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EXPERIMENTAL STUDIES ON PAPERCRETE

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ABSTRACT

The main objective of this study is to utilize the waste materials like paper, fly ash, rice husk ash into an effective building material. In this work an attempt has been made to introduce an alternative, cost effective, ecofriendly innovative building material in the form of brick. Here sand, cement, earth and other waste material like paper, fly ash and rice husk were mixed in various proportions and an optimum composition has been arrived. Papercrete brick have been made with sizes 230x110x80mm with the various proportions. Among the various combinations the padobe brick gave more compressive strength 6.47N/mm2 and recommended for even load bearing walls. Among the fibrous bricks some of the combinations got a compressive strength more than 3.5N/mm2 but failed to satisfy the water absorption requirements and hence recommended for inner partition walls. The water absorbed by padobe was found to be 14.95% and shows its suitability. The weight of the padobe brick is found to be between to 1/3rd of the conventional clay bricks. Since these bricks are relatively less in weight and more flexible and hence it is an ideal material for earthquake prone area. So, it can have a check on environmental pollution by utilizing the waste material to develop an effective and economical construction material.

Key Words: Paper, Concrete, Papercrete, Padobe bricks and Strength

1. INTRODUCTION

India's present housing shortage is estimated to be high as 3.1 million as per 2001 census and out of these shortage 24 million units are in rural area and 7.1 million units in urban areas. The government of India has targeted the year 2010 for providing housing for all. Such a large housing construction activities require huge amount of money. Out of this total cost of housing construction, building materials contribute to about 70% cost in developing countries like India. While taking the building materials, brick remains one of the most important building materials in India. Notably the Indian brick industry, which is the second largest producer in the world, next only to china, has more than 1,00,000 operating units, producing about 140 billion bricks annually. The industry has an annual turnover more than Rs.140 billion. This is one of the largest employment-generating industries employing millions of workers. The conventional brick making is an energy intensive process. The conventional brick making practice consumes huge quantities of fuel (almost 30 -40% of the production cost in India) in terms of coal, firewood, and other biomass fuel. It is estimated that the Indian brick industry consumes more than 24 million tons of coal annually, in addition to several million tons of biomass fuels. Kilns are also notorious as highly polluting establishments, affecting not just flora, fauna, but also posing threats to human health. The above stated problems were solved by introducing an alternative, cost effective, eco-friendly innovative building bricks. These alternative bricks were made with papercrete. Papercrete is a tricky term. The name seems to imply a mix of Paper and concrete, hence Papercrete. Different types of Papercrete contain 50 – 80 % of waste paper. Papercrete additives can be Portland cement, sand, fine earth, clay, fly ash, rice husk ash, powdered glass, Styrofoam and other additives. In this study sand, cement, earth and waste materials like paper, fly ash, rice husk ash were mixed in various proportions and a suitable proportion suggested based on more strength, less cost, inflammable, less water absorbance and more eco-friendly. The characteristics of these successive proportions were analysed in this study.

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2. MATERIALS CHARACTERISTICS

Materials are the important criteria to produce a product. The materials should be easily available and eco-friendly. In this study waste materials like Paper, Fly ash, Rice husk ash were utilized to produce building bricks. The 43 grade ordinary Portland cement, river sand and clay is used as base material in the study. The tremendous increase in use of paper products like tissue paper, tea bags, filter paper, lightweight online-coated paper, medical grade coated paper etc., are disposed as waste and it is accounted around 1600 m3 per day in India. Even though the waste papers are recycled in paper industry only 29% and it is comparatively lower than the global average of 36%. Hence it is decided to utilize the paper waste in the construction industry. Paper is principally wood cellulose, which is considered as fibrous material and it is the main component of plant cell walls. Cellulose is a natural polymer, a long chain of linked sugar molecules made by the linking of smaller molecules. The links in the celulose chain a type of sugar, ß-D glucose. The cellulose chain bristles with polar –OH groups. These groups form many hydrogen bonds with –OH groups on adjacent chains, bundling the chain together. The chains also pack regularly in places to form hard, stable, crystalline regions that give the bundled chains even more stability and strength and this chemical property of the paper is suitable for papercrete. The tensile strength of the paper also seems to be sufficient to improve the behavior of papercrete. With the boom population and industrial growth, the need for power has increased manifold. Nearly73% of India's total installed power generation capacity is thermal, of which 90% is coal-based generation produces huge quantity of fly ash and the disposal is a critical problem. Fly ash posses pozzolanic characteristics can be used for the manufacture of cement, concrete, and lime/cement based bricks/blocks. Rice milling generates a by-product known as husk and it contains around 85%-90% silica. Colour of this RHA is grey and its size is 25 microns. But the particle size of cement is about 100 microns. So the RHA is used to fill the voids formed by cement. So the cement can be replaced effectively.

