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EXPERIMENTAL INVESTIGATION TO REDUCE HEAT INFILTRATION THROUGH ROOF STRUCTURE AND MODEL DEVELOPMENT FOR SIMULATION USING RICE HUSK AND WHITE TILES INSULATION

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Abstract: This paper presents an experimental study aimed at reducing heat infiltration through roof structures utilizing rice husk and white tiles insulation. With rising concerns over energy consumption and environmental sustainability, effective thermal insulation methods are imperative. Rice husk, an abundant agricultural byproduct, and white tiles, a commonly used roofing material, offer promising potential as eco-friendly and cost-effective insulation solutions. This research investigates the thermal performance of roof structures incorporating rice husk and white tiles insulation through experimentation and subsequently develops a simulation model for predicting heat infiltration. The results demonstrate significant reductions in heat transfer, validating the efficacy of the proposed insulation strategy. The developed simulation model provides a valuable tool for assessing and optimizing the thermal performance of roof structures, contributing to energy efficiency and sustainable building practices.

Keywords: **Heat infiltration, Roof insulation, Rice husk, White tiles, Experimental investigation, Simulation model.**

1. Introduction: The building sector accounts for a substantial portion of global energy consumption, with heating and cooling requirements being major contributors. In tropical and subtropical regions, heat infiltration through roofs significantly impacts indoor comfort levels and energy usage. Traditional insulation materials, while effective, often pose environmental concerns due to their manufacturing processes and disposal. Alternative materials derived from agricultural waste, such as rice husk, offer sustainable solutions to mitigate heat transfer and reduce environmental impact. This study focuses on investigating the thermal performance of roof structures incorporating rice husk insulation through experimentation and subsequently developing a simulation model for predictive analysis. Reducing heat through a roof is crucial for maintaining comfortable indoor temperatures and lowering energy costs, especially in hot climates or during summer months. Innovative insulation techniques offer effective ways to achieve this goal while also promoting sustainability and energy efficiency. Here's an analysis of some innovative insulation techniques for reducing heat through a roof.

Reflective Roof Coatings: Reflective roof coatings consist of white or light-coloured materials that reflect sunlight away from the building, reducing heat absorption. These coatings can be applied to existing roofs and are particularly effective in warmer climates.

Cool Roofs: Cool roofs are designed to reflect more sunlight and absorb less heat than traditional roofs. They are often made of highly reflective materials such as white membrane roofing or coated metal. Cool roofs can significantly reduce rooftop temperatures and lower cooling costs.

Green Roofs: Green roofs, also known as living roofs, are covered with vegetation, which helps to insulate the building and absorb heat through evapotranspiration. Green roofs can reduce rooftop temperatures, improve air quality, and provide additional insulation.

Radiant Barriers: Radiant barriers are installed in the attic or under the roof to reflect radiant heat away from the building. These barriers consist of reflective materials, such as aluminium foil, and can effectively reduce heat transfer through the roof.

Spray Foam Insulation: Spray foam insulation is applied directly to the underside of the roof, creating a continuous barrier that seals gaps and prevents heat transfer. It provides excellent thermal resistance and can improve energy efficiency by reducing air leakage.

Phase Change Materials (PCMs): PCMs absorb and release heat energy as they change phase, effectively regulating temperature fluctuations. When incorporated into roof insulation materials, PCMs can help to stabilize indoor temperatures and reduce the need for mechanical cooling.

Aerogel Insulation: Aerogels are lightweight materials with high thermal resistance, making them excellent insulators. Aerogel-based insulation can be applied to roofs to reduce heat transfer while minimizing added weight and bulk.

Thermal Imaging and Monitoring: Innovative techniques such as thermal imaging and monitoring systems can be used to identify heat loss areas in the roof and assess the effectiveness of insulation measures. This data-driven approach allows for targeted improvements and optimization of energy efficiency.

Methods to reduce energy consumption in buildings

Passive cooling systems use simple, low-cost techniques to provide summer comfort in warm climates for people and animals in buildings. Such systems can also be used to keep food, liquids, and other materials at temperatures that will prevent spoiling or other deterioration. Passive cooling is far less costly to operate than active cooling systems such as air conditioning which typically use vapor-compression or absorption refrigeration and require complex electromechanical equipment and a power supply. Passive cooling methods use simple mechanisms and require no input of electrical energy or conventional fuels. The need for passive solar cooling, and the selection of appropriate methods for achieving it, depend primarily on the climatic conditions of a region, the cultural context, and the materials available locally. Throughout history, humans and animals have learned and benefited from passive cooling techniques. Most creatures seek shade for protection against heat. Homes are often built in wooded areas. Favourable breezes are sought. Historically, building materials have often been chosen for their effectiveness in tempering solar heat in summer.

