Innovative Saw-dust wall tiles for Thermal Insulation of Buildings

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ABSTRACT

Thermal comfort in buildings is a priority in the regions of extreme climatic conditions. The buildings in such severe climatic zones can be thermally insulated which may on one hand optimally help in minimising the annual energy cost by curtailing the requirement of air conditioning systems or on the other hand contribute by reducing the emission of carbon dioxide into the environment resulting from the traditional methods of heating like burning of fire wood, charcoal, and coal in harsh cold winters. Owing to its low thermal conductivity and high R-value, saw-dust which is a by-product resulting from sawing of timber from sawmills, has been experimented with to discover its feasibility as a material for thermal insulation of buildings. This study investigates the potential of innovative wall tiles developed from saw-dust as a means of thermal-insulation material to prevent heat loss or heat gain by conduction through masonry walls.

Keywords: Thermal insulation, sawdust tiles, thermal conductivity, R-value, economy.

1.INTRODUCTION

Thermal insulation of buildings has become a grave concern due to uneven variation of temperatures. Due to global warming the summers are becoming hotter and the winters are becoming colder. In order to optimize the conditions, more and more emphasis is laid on thermal insulation. So far various techniques have been devised by various researchers and scientists for improving the thermal insulation of buildings. To maintain a constant comfortable temperature, it is usually necessary to install conventional air-conditioning units. These units, besides consuming energy, usually aggravate the peak electricity load. Using good insulating material or using new concepts to achieve the same objective may reduce, or eliminate, the need for such units. Thermal insulation in buildings is an essential factor to achieve thermal comfort for its occupants. Thermal insulation reduces unwanted heat loss or heat gain and can decrease the energy demand of heating and cooling systems. Many of the materials used for the purpose deal with resistance to heat conduction and convection by the simple method of trapping large amounts of air (or other gas) in a way that result in a material that employs the low thermal conductivity of small pockets of gas, rather than the much higher conductivity of typical solids. Thermal insulation systems and materials aim at reducing the transmission of heat flow. The thermal conductivity and thermal resistance (R-values) are generally used to define the insulation properties in steady state. Thermal conductivity often referred to as the 'K' or 'λ' (lambda) value, is a constant for any given material, and is measured in W/mK (watts per Kelvin meter). The higher the λ value, the better the thermal conductivity. Good insulators will have as low a value as possible. Steel and concrete have very high thermal conductivity and therefore very low thermal resistance. This makes them poor insulators. The thermal resistance- R-value is a measure of the thermal resistance of a material of specific thickness, that is, its resistance to the transfer of heat across the material. The higher the R-value of a material, the more effective it is as an insulator. The R-values can be used as part of a labelling system to enable comparison of the thermal performance of different materials, such as thermal insulation or as part of the calculation of heat transfer across the fabric of a building. R-values can be determined by dividing the thickness of a material (in metres) by its thermal conductivity and is expressed in the units of m^2K/W (square metre kelvins per watt).In recent years, many research works have been carried out on various materials such as sheep wool[1], cellulose[2], glass wool[3], rock wool[4], expanded polystyrene[5], hemp fibres[6],cattail fibres[7],and vacuum insulation panels[8] for use as thermal insulation materials. The thermal conductivity values for sheep wool (0.038 W/mK), cellulose(0.035-0.038 W/mK), glass wool(0.034-0.038 W/mK), rock wool(0.032-0.044 W/mK), expanded polystyrene (0.038 W/mK), hemp fibres

(0.040 W/mK),cattail fibres (0.038 W/mK), and vacuum insulation panels (0.006-0.008 W/mK) have been reported by the researchers for these materials.

2. Materials and Methods

In order to replicate the thermal performance of the saw-dust panels in an actual structure, a small prototype structure of dimensions 2'x2'x2' was constructed with conventional masonry walls and removable reinforced concrete roof slab. The prototype was thermally insulated by using special wall tiles developed from sawdust. The walls and roof were fully instrumented with thermocouples to permit temperature evaluation inside and outside of the prototype. The Guard heater was used to raise the temperature within the prototype and the temperature was raised to 74°C to study the performance of the sawdust panels towards the resistance to flow of heat energy through the process of conduction. The outside temperature of the prototype was kept within 20°C by keeping the prototype in water bath. After raising the inside temperature to 74°C, the guard heater was switched off and temperature was allowed to fall with time, and the temperature variation was recorded every minute till the temperature attained a steady state. The experiment was several times repeated on the model with and without the saw-dust panels for different thicknesses.

