Exploratory study on manufacturing of cost-effective floor tiles using Coir Pith

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Abstract— **With limited resources on earth today, to re-cycle and convert waste materials into beneficial resources is very important. Any product of coir sector, coir pith has been identified as a potential construction material in recent research probe. The main objective of the current work is to find out the optimum mix proportions to maximize the breaking strength and to perform tests on optimum mix tile and a group III tile as perIS-13630 which is compared with the standard specifications of ceramic tiles as per IS 15622:2000. This report presents a method to manufacture tiles out of dry coir pith and powdered thermocol. Influence of the source of coir pith, particle size and proportion of mix also has been laid out. Furthermore, microscopic studies were also conducted to compare the trend of breaking strength. The average breaking strength, flexural strength, water absorption, wear, linear thermal expansion obtained for the tiles with optimum mix are 658.55N, 3.92N/mm^2, 12.19percent, 0.93mm, 5.5 × 10^{-6} K^{-1} respectively which are comparable with the values for group III ceramic tiles as per IS15622:2006. The bulk density value obtained was 0.996g/cm3 which shows that it is a light weight material. Eventhough group III ceramic tiles dominate in strength, coir-pith tiles are inferred to be 34percent cheaper than group III ceramic tiles. As the resulting tile properties resemble with properties of wood, subtle changes can be adopted in the procedure to produce a substitute for wood.**

Keywords- Powdered thermocol; ceramic tiles; coir-pith tiles;

I. INTRODUCTION

By product of coir sector, coir pith has been identified as a potential construction material in recent research probe.The long fiber of coir is extracted from the coconut husk and utilized in the manufacture of brushes, auto mobile seat and mattress stuffing, drainage pipe filters, twine and other products. Extraction of 1kg of coir fiber on an average will leave 2kg of coir pith. A considerable amount of coir pith in the order of 7.5 million tons is produced annually in India and accumulated in the coir industrial yards, causing environmental pollution and disposal problems[1]. Therefore, attempts are being made to covert this waste material into useful products.

A. Relevance

The coir pith, which is available in plenty in Andhra Pradesh, the present study will eliminate the need of costly imports and provide better revenue for coconut farmers. This will also be an environmental friendly solution for management of coir pith, which is considered as a waste by product of coir industry[2]. Thermocol is manufactured by using HFCs, or hydro fluoro carbons, which have negative impacts on the ozone layer and cause global warming. HFCs are less detrimental to the ozone than CFCs, which they replaced in the manufacturing of Thermocol, but their impact on global warming is much more serious[3]. Disposal of thermocol has been proved to be a challenging task. One of the main reuse of thermocol is recycling it by cutting and painting it and turning it into a decorative item. Thermocol is also used to mount drawing sand photographs in exhibitions and stalls in fairs. But a majority of them remain buried in the heap of trash in dumping grounds.

B. Motivation

With the greater demand on ceramic tiles whose parent ingredient is natural clay, there is a drastic scarcity in natural clay due to extensive mining in and around Calicut[4]. Thus, it is necessary to find an alternative to replace the same. As Andhra Pradesh being blessed with large number of coconut trees and heaps of coir wastes piling beside coir industries, it would be a pivotal alternative to natural clay in the production of floor tiles.

II. RAW MATERIALS AND TREATMENT

The two major raw materials coir-pith and thermocol, both of which are easily available in a state like Andhra Pradesh. After the procurement of these raw materials it is very necessary to treat it in a properway. As concluded from the previous works, size of coir pith will play an important role in the mix and strength of the final product. When thinner isused to dissolve thermocol it is very necessary that thermocol has to be powdered to the maximum extent so that least amount of thinner is used. Coir-pith was collected from two sources[5] (Bey pore and Mambetta) to study the influence of the age and condition of coir pith on the mix and final product[6]. Coir-pith was dried under sun and sieved to 3 different sizes to study the influence of size on mix and final product. Thermocol pieces were collected from segregation yards and shredded to fine powders using sand paper. Thinner preferably enamel thinner readily available in the market was procured.

III. METHODOLOGY

A. Mixing

The method consists of simple mixing, filling and loading processes. Mixing was done in a container that can be kept air tight. After adding coir pith and thermocol it was mixed well to make the mixture homogenous to the maximum extent. Further the mixing was continued with subsequent spraying of thinner (about 100ml). The thermocol was dissolved gradually with progress and the mix transformed to dough after complete dissolution of thermocol. For maximal utilization of the thinner, the container was kept air tight for around 15 minutes.

