Experimental Study on Thermal Performance of Hollow Weathering Roof Tiles with Alternative Materials

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Abstract- Roof tile is a building component imparts protection against thermal radiation. In recent years heat absorption on the roof of the buildings is a major concern. Hence in this paper, an effort has been taken to analyse and to reduce the exterior temperature across the building roof using the hollow cement mortar roofing tile with an alternative material such as fly ash, quarry dust, and sawdust in various proportions. An Investigation by Central Building Research Institute, Roorkee (IS-3951) on hollow clay tiles has recognized that these tiles act as lightweight material for roof construction because of its hollowness and impart thermal insulation to the building. In this project Fly ash was partially replaced with cement up to 40% by weight of cement in different percentages as 0%, 10%, 20%, 30%, and 40%. And saw dust was partially replaced with quarry dust by weight of quarry dust in different percentages as 0%, 0.6%, 1.2%, and 1.8%. The water absorption, bulk density and thermal conductivity of each alternative material were compared. The results reveal that there is a considerable increase in the flexural strength, compressive strength, and reduction in thermal conductivity of the roof tiles.
Keywords – Hollow cement mortar, weathering roof tile, thermal insulation, fly ash, saw dust, quarry dust, water absorption.

I. INTRODUCTION

In moderate and hot climates there is an increase in the heat of the building, to reduce the exterior temperature and to have comfort cooling we have the practice of modifying the weather coarse of the roof. The present study was to carry out to develop the next generation of roofs and weather course, which may include strategies of radiant barriers, low-emittance (low-e) surfaces in the airspace, insulation, and advanced thermal mass (i.e., phase change materials [PCMs]) that complement the thermal performance of cool roofs. In India, most of the RCC building's roofs are built with 150mm thick RCC and a weathering course of thick 100mm (weather course: a mixture of broken building bricks and lime mortar) generally laid over RCC roof. Here in this study a new concept of producing a hollow roof tile with low heat absorbing capacity using alternative materials like fly ash, quarry dust and saw dust by different proportions was introduced.

II. EXPERIMENTAL PROGRAMME

2.1 Materials

Cement, Sand, Quarry dust, Fly ash, Saw dust.

2.2. Specimen details

The volume of tiles is divided into three portions namely

i. Top Tile
ii. Bottom Tile
iii. Junction

The Size of mould is = 200mm x 200mm x40mm (Tolerance ± 5mm) IS: 3951(Part II) – 1975.

Table -1 Volume of the mould

S. No.	Description	No	Length	Breadth	Height	Volume	Unit
1	Top & Bottom Tile	2	0.2	0.2	0.01	0.0008	m^3
2	Hollow Portion						
	L-Type	4	0.043	0.043	0.02	0.000148	m^3
	S-Type	5	0.032	0.032	0.02	0.000102	m^3
				Sub Volume		0.00105	m^3

Figure 1. Detailes of the mould

2.3. Mixing and casting

A thin plastic sheet is placed over a solid plate.The wooden plate, which is applied with oil, is rested on the plastic sheet. The mould is filled with mortar, which is followed by hand compaction. Vibration is done using a vibrator until air voids are removed and de-moulding is done. Each tile is made of two parts and they are bonded together and the next day it was casted using cement mortar paste.

(a) (b) (c)

Figure 2. (a) Casting of bottom part of roof tiles (b) Casting a mortar cube in a tile to form a hollow space (c) Casted roof tiles

2.4. Fly ash weather roof tiles

The concrete mix used for tiles is one part by weight of cement to 3 parts by weight of quarry dust (1:3). Four different mix proportion of cement partially replaced with fly ash as 0%, 10%, 20%, 30% and 40% were used.

2.5. Saw dust weather roof tiles:

The concrete mix used for tiles is one part by weight of cement to 3 parts by weight of quarry dust (1:3). Four different mix proportion of quarry dust partially replaced with saw dust as 0%, 0.6%, 0.12%, and 0.18% were used. The tiles are cured for 28 days to attain its full strength.

