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RESEARCH ARTICLE

Comparison of Thermal Insulation Properties of Various Construction Materials

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Abstract

In case of buildings built in extreme condition areas, heating is done during winter and cooling is done during summer. It leads to consumption of a lot of electric power, which can be reduced to great extent if thermal insulated construction materials are used. Proper selection of construction materials would go a long way in reducing the energy consumption of the building. Various construction materials have different thermal insulation properties and thus, their suitability for various conditions vary. Hence, an experimental study is carried out on various construction materials namely ferrocement and Reinforced Cement Concrete (RCC) wall panels and comparison is made for relative insulation properties. On the basis of several experiments, it has been observed that RCC wall panels with cavity inside making a total of thickness 120 mm showed very good insulation properties relative to other panels.

Keywords: Ferrocement, reinforced cement concrete, thermocouple, temperature difference, thermal insulation.

Introduction

In building envelope, wall is an important building component, which requires proper design and construction, as it is most exposed to climatic elements. In summer, the temperature outside the building is higher relative to the inside temperature and vice-versa during winter. This temperature differential is maintained by adopting suitable materials for construction of walls, roof, window and doors of the building. In literature, there are few studies available which deals with thermal insulation properties. Indian Standard (IS: 3792-1978) gives information about physical properties of various construction materials including thermal resistance. Raynham (1975) investigated the variation of temperature in concrete roof with and without insulation layer. Sudhakumar (2001) investigated the thermal behavior of hollow and in filled ferrocement roofing panels under steady state heat flow condition. Maghrabi (2005) compared the thermal insulation properties of different construction materials. Castellon *et al.* (2009) reported that it is possible to improve the thermal comfort and reduce the energy consumption of a building without substantial increase in the weight of the construction materials with the inclusion of thermal insulation also known as phase change materials (PCM). Ozel (2011) investigated thermal performance of building walls made of concrete and bricks. Manohar (2012) conducted many experiments on adding agriculture by-products in various construction materials and found that thermal insulation properties are improved. Nikil *et al.* (2013) investigated the thermal response of a non-air conditioned building by using insulation of various thicknesses at different position of the wall and roof at cold stations of India. Keeping the above facts in view, the main objective of the present study is to compare thermal insulation properties of various construction materials experimentally.

Materials and methods

Wall specimens: Wall panels of ferrocement and RCC of building construction material with same cross-sectional area but different thickness were selected for the present study. Two ferrocement wall panels of overall size 1.0 × 1.0 × 0.025 m were cast with cement sand ratio of 1:2, water cement ratio of 0.4 and wire mesh of very small dia (Fig. 1 and 2).

Fig. 1. Samples of ferrocement wall panel.

a. Wire mesh

b. Laying of mortar

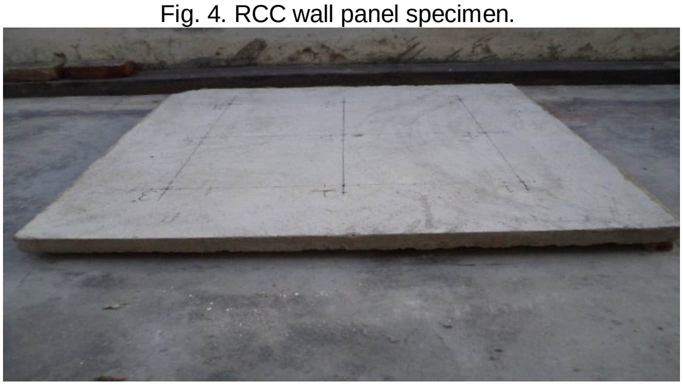
Table 1. Details of walls prepared using ferrocement and RCC wall panels.

Type of wall	Nomenclature	Total wall thickness (mm)	Surface area (m × m)
Ferrocement wall	A	25	1 × 1
RCC wall	B	40	1 × 1
Cavity wall - 1 (25 mm thick ferrocement wall + 40 mm air space + 25 mm ferrocement wall)	C	90	1 × 1
Cavity wall - 2 (40 mm thick RCC wall + 40 mm air space + 40 mm RCC wall)	D	120	1 × 1
Cavity wall -3 (25 mm thick ferrocement wall + 40 mm air space + 40 mm RCC wall)	E	105	1 × 1

Fig. 2. Ferrocement wall panel specimen.

Fig. 3. Steel bar for RCC wall panel.

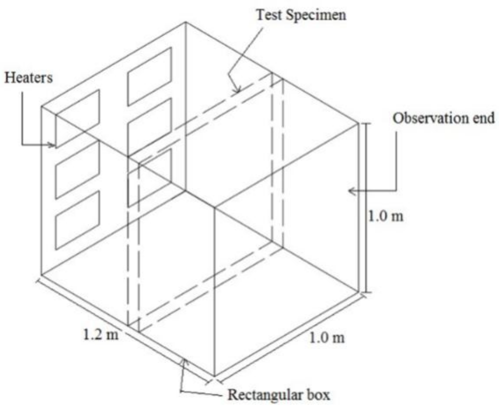
Fig. 4. RCC wall panel specimen.