Some builders in temperate regions have adopted the low mass approach, using walls and floors of wood, which doesn't store much heat. Others, needing insulation against winter cold, have learned to use dense adobe or masonry walls. In summer these delay the infiltration of heat until evening, when the structure can be opened and cooled with night air, breezes, and radiation to the night sky. An ancient and very effective passive cooling method involves building in caves of limestone or other workable material. The temperature of rock below the surface remains relatively stable, winter warmth as well as summer cooling. In ancient times the Persians learned to cool their buildings with thermal chimneys, tall towers that warmed in the sun and drove warm air up and out (because warm air rises), and thus pulled cooler air into the building through openings near the ground on the shady side.

The modern concept of passive cooling is based on these old and effective methods, plus better knowledge and materials. Higher-efficiency boilers and radiant heating systems, including tank less water Heaters. Better methods to control moisture in buildings, to allow comfort with less Cooling energy. Reducing losses of conditioned air with better duct sealing techniques. Ground-coupled heat pumps (geothermal heating systems) that reduce whole-Building energy consumption by 30%. Basic Theory Passive solar cooling uses two basic concepts: preventing heat gain, rejecting unwanted heat. The first concept that of heat-gain control, is of far greater importance than is generally recognized. Factors involved they are Site considerations: Location, Orientation, Vegetation, Land massing, Microclimate modification. Architectural features: Building exposure, Surface/volume ratio, Screens, Shades, Wing walls, Overhangs. Building component features: Insulation, Glazing, Mass, Material type, Texture, Finishes. The second concept the rejection of unwanted heat, can be divided into three major categories are Direct loss, Indirect loss and Isolated loss.

A thermal chimney or mechanical means are required to drive the air flow as shown in the three drawings above. These objectives of heat gain control and the rejection of unwanted heat are accomplished by the following different methods shading from the sun. They are Reflection of solar heat, Insulation, Ground cooling, Wind cooling (natural breeze or induced convection), Water cooling, Evaporative cooling, Dehumidification, Night radiant cooling, Night cooling of thermal mass in buildings, Exotic passive cooling methods and Seasonal cold storage.

Passive cooling methods

The various methods of achieving passive cooling can be used separately or combined, depending on site, climate, available materials and skills, and economic considerations. The discussion that follows treats the different passive cooling methods in order of their simplicity and cost effectiveness. Shading from the Sun. The simplest and most effective passive cooling technique is to keep the sun's heat from entering a building. This is accomplished primarily by shading, using: The building itself (roof, walls), other buildings, terrain features, Supplemental shade (trees, vines, etc.), Awnings, shutters, curtains, drapes When a new building is planned, shading should be included for effective heat prevention. With an existing building, benefits may be constrained by its design and by the amount of money and labour available for upgrading the building. The provision of supplemental shading, such as vegetation or awnings, is only a first step.

Trees must be kept healthy, so they will continue to provide shade as well as the evaporative cooling their transpiration of moisture yields. Movable shades must be properly maintained and effectively operated to keep solar heat out of a building during the day but allow circulation of cooler air at night.

Reflection of Solar Heat: Light-colored roofs, walls, and other shading have the important advantage of reflecting much more heat than darker materials do. A white roof may absorb only 25 percent of solar heat, far less than the 90 percent absorbed by a black one. This greatly reduces the amount of heat getting into the building and simplifies the task of comfort cooling. Aluminium foil installed in an attic or ceiling (shiny side up) further reduces the amount of radiant heat getting into the building. Reflective films can be applied to windows and other glass areas to keep out more heat while remaining transparent.

Insulation: Insulation usually is considered a means of keeping heat inside a building, but it can also keep heat out and thus provide cooling in summer. If insulation was still not installed in a building originally because winters are mild, it may be economical to install it for comfort in summer. Walls and ceilings may be filled with conventional insulation materials such as cellulose, vermiculite, rock wool, or glass Fiber. Various kinds of rigid foam board may be used either inside or outside of walls. Potentially toxic materials (including those that emit toxic fumes when burning) should not be used inside. A number of materials that have insulative properties may be available locally and can serve as homemade insulation. Also wood Fiber, shredded sea weed, etc., can be used for insulation.

Water Cooling: A stream or pond may provide some passive cooling. Water can be piped or pumped through radiators to carry away surplus heat and thus cool the air inside a building. The warmed water can then be returned to its source and not be wasted. Very cold, underground streams have been used for passive cooling of buildings

Ground Cooling: Like water, earth or subsurface rock reduces extremes of heat and cold. Although the surface temperature of soil rises during hot summer days, soil at a depth of several feet is much cooler and generally remains constant year-round. Cool cave habitats date back thousands of years, and modern versions are being built, generally for office buildings or for storage. A new generation of underground homes is popular as builders seek even temperatures year-round with little or no expense for heating or cooling. These earth-sheltered homes are excavated and/or beamed with earth for added insulation. The temperature of the earth varies according to the seasons. That is, the highest temperature at each level is reached in the summer months and the lowest temperature during the winter months in a given region.