III RESULTS AND DISCUSSION

3.1. Warpage Test:(Is 654: 1992)

The warpage measured shall not exceed 2 percent along the edges and 1.5 percent along the diagonals. Place a straight edge flat over the tile resting on a plane surface so as to leave a maximum gap between the straight edge and the surface of the tile, as judged by the naked eye. Insert the measuring metallic wedge in the gap and measure the maximum value of the gap. Each specimen shall be so marked that it may be identified at any time.

Table-2 Warpage test results

Sample No	Along the edge (%)	Along the diagonals (%)
Sample-1	0.5	0.71
Sample-2	0	1.41
Sample-3	0	0.35
Sample-4	1.0	0.71
Sample-5	0.5	0.71
Sample-6	1.0	0.71

3.2. Permeability test (IS 654: 1992)

Six tiles shall be used for this test from the sample selected. The test shall be conducted in a rectangular trough which is open at the bottom, the dimensions at the bottom being equal to the size of the Mangalore Pattern tile. When the tile is kept against its bottom, it shall be held in position and the fitment shall facilitate easy plugging of the space between the edges of the tiles against leakage of water. The test shall be conducted at a temperature of 27 ± 2°C and relative humidity of 65±5 percent. The tile shall be fitted at the bottom of the trough and the space between the tile and the sides of the trough plugged water-tight with a suitable material like wax, bitumen, etc. Water shall be poured into the mould so that it stands over the lowest tile surface to a height of 5 cm. The water in the trough shall be allowed to stand for a period of six hours. The bottom of the tile shall then be carefully examined to see whether the water has seeped through the tile. It was found there is no leakage in the tiles.

3.3 Compressive strength

A steel plate not less than 10 mm thick machined on one face to give a smooth plane surface, shall be firmly supported with the machined surface up and levelled in two directions at right angles by means of a spirit-level. The machined face shall be coated with a film of mould oil to prevent mortar from adhering. The load was applied gradually.

Table- 3 Compressive strength of conventional roof tiles

Days	7	14	21	28
Compressive strength (N/mm^2)	2.8	3	4	4.75

Table-4 Compressive strength of fly ash

Partial replacement of Cement with fly ash	Compressive strength(N/mm^2)			
	7 days	14 days	21 days	28 days
0%	2.57	3.15	4.17	4.47
10%	2.55	3.07	3.98	4.38
20%	2.5	3.03	3.97	4.34
30%	2.5	2.98	3.82	4.2
40%	2.32	2.87	3.45	4

Table-5 Compressive strength of fly ash

Partial replacement of quarry dust with saw dust	Compressive strength(N/mm^2)			
	7 days	14 days	21 days	28 days
0%	2.57	3.15	4.17	4.47
0.6	2.3	2.36	2.47	3.41
1.20%	1.65	1.82	2.03	3.12
1.80%	1.083	1.35	1.68	2.62

3.4 Bulk Densi Ty: Is 3951 (Part Ii) – 1975)

The mean bulk densities of the tiles when tested as per method given in IS : 3951 (Part II) – 1975. The test specimen shall be dried at 110˚C to constant weight, cooled and weighed. The bulk volume of the tile is determined by measuring the external dimensions without counting the grooves. Bulk density (D) shall be calculated by the formula, D = where w is the weight of the dry sample and v is the bulk volume.

Table-6 Comparison of the bulk density of fly ash Quarry dust and saw dust

Sample	sand	Quarry dust	Fly ash					Saw dust			
			0%	10%	20%	30%	40%	0%	0.6%	0.12%	0.18%
Bulk density (Kg/m^3)	1472.0	1462.5	1462.5	1490.0	1500.0	1512.5	1527.5	1462.5	1427.5	1425	1423

3.5 Water absorption test: IS (3951 (Part II) – 1975)

The test specimen shall be dried to constant weight in a ventilated oven at 110°C. If the specimen is known to be relatively dry this may be accomplished within 24 hours; if wet, drying may be prolonged till constant weight is attained. The specimen shall then be cooled approximately to room temperature and weighed (W1). The cool specimen shall be completely immersed in clean water 27±2 °C for 24 hours. Each specimen shall be removed/drained; the surface water wiped off with a damp cloth and weighed (W2). Weighing of each specimen shall be completed within three minutes after removal from water.

