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Low Cost Housing Techniques by Replacing Conventional Materials

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Abstract: Economy is a thing of concern since past. Several techniques are been adopted to achieve it. This paper adopts the following alternatives; they are Bamboo as a replacement for steel, mortar filler and fly-ash bricks. As the other two are readily available, this paper aims at determining the feasibility of bamboo as a structural replacement for steel. Beams were casted for M20 with bamboo as reinforcement and were tested for flexural strength. Tensile tests and flexural tests have proved that bamboo can absorb energy thus making it a replacement of steel. Such techniques are eco-friendly and are also economical which is of great concern while providing housing for rural areas.

Keywords—Bamboo reinforcement, Flexural Test, Fly-ash bricks, mortar filler

Food, clothing and housing are the three essential amenities for human existence. As per census 2011, 78 million Indians don't have a shelter. We still rank as the 124th wealthiest country in the world. More than 90 million Indians earn less than a dollar each day. The number of people living in slum is projected to rise to 93 million in 2011 or 7.75% of the total population. Being in such an adverse situation it is impossible to have shelter for everyone. This is because as they cannot afford basic housing as which is estimated that the basic apartment is $175 per month. To provide shelter for such a huge number is a million dollar question.

To compensate this it is important to turn towards alternate technologies of construction. As the government is aiming towards, providing shelter for every Indian by the year 2025 and to achieve that in that time low cost houses have to be designed. According to conventional practice we use the following things for construction:

1. Steel
2. Concrete
3. Bricks
4. Mortar

STEEL

Concrete is very weak in tension and to provide a rigidity and to compensate for tensional forces steel is used. Since the inception of concrete, steel is accompanied with it. This bonding cannot be broken for heavy constructions but when it comes for rural housing there is an alternative. Several studies are been going on to increasing the strength and durability of concrete by adding some admixtures and also alternatives for aggregates, etc. But when it comes for rural housing there is no need of such things as strength and other parameters required are not so vital and also don't require much attention. However, adopting such techniques act as only partial replacement and do not reduce the cost much convincingly. So the only way left is to find an alternative for steel.

CONCRETE

The most remarkable invention of 19th century is the concrete. Since its inception its consumption rate has never fallen. There are some studies which provide technologies to increase the strength of concrete and also use of non-renewable wastes. But all this may increase the total cost, this paper does not focus on its alternatives.

BRICKS

When it comes for housing brick masonry is used to cover the faces of the structure. They may be clay bricks or the fly-ash bricks. Both these types are widely used these days. For a typical house, approximately 25% of the total cost is spent only on bricks; if we could replace it with alternatives this could be economical.

PLASTERING MORTAR

This type of mortar is used for plastering of brick masonry. This is composed of cement and fine aggregates in the ratio of 1:6 (Depending upon the requirements). Now days, the availability of fine aggregates has declined which increased its cost. Reduce of use of fine aggregates will influence the total cost of the construction. On replacing this with alternates that reduce the consumption of fine aggregates and also cement that could enhance for a low cost construction.

PROPOSED DESIGN

BAMBOO

Bamboo is proposed as an alternative for steel. The reason for adopting bamboos is because of its high tensile strength. This strength is more in the direction parallel to the fibers, which run longitudinally along the length of the column, and low strength in a direction perpendicular to the fibers. Bamboo is easily accessible as it grows in almost every tropical and subtropical region; this lowers the cost of construction and increases the strength of the buildings.

FLY-ASH BRICKS

Fly ash cement/lime solid blocks with compressive strength of 75 kg/sq.cm - IS: 12894-1990 - CLASS - 7.5 of size 290 x 200 x 140mm are proposed.

MODIFIED PLASTER

It is a modified mortar filler and plaster. This technology is however new to us but is been widely adopted in cities like Bengaluru. This technique apart from reducing cement consumption also reduces fine aggregates mostly river sand that has turned too costly and also its availability is also been limited.

Table 1: Different Mix-Proportions of modified filter

Mix Type	Modified Filler (Kg)	Cement (Kg)
Type-01	40	2.5
Type-02	40	3.25

This mix design should be adopted depending upon the strength required like for ceiling where the bonding is low because of gravity cement quantity should be increased. For other external purposes cement quantity may be deduced.