Evaporative Cooling: Moist air sometimes provides cooling in warm climates. This technique has been used for centuries by placing pools and fountains in courtyards or other areas adjacent to buildings. Combined with a breeze from the proper direction, this natural evaporative cooling provides comfort at little cost (Fig.1.8). Mechanical evaporative coolers using electrically driven fans provide excellent comfort in and areas. This cooling equipment was developed slowly from primitive evaporative coolers consisting only of a wet cloth or fibrous material hung in a window or doorway exposed to a breeze. Such simple coolers can be improvised today with some effect. Where water is readily available and expendable, larger applications of evaporative cooling can be made. Water can be sprayed or trickled on a roof to cool it.

In some cases, a pond of water can be created on a flat, watertight roof. In dry arid climates, the evaporative effect of the pool is enhanced by night radiation of heat from the water to the night sky. Evaporative cooling depends on a very dry climate to be effective. When the air is humid and already laden with moisture, adding more water decreases comfort. Moreover, pumping systems may be costly.

Future of passive cooling system

Rudimentary forms of passive cooling have been used successfully for centuries and much-improved technology is available today. However, continued research and development suggest that even greater improvements will be possible in the future. As population increases in hot regions and as energy becomes scarcer and more costly, the demand for passive cooling increases. Although it is presently only a minor contributor to human comfort when compared with conventional cooling methods, the growing demand will create a large potential market. This will stimulate better design and more effective systems and equipment. Better materials and equipment for use in passive cooling seem assured because of advances in allied fields, and the increasing focus on passive cooling technologies.

Among these advances are Improved heat rejecting metals and other materials, Automatic movable insulation and shading devices, Reversible chemical reactions for heat exchange, Selective window glazing for heat rejection and Improved desiccant materials. Those interested in passive cooling should guard against too high expectations, however. Passive cooling does not, and probably will not in the foreseeable future, compare in effectiveness with conventional electrical and mechanical cooling techniques. But to the hot and uncomfortable person for whom such equipment is out of reach, passive cooling can be a step up in comfort at a small price.

2. Laboratory scale building construction

Though much has been claimed about the green roofs, the deterioration of roof coating reflectivity over time is a major setback. In addition, for tropical countries like India, which are most dust prone, settlement of dust over the roof coatings may totally spoil the purpose for which it has been provided. Though new roof materials are proposed, public awareness and response is a matter of concern. However, a passive technique for a roof, free from above draw backs is best suitable and need of the hour. Reinforced concrete (RC) is a composite material in which concrete's relatively low tensile strength and ductility are counteracted by the inclusion of reinforcement having higher tensile strength or ductility.

The reinforcement is usually, though not necessarily, steel reinforcing bars (rebar) and is usually embedded passively in the concrete before the concrete sets. Reinforcing schemes are generally designed to resist tensile stresses in particular regions of the concrete that might cause unacceptable cracking and/or structural failure. Modern reinforced concrete can contain varied reinforcing materials made of steel, polymers or alternate composite material in conjunction with rebar or not.

Reinforced concrete may also be permanently stressed (in compression), so as to improve the behaviour of the final structure under working loads. Indian climate conditions. The details of the study are discussed in this paper. In India, the roof of most of the RCC buildings are built with about 150 mm thick RCC. About 150 mm thick layer of weathering course (mixture of broken building bricks and lime mortar) is normally laid over the RCC roof as weather proof.

We introduced new concept wherein coconut shell insulation is added between the RCC and WC are modelled and analysed in transient heat transfer condition. Hence, the performances of coconut shell insulation roof along with conventional one is carried out for a typical. Below photo is show our laboratory building

Fig 1: Laboratory Scale Building Construction

Roof configuration

Below table shows the configurations of our building. We are construct four types of roofs. Three roofs are insulated. One roof not to be insulated.

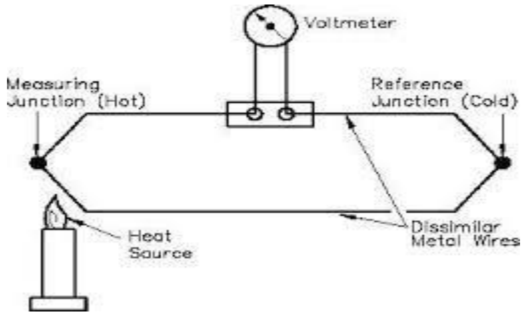
	Layer	Layer material	Dimension (mm)	Density (kg/m³)	Specific heat (J/kg K)	Thermal conductivity (W/mK)
R1	Top	RCC	150	2300	1130	1.63
	Middle	-	-	-	-	-
	Bottom	-	-	-	-	-
R2	Top	White tile	25	1500	700	0.25
	Middle	Weathering course	150	1300	800	0.75
	Bottom	RCC	150	2300	1130	1.63
R3	Top	White tile	25	1500	700	0.25
	Middle	Puf	150	32	820	0.26
	Bottom	RCC	150	2300	1130	1.63
R4	Top	Clay tile	25	1500	700	0.15
	Middle	Coconut shell	150	1100	900	0.95
	Bottom	RCC	150	2300	1130	1.63

Instrumentation used

To analyse the thermal performance of the proposed insulation layer, two model rooms were constructed on top of the institute mechanical engineering department building. The temperature at the interface were continuously sensed using thermocouples, and recorded via data logger connected with computer system.