2.1 Preparation of Sawdust Tiles

Sawdust or wood dust is a by-product of cutting, grinding, drilling, sanding, or otherwise pulverizing wood with a saw or any other tool. It is composed of fine particles of wood. At saw mills, unless reprocessed into particle board or any other product, sawdust may get collected and heap up and add harmful leachates into local water systems, creating an environmental hazard. If sawdust is properly shaped into facing or wall tiles of sufficient thickness it will act as an effective insulating material. For employing sawdust as an insulating material, it necessarily needs to be in a shape and form that can be installed in the prototype and in actual building structures. For this purpose, wall tiles were made from sawdust. Organic resin was used as a binding material. The organic resin was made by mixing water, flour, vinegar, sugar, and salt in the ratios 1:0.5:0.1:0.05:0.025 respectively by weight. The mixture was heated at a steady temperature and stirred continuously till a white gel-like substance was produced. The innovative sawdust wall tiles were thus prepared by thoroughly mixing the sawdust with the organic resin developed for the purpose and the mixture of sawdust and resin was poured into the moulds and pressure was applied for compacting the sawdust tiles to required shape and size with the dimensions as 20x10x3.5cm. After removing the sawdust tiles from the moulds, these were sun-dried for 8 hours and later shifted to the oven for further drying for two days. After removing the sawdust tiles from the oven, the tiles possessed sufficient strength to be installed for the purpose of thermal insulation. The sawdust tiles developed in this research for thermal insulation purposes are shown in fig.1 and their installation is shown in the prototype in fig.2.

Fig.1. Sawdust Tiles developed for thermal insulation

Fig.2.Installation of sawdust tiles in prototype

2.2 Procedure for calculating thermal Conductivity of sawdust tiles

The procedure which was used for measurement of thermal conductivity of the sawdust tiles was, "comparative cut bar method". This method is widely used for determining thermal conductivity and is based on the principle of comparing thermal gradients. In this method heat flux is passed through samples whose conductivity is known and those whose conductivity is unknown. The sample whose conductivity is unknown is sandwiched between two reference samples as shown in fig.3.

Fig.3.Cut-bar method set up for measurement of thermal conductivity

If K_r is the thermal conductivity of the reference samples and K_s is the thermal conductivity of the material whose thermal conductivity is to be calculated, then the heat flux through the sample is calculated from the expression given as:

$$\frac{Q}{A} = Ks\frac{\Delta Ts}{L} = Kr\,\frac{\Delta T1 + \Delta T2}{2} \cdot \frac{1}{L}$$

$$Ks = \frac{Kr\dfrac{(\Delta T1 + \Delta T2)}{2}}{\Delta TS}$$

Where, K_S = Thermal conductivity of the insulating material sandwiched between reference samples.

K_r =Thermal conductivity of reference sample.

ΔT_1 = Temperature gradient across the reference sample on heating side.

ΔT_2 = Temperature gradient across the reference sample on cooling side

In order to determine its thermal conductivity, the sawdust was first transformed into the form and shape of tiles with dimensions 20x10x3.5cm by using the organic resin developed to be used as a binder for the purpose. After drying them in oven, the sawdust wall tile was sandwiched between two modular bricks of similar dimensions. The bricks were reduced to required thickness by chipping down one-third of the brick. After sawdust wall tile was sandwiched between two modular bricks of known conductivity, heat was applied on one side with the help of Heat Guards with interfaces fully instrumented with thermocouples and corresponding temperature gradient was recorded. By determining the temperature gradient, thermal conductivity of the sawdust wall tiles was determined.

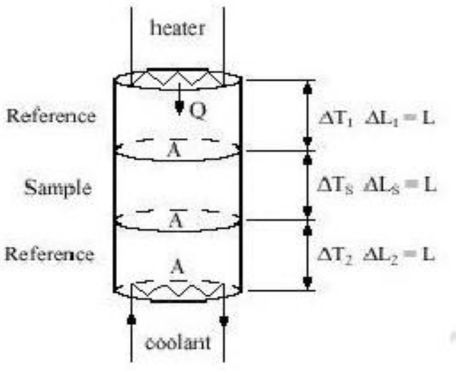

Fig.4.Set-up for measurement of thermal conductivity of sawdust tiles

3.Results and Discussions

3.1 Thermal Performance

The effect of installing innovative sawdust wall tiles as insulating material in the prototype was observed by recording the corresponding temperature variation with time. The insulation was done only on four walls in the first round of testing. After analysing the results obtained from the prototype with and without sawdust tile insulation, it was observed that the sawdust wall tile insulation was very much effective in trapping the heat inside the prototype. The reason being obviously the low density and low thermal conductivity of sawdust tiles. The graph shown in fig.5 depicts the relative drop in temperature with time when the prototype was insulated with sawdust wall tiles as well as when no insulation was provided. It can be seen that the sawdust wall tiles are efficiently able to maintain a comfortable temperature within the prototype for a long duration of time. The calculated thermal parameters for the sawdust tiles and standard bricks are shown in Table1 and Table 2 respectively. As can observed from these tables, the thermal performance of the prototype insulated with sawdust wall tiles is sufficiently enhanced as compared to that without insulation. As can be seen from the results, the thermal conductivity of sawdust tiles is very low as compared to standard bricks and the thermal resistance -R-value of the sawdust tiles is very high in comparison to standard bricks, suggesting that sawdust tiles are an efficient means of thermal insulation.