The dough was then transferred to a mould of 15 cm × 15 cm × 20 cm keeping separation plates after each trial mixes. Depending upon the mould height, 3-5 tiles can be produced in a single press. A gradual load of 12 tons in 3 minutes was applied under a CTM.

Figure I Dough after mixing

The tiles were further restricted from immediate expansion by a restriction mechanism. After 6 hours, the mould was disassembled and tiles were taken out. Trials were made out from coir pith from two different sources, particle sizes and proportions to study the effect of these on the mix and on the final product.

Table. 1: Curing Procedure Sequence

Days	Process	Observations
1 – 7	Air Curing	Tiles gain strength, impressions formed when forcefully pressed
		Color: Dark black changes to normal black
8 – 16 days	Sun drying: kept under sunlight. Tiles flipped every 2 hours	Tiles gain strength, no impressions formed when pressed
		Color: Black in the center region and brown at the edges
	Sun drying	Color: Complete brown

Figure II Coir Pith

Figure IIIThermocol Powder

B. Pressing and Curing

A coating of touchwood was applied on the tiles. Breaking strength and water absorption tests were conducted on 3 samples of each trial. The tiles were found to be soft just after they were taken out of the mould. The tiles gradually hardened when left in the open air for 24 hours. Upon further drying in sun for 16 days, the tiles hardened and resembled wood. The summary of the curing procedure is shown in Table 1. Tiles just after pressing and after 20 days curing are shown in Figures below.

Figure IVTiles Just after pressing

Figure VTiles after 20 days curing

C. Tests and analysis on tiles of varying proportion

1) Breaking strength test (IS:13630)

Breaking strength and water absorption tests were performed on 3 samples of each CP/TC ratio. The apparatus shown in figure VI below is used to find breaking strength (s). The test procedure pertains to IS:13630.

$$S = FL / b \qquad (1)$$

Where F = Load required to break tile in N
L = Span of support rods in mm
b = Width of tile in mm.

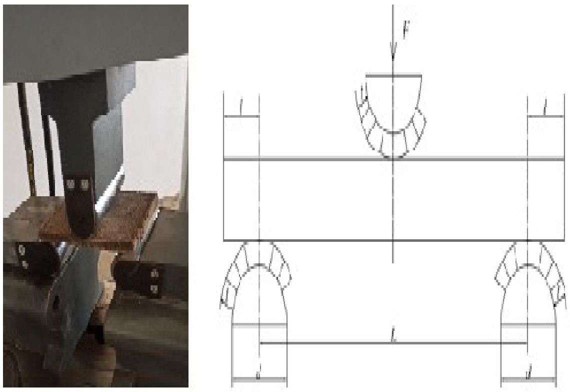

Figure VI Three-point loading in UTM

1) Water Absorption (IS:13630)

Place the tiles vertically, with no contact between them, in water in the heating water apparatus/water bath as shown in Fig. VII so that there is a depth of 50 mm water above and below the tiles. Maintain the water level of 50 mm above the tiles throughout the test. Heat the water until boiling and continue to boil for 2 hr. Then remove the source of heat and allow the tiles to cool, chill completely immersed in this water overnight. For each tile, calculate the water absorption as a percentage of the dry mass using the expression:

$$\frac{m2 - m1}{m1} \times 100 \qquad (2)$$

Figure VII Water absorption test

D. Analysis of Test Results

1) Influence of source of coir pith

Trials made out of coir pith from different sources have been listed in Table 2. Even though both the coir pith samples were dried for the same duration, the final mix produced by all trials from source 1 resulted in poor mix and the resulting tile had large cracks. While trials from source 2 produced a better mix and tiles with less cracks. It is inferred that tiles made out of coir pith samples from source 1 failed due to the intrusion of moisture to the mix from the fresh coir . Hence it is inferred that the condition, age of the coir pith have profound influence on the overall ease of mixing procedure as well as in the quality of the final product.

2) Influence of Particle size of coir pith on tiles.

The influence of particle size of coir pith on mix and tiles formed is shown in Table 2.

Table I Mix and tile description for different particle sizes of coir pith.

