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Theoretical Analysis of Composite Roof with Respect to Comfort in Building Envelope

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Abstract – **A New composite materials for roofs of four types are theoretically analysed for thermal outputs and cooling of space below roof. The adoptive comfort temperature of 26 °C in composite zone can be achieved.**
The composite materials, considered are concrete (M20) plus Polyurethane foam, concrete plus Polystyrene (thermocol), G.I. Sheet with Polyurethane foam and G.I. sheet with Polystyrene. This composite material sandwich between reflective coating, water proofing compound layer and are further analysed for techno-economical feasibility.
It is reviewed and analysed that, the composite material concrete with Polystyrene and G.I. sheet with Polystyrene are better suited for low cost and durable roof in passive designs of building applications.

Key Words – **Composite roof, passive roofs, roof thermal analysis, roof and comfort analysis, roof cooling effect, roof thermal balance.**

1. Introduction

The physical manifestation of some of the concepts on building configuration that can reduce heat gain in varied a hot climate is depicted by various factors like, Walls, Windows, Roofs, and Adjacent Walls etc.
It is observed that in an average building envelope @ 23 % of the heat is transferred through roof and is maximum as compared to the walls, windows etc.
The work therefore is concentrated on the composite roofs.its thermal analysis vis-à-vis heat load and comfort in side

1.1. Thermal analysis of composite roof

Four types of roofs are used. Thermal analysis of the composite roof carried out using the equation from [1] in terms of thermal conduction-convection and transmittance etc. respectively.

1.2. Composite Roof

Basically, it is a mixture of multiple materials that are compressed and blended together. They bear different physical or chemical properties, that when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure. The new material may be preferred for many reasons: common examples include materials which are stronger, lighter or less expensive when compared to traditional materials. The Composite roofing looks like any other roof and can be casted at site with due care and high tech practices. These composites are tested for ISO9705for its fire resistances but are not analysed for thermal transmittance for passive design applications.
Typical engineered composite materials include:

- Composite building materials such as cements, concrete.
- Reinforced plastics such as fiber-reinforced polymer
- Metal Composites.
- Ceramic Composites (composite ceramic and metal matrices).
- Polyurethanes and polystyrenes

This work analyses the different composite roofs with specific combination of above to resist the heat.

2. Methodology

2.1. Selection of roof composite materials
2.2. Heat balance
2.3. Analysis

2.1. Selection of roof composite materials

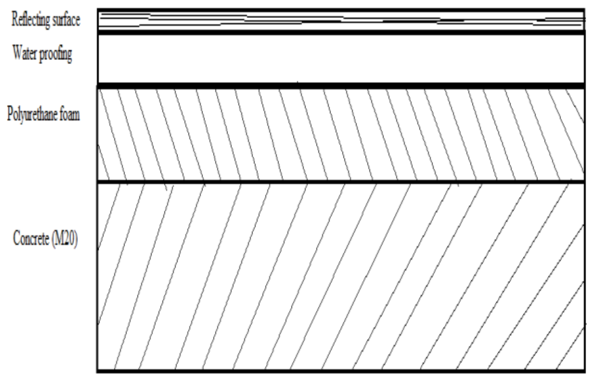

Fig. 1. General composite roof design

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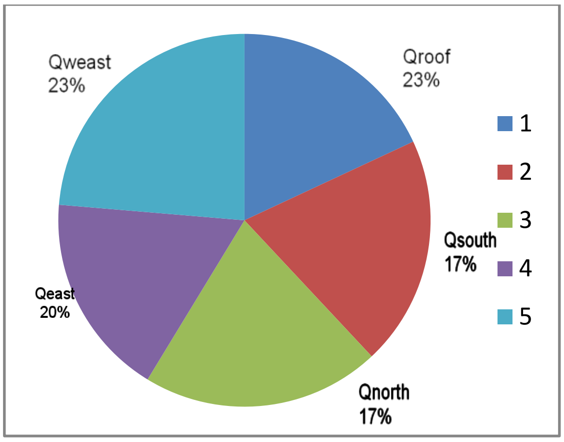


Graph.1. Pie chart on solar radiation by heat load.

2. 1. Heat Balance

Heat transfer by roof conduction and convection equations

Abbreviation:-
Q= rate of heat conduction
A = surface area (m2)
U = thermal transmittance (W/ m2- K)
ΔT = temperature difference between
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,x4 are the thickness of reflective surfaces, water proofing, Polyurethane foam, and concrete(M20), respectively.
k1,k2,k3,k4 are the thermal conductivity of reflective surfaces, water proofing, Polyurethane foam, 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 respectively, are the inside and outside heat transfer coefficients. 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.

$$Q\,total = \frac{\Delta T}{(x1/K1*A)+(x2/K2*A)+(x3/K3*A)+(x4/K4*A)}$$

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

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

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

OR

$$Q = Q4 = \frac{(T4 - T5)}{(x4/K4*A)} \qquad T4 = T5 + \frac{(Q3\ X\ x3)}{(K3\ X\ A)}$$

2.3. Analysis

1) Case 1 concrete with foam, foam thickness changes. And concrete with foam, outside temperature (°C) changes.

