Theoretical and Experimental Analysis of use of Earth Berming to improve comfort in Building Envelop

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Abstract - Earth Berming are used to reduce thermal load in building envelop and is passive technique to achieve comfort. The composite walls with insulation are costly and hence are limitedly used. It is necessary to try different local material using earth berming building envelop. The thermal analysis of earth berming composite wall become complex if it is added with passive land escapes.

This research work is associated with theoretical analysis of earth berming systems of different composites as under and evaluation of it performance by experimental methods. The composite materials, considered are,
1. Lawn plus lateritic soil, brick wall with plaster on either side
2. Lawn plus black cotton soil, brick wall with plaster on either side
3. Lawn plus porous soil, brick wall with plaster on either side

The work consist considers different soil material in triangular shape 200mm by 300mm with slope 1:1.5 and earth berming wall filled using materials such as Black cotton soil, Black cotton soil with lawn, Porous soil, Porous soil with lawn, Laterite soil, Laterite soil with lawn. The prototype earth berming building are developed at laboratory scale and tested, evaluated for its thermal transmittance U values.

It is observed that the earth berming building using Laterite soil with lawn insulation has least thermal transmittance U value (W/m²K) followed by 0.245. Respectively.

Key Words: Earth berming, Thermal balance, Passive wall, Wall cooling effect, Wall thermal analysis, Wall and comfort analysis. Energy conservation, Insulation, Building Envelop, Building Insulation

1. ABBREVIATIONS

A = Surface Area (m²)
Ai = Area of the ith Transparent Element (m²)
B = Soil (m³)
C = External plastering (m²)
C = Specific heat of Air (J/kg-K)
D = Brick mashnari (m³)
E = Internal plastering (m²)
F = Lawn (m²)
K1 = Thermal conductivity of lawn (w/m²-K)
K2 = Thermal conductivity of soil (w/m²-K)
K3 = Thermal conductivity of external plastering (w/m²-K)
K4 = Thermal conductivity of brick wall (w/m²-K)
K5 = Thermal conductivity of internal plastering (w/m²-K)
j1 = Thermal conductivity of its material(W/m²-K)
L = Latent heat of evaporation (j/kg-k)
Li = Thickness Layer (m)
