Experimental Thermal Analysis of Composite Roof and Its Effects on Overall Thermal Resistant in Building Envelope

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Abstract – *A design and analysis of three types of composite roof has been evaluated. The adoptive temperature in the range of 22ºC to 32ºC in moderate zone is achieved. It is important, that a designer should be able to calculate the temperatures and heat transfer rate for any combination of materials exposed to any climatic conditions. The new innovative and modified composite roof helps make building envelope cool in summer and warm in winters and saves energy in respective seasons.*

The composite materials, innovated are concrete (M20), Expanded Polystyrene (thermocol) foam insulation plus ferroconcrete; concrete plus Polyethylene foam insulation plus ferroconcrete and concrete, Polyurethane foam insulation plus ferroconcrete material. This composite material is sandwiched between water proofing compound layer and are further analyzed for techno-economical feasibility.

It is reviewed and analyzed that, the composite material concrete with Polyurethane foam is better suited for low cost and comfort as durable roof in passive designs of building applications. These composite materials properties are good for comfort in building conditions as compared to other materials.

Key Words: Composite roof, comfort conditions, energy saving in building envelope, roof thermal analysis, roof and comfort analysis, techno-economical feasibility, roof cooling effect, roof thermal balance.

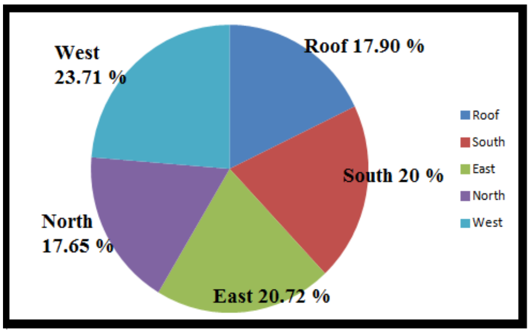
1. INTRODUCTION

In building design simple techniques such as orientation, aspect, prospect, shading of windows, colour, and vegetation among others create comfortable conditions. Such techniques pertain to the building envelope. Building envelopes not only provide the thermal divide between the indoor and outdoor environment, but also play an important role in determining how effectively the building can utilize natural resources like heat, light and wind. Thus, intelligent configuration and moulding of thebuilt form and its surroundings can considerably minimize the level of discomfort inside a building, and reduce the consumption of energy required to maintain comfortable conditions.

The physical manifestation of some of the concepts on building configuration that can reduce heat gain in arid and hot climate is depicted by various factors like, Walls, Windows, Roofs, and Adjacent Walls etc.

In building envelope most of the important part is roof. Roof of a building receives a significant amount of solar radiation. Thus, its design and construction play an important role in modifying the heat flow, day lighting and ventilation.As per Indian Standard code 3792 (1978), the heat gain through roofs may be reduced by the following methods:

- Insulating materials may be applied externally or internally to the roofs. In case of external application, the insulating material needs to be protected by waterproofing to avoid intrusion of moisture inside the living space.
- For internal application, the insulating material may be fixed by adhesive or by other means on the underside of the roofs. A false ceiling of insulation material may be provided below the roofs with air gaps in between.
- Shining and reflecting material (e.g. glazed china mosaic) may be laid on top of the roof.
- Movable covers of suitable heat insulating material, if practicable, may be considered.
- White washing of the roof can be done before the onset of each summer.
- Typical heat loads in filtering from various sides of building envelope in moderate zone in India are calculated and is represented in graph 1. below. Almost 17.9% of heat is due to roof.



Graph.1. Pie chart on solar radiation by heat load

1.2 Composite Roof:

Composite roof is a mixture of multiple materials that are compressed and blended together. They possess different physical or chemical properties, that when combined, produces a material with characteristics different from the individual components. In composite roof new material can be preferred, for many reasons: common examples include materials which are stronger, lighter and less expensive when compared to traditional materials. The composite roof looks like any other roof and can be casted at site with due care and high tech practices. These composites are tested for ISO: 9705 for its fire resistance but are not analyzed for thermal transmittance for passive design applications.