Two RCC wall panels of overall size 1.0 × 1.0 × 0.04 m were cast with cement, sand and aggregate ratio of 1:2:4, water cement ratio of 0.4 and steel bar of 6 mm dia (Fig. 3 and 4). Five types of walls were prepared for study using ferrocement and RCC wall panels (Table 1).

Experimental setup: The test setup was built using plywood having thickness 12 mm. It was a rectangular shape box with open ends (Fig. 5).

Fig. 5. Test setup.



a. Line diagram

b. Side view

Length of the test setup was 1.2 m and cross-section area of open face was 1 m × 1 m. Six room heaters were used as heat source to heat one face of the selected specimen. All six heaters were connected in series to power control system. A power controller was used to maintain the temperature. All six heaters were fixed with rods of angle section at one end (Fig. 6). Wall specimens were fixed at a distance 450 mm from heater and were held up by using screws. Air leakage was sealed with clay materials along four sides. Thermocouples were attached by adhesive tape onto the area on which the heat was applied. Experimental setup had total nine thermocouples and three digital multimeter for display.

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Fig. 6. Heat source.

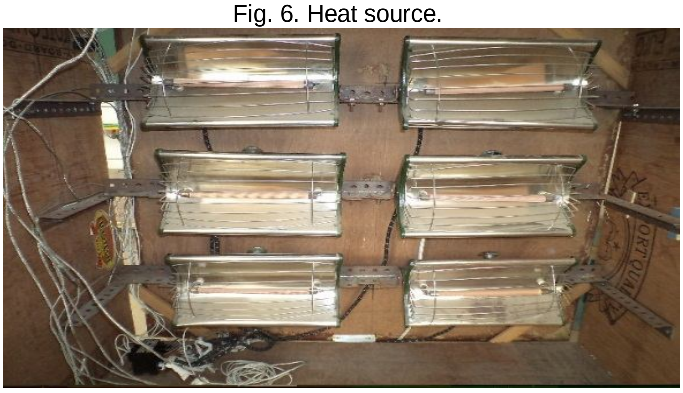


Fig. 7. Temperature measuring equipments.

a. Thermometer b. Thermocouple

The temperature on the reverse surface of the specimens was measured by a digital thermometer, model-testo 835 H1 and by thermocouple sensor (Fig. 7). The temperatures on the opposite face of the heated face were recorded at nine points of each wall specimen at 10 min interval up to 3 h.

Test procedure: Ferrocement and RCC wall panels having thickness 25 mm and 40 mm respectively were tested at three different temperatures (40, 50 and 60°C) for 3 h with interval of 10 min. The panel made by joining ferrocement and RCC wall panel with 40 mm air gap was also tested for 3 h in same manner. The specimens were placed in test setup at a distance of 450 mm from heaters and temperature on reverse face was recorded at 9 points. Then, average temperature was calculated and graph between average temperature and time was plotted. Three wall panels having thickness 25, 40 and 105 mm were tested in winter season and in all cases initial temperature was about 18.5°C. But the other two wall panels having thickness 90 and 120 mm were tested in summer season when initial temperature was about 26°C.

Results and discussion

Figures 8 to 12 shows the temperature variation in various panels of ferrocement and RCC wall panel for a heat flow-up to 3 h.

Fig. 8. Variation of temperature on reverse face of ferrocement wall panel.

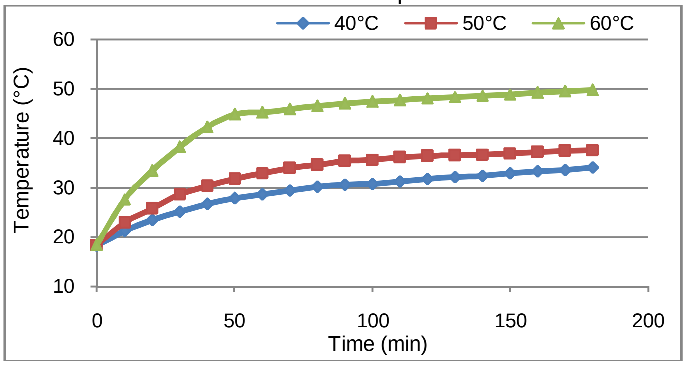


Fig. 9. Variation of temperature on reverse face of RCC wall panel.

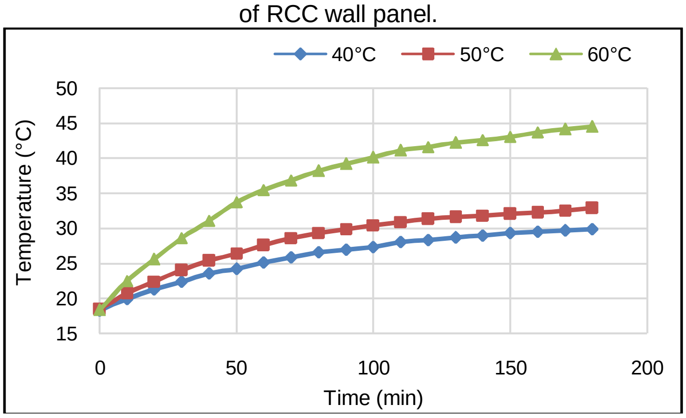


Fig. 10. Variation of temperature on reverse face of panel of combined ferrocement and RCC wall.