3. METHODOLOGY

Papercrete derivatives like fibrous concrete and padobe was used in this project. The concept of those derivatives is different with each other. When the water is added to paper and Portland cement drains from the mix, it comes out almost completely clear. There is no messy and eco-unfriendly cement sediment left on the ground, running into waterways etc., papercrete can be produced using solar energy. In the papercrete matrix, fibers and fibrils network forms a matrix, which becomes coated with Portland cement. When these networks of fibers and fibrils dry, they intertwine and cling together with the power of hydrogen bond. Coating this fiber with Portland cement creates a cement matrix, which encases the fibers for extra strength. Raw cellulose has comparatively rough texture and Clay, fly ash is added to make the cellulose very smooth. When the water drains out and evaporates, it leaves tiny air pockets throughout the matrix. This is what makes the material light and good insulator. Padobe brick are having clay as the binding material instead of cement. The clay content is too high in conventional bricks means, the bricks may crack when drying. But adding paper fiber to the earth mix strengthens the block and gives it some flexibility, which helps prevent cracking. When the padobe is burnt, the paper in the padobe increases the temperature easily and reduce burning time and fuel. While burning the padobe bricks, the paper in the brick burn first and deposit ash inside the brick. It reduces the weight of the brick and fills the voids also.

4. MANUFACTURING OF BRICKS

There were no clear past details about the project. So the procedure that is given below was followed by our own. The equipments which were used in this project are decided as per our convenience.

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4.1 Material Collection

Even though there is a lot of sources available to get waste paper, the paper that was wasted in our college premises were collected. Fly ash is the easily available material from the power plants and for our study the fly ash was collected from Ennore power plant. Rice Husk Ash is the locally available waste anywhere in Tamilnadu. All the rice mills in Avadi are dumping the rice husk ash in a low-lying area as a waste. For this project RHA was collected from a rice mill that is situated in Avadi. Clay is another one binding material that is used in padobe bricks. So various samples of earth were collected from our college campus and shake test was conducted. The earth having clay content 44.44% was used in our study.

4.2 Pulp Generation

The papers, which were collected, cannot be used directly. It should be made into paper pulp before mixing with other ingredients. The papers were tear in to small pieces of papers and were immersed, not in a bulky manner, in water to make the pieces completely wet. The papers were kept in a tank for 2 to 3 days otherwise until the paper degrade into a paste like form. After that particular period, the papers were taken out and hammered papers were scratched manually on the ground. Then the papers were mixed with required quantity of water and then, papers were grinded manually.

4.3 Mixing

After all the ingredients were ready, the mixing was done. The mixing process of Fibrous Concrete Bricks (FCB) and padobe bricks are different, and that processes are given below.
In this type nearly 10 proportions were used to find the suitable proportions and is represented in the Table1

Mix	Proportion	Contents
FCB1	1:3	Cement: Paper
FCB2	1:4	
FCB3	1:2:4	Cement:Sand:paper
FCB4	1:3:6	
FCB5	1:0.5:2:4	Cement:fly ash:sand :
		paper
FCB6	1:2:4	Cement:fly ash:paper
FCB7	1:3:6	
FCB8	1:2:4	Cement:RHA: paper
FCB9	1:3:6	
FCB10	1:2:2:2:6	Cement: fly ash: RHA: sand: paper

Clay and paper are mixed in 3: 1 proportion for making padobe bricks. The earth clay having more than 30% clay and paper were measured by volume batching.

4.4 Moulding, Curing and Burning

After mixing, the mix is placed in the mould before 30 minutes. In this study, the bricks were moulded manually by hand. The papercrete bricks need more time to dry. So only solar drying was allowed. In this, the bricks were laid longitudinally in stacks of width equal to 2 bricks. The Fibrous concrete bricks were allowed only for drying, but the padobe bricks were burnt. It imparts hardness and strength to the bricks and makes them dense and durable.

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5. ANALYSIS AND RESULTS

After casting the bricks, they were analyzed for using as a brick. Various tests were carried out to check the properties of the bricks. And the results of that test were analyzed with the existing and standard results.

5.1 Compression Test

This test was carried out by a compression testing machine (100T) for both fibrous concrete and padobe bricks. While testing the fibrous concrete brick great care must be taken, because fibrous concrete brick never failed catastrophically, it just compressed like squeezing rubber. So load was applied up to full compression. The fibrous concrete brick failed at the higher load and the outer faces only cracked and peeled out. But padobe bricks behaved like conventional clay brick.