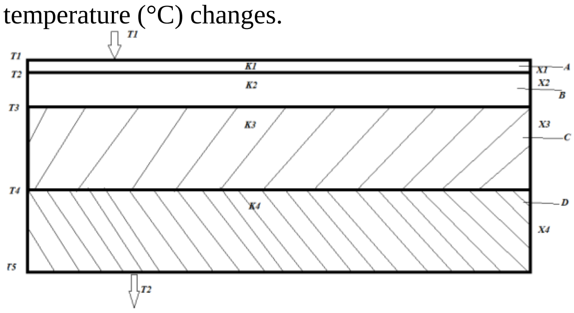
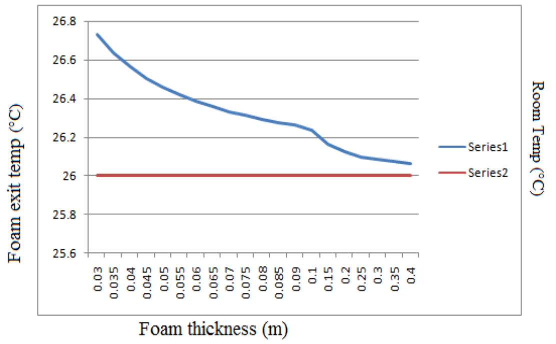
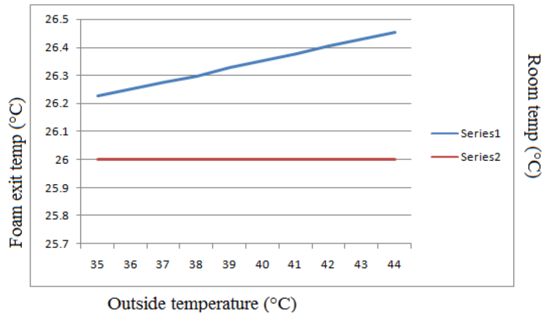


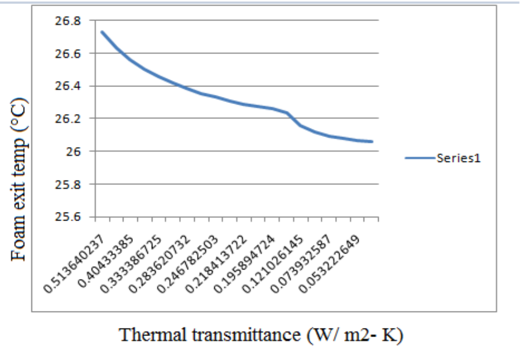
Fig. 2. General composite roof design in case 1.



Graph. 2. Foam exit temp (°C) Vs foam thickness (m2)



Graph. 3. Foam exit temp oC Vs outside temperature (°C)



Graph. 4. Foam exit temperature (°C) Vs thermal transmittance (W/ m2- K)

2) Case 2 concrete with thermocol, thermocol thickness changes. and concrete with foam, outside temperature (°C) changes.

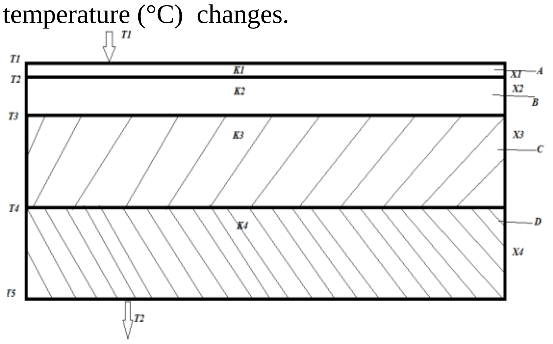
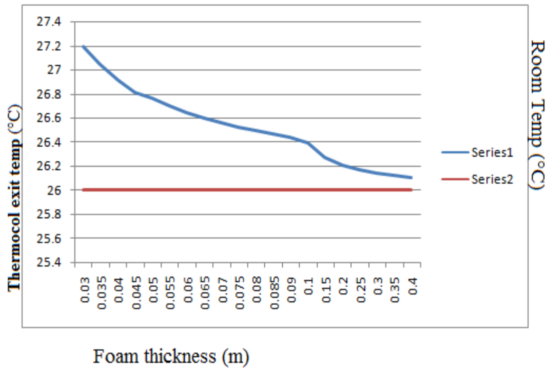
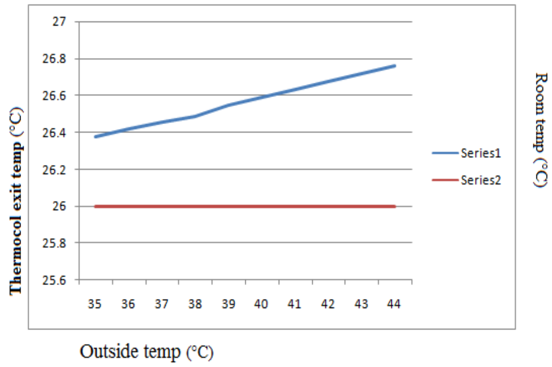