Typical engineered composite materials include:

- Composite building materials such as cements, concrete, ferroconcrete.
- Reinforced plastics such as fiber-reinforced polymer.
- Metal Composites.
- Ceramic Composites (composite ceramic and metal matrices).
- Polyurethane foam and polystyrene foam and polyethylene foam insulation material.

2.0 The research criteria

2.1 Selection of roof composite materials
2.2 Heat balance and its thermal Analysis
2.3 Analysis

2.1. Selection of roof composite materials

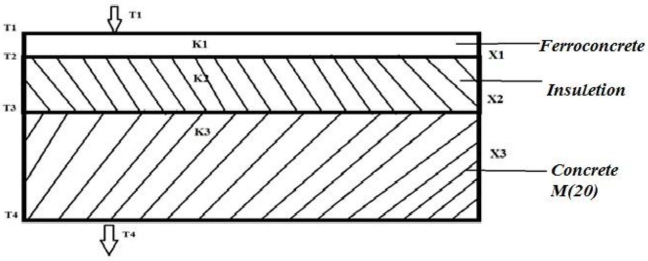


Figure-1: General composite roof design

2.2 Heat Balance and its thermal Analysis

Heat transfer by roof conduction and convection equations

Abbreviation:-
Q= rate of heat conduction (w)
A = surface area (m2)
U = thermal transmittance (W/ m2- K)
ΔT = temperature difference
Rt = total thermal resistance
hi =inside heat transfer coefficients
ho= outside heat transfer coefficients
L j =thickness of the jth layer.
K j =thermal conductivity of its material.
i = building element.
Nc = number of components.

x1, x2, x3 are the thickness of ferroconcrete, insulation , and concrete(M20), respectively.
k1, k2, k3 are the thermal conductivity of ferroconcrete, insulation, and concrete(M20), respectively.
The rate of heat conduction (Q conduction) through any element such as roof, wall or floor under steady state can be written as [1]

Q, conduction = A U ΔT

Where,
A = surface area (m2)
U = thermal transmittance (W/ m2- K)
ΔT = temperature difference between inside and outside air (K).

It may be noted that the steady state method does not account for the effect of heat capacity of building materials.

U is given by[1]

U=1/Rt

Where Rt is the total thermal resistance and is given by [1]

$$R_T = \frac{1}{h_i} + \left(\sum_{j=1}^{m} L_j / k_j \right) + \frac{1}{h_o}$$

hi and ho are the inside and outside heat transfer coefficients respectively. Lj is the thickness of the jth layer and kj is the thermal conductivity of its material.

U indicates the total amount of heat transmitted from outdoor air to indoor air through a given wall or roof per unit area per unit time. The lower the value of U, the higher is the insulating value of the element. Thus, the U-value can be used for comparing the insulating values of various building elements.

Equation is solved for every external constituent element of the building i.e., each wall, window, door, roof and the floor, and the results are summed up. The heat flow rate through the building envelope by conduction is the sum of the area and the U-value products of all the elements of the building multiplied by the temperature difference. It is expressed as:

$$Q_c = \sum_{i=1}^{N_c} A_i\, U_i\, \Delta T_i$$

where,
i = building element.
Nc = number of components.

$$Q\,total = \frac{\Delta T}{(x1/K1*A)+(x2/K2*A)+(x3/K3*A)}$$

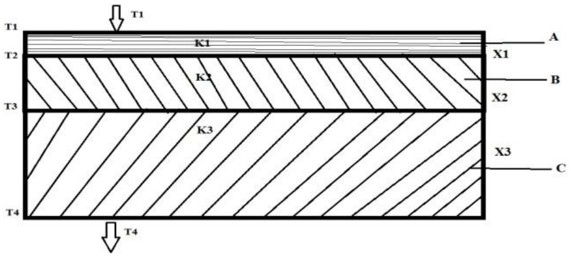
$$Q = Q1 = \frac{(T1 - T2)}{(x1 / K1 * A)} \qquad T2 = \frac{T1 - (Q1 X x1)}{(K1 X A)}$$

$$Q = Q2 = \frac{(T2 - T3)}{(x2 / K2 * A)} \qquad T3 = \frac{T2 - (Q2 X x2)}{(K2 X A)}$$