Table 2 Compressive strength of fibrous concrete and padobe bricks

S.No	Mix	Specimen	Load(kN)	Surfacearea mm	CompressiveStrengthN/mm	AverageN/mm
1	FCB1	1	75	23,320	3.22	3.33
		2	80	22,984	3.48	
		3	77.5	23,520	3.30	
2	FCB2	1	55	22,866	2.41	2.55
		2	60	22,826	2.63	
		3	60	23,088	2.60	
3	FCB3	1	97.5	22,763	4.28	4.21
		2	95	22,523	4.22	
		3	95	23,072	4.12	
4	FCB4	1	85	23,088	3.68	3.62
		2	85	23,415	3.63	
		3	82	23,310	3.54	
5	FCB5	1	75	21,825	3.44	3.52
		2	80	22,321	3.58	
		3	75	21,185	3.54	
6	FCB6	1	92	23,400	3.95	3.94
		2	95	24,062	3.94	
		3	92.5	23,400	3.93	
7	FCB7	1	60	23,956	2.50	2.44
		2	55	23,608	2.33	
		3	55	23,072	2.38	
8	FCB8	1	85	23,625	3.60	3.65
		2	87.5	23,744	3.69	
		3	87.5	23,850	3.67	

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A brick used for construction should have compressive strength more than 3.5 N/mm2.Out of eleven mix, 6 types of brick mix got compressive strength more than 3.5 N/mm2. The bricks that got a compressive strength of less than 3.5 N/mm2 are not suitable for construction and these 5 types of bricks were rejected from the analysis.

5.2 Water Absorption Test

The water absorption test results obtained are presented in Table 3. For FCB2 mix the value is greater than 100 %.

Table 3 Water absorption test results

S.no	Mix	Dry weight, W2 (Kg)	Wet weight, W3 (Kg)	Water absorption Ratio (%)
1	FCB1	0.841	1.658	97.15
2	FCB 2	0.677	1.560	130.43
3	FCB 3	1.543	1.994	29.22
4	FCB 4	1.527	2.187	43.22
5	FCB 5	1.992	2.626	31.82
6	FCB 6	1.472	2.258	53.39
7	FCB 7	1.000	1.820	82.00
8	FCB 8	0.801	1.380	72.00
9	FCB 9	0.676	1.300	92.00
10	FCB 10	1.582	2.680	69.40
11	PB 11	1.956	2.249	14.98

5.3 Fire

The fire test was carried out only for fibrous concrete bricks not for padobe brick. The fibrous concrete bricks were fired for nearly an hour and observations are made. From the above test, it was observed that the fibrous concrete bricks did not burn with an open flame but they smoldered like charcoal. If the interior plaster and exterior stucco is provided on the fibrous concrete bricks, the bricks won't burn.

5.4 Weight

All the bricks were weighed in a electronic weighing machine are presented in Table 4. In this proportion fly ash and rice husk ash based bricks weigh 1/3 rd. of the conventional brick, while padobe and sand based bricks are having weight 2/3 rd. of conventional brick. So this bricks are light weight and it will also reduce total cost of construction due to the reduction in dead load.

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Table 4 Weight of fibrous concrete and padobe brick

S.no	Mix	Average weight (Kg)	Average weight (N)
1	FCB 1	1.081	10.60
2	FCB 2	0.888	8.71
3	FCB 3	1.711	16.78
4	FCB 4	1.736	17.03
5	FCB 5	2.002	19.63
6	FCB 6	1.704	16.71
7	FCB 7	1.196	11.73
8	FCB 8	1.095	10.74
9	FCB 9	0.785	7.70
10	FCB 10	1.755	17.22
11	PB1	1.956	19.19

5.5 Soundness Test

In this test two bricks from same proportion were taken and they were struck with each other. The bricks were not broken and a clear ringing sound was produced, hence the bricks are sound enough.

5.6 Structure Test

In this test, the bricks were broken and the structures of that bricks were examined to see whether they were free from any defects such as holes, lumps, etc (Fig.2).

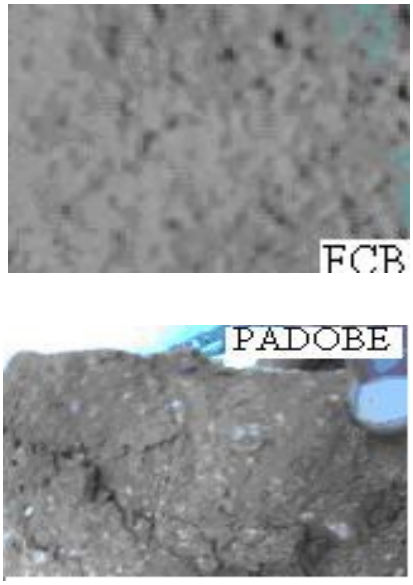

Fig.2 Inner structure of fibrous concrete brick and Padobe brick

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5.7 Nailing

Fibrous concrete bricks are less hard when compare to conventional bricks and padobe bricks. So this test was carried out to find out whether bricks hold the nail or not. A nail was hammered in the brick and a screw is also screwed in the brick. In this two (Fig.4), fibrous concrete brick did not hold nails any better than dry wall, but screws worked well and hold a considerable weight. So, the screws are the anchors of choice for fibrous concrete bricks.