Thermocouple

A thermocouple is an electrical device consisting of two dissimilar conductors forming electrical junctions at differing temperatures. A thermocouple produces a temperature-dependent voltage as a result of the thermoelectric effect, and this voltage can be interpreted to measure temperature. Thermocouples are a widely used type of temperature sensor. Thermocouples are widely used in science and industry. Applications include temperature measurement for kilns, gas turbine exhaust, diesel engines, and other industrial processes. Thermocouples are also used in homes, offices and businesses as the temperature sensors in thermostats, and also as flame sensors in safety devices for gas-powered major appliances.



Block Diagram Showing Working Principle of Thermocouple

Data Logger

A data logger (also data logger or data recorder) is an electronic device that records data over time or in relation to location either with a built-in instrument or sensor or via external instruments and sensors. Increasingly, but not entirely, they are based on a digital processor (or computer). They generally are small, battery powered, portable, and equipped with a microprocessor, internal memory for data storage, and sensors. Some data loggers' interface with a personal computer, and use software to activate the data logger and view and analyse the collected data, while others have a local interface device (keypad, LCD) and can be used as a stand-alone device. Data loggers vary between general purpose types for a range of measurement applications to very specific devices for measuring in one environment or application type only. It is common for general purpose types to be programmable; however, many remain as static machines with only a limited number or no changeable parameters. Electronic data loggers have replaced chart recorders in many applications.

One of the primary benefits of using data loggers is the ability to automatically collect data on a 24-hour basis. Upon activation, data loggers are typically deployed and left unattended to measure and record information for the duration of the monitoring period. This allows for a comprehensive, accurate picture of the environmental conditions being monitored, such as air temperature and relative humidity.

Fig 2: photography of the data logger

Data logger is connected to a computer installed eScan9.0 software and the thermocouples are placed at the various nodes of the roof and continuous half an hour average temperature values were taken to the computer and logged into the computer hard drive.

3. Numerical formulation

A solid body is said to be in a steady state if its temperature does not vary with time. However, if there is an abrupt change in its surface temperature or environment it takes some time before the body to attain an equilibrium temperature or a steady state. During this interim period the temperature varies with time and the body is said to be in an unsteady or transient state. The steady state is thus the limit of transient temperature distribution for large values of time.

In general, the temperature field in any transient problem is given by

$$T = T\,(x, y, z, t) \qquad \text{-(1)}$$

The solution of an unsteady state problem will be more complex than that of a steady state one because of the presence of another variable 'time', t. In other words, a one-dimensional transient problem would be as complex as a two-dimensional steady state problem. Two and three-dimensional transient heat conduction problems are even more difficult to solve through mathematical methods.

The energy balance on a volume element during a time interval Δt can be expressed as

$$\begin{pmatrix}\text{Heat transfer into the}\\ \text{volume element}\\ \text{from all of its surfaces}\\ \text{during } \Delta t\end{pmatrix} - \begin{pmatrix}\text{change in energy}\\ \text{content of the}\\ \text{volume element}\\ \text{during } \Delta t\end{pmatrix} = \begin{pmatrix}\text{Heat generated}\\ \text{within the}\\ \text{volume element}\\ \text{during } \Delta t\end{pmatrix} \qquad \text{-(2)}$$

Finite difference technique

In many practical situations the geometry or boundary conditions are such that an analytical solution has not been obtained at all, or if the solute has been developed, it involves such a complex series solution that numerical evaluations become exceedingly difficult. For such situations the most fruitful approach to the problem is one based on finite difference technique, the basic principles of which is outlined in this section

Steady State

Consider a two-dimensional body which is to be divided into equal increments in both X and Y directions, as shown in Fig. the nodal points are designated as shown, the m locations indicating the X increment and the n locations indicating the Y increment. Finite difference is used to approximate differential increments in the temperature and space coordinates; and the smaller we choose these finite increments, the more closely the true temperature distribution will be approximated.

