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An Experimental Study on Cement and Fibre based Roofing Tile as an Alternative to Mangaluru Tile

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Abstract - *The roof is defined as the uppermost part of the building, provided as a structural covering to protect building from weather, thermal insulation, fire resistance and sound insulation. The traditional Mangaluru tile is used as the roofing tile and production of tile leads to excessive consumption of wood or coal for generation of heat which directly accounts for high air pollution and related environmental hazards. Therefore, it is necessary to produce an alternate material with good roofing properties with less environmental impacts and economic affordability. The study is done to produce tile units with varying cement mortar proportions and also by incorporating the fibers in the center of layers of mortar for all the varied mortar units. The study is done on producing the units for good strength aspects, water absorption and density parameters. The specimens were casted with 1:2, 1:3, 1:4 cement sand proportions and also with fibres. The testing of units with varied proportions and fibre ingresses units for 7 and 28 days breaking load test and computing load of all specimens. The percentage variation in strength, density, water absorption and production costs are computed and compared with traditional Mangaluru tile for same parameters. The cement based, fibre incorporation can produce roofing tile with high strength properties, durability and less cost in production with less environmental impacts during production. The decreased density per tile also reduces the cost for roof frame fabrication. The experimental study concludes cement based with fibre roofing tile as effective replacement to Mangaluru tile.*

Key Words: **Roofing tile, Mangaluru tile, Cement mortar, fibre, Alternate material, Production cost.**

1. INTRODUCTION

Roof is the integral building element, takes about 25% of the total expenditure of construction. Roofing tiles are commonly made of clay, which has a waterproofing property, the primary capacity is to give a defensive encompass against various climate and climatic conditions. Material tile is increasingly prudent when contrast with RCC section, because of which will in general form their home with Roofing tile. Consequently there is a requirement for investigation for more up to date or alternate material to Mangaluru roofing tile. In any case, in nation like India, Mangaluru tiles are commonly utilized as roof tiles, tastefully it has mix of both Spanish and Italian styles of engineering blended. However the production of Mangaluru roofing tiles requires earth and the tiles are heated at about 1200 degree Celsius to impart the desired mechanical properties which in turn leads to excessive consumption of wood or coal for production of heat which directly accounts for high air pollution and related environmental hazards. Therefore, it is necessary to produce an alternate material with good roofing properties with less environmental impacts and economic affordability.

1.1 Cement Mortar Tile

The mortar is a semi-solid mixture obtained by mixing cement, sand, water in definite proportions to obtain consistent, workable, and homogenous, controlled bleeding which acts as composite for adhesion of structural units, binding, filling, repair works and other adhesive application of structural elements. In this study the cement mortar is used in the production of tiles with similar dimension to Mangaluru tiles by employing different proportions of mortars and also by incorporating fibers with the mortars. The cement mortars are produced for plaster consistency with definite water and constituent ratios. The cement mortar having binding and adhesive properties, so it can be cast to the moulds and compacted to desired tiles shape, size and configurations. The cast mortar tiles are then allowed for curing process to gain strength and mechanical properties.

1.2 Objective of the Study

- To prepare the various proportions of the mortar and also the units with fibre incorporation
- To cast the units of dimensions 400*200*15 by compaction with metal template moulds.
- The testing of units with varied proportions and fibre ingressed units for 7 and 28 days breaking load test and computing load of all units.
- To study the percentage variation of breaking load of all units and also water absorption variations.
- To compute the production costs of all units and compare the same with Mangaluru tile.

2. MATERIAL CHARACTERIZATION.

This contains the test methods, procedures based on Indian standard codal specifications for the investigation of material properties which are used for the experimental processes and the characterization of the same. The primary

importance is to produce economic tiles with increased flexural strength. The materials including the ingressing fibres are tested to determine their mechanical properties before using them in casting and experimental testing of tiles units.

2.1 Mangaluru tile specification

As per IS 654: 1992 the specification on dimension, tolerance of size and pattern of machine pressed tiles. The code also specifies the breaking load, water absorption and permeability limits.