In order to find out the exact cost difference between conventional design and the proposed alternative a typical house (Fig 1) was considered and cost estimation was done.

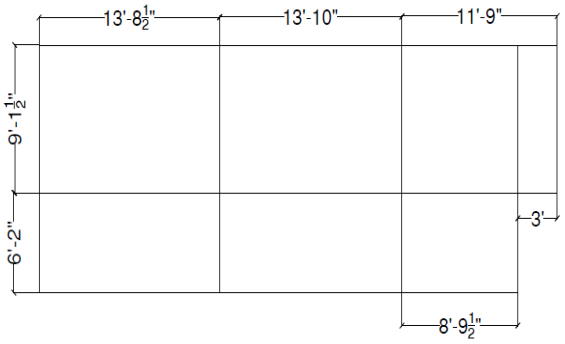

Fig 1: Layout of the site plan used for cost estimation. The elevation was 3.5m

TESTS DONE

Tests were done on bamboo for tensile strength; beams were casted with bamboo as reinforcement and were tested for flexural strength. The tests were done on several samples that justify the usage of bamboo. For tensile strength culms of bamboo with and without nodes were taken and tested under Universal Testing Machine and compared with sample of conventional steel. Similarly beams were casted with steel and bamboo reinforcement and were compared. While testing because of casting irregularities and loading obligations shear failure was observed before the crack prolonged after initiation. To overcome this shear reinforcement made of steel was provided. This proved successful as the crack initiated exactly in the gauge length.

Table 2: Variation of cost for Conventional and proposed design

Work Description	Cost (in Rupees ₹)		Variation (in Rupees ₹)
	Conventional Design	Proposed Design	
Excavation	35,273*	35,273*	0
Brick Work (fly-ash)	1,41,000*	1,23,400*	17,847
Plastering	18,850*	11,310	7450
Flooring	52,000*	52,000*	0
RCC	1,50,000*	1,50,000*	0
Reinforcement	2,00,000*	30,000	1,70,000
Total cost (Rs.)	**6,17,000**	**4,00,050**	**1,85,150**

*All rates are according to SSR-2013-2014

Table 03: Description of tests

S.No	Test specification	No. of samples tested
1	Tensile Test	2
2	Beams (Flexural strength)	7
3	Cubes (Compressive Strength of mix)	3

TENSILE TESTS

Samples were loaded under UTM to determine its tensile strength. To achieve these samples were in the following manner.

1. Sample with nodes at its center.
2. Sample without nodes throughout the length.
3. Samples with nodes that are held up in jaws.

CONCRETE MIX-DESIGN

IS mix design used for steel reinforcement was adopted for bamboo also. The mix design was M20. This was because for general construction M20 is mostly adopted and the behavior of bamboo for such mix-design was important to be determined. Initially cubes were casted to determine the exact strength of mix.

As stated above M20 mix design was adopted with the ratio of 1:1.5:3 (Cement: Fine aggregates: Coarse aggregates). For this the materials were used;

Cement

For cement Ordinary Portland cement of 53 grade of "Anjani Cement" was used. According to the design 320 kgs was used for 1 m^3 volume.

Aggregates

River sand that passed through 9.5mm sieve was used. For aggregates maximum size of 20mm were used. To find different parameters of aggregates such as specific gravity, bulk modulus and absorption capacity procedures prescribed in Indian Standard were followed.

Water

Normal municipality water was used for mix and for curing. $\frac{W}{C}$ = 0.55 accordingly water was mixed.

Procedure for mixing the concrete;

1. 500 ml of water was placed in the mixer followed by coarse aggregates.
2. Fine aggregates were placed after that.
3. Then cement was placed and allowed for dry mixing for 1 minute.
4. After that water was continuously poured while mixing for about 3 minutes and then poured in the moulds for specimens.

BEAM TESTS

Beams were casted with bamboo as longitudinal reinforcement. For shear reinforcement steel was used. The reason for adopting steel reinforcement is because as we are more concerned about the economy. According to a study done by Mark[1] and Russell[1] which was aimed at calculating the cheapest way of providing stirrups proved that use of steel for shear reinforcement was most economical. In this paper, the combination was used i.e. for longitudinal reinforcement bamboo was used and for stirrups steel was used. The beams were loaded under "Two-point loading". A total of 7 beams were casted of which 3 were with longitudinal bamboo reinforcement and steel stirrups, 3 were with only longitudinal bamboo reinforcement and 1 with longitudinal bars of steel and steel stirrups.