Table- 7 Comparison of Water absorption

Sample	sand	Quarry dust	Fly ash					Saw dust			
			0%	10%	20%	30%	40%	0%	0.6%	0.12%	.0.18 %
Water absorption (%)	3.3	3.41	3.41	3.41	3.25	3.17	2.23	3.41	4.21	4.28	4.62

3.6. Flexu Ral Strength: (Is 2690 (Part 2): 1992)

The apparatus shall consist of two parallel self-aligning cylindrical steel bearers, with the bearing surface rounded to 40 mm diameter and so placed that the distance between the centres could be altered. The load shall be applied through a third steel bearer of similar shape placed midway between the parallel to the supports be at a uniform rate of 450 to 550 N/min. The loading device may consist of a bucket connected either directly or through levers to the loading arm. The tiles should be soaked in water at a temperature of 27°C for 24 hours before testing. To ensure uniform distribution of load at supports, provide suitable packing between the tile and the bearers. Apply the load with the direction of the load perpendicular to the span at a uniform rate of 450 to 550 N/min the specimen is supported on the bottom parallel bearers separated by a distance of minimum three-fourths (3/4) of the length of the tile

Fig 3. Flexural strength test on tile

Table-8 Comparisons of the Flexural strength of fly ash, saw dust and quarry dust

Sample	sand	Quarry dust	Fly ash					Saw dust			
			0%	10%	20%	30%	40%	0%	0.6%	0.12%	0.18%
Flexural strength(N/ mm^2)	9.00	9.00	9	8.75	8.73	8.65	8.50	9	5.75	7.6	7.4

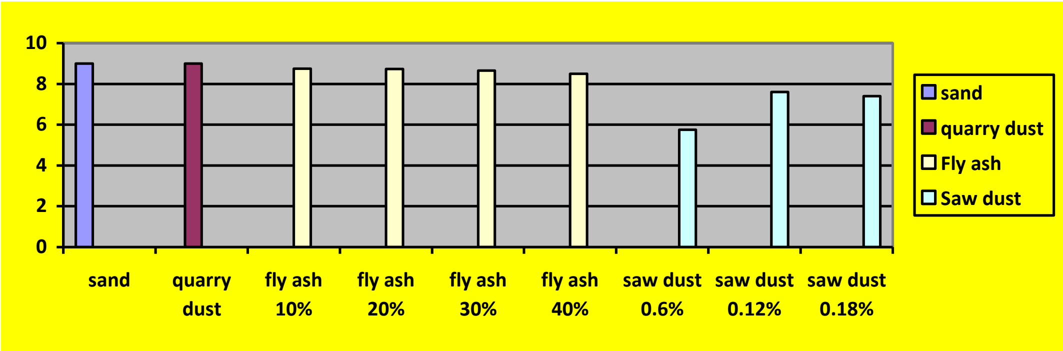
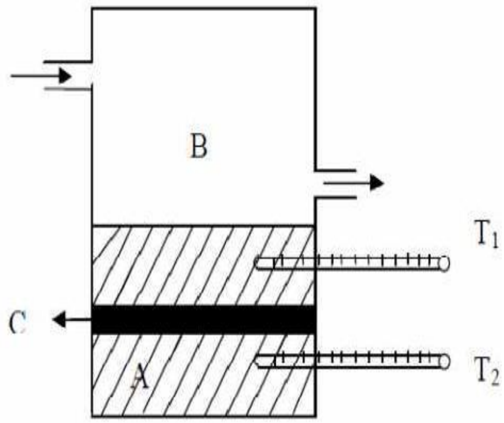


Fig 4. Comparison of the Flexural strength of roof tiles

3.7.Thermal Conductivity: (Is 3346-1966)

Determination of thermal conductivity (K), of a bad conductor (hollow tiles) by Lees disc method. This apparatus consists of three parts A, B and C



(a) (b)

Fig 5. (a) Setup for thermal conductivity (b) Thermal conductivity apparatus

A is a solid brass plate of mass m, thickness d, specific heat s and radius. It is held horizontal by three threads from a stand attached to three hooks at its sides. The hollow tiles C is cut to the same size and is placed above A. B is a hollow brass cylinder placed above C through which steam is sent. C is of the same cross-section as A or B. Two thermometers T1 and T2 measure the temperatures of B and A respectively. The thickness t of the hollow tiles is first found. Steam is passed through B and its temperature is measured by the thermometer T1.