Table -1: Water absorption and breaking load limits.

Characteristics	Requirement for Class AA	Requirement for Class A
Water absorption (%) (max)	18	20
Breaking load (kN) (min)	**1.0** (410 * 235 mm) **1.10** (420 * 250 mm and 425 * 260 mm)	**0.80** (410 * 235 mm) **0.90** (420 * 250 mm and 425 * 260 mm)

2.2 Cement

The Ordinary Portland Cement 53 grade (confirming IS 12269: 2013) was used. Cement was stored in clean and airtight condition.

Table -2: Physical characteristics of cement

Sl. No	Characteristics	Result	Requirement BIS : 12269:2013	Reference
1	Normal consistency (%)	29%	-	BIS 4031:1988 (Part 4)
2	Specific Gravity	3.19	-	
3	Setting Time A) Initial Set (minute) B) Final Set (minute)	 40 310	 30.00 (min) 600.00 (Max)	BIS 4031:1988 (Part 5)
4	Soundness Le-Chatelier Expansion (mm)	2.0	10.0 (Max)	BIS 4031:1988 (Part 3)
5	Compressive Strength (MPa) 3 days 7 days 28 days	 29 40 55	 27 37 53	BIS 4031:1988 (Part 6)

2.3 Fine aggregate

Manufactured sand (M-sand) was procured. M-Sand was confirming to zone II as per IS 383: 2016. The tests were conducted as per IS 2386: 1963.(Water absorption 1%)

Table-3: Physical properties of Fine aggregate

Sl no	Physical properties	Methodology as per IS	Test result	Requirements as per IS 383-2016
1.a	Fineness modulus	IS 2386(PART 1)-1963	3.06	-
1.b	Gradation zone	IS 2386(PART 1)-1963	Zone 2	Zone I-IV
2	Specific gravity	IS 2386(PART 3)-1963	2.604	2.5-2.9
3	Bulk density	IS 2386(PART 3)-1963	1740	1500-1800 kg/m^3

2.4 Water

The available water in the laboratory was used as mixing and curing water. The pH of the water was recorded as 7.7.

2.5 Coir fibre

Coir strands are found between the hard, inward shell and the external layer of a coconut. The individual fiber cells are thin and empty, with thick dividers made of cellulose. It offers protection against temperature and sound, High protection from against load so more durable, static free, resistant to organisms, decay and moth

2.5 Glass fibre

It is manufactured using tiny glass filaments and it is very solid lightweight and vigorous material. The crude materials are more affordable and less fragile. Glass is notable, great execution and old fibre. it experiences prolongation before it breaks, penetrability is low as dampness gets adsorbed on surface as opposed to engrossing.

3 METHODOLOGY OF WORK

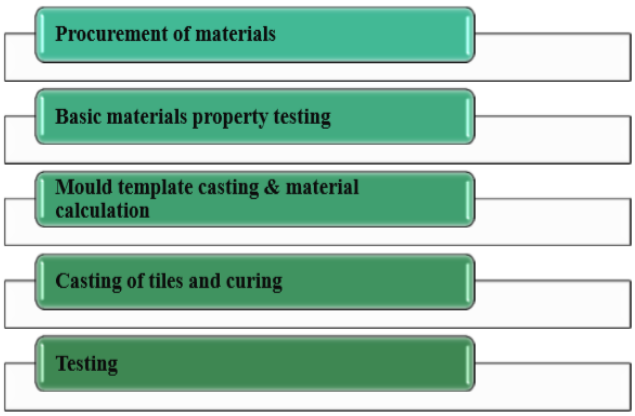

Figure 1: Methodology of work

3.1 Tile casting

- The mild steel mould template was fabricated and used for casting process. The size of the template is **400*200*15** mm

- The template was fitted with battens to provide grooves in cast tile mould specimens so that interlocking of tiles is possible.
- The mortar was prepared in accordance with IS: 2250-1981 for plaster consistency. The mortar was prepared by hand mixing.(**1:2, 1:3, 1:4** cement sand proportion mortar and with fibre)
- The mortar was placed in two layers with optimum hand compaction. The template is then kept in hydraulic press with upper and lower templates to impart the tile mould shape.
- The cast moulds are kept in moist room and after 24 hours of casting the same were transferred to curing tank for curing (7 and 28 days).The specimens with fibre ingress were done by placing fibres in between mortar layers.