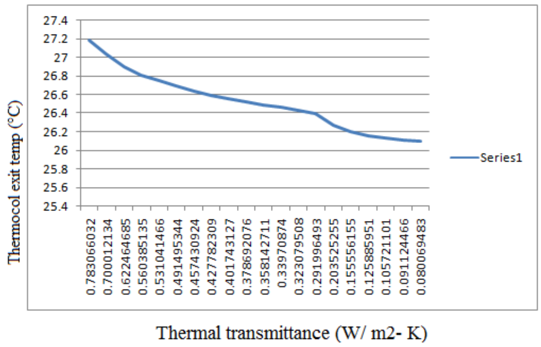
Fig. 3. General composite roof design in case 2.



Graph. 5. Thermocol exit temperature (°C) Vs thermocol thickness (m2)



Graph.6. Thermocol exit temperature (°C) Vs outside temperature (°C)



Graph.7. Thermocol exit temperature (°C) Vs thermal transmittance (W/ m2- K)

3) Case 3 G. I. Sheet with foam, foam thickness changes. And G. I. Sheet with foam, temperature outside (°C) Changes.

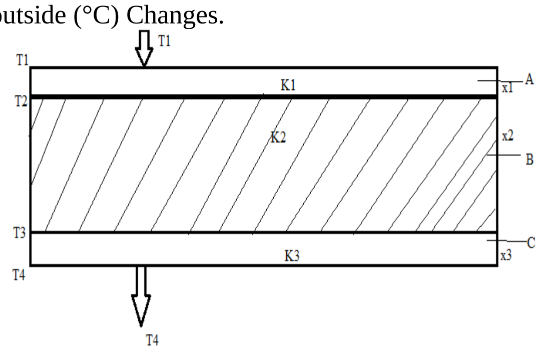


Fig. 4. General composite roof design in case 3.

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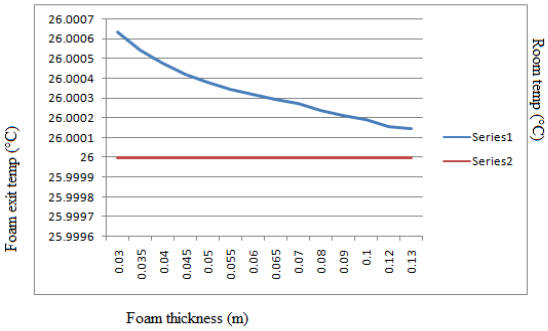
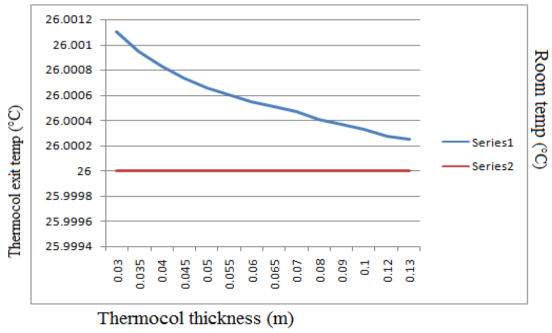
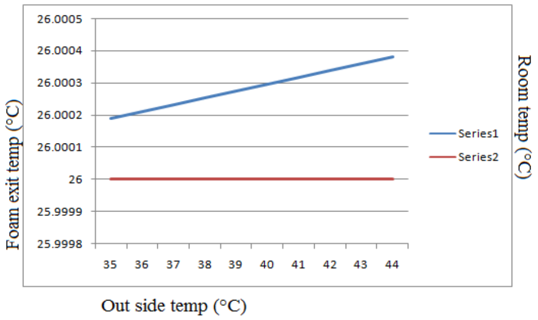


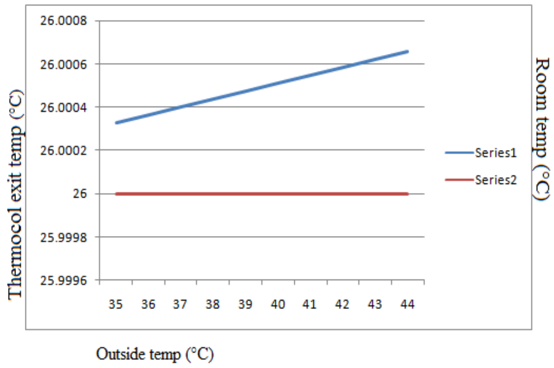
Graph no.8. Foam exit temperature (°C) Vs thickness of foam (m2)