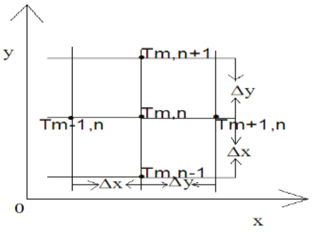


Fig 3: Steady State Heat Conduction

The temperature gradients may be written as

$$\frac{\delta^2 T}{\delta^2 x_{m,n}} = \frac{T_{m+1,n} + T_{m-1,n} - 2T_{m,n}}{(\Delta x)^2} \qquad -(3)$$

$$\frac{\delta^2 T}{\delta^2 y_{m,n}} = \frac{T_{m,n+1} + T_{m,n-1} - 2T_{m,n}}{(\Delta y)^2} \qquad -(4)$$

For steady state, the Laplace equation applies

$$\frac{\delta^2 T}{\delta^2 y_{m,n}} = \frac{T_{m,n+1} + T_{m,n-1} - 2T_{m,n}}{(\Delta y)^2} \qquad -(5)$$

Assuming thermal conductivity constant.

Thus, the finite – difference approximation for equation (5) becomes,

$$T_{m+1,n} + T_{m-1,n} + T_{m,n+1} + T_{m,n-1} - 4T_{m,n} = 0 \qquad -(6)$$

As Δx= Δy,

For the case of constant thermal conductivity, the heat flow may all be expressed in terms of temperature differentials. Equation states very simply that the net heat flow into any node is zero at steady state conditions.

Unsteady state

Consider the system shown in Fig. (4.2), which is of a 2.D region with a sudden temperature difference imposed. In this case, how temperature at any point within the region varies with time is the major factor. The region has been divided into a grid containing a number of nodal points. Five interior nodes are labelled with subscripts m & n to denote spatial position. The superscripts denote a time. For a region having constant properties with no internal heat generation.

$$\frac{\delta^2 T}{\delta^2 x} + \frac{\delta^2 T}{\delta^2 y} = \frac{1}{\propto}\frac{\delta T}{\delta t} \qquad -(7)$$

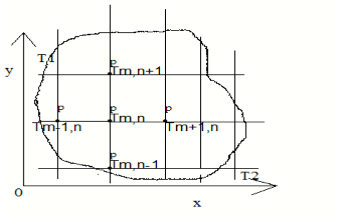


Fig 4: Unsteady State Heat Conduction

Forward Difference Techniques

The equation (7) can be rewritten in finite difference form

$$\frac{\delta^2 T}{\delta^2 x_{m,n}} = \frac{T^P_{m+1,n} + T^P_{m-1,n} - 2T^P_{m,n}}{(\Delta x)^2} \qquad -(8)$$

$$\frac{\delta^2 T}{\delta^2 y_{m,n}} = \frac{T^P_{m,n+1} + T^P_{m,n-1} - 2T^P_{m,n}}{(\Delta y)^2} \qquad -(9)$$

Just as the space variables are divided into ΔX by ΔY increments, time will also be divided into discrete time increment Δt. The parameter P is an integer used to denote the time, ‘t’ that has elapsed according to

$$t = p\Delta t \qquad -(10)$$

The finite difference solution provides value of temperature at discrete points in the region for various values of time that are apart by the time interval Δt.

The first derivative of temperature with respect to time can be written in several ways, one of which is

$$\frac{\delta T}{\delta t_{m,n}} = \frac{T^{P+1}_{m,n} - T^P_{m,n}}{\Delta t} \qquad -(10)$$

The numerator of the right-hand side of equation contains the temperature of node m, n at some future time Δt away ($T_{m,n}^{P+1}$) and the temperature of node m, n at the present time. The expression is thus referred to as a forward difference scheme.

Substituting and setting ΔX = ΔY in equation (7)

$$T^P_{m+1,n} + T^P_{m-1,n} + T^P_{m,n+1} + T^P_{m,n-1} - 4T^P_{m,n} = \frac{(\Delta x)^2}{\propto\Delta t}[T^{P+1}_{m,n} - T^P_{m,n}] \quad \text{-(12)}$$

$$T^{P+1}_{m,n} = \frac{\propto\Delta t}{(\Delta x)^2} T^P_{m+1,n} + T^P_{m-1,n} + T^P_{m,n+1} + T^P_{m,n-1} + [1 - \frac{4\propto\Delta t}{(\Delta x)^2}]T^P_{m,n} \quad \text{-(13)}$$

This expression gives the temperature at any interior node m, n at a future time t+Δt explicitly in terms of the temperature at node m, n and its surrounding nodes at the preceding time. The equation is thus referred to as an explicit formulation.

The temperature at every interior node might be known from the initial condition (P =0, t=0). Equation (10) is used to calculate the temperature at every interior node after one time interval (P=1, t= (1Δt). Once these are known the same equation is used again to calculate the temperature after another time interval (P=2, t=(2Δt) the process is repeated until a desired time or condition is reached.