Figure -2: Metal template for casting(400*200*15 mm)

3.2 Tile testing procedures

The following tests are performed to assess the flexural strength and water absorption properties.

3.2.1 Flexural strength test

i. The breaking load test for Mangaluru tile is done according to IS 15658:2006 codal specification.
ii. The test methods shall confirm to IS 516 with certain modifications.
iii. The test was conducted in UTM with measuring range up to 600kN.
iv. The testing was done like a simple beam with loading through roller in midspan of the tile. The supports were placed on the either side with 50 mm from edges.

$$F_b = 3Pl/2bd^2$$

F_b=Flexural strength in N/mm^2
P=Maximum load in N
l=Gauge length in mm
b=Average width measured on both faces in mm
d=Average depth measured on both faces in mm

Figure-3: Mangaluru tile testing

Figure-4: Cement tile testing

3.2.2 Water absorption test (W_b %)

The test was carried out as per IS 654:1992 codal specifications.

- The cast tiles specimen should be placed in oven at 105 to 110° C till it attains constant weight. The weight is noted as W_1
- The same specimens are kept in water for 24 hours, wiped thoroughly and noted as W_2.
- Water absorption percentage(W) is given by formula **$W= (W_2-W_1)/W_1 *100$ %**

3.2.3 Production cost

The production cost of each tile is calculated by working out the material costs; the cost for 1000 tiles is computed.

i. Volume of 1 mould = 0.4m * 0.2m * .015m = 0.0012 m^3
ii. For 1000 tiles, volume = .0012*1000 = 1.2 m^3
iii. Mortar proportion= 1:2
iv. Volume of Cement for 1000 moulds = 1/3 * 1.2 = 0.4 m^3 = Approx. 12 bags.
v. Volume of M-Sand for 1000 moulds = 2/3 *1.2 = 0.8 m^3 = 1280 Kg.

vi. Cost of Cement for 1000 moulds = 400 * 12 = Rs. 4800.
vii. Cost of M-Sand for 1000 moulds = Rs. 1130.
viii. Cost of Water for 1000 moulds = Rs. 140
ix. Cost of Labour for 1000 moulds = Rs. 500

4. RESULTS

Table-4: Comparison of results of all specimens

Sl no	Tile type	Density (Kg/m³)	FS (N/mm²)	Cost of 1 tile (Rs)	W_b %
1	Mangaluru tile	1.48	3.56	23	18
2	1:2 PMT	1.85	6.72	6.56	2.7
3	1:3 PMT	2.01	5.21	5.47	2.98
4	1:4 PMT	2.18	4.98	4.74	3.23
5	1:2 CFMT	1.81	6.91	6.62	3.34
6	1:3 CFMT	1.78	5.76	5.52	3.56
7	1:4 CFMT	1.98	5.11	4.77	3.67
8	1:2 GFMT	2.06	7.37	7.77	3.47
9	1:3 GFMT	2.11	6.91	6.33	3.19
10	1:4 GFMT	2.26	6.50	5.45	3.1

Note*
PMT-Plain cement mortar
CFMT-Coir Fibre Mortar Tile
GFMT-Glass Fibre Mortar Tile