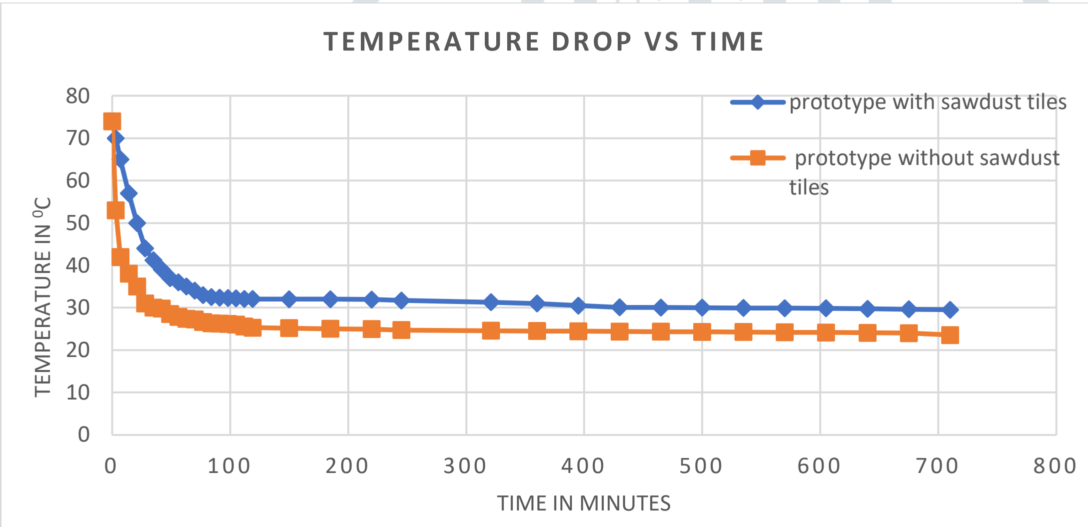

Fig.5 Variation of temperature with time within the prototype with and without sawdust tiles

Table 1. Measured average thermal properties of Sawdust tiles

Property	Average measured value
Thermal conductivity, (W/mK)	0.075
Thermal Resistance R-Value at 100mm (Km^2/W)	1.33

Table.2. Measured Average thermal properties of standard bricks

Property	Average measured value
Thermal Conductivity [W/m K]	0.95
Thermal resistance-R-value at 100 mm [$K\ m^2/W$]	0.10

3.2 Effect of thickness of sawdust tiles on thermal insulation

The experiments were conducted by varying the thickness of the sawdust wall tiles within the prototype. It was observed that there was considerable reduction in loss of heat as the insulation thickness was increased. Figure shows the relative comparison between same insulation material of varying thickness. It is however obvious that heat loss will be less when thickness of insulating material will be increased but there should be a balance between the insulation thickness and economy. As was observed from the experimental results when 50 mm thick sawdust wall tile was installed in the prototype as an insulation material, it was adequate to maintain comfortable temperature for 12 hours of observation. Based on the thermal conductivities, we can say 50 mm of sawdust tile and 600 mm thickness of brick masonry will give the same thermal resistance.

3.3 Density of sawdust tiles

The density measurements for the sawdust tiles were made by determining the two parameters namely volume and weight of the sawdust tiles. The volume was determined by measuring the dimensions of sawdust tile and its weight was also determined. It was found that the density of the sawdust tiles is very low varying from 330-360 kg/m^3 depending upon the degree of compaction. The lower density values also reflect the high thermal performance.

3.4 Economic analysis

For a material to be used in construction it should perform its intended function properly and in addition it should be economical. A relative comparison of cost was made between the wooden panel and sawdust wall tiles, and it was found that sawdust wall tiles are a good replacement for wood panel in terms of thermal insulation properties as well as cost. The comparison of cost analysis for a room of size 12x12 feet and storey height of 10 feet is shown in table 3. It is found that cost of the sawdust wall tile insulation is almost one-third of the wood panelling. It was assumed that panelling is done to four walls and ceiling.

Table 3. Economic analysis of insulation materials

Insulating material	Area of one panel (square feet)	Surface Area of room to be insulated (square feet)	Cost of panel per square feet (in rupees)	Total cost of insulation material (in rupees)
Wood panels	0.25	576	68	39168
Sawdust wall tiles	0.19	576	22.5	12960

4. Conclusion

After analysing the results, it was found that sawdust can be converted into a useful insulation material by making sawdust tiles. It was found that the innovative sawdust tiles developed, possessed low thermal conductivity of 0.075 W/mK, which makes them better insulation products. Thus, it can be concluded that 60 mm thick sawdust wall tile and 600 mm thick brick masonry will give the same thermal resistance. It can also be concluded that the sawdust tiles are light weight having density in the range 330-360 kg/m^3 and will not contribute much to the dead weight of the building.

Economic analysis of insulation materials was carried and it was found that these insulation materials are better replacements in comparison to conventional thermal insulation materials in terms of both cost as well as thermal insulation properties. While comparing the costs of wood panelling and that of the sawdust tiles for thermal insulation, it was found that cost of sawdust tiles was approximately one-third of that of wooden panels.

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