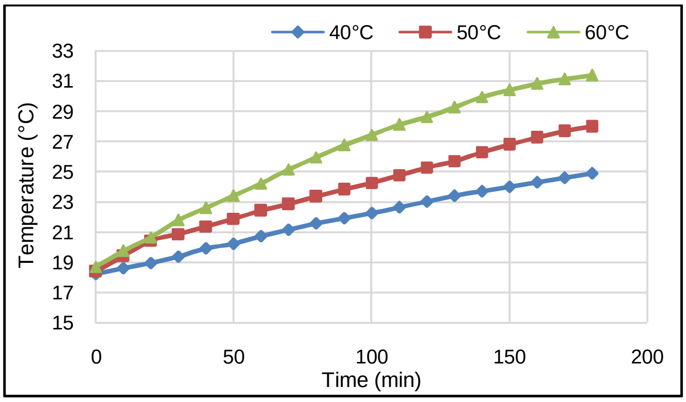
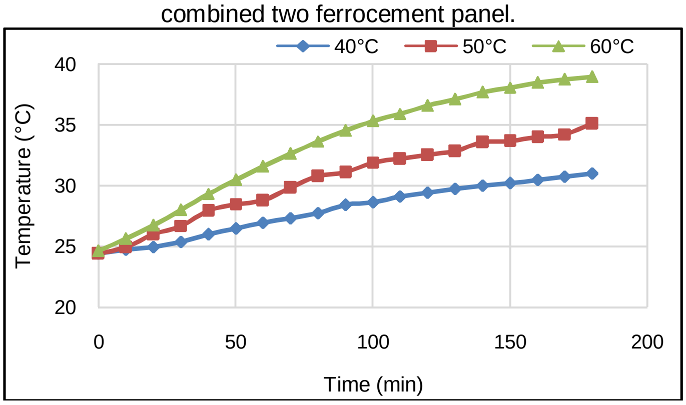


Fig. 11. Variation of temperature on reverse face of panel of combined two ferrocement panel.



Measurements taken at a particular location of the specimen showed an exponential rise in temperature during the first few hours, before the steady state condition attains. Following observations are also made from the figures.

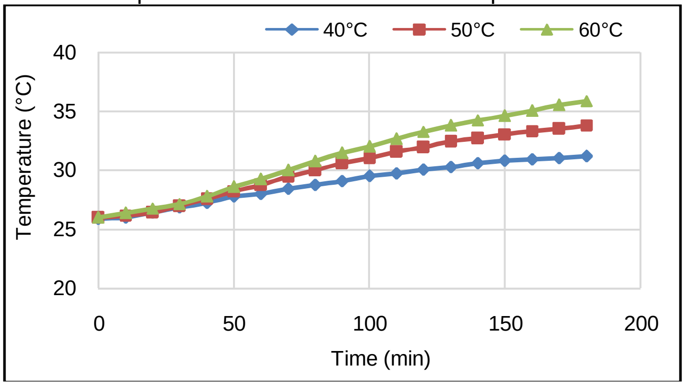
1. Ferrocement wall panel 'A' shows a sudden increase of temperature from 0 to 50 min and then attains a steady state condition.
2. In case of 40 mm RCC wall panel 'B', maximum rise in temperature after same time gap is less as compared to ferrocement wall panel.
3. Panel 'E' joining the ferrocement and RCC wall with 40 mm air gap between them had minimum rise in temperature as compared to ferrocement and RCC wall panels used independently. Temperature difference between two surfaces is about 16°, 21° and 30°C at the applied temperature of 40°, 50° and 60°C respectively after 3 h.
4. Panel 'C' joining the two ferrocement panels with 40 mm air gap reduced the temperature increase as compared to 105 mm thick panel 'E' at all temperatures. Even at higher temperature i.e. 60°C, panel 'C' shows an increment of 15°C in 3 h.
5. Providing 40 mm air gap between two RCC wall panels reduced the temperature increment considerably. However, no improvement is seen in 120 mm thick RCC wall panel 'D' as compared to 90 mm thick ferrocement wall panel 'C'.

Conclusion

The following are the conclusive points derived from the present study:

1. Ferrocement wall panel is a good thermal insulation layer even if it has very small thickness.
2. Thermal insulation property of RCC wall panel is better than ferrocement wall panel.
3. Cavity walls have better insulation property than solid walls.
4. Cavity wall with both leaves made of RCC wall panel gives best thermal insulation as compared to other two cavity walls.

Fig. 12. Variation of temperature on reverse face of panel of combined two RCC wall panels.



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