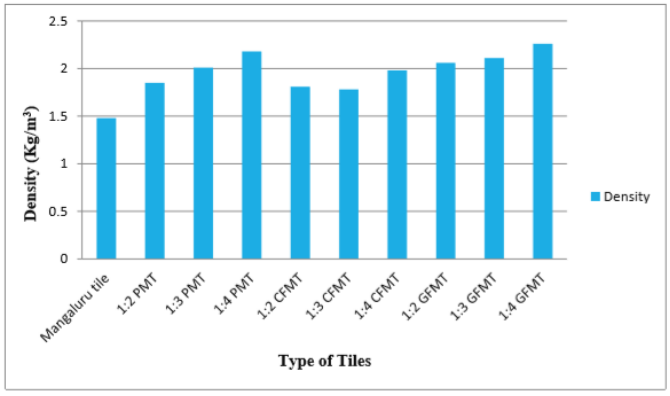

Figure-5: Density comparison of tiles

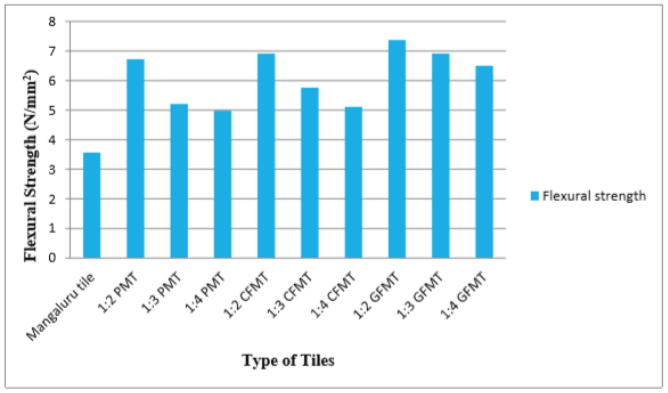

Figure-6: Flexural strength comparison of tiles

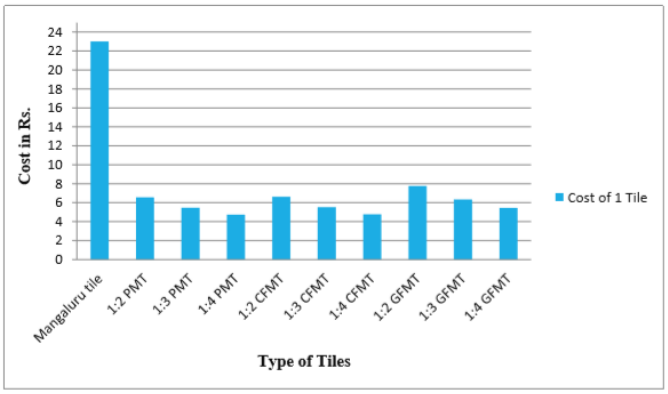

Figure-7: Cost comparison of tiles

5. CONCLUSIONS

i. The cement based tiles showed more strength properties than Mangaluru tile.
ii. The 1:2 mortar tiles with glass fibre have maximum strength (7.37 MPa) among all the cast tiles and in comparison with Mangaluru tile. It is due tensile strength of the glass fibres.
iii. The 1:2 coir fibre gave 6.91 MPa of strength as the coir exerts more energy and resulted in good strength
iv. The 1:2 plain mortar tiles has maximum strength among the tiles without fibres, this is because of the strength imparted due to increased proportion of cement.
v. The coir tile has maximum amount of water absorption percentage compared to other cast tiles but it is within the codal specifications (6%).
vi. The plain mortar tile and glass fibre tile has water absorption percentages within the permissible limits and lesser compared to Mangaluru tile.
vii. The percentage of water absorption increased with coir fibre content.
viii. The density of the tile is maximum in highest sand proportioned tile and density is maximum in 1:4 glass fibre tiles. The increase in density results in cost overrun of roof frame fabrication works due to increase in section of supports.

ix. The production cost comparison made between the cement based tiles and Mangaluru tile, the cement based tiles are more economical.

x. The 1:2 glass fibre tile has the best strength properties and the production cost is very less compared to Mangaluru tile. This tile is the best outcome of the study.

xi. The study can be concluded as, the cement based, fibre incorporation can produce roofing tile with high strength properties, durability and less cost in production with less environmental impacts during production. The decreased density per tile also reduces the cost for roof frame fabrication. The experimental study concludes cement based with fibre roofing tile as effective replacement to Mangaluru tile.

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