For one dimensional problem, where temperature varies only with Y and t; equation (7) becomes

$$T^{P+1}_{m,n} = \frac{\propto\Delta t}{(\Delta y)^2} T^P_{m+1} + T^P_{m-1} + (1 - \frac{2\propto\Delta t}{(\Delta y)^2}) T^P_m \quad \text{-(14)}$$

Finite difference version of the Fourier number is

$$f_o = \frac{\propto\Delta t}{(\Delta y)^2} \quad \text{-(15)}$$

The value of f_0 must be specified when solving a problem. When the space increments ΔY is chosen and f_0 is specified, then Δt is automatically determined for a given material through equation (15). A larger ΔY and a larger Δt help to affect a solution more rapidly. Alternatively, smaller ΔY's and Δt^' s yield more accurate results. Limits on fo are required for convenience as well as for guidance.

Now if f_0> ½ in equation (4.14), then the coefficient of ($T^P_{m,n}$) becomes negative. Further, if the adjoining nodes are all equal but less than T^P m, then at the conclusion of the time interval, $T_m{}^{p+1}$ might not be equal to or less than T^p_{m+1} and T^p_{m-1}. Thus equation (14) would predict that heat has been transferred from a node at some temperature to a node at higher temperature. This violates what actually happens in a system, so equation (14) ceases to be an effective model.

Therefore,

$$f_o = \frac{\propto\Delta t}{(\Delta y)^2} \leq 1/2 \text{ (One-dimensional system) -(16)}$$

$$f_o = \frac{\propto\Delta t}{(\Delta y)^2} \leq 1/4 \text{ (Two-dimensional system) -(17)}$$

If $f_o = 1/2$

Equation (14) gives,

$$T^{P+1}_{m,n} = \frac{T^P_{m+1} + T^P_{m-1}}{\Delta t} \quad \text{-(18)}$$

The temperature at the future time t+Δt is the arithmetic average of the temperature of the surrounding nodes during the preceding time t.

Backward Difference Technique

A corresponding analysis exists for an arrangement called the backward difference technique. Instead of writing second derivate with a superscript of P

For any interior node m, n

$$\frac{\delta^2 T}{\delta^2 x_{m,n}} = \frac{T^{P+1}_{m+1,n} + T^{P+1}_{m-1,n} - 2T^{P+1}_{m,n}}{(\Delta x)^2} \quad \text{-(19)}$$

$$\frac{\delta^2 T}{\delta^2 y_{m,n}} = \frac{T^P_{m,n+1} + T^P_{m,n-1} - 2T^P_{m,n}}{(\Delta y)^2} \quad \text{-(20)}$$

The 2.D unsteady differential equation (17), then becomes.

$$T^P_{m,n} = \frac{\propto\Delta t}{(\Delta x)^2} T^{P+1}_{m+1,n} + T^{P+1}_{m-1,n} + T^{P+1}_{m,n+1} + T^{P+1}_{m,n-1} + [1 - \frac{4\propto\Delta t}{(\Delta x)^2}] T^{P+1}_{m,n} \quad \text{-(21)}$$

This equation does not provide for explicitly calculating the temperature at an interior node at the future time P+1. A whole system of equations must be written for entire nodal system and solved simultaneously. This scheme is thus referred to as an implicit formulation. The advantage of the explicit formulation is that future temperature can be calculated directly. The disadvantage is that the stability of the calculation is fixed by selection of ΔX and Δt. The advantage of implicit method is that no such stability criterion must be satisfied. Thus, any time increment can be selected. A large increment of time would reduce the number of calculations required. The disadvantage of the implicit method is that a large number of calculations are required for each time increment to solve the simultaneous equations.

4. Result and discussion

The temperature measurements were continuously recorded for four days and the four-day average values are analysed for thermal performance. The following graph explains the variation in concrete roof bottom surface temperature with and without insulated surface temperature values were also tabulated in tables.

VARIATION OF ROOF BOTTOM SURFACE TEMPERATURE

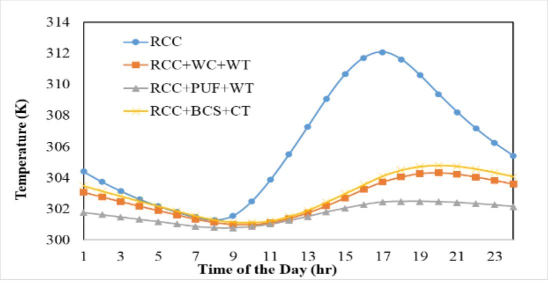


Fig 5: Variation of roof bottom surface temperature on four-day average

The maximum temperature on concrete roof bottom without insulation is 312k at 4.30 pm. However, the maximum temperature on concrete roof bottom with weathering course insulation is 304k at 8 pm. The maximum temperature on concrete roof bottom with polyurethane foam insulation is 302k at 8 pm. the maximum temperature on concrete roof bottom with coconut shell insulation is 305k at 8 pm. The polyurethane foam insulated roof heat reduction is more than 10 k.