TEST RESULTS

Tensile Test Results

Specimens were loaded under the UTM to know the pattern of failure of specimens under loading. The following pattern was observed; specimens with nodes in between failed exactly at the nodes and specimens without nodes in between showed ductile nature and then failed. Through the investigation it was observed that the density of fibers at the nodes was more. Some specimens failed due to excessive compression in between the jaws. The failure pattern of specimen is shown in fig

Fig 2: Failure of specimen due to axial load.

Table 4: Tensile strength of specimens

S. No	Type	Peak Load (kN)	Area (mm^2)	Tensile Strength (MPa)
1	Bamboo	33400	200.96	166.2
2	Bamboo	33200	200.96	165.2

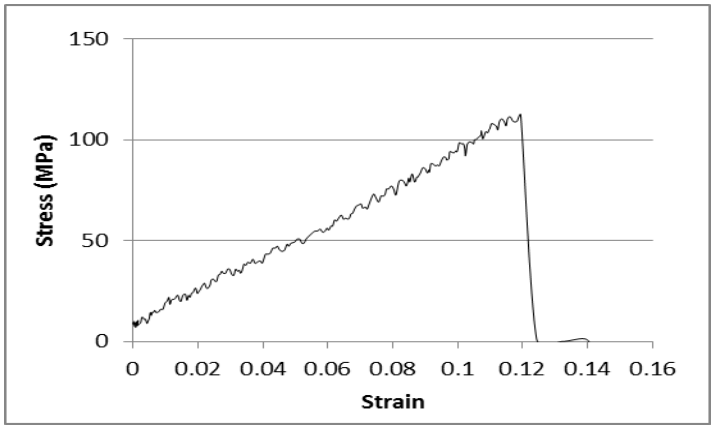

Fig 3: Stress vs. Strain behavior of bamboo under tensile loading

Compressive strength of Cubes

Cubes were casted to determine the strength of mix-design**.** After 28 days of curing they were tested under CTM and following are the results;

Table 5: Compressive strength of cubes casted with the above mentioned mix-design

S.No	Peak Load (N)	Area (mm^2)	Compressive Strength (MPa)
1	490000	22500	21.7
2	435000	22500	19.3
3	525000	22500	23.3

Beam test Results

Casted beams were carefully placed under the UTM with a special arrangement to induce two-point loading as in fig; and the failure pattern was observed;

Fig 4: Initiation of failure pattern

Table 5: **Showing peak load taken and displacement of beams under loading**

S.No	Reinforcement Type	Peak Load (kN)	Displacement (mm)
1	Bamboo-1	45.26	9
2	Bamboo-2	24.8	30.77
3	Bamboo-3	37.1	9.65
4	Bamboo -11 (Without shear reinforcement)	18.6	9.02
5	Bamboo -12 (Without shear reinforcement)	18.8	26.97
6	Bamboo -13 (Without shear reinforcement)	30.3	14.95
7	Steel	89.8	3.65

Table 6: Showing Stress and flexural moment of beams

Sample	Moment (kN.mm)
Bamboo-1	4029.1
Bamboo-2	2238.9
Bamboo-3	3315.1
Bamboo -11 (Without shear reinforcement)	1696.4
Bamboo -12 (Without shear reinforcement)	1713.9
Bamboo -13 (Without shear reinforcement)	2720.15
Steel	7926.4

CONCLUSION

This work provides appropriate technique for a low cost housing using the proposed materials in RC structures. This provides bamboo as a good replacement for steel, although the tensile strength of bamboo is only half of that of steel but from flexural strength it can be conceived that it could resist cracking up to certain limit. As this paper is mainly aimed for rural housing where the structural loads are very low this technique can be adopted. This also proved that bamboo as a replacement of steel which can be used for masonry work instead of plain concrete. It is not that everywhere this could give the same desired value. But can be used where the availability of bamboos is high. The other techniques that we have adopted are existing, so not tests are done on them. In fact this is what the actual aim of Green concrete that to use the locally available products for construction neglecting the conventional practices that generate huge pollution while they are manufactured. There is still ample of scope to research regarding the application of this technique in different conditions.

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