Fig.3 Nailing and Screwing on Bricks

5.8 Cutting and Joining

In this test fibrous concrete brick were cut into exactly two pieces (Fig.4) and padobe bricks were broken into two parts. The fibrous concrete brick piece structure was homogenous, compact, and free from defects. The padobe bricks pieces had uniform surface and it was free from any defects. The padobe brick structure contains white ashes due to burning of inner papers. The two fibrous concrete brick pieces can be hold together by putting a medium amount of glue on the bottom piece Fig.5.This would seem to indicate that papercrete could be used in application calling for quick assembly by cutting the pieces to size in advance and letting the user simply glue them together. But padobe bricks are behave like conventional brick.

Fig. 4 Brick pieces

Fig. 5 Joined brick pieces

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5.9 Plumbing and Electrical

Installing plumbing lines is very easy in fibrous concrete bricks when compare to padobe bricks (Fig.6 and 7). Electrical runs were cut with a circular saw or chain saw. To make holes for outlets, horizontals and vertical slits was cut with a circular saw. Then unwanted pieces were removed with a screwdriver.

Fig. 6 Hole in the Brick

Fig. 7 Channel in the brick

6 COST ANALYSIS

In this Study, cost was calculated only for the successful 6 proportions. And cost for production of 1 lakh brick was calculated. Labour and manufacturing cost was assumed as 10% of material cost. The above table furnishes the rate of brick for all successful proportions. The rate of one conventional clay brick varies from Rs. 3.50 – 4.50. So the rate of padobe brick is only 7% of conventional brick. In the 5 fibrous concrete bricks, FCB3, FCB4 and FCB5 bricks (ie., sand based bricks) cost is nearly equal to the conventional concrete bricks, but they are weighing only the 2 / 3rd of conventional brick and it reduces the total cost of construction. The FCB 6 and FCB 8 bricks cost is 15% lesser than conventional clay brick. The weight of FCB6 is ½ of conventional brick and the weight of FCB8 is 1/ 3rd of the conventional brick's weight only. So the total dead load will be reduced and the total cost of construction is reduced.

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S.no	Mix	Material used	Cost/ Kg	Cost of Material (Rs)	Total Cost Rs (Rs.lakhs)
1	FCB3	Cement	3.50	1,44,715	2.15
		Sand	0.5	44,760	
		Paper	1	5,552	
2	FCB4	Cement	3.50	1,01,301	1.95
		Sand	0.5	46,997	
		Paper	1	5,829	
3	FCB5	Cement	3.50	1,35,069	2.01
		Fly ash	0.1	936	
		Sand	0.5	41,775	
		Paper	1	5,181	
4	FCB6	Cement	3.50	1,44,714	1.69
		Fly ash	0.1	4,013	
		Paper	1	5,551	
5	FCB8	Cement	3.50	1,44,714	1.65
		Rice husk ash	-	-	-
		Paper	1	5,551	
6	PB1	Earth	0.1	23,407	0.29
		Paper	1	6,072	

7 CONCLUSIONS

Padobe brick is giving more strength and weight of this brick is 1/3rd of conventional clay brick. Cost of one padobe brick is 29 paisa and it is comparatively 7% of the conventional bricks. The fibrous concrete bricks can be used for non - load bearing partition walls and these bricks are not suitable for water logging areas and external walls. Weights of the fibrous concrete bricks are 1/3rd of the conventional clay brick. Cost of the fibrous concrete bricks is more or less equal to the conventional clay brick's cost. But, due to less weight of these bricks, the total dead load of the building will be reduced. For residential building dead load occupies the 40 – 45% of total cost of construction and for official building, dead load occupies the 30-35% of total cost. So, using the fibrous concrete brick in a building, total cost can be reduced from 20 to 27%. Fibrous bricks are relatively light weight and more flexible, these bricks are potentially an ideal material for earthquake prone areas. Fibrous concrete bricks can be easily cut in to desire shape, so the wastage of brick can be reduced. Also Plumbing and electrical work can be done very easily in these types of brick walls. Papercrete brick will have more resistant to heat flow, so these types of brick walls are suitable for the tropical countries like India. Since waste materials are used to manufacture fibrous concrete bricks, the waste materials are effectively utilized without affecting the environment.

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