Table 1: Temperature variation of various roof

TIME	RCC	RCC+WC+WT	RCC+PUF+WT	RCC+BCS+CT
1	304.40	303.06	301.75	303.48
2	303.73	302.75	301.61	303.14
3	303.14	302.46	301.47	302.82
4	302.62	302.17	301.32	302.49
5	302.17	301.89	301.18	302.17
6	301.80	301.61	301.02	301.87
7	301.46	301.33	300.87	301.55
8	301.29	301.12	300.78	301.29
9	301.56	300.99	300.78	301.15
10	302.48	300.98	300.87	301.12
11	303.87	301.10	301.02	301.23
12	305.52	301.37	301.25	301.51
13	307.28	301.74	301.51	301.91
14	309.08	302.18	301.79	302.43
15	310.66	302.71	302.04	302.98
16	311.72	303.25	302.27	303.55
17	312.08	303.72	302.44	304.11
18	311.61	304.04	302.47	304.49
19	310.59	304.26	302.48	304.72
20	309.38	304.32	302.45	304.79
21	308.22	304.23	302.41	304.74
22	307.16	304.04	302.33	304.57
23	306.23	303.83	302.25	304.34
0	305.42	303.59	302.14	304.07

The table shows the experimental values of various roofs. The heat entering the room is proportional to the temperature between the room air temperature and the inner surface temperature of the room. Higher the temperature difference, higher the amount of heat infiltration per unit area into the room. The heat flux variation of various insulated and non-insulated roof values is given to the table 3.

Table 2: heat flux of various roofs

TIME	q(RCC)	q(RCC+WC+WT)	q(RCC+PUF+WT)	q(RCC+BC+CT)
1	84	70.63	57.54	74.83
2	77.3	67.54	56.13	71.41
3	71.4	64.57	54.67	68.18
4	66.2	61.66	53.16	64.91
5	61.7	58.85	51.79	61.74
6	58	56.09	50.21	58.69
7	54.6	53.27	48.70	55.48
8	52.9	51.21	47.84	52.93
9	55.6	49.86	47.78	51.46
10	64.8	49.79	48.68	51.24
11	78.7	50.96	50.15	52.29
12	95.2	53.73	52.49	55.09
13	113	57.38	55.09	59.06
14	131	61.80	57.94	64.28
15	147	67.10	60.41	69.81
16	157	72.46	62.67	75.53
17	161	77.19	64.37	81.07
18	156	80.44	64.72	84.88
19	146	82.64	64.78	87.21
20	134	83.18	64.52	87.94
21	122	82.26	64.05	87.36
22	112	80.43	63.32	85.66
23	102	78.29	62.49	83.40
0	94.2	75.85	61.44	80.74
total heat flux entering the room (W/m^2)	2395	1587.16	1364.94	1665.16

The heat entering the room is proportional to the temperature between the room air temperature and the inner surface temperature of the room. Higher the temperature difference, higher the amount of heat infiltration per unit area into the room. Without insulated room heat flux is very high that is show in fig.

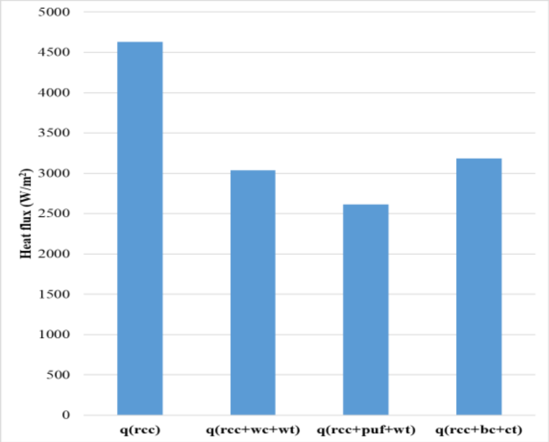


Fig 6: heat flux comparison graph

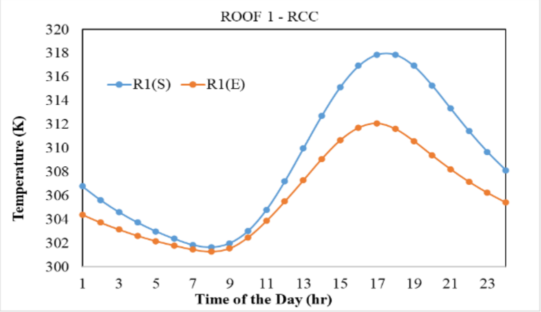
Table 4: simulated values of roof surfaces