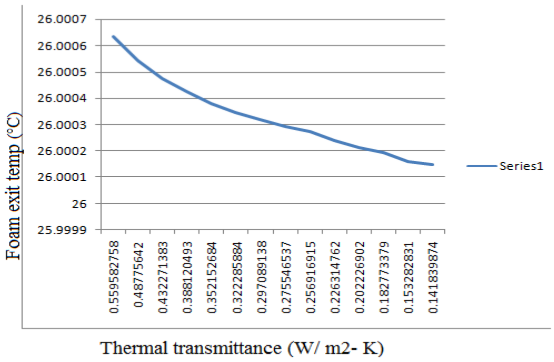
Graph.11. Thermocol exit temperature (°C) Vs thickness of thermocol (m2)



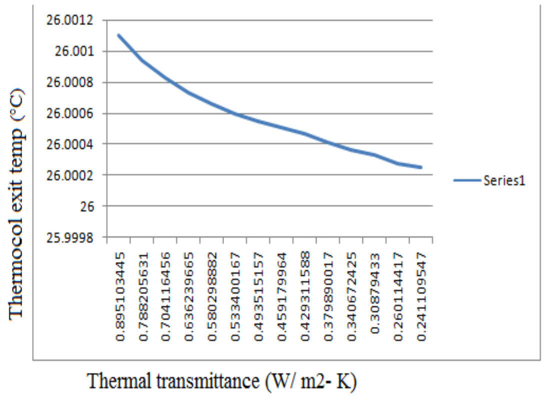
Graph no.9. Foam outlet temp (°C) Vs outside temperature (°C)



Graph.12. Thermocol exit temperature (°C) Vs outside temperature (°C)



Graph. 10. Foam exit temperature (°C) Vs thermal transmittance (W/ m2- K)



Graph.13. Thermocol exit Temperature (°C) Vs thermal transmittance (W/ m2- K)

4) Case 4 G. I. Sheet with thermocol, thermocol thickness changes. and G. I. Sheet with thermocol, temperature outside (°C) changes.

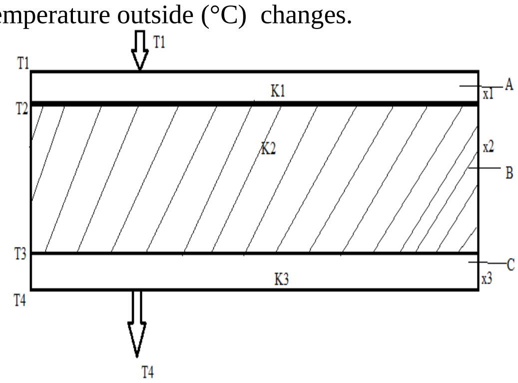


Fig. 5. General composite roof design in case 4

3. Techno Economical Analysis

1) Case 1.Concrete with foam.
   Total cost =1028 Rs/m^2
2) Case2. Concrete with thermocol.
   Total cost=828 Rs/m^2
3) Case3. G.I. Sheet with foam
   Total cost = 840 Rs/m^2
4) Case4. G.I. Sheet with thermocol
   Total cost = 640 Rs/m^2

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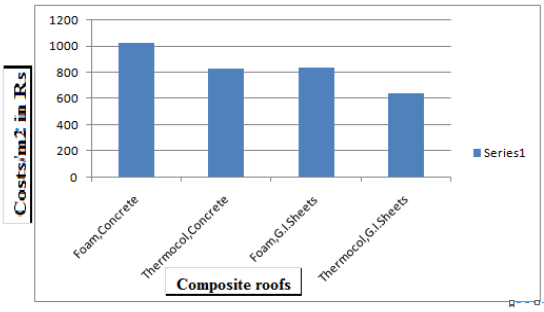

Graph 14. Composite roofs VS Costs/m2 in Rs

4. Results and Recommendation

The following assumption are made for theoretical analysis and results are tabulated as shown in figure.

1) Considering the outside climate condition the comfort temperature is achieved by varying insulation thicknesses.
2) The inside comfort temperature is analyzed by changing outside temperature with respect to thicknesses of insulation.

This work reviews and analyzes four types of roof composites. It is expressed, that among four samples reviewed for thermal balance w.r.t cost the concrete with the polystyrene and G.I. Sheet with polystyrene combinations are economical and durable which can withstand testing as recommended by ISO 9705.For easy installation pre fabricated composite roof such as G.I. Sheet with polystyrene is suitable. Further investigation by experimental analysis is required to strengthen the result.

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