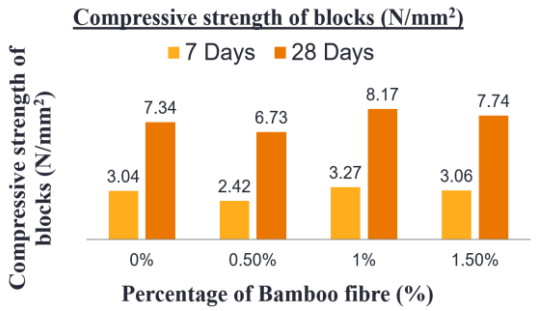
Specimen	Load failure (KN)	Compressive strength (N/mm^2)	Average Compressive strength (N/mm^2)
0% fibre + 0% Alccofine	116	2.63	3.04
	150	3.40	
	137	3.11	
0.5% fibre + 10% Alccofine	95	2.15	2.42
	116	2.68	
	107	3.43	
1.0% fibre + 10% Alccofine	125	2.84	**3.27**
	161	3.65	
	147	3.34	
1.5% fibre + 10% Alccofine	136	3.09	3.06
	122	2.77	
	147	3.34	

Table8: Compressive Strength of blocks at 28 Days in (N/mm^2)

Specimen	Load failure (KN)	Compressive strength (N/mm^2)	Average Compressive strength (N/mm^2)
0% fibre + 0% Alccofine	323	7.34	7.34
	316	7.18	
	331	7.52	
0.5% fibre + 10% Alccofine	296	6.72	6.73
	303	6.88	
	291	6.61	
1.0% fibre + 10% Alccofine	367	8.34	**8.17**
	354	8.04	
	358	8.13	
1.5% fibre + 10% Alccofine	345	7.84	7.74
	340	7.72	
	338	7.68	

COMPARISON OF RESULTS

The results of compression strength for conventional block and blocks with bamboo fibre are compared in the given chart.



b) WATER ABSORPTION OF BLOCKS

Water absorption is the amount of water absorbed by the block is generally expressed in percentage. For the water absorption test, the specimen is oven-dried in a ventilated oven at 100°C to 115°C for more than 2 hrs. The weight of the dried specimen is noted as w_1, and the specimen is completely immersed in water for 24 hours. After the completion of the soaking period, the surface of the specimen is gently wiped, and the weight is noted as w_2 and for all percentage of blocks. Following formulae calculate the water absorption value and the values are tabulated in the Table9.

Water absorption = $[(w_2 – w_1) / w_1] \times 100$

Where, w_1 – Dry weight of specimen; in kg,
w_2 – Wet weight of specimen; in kg,

Table 9:Water Absorption test of blocks

Specimen	Dry weight (Kg)	Wet weight (Kg)	Water absorbed (%)	Average water absorbed (%)
0% fibre + 0% Alccofine	14.19	14.36	1.19	1.22
	14.36	14.54	1.25	
0.5% fibre + 10% Alccofine	14.78	15.03	1.69	1.69
	14.64	14.89	1.70	
1.0% fibre + 10% Alccofine	15.03	15.34	2.06	2.16
	14.98	15.32	2.26	
1.5% fibre + 10% Alccofine	15.15	15.61	3.03	3.27
	15.34	15.88	3.52	

The water absorption capacity of blocks gradually increases with the addition of bamboo fibre in the block when compared to the conventional block.

c) BLOCK DENSITY TEST

Block density is calculated by dividing the Mass of a block by the overall volume, including holes of cavities and end recesses, and it is generally expressed in Kg/m^3.

Block density test is performed on the blocks to classify the blocks according to their grades. The following are classified below:

Grade A - These are used as load-bearing units and shall have a minimum block density of 1500 kg/m^3. These shall be manufactured for minimum average compressive strengths of 3.5 to 10.0 N/mm^2 respectively at 28 days.

Grade B - These are also used as load-bearing units and shall have a block density between 1100 kg/m^3 and 1500 kg/m^3. These shall be manufactured for minimum average compressive strengths of 3.5 and 5.0 N/mm^2 respectively at 28 days.

For the block density test, we have taken block dried in normal temperature. The Mass of the dried block is weighed in the weighing machine and noted in terms of kg, followed by volume calculation of the block.

Following formulae calculate the block density and their values are tabulated in Table 10.

$$\text{Block Density} = \frac{\text{Mass of the block (Kg)}}{\text{Volume of theblock (cm}^3\text{)} \times 10^6 \text{ kg/m}^3}$$

Table10:Water Absorption test of blocks

Specimen	Block density (Kg/m^3)	Average Block density (Kg/m^3)	Grade
0% fibre + 0% Alccofine	1495	1502	Grade A
	1509		
0.5% fibre + 10% Alccofine	1523	1519.50	Grade A
	1516		
1.0% fibre + 10% Alccofine	1538	1541.50	Grade A
	1545		
1.5% fibre + 10% Alccofine	1572	1568	Grade A
	1564		

V. CONCLUSION

The study investigated the use of Bamboo fibre as partial addition and Alccofine – 1203 as partial replacement of cement in the concrete for casting BFRHC blocks. The properties of both Bamboo fibre and Alccofine – 1203 were equally examined. The study is concluded as follows:

1. The strength properties of BFRHC blocks containing bamboo fibre of 0.5%, 1.0%, 1.5% were investigated.
2. They primarily study determined the feasibility of bamboo fibre in concrete for sustainable construction development.
3. Modulus of elasticity of concrete increases by the addition of bamboo fibres.
4. The compressive strength of blocks is increased with the addition of bamboo fibre up to 1.0% and further any addition of bamboo fibre the compressive strength decreases. For 1.0% replacement in the 7 days, the compressive strength is **3.27 N/mm^2**and for 28 days is **8.17 N/mm^2**.
5. The blocks are classified as **A (5.5) Grade** as it meets the minimum compressive strength mentioned in IS 2185-1 (2005): Concrete masonry units, Part 1: Hollow and solid concrete blocks(Clauses 5.1,5.2 and 9.4)
6. The blocks have a water absorption capacity of less than 10 %. Hence the blocks are safer to use in masonry works.
7. The blocks have a minimum block density of 1500 kg/m^3 and classified into **Grade A**. Hence the blocks can be used as both load-bearing and non – load-bearing units in masonry works.
8. We have put forth a simple step to minimize the cost for construction with the usage of bamboo, which is freely available.
9. The problem of a decrease in compressive strength may be addressed with the use of supplementary cementitious materials (SCM).
10. The results indicated that the use of Bamboo fibre with Alccofine-1203 has mildly enhanced the mechanical properties of concrete.

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