TIME	RCC	RCC+WC+WT	RCC+PUF+WT	RCC+BCS+CT
1	306.79	304.12	301.29	303.92
2	305.62	303.82	301.08	303.63
3	304.61	303.51	300.87	303.33
4	303.74	303.18	300.68	303.02
5	302.99	302.86	300.50	302.71
6	302.36	302.55	300.34	302.41
7	301.85	302.26	300.18	302.12
8	301.65	301.98	300.06	301.85
9	301.99	301.75	299.98	301.62
10	303.02	301.58	299.98	301.46
11	304.81	301.52	300.08	301.40
12	307.22	301.58	300.29	301.45
13	309.97	301.78	300.59	301.64
14	312.72	302.11	300.95	301.95
15	315.14	302.54	301.33	302.36
16	316.94	303.04	301.69	302.84
17	317.89	303.55	301.99	303.33
18	317.89	304.01	302.20	303.78
19	316.94	304.39	302.28	304.14
20	315.29	304.64	302.25	304.39
21	313.35	304.75	302.12	304.50
22	311.44	304.73	301.94	304.48
23	309.69	304.60	301.73	304.36
0	308.14	304.39	301.51	304.17

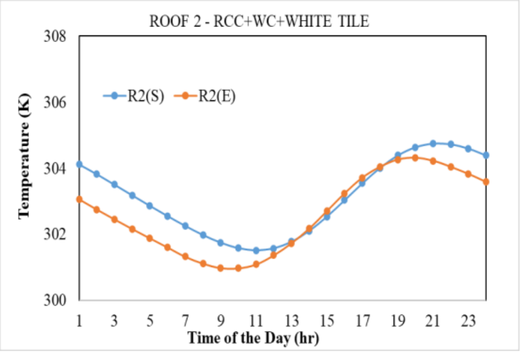
THEORETICAL AND EXPERIMENTAL VALUES COMPARISION

The simulated values are found by using the MATLAB software and the values are compared to theoretical values. Then find the graph plotted and the variation are determined.

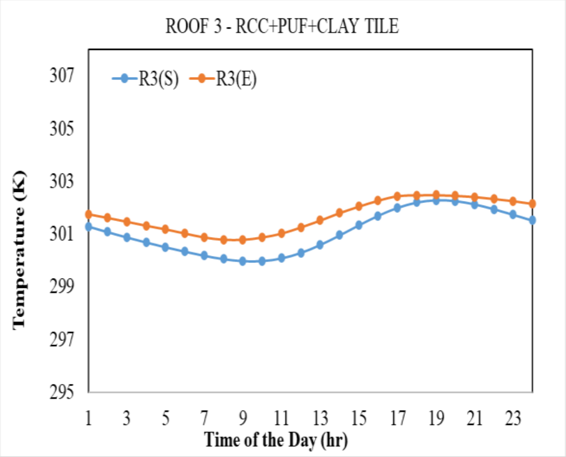
Roof 1 Comparison



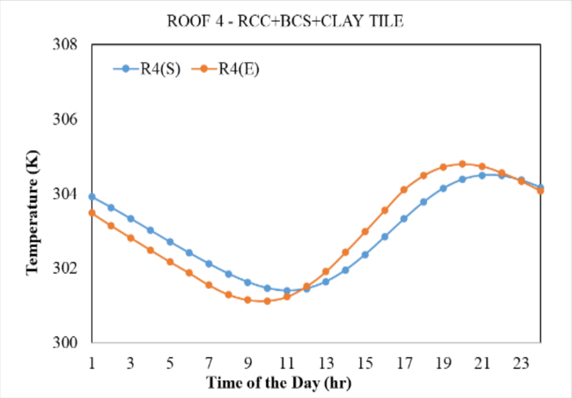
Roof 2 Comparison



Roof 3 Comparison



Roof 4 Comparison



CONCLUSION

“Go green to save the earth,” that’s the motto of this project work. Experimental model was created and real time temperature merriments were recorded to find the effectiveness of new insulated materials. Heat reduction analysis through thermal insulation tiles is carried out for improving the thermal comfort for building without air conditioning. Similarly for air-conditioned building, power consumption can be reduced, thereby the expenditure towards electricity. The following are the major findings of the investigation.

1. By adopting this new innovative thermal insulation tiles, average heat flux entering into the room is reduced by 56 % compared to conventional RCC roof without insulation during office hours.
2. By adopting this new innovative thermal insulation technique in roof 3, average heat flux entering the room is reduced by 43% compared to conventional concrete roof.
3. This new insulation will reduce the roof bottom surface temperature by 10ºC in comparison with RCC roof without insulation.

4. When compared to conventional weathering course roof (Roof-2), Roof-3 are found to reduce the heat entering into the room by about 60%.
5. Simulated values are more or less equal to the theoretical values. So, the experimental values are suitable for commercial building construction.

Thus, the new innovative insulation technique provides very good thermal insulation and makes huge savings in electricity cot. By adopting this innovative technique, the building can be made more affordable and comfortable for living.

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