Size (S) in mm	Mix	Tile Description	Average Breaking Strength (N)
0.075 < S < 0.1	Lumps	Wide Cracks	---
0.06 < S < 0.075	Moderate	Less Cracks	325
S < 0.06	Dough	Negligible Cracks	533

3) Influence of proportion on curing period

Trials with low CP/TC ratio took more days to gain strength. Table 3 shows the number of days for curing. A tile is assumed to be completely cured if it does not bend on application of force with bare hands and does not give any smell of thinner. As expected, the tiles with less CP/TC ratio (i.e. with more thermocol content took more number of days to get cured).

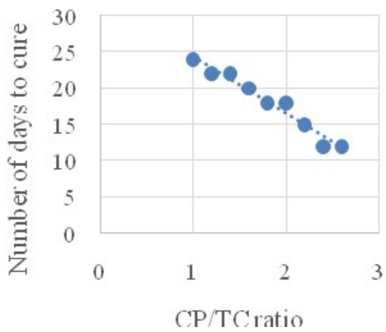

Figure VIIIVariation of curing Period with CP/TC ratio

A graph is drawn between CP/TC ratio and number of curing days as shown in the figure VIII.

Table II Number of curing days for different proportioned tiles

Trials	1	2	3	4	5	6	7	8	9
CP/TC ratio	1	1.2	1.4	1.6	1.8	2	2.2	2.4	2.6
Number of Days	24	22	22	20	18	18	15	12	12

4) Influence of Proportion on Breaking strength

Table IV shows the results of average breaking strength on trials with different CP/TC ratio. Highest breaking strength observed being 650.68 N for a tile with CP/TC ratio of 1.6. Fig. 2.5 shows the plot for the same. Strength is observed to be high inside a specific range of CP/TC ratio.

5) Influence of proportion on Water absorption

Table V shows the results of average of water absorption for tiles with different CP/TC ratio. Fig. 2.6 is the plot for the data. Bulk density obtained was 0.994 g/cm^3.

E. Optimization

Since with variation in CP/TC ratio affects the strength, water absorption and curing period with dissimilar trends, there is a need to optimize the proportion of the mix with a desirable objective.

1) Objectives

The objective could be minimization or maximization of any of the above properties. From an Engineer's (Building material) point of view, with an objective of maximizing the breaking strength optimization was done.

2) Constraints

a) Constraint a:

As per IS 15622 tiles are initially classified depending on the water absorption results are shown in Table IV. But the tiles produced from coir pith were found only to have a maximum breaking strength of 750N. Therefore, this constraint aimed at having water absorption greater than 10% thus allowing it to fall in Group B III (which requires a least strength of 500N).

Table III Classification of Tiles based on Water absorption

Water Absorption	**Classification**
Less than 0.08%	Group B I a
Between 0.08%-3%	Group B I b
Between 3%-10%	Group B II
Greater than 10%	Group B III

b) Constrain b

Curing period has a great influence on the final cost of the product on the market. For an efficient supply chain, the number of days for curing the tiles was constrained to 20 days.

3) Results of Optimization

Optimization resulted in a value of CP/TC ratio of 1.56 which corresponds to interpolated values as shown.Tiles with CP/TC ratio of 1.56 will be manufactured and all tests will be performed in accordance with ceramic tiles testing BIS 13630.

Table IV Summary report using MS Excel

Property	**Value**
Curing period	20 days
Breaking Strength	641.35 N
Water Absorption	10.99%

IV. COMPARISION WITH GROUP III TILES

From the tests conducted on various coir pith tiles with various CP/TC ratio and optimization, it was inferred that tiles with a CP/TC ratio of 1.56 is expected to have maximum breaking strength while it satisfies all other constraints. In order to verify the trend and to compare with values for group

III tiles, further tests were conducted on both tiles (i.e., Coir pith tiles and G-III ceramic tiles).

Table VComparison of Coir Pith tiles and G-III tiles

Parameter	Units	1.56 CPT	Group III CT	Standard Specification
Breaking Strength	N	658.55	1081.64	500
Flexural Strength	N/mm^2	3.92	6.40	15
Water Absorption	%	12.19	10.81	10
Wear1	Mm	0.93	0.58	< 3.5
Bulk Density	g/cm^3	0.996	3.60	-
Linear Thermal Expansion	K^{-1}	$5.50\ X10^{-6}$	$2.24\ X10^{-6}$	$< 9.0\ X10^{-6}$