Table-9 Observations of Thermal conductivity

Temperature ^{o}C	Time(sec)
65	0
64	51
63	115
62	170
61	231
60	294
59	361
58	430
57	504

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56	585
55	673

Table-10 Comparisons of the Thermal conductivity of the single layer

Sample	Clay	sand	Quarry dust	Fly ash				Saw dust		
				10%	20%	30%	40%	0.6%	0.12%	0.18%
Thermal conductivity (W/mK)	0.0723	0.1050	0.1120	0.1120	0.1116	0.1113	0.1104	0.1096	0.1050	0.0992

Table-11 Thermal conductivity of fly ash tiles

S. No	Sample	Thermal conductivity (W/ m K)
1.	fly ash 0%	0.0363
2.	Fly ash 10%	0.03627
3.	Fly ash 20%	0.0362
4.	Fly ash 30%	0.03616
5.	Fly ash 40%	0.0361

Table-12 Thermal conductivity of saw dust

S. No	Sample	Thermal conductivity (W/ m K)
1.	saw dust 0%	0.0363
2.	Saw dust (0.6%)	0 .03625
3.	Saw dust (0.12%)	0.0205
4.	Saw dust (0.18%)	0.0203

Table-13 Comparison of Thermal conductivity

Sample	Clay	sand	Quarry dust	Fly ash				Saw dust		
				10%	20%	30%	40%	0.6%	0.12%	0.18%
Thermal conductivity(W/ mK)	0.0723	0.0350	0.0363	0.0363	0.0362	0.0362	0.0361	0.0363	0.0205	0.0203
% of reduction in thermal conductivity compared with clay tile	-	51.59	49.79	49.79	49.93	49.93	50.0	49.79	71.92	71.92

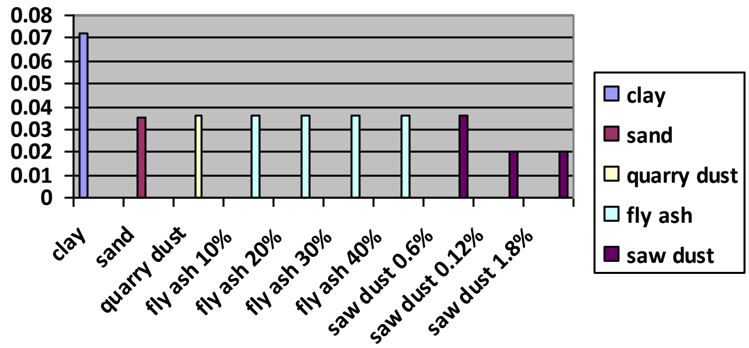

Fig.6 comparison of thermal conductivity

IV. CONCLUSION

The following conclusions are drawn from the present investigation

- Due to lower thermal mass and thermal conductivity of bare RCC roof, heat entering the room was higher and the roof was more sensitive to solar heat flux variation. By laying hollow weathering roof tile, it was noticed that there is a reduction of 50% in heat transmission compared to solid clay roof tiles.
- And another experiment conducted on hollow saw dust tiles showed a reduction of 71.92% of (0.0203) heat entering the room compared to solid clay tiles (0.0723). It is also found that the emission of carbon dioxide (Co_2) is reduced by adding fly ash to the tiles. Apart from this soundness is controlled and the thickness of weathering coarse (WC) is reduced. The comparison of test results indicates that the code has accurately predicted the major heat transfer phenomenon of different alternative material tiles.

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