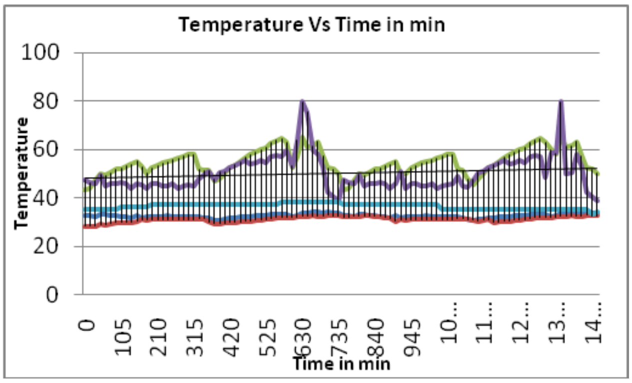
$$Q = Q3 = \frac{(T3 - T4)}{(x3 / K3 * A)} \qquad T4 = \frac{T3 - (Q3 X x3)}{(K3 X A)}$$

2.3 Analysis

Case 1

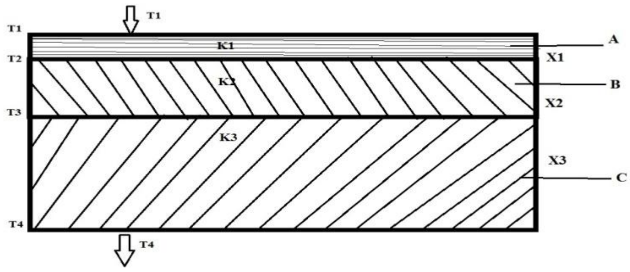


Figures - 2: Composite roof structure with polystyrenefoam as an insulation material.
Where
A= Water Proofing ferroconcrete material,
B= Polystyrene Foam,
C= Concrete (M20),
K1= Thermal Conductivity of Water Proofing ferroconcrete material,
K2= Thermal Conductivity of Polystyrene Foam
K3= Thermal Conductivity of concrete (M20),
X1= Thickness of first layer offerroconcrete material,
X2= Thickness of Polystyrene Foam
X3= Thickness Concrete (M20),
A= A1= A2= A3= Heat Transfer area.

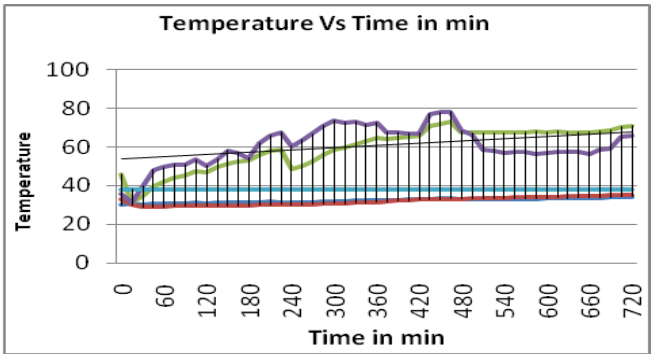


Graph-2: All temperature in case 1 (Polystyrene foam insulation) Vs Time in minute

Case 2 Figures No 3: Composite roof structure with polyethylene foam as an insulation material.

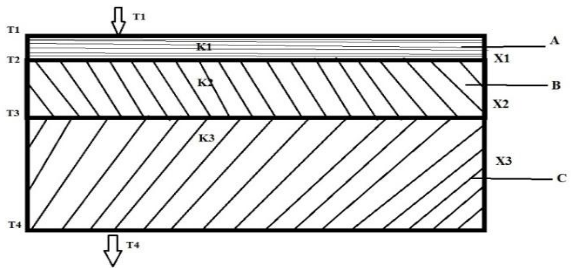


Where
A= Water Proofing ferroconcrete material,
B= Polyethylene Foam,
C= Concrete (M20),
K1= Thermal Conductivity of water proofing ferroconcrete material,
K2= Thermal Conductivity of Polyethylene Foam,
K3= Thermal Conductivity of concrete (M20),
X1= Thickness of layer first ferroconcrete material,
X2= Thickness of Polyethylene Foam,
X3= Thickness Concrete (M20),
A= A1= A2= A3= Heat Transfer area.



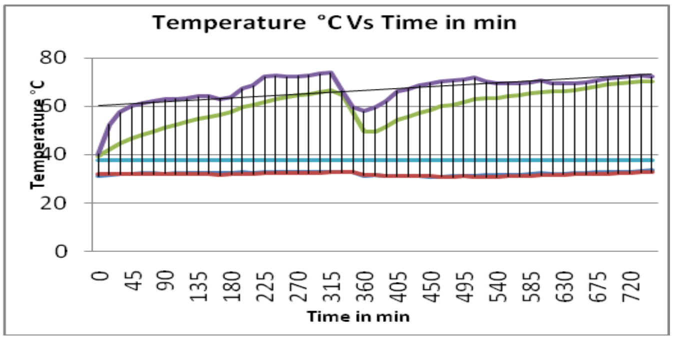
Graph.3: All temperature in case 2 (Polyethylene foam insulation) Vs Time in minute

Case 3 Figures-4: Composite roof structure with polyurethane foam as an insulation material.



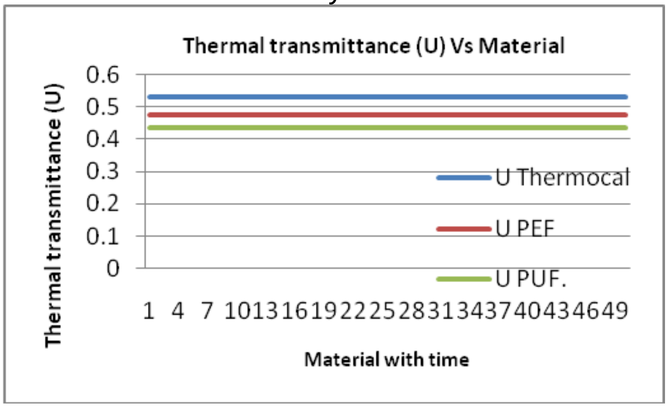
Where
A= Water Proofing ferroconcrete material,
B= Polyurethane Foam,
C= Concrete (M20),
K1= Thermal Conductivity of water proofing ferroconcrete material,
K2= Thermal Conductivity of Polyurethane foam,
K3= Thermal Conductivity of concrete (M20),
X1= Thickness of layer first ferroconcrete material,
X2= Thickness of Polyurethane Foam,

X3= Thickness Concrete (M20),
A= A1= A2= A3= Heat Transfer area.



Graph-4: All temperature in case 3 (Polyurethane foam insulation) Vs Time in minute

2.3 Techno comfort analysis



Graph- 5: Thermal Transmittance (U)Vs Materials in all case

3. CONCLUSIONS

The following results were obtained from the analysis of the composite roof structures.

In case of composite roof with insulation of polystyrene foam, it is observed that the increase inthe inside room temperature is less with respect to time. If outside average temperature is 53.13°C then inside room temperature is 32.60 °C.

In case of composite roof with insulation of polyethylene foam, it is observed that the increase in the inside room temperature is less with respect to time. If outside average temperature is 60.7 °C then inside room temperature is 32.28 °C

In case of composite roof with insulation of polyurethane foam, it is observed that the increase in the inside room temperature is less with respect to time. If outside average temperature is 66.84 °C then inside room temperature is 32.10 °C.

Finally it is concluded that the inside room temperature value of composite roof with polyurethane foam using material is effective in transfer of less heat inside the room and hence itis recommended that the practice of PUF in composite roof will result in energy saving and energy conservation in building envelope.

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