Table VI Average breaking strength for different tiles

Trials	1	2	3	4	5	6	7	8	9
CP/TC ratio	1	1.2	1.4	1.6	1.8	2	2.2	2.4	2.6
Average Breaking strength (N)	600.37	621.57	631.73	650.68	639.94	622.06	616.42	612.36	610.97

Table VII Water absorption for different tiles

Trials	1	2	3	4	5	6	7	8	9
CP/TC ratio	1	1.2	1.4	1.6	1.8	2	2.2	2.4	2.6
Average water absorption (%)	8.62	9.75	10.27	11.27	13.19	12.32	12.90	13.96	14.09

Figure IX Sample before and after Abrasion test

Also, chemical resistance test was performed on both tiles which resulted in no change on the proper surface or the non-cut edge of the tiles. From Table IX, it can be concluded that both Group III ceramic tiles as well as coir pith tiles satisfy all minimum requirements except modulus of rupture as per standards. It can also be concluded that group III ceramic tiles have dominant values in all the parameters at the same time coir pith tiles is expected to less costly than ceramic tiles. When economic, sustainability factors play a major role in the project; sometimes it would be better to use less costly, more sustainable products for a green future.

V. Cost Evaluation

In order to justify the term 'cost-effective' in the project title, cost evaluation was performed and compared with the existing standard rates of group III tiles in the market. Since the total cost involves various factors like initial investment, administration expenses, operating expense, commercial expenses etc., it will be difficult to incorporate all these factors to compare with the standard rates. Therefore, operating expenses were calculated for coir-pith tiles and compared with the operating expenses for group III tiles. Miscellaneous expenses are taken to be 4% of Cost of Goods Sold & Operating Expenses.

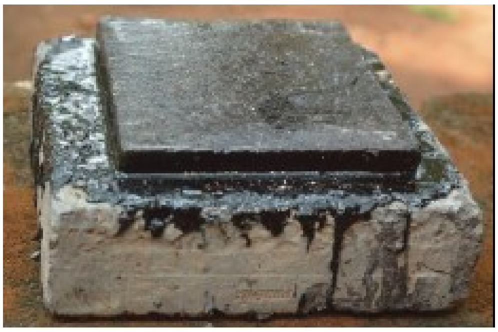

Figure XBitumen used to adhere coir pith tiles on concrete

Standard rate of group III tiles being ₹ 35 per ft^2, its operating expenses is expected to be 50% of the total expenses i.e., ₹ 17.5 per ft^2 while for coir-pith tiles it costs ₹ 11.44 per ft^2 which is 34.6% less than for Group III tiles. The main scope of coir pith tiles as floor tiles, for which bitumen will be used to adhere it with the base as shown in Fig X. Cement grout, other adhesives available in the market can be used for this purpose after checking for any reaction with coir pith.

Table VIII Standard rates of elements

Sl. No.	Element	Description	Unit	Rate
1	Coir Pith	0.05mm dry	per kg	4
2	Thermocol	Waste pieces	per kg	1
3	Thinner	Enamel	per L	80
4	Electricity	-	per unit	5.7
5	Labour	-	per day	500

VI. Conclusions

Tiles have been manufactured out of coir-pith and thermocol. Breaking strength, water absorption tests were conducted on the tiles as per IS 13630: 2006, which is the IS standards for tests on ceramic tiles. From the test results on the tiles, it is inferred that the proportion of these ingredients have profound influence on the curing period, breaking strength and water absorption of the final tiles. From the test results, it was also observed that the tiles have comparable result values as that for Group III ceramic tiles (as per IS 15622: 2006). Bulk density for the coir pith tiles was found to be less than 1 which implies that these tiles are light weight. The optimum proportion for obtaining the maximum breaking strength with least curing period is for a CP/TC ratio of 1.56. This implies the tiles will comprise of 39% thermocol content and rest coir pith. The optimum tiles were subjected to further more tests as per IS 13630: 2006 and the results were compared with test results on Group III ceramic tiles. Even though Group III ceramic tiles slightly dominate in strength parameters, coir pith tiles are expected to be 34% less costly than ceramic tiles. The resemblance of the tiles with that of wood (semi-ductile failure) opens an eye for a substitute for wood. If adopted, this can be a rebuttal to the high cost of wood and deforestation. Coir pith together with thermocol can be used to produce building materials like floor tiles, wall tiles, partition wall, interior door frames, staircase handrails etc. thus increasing the tally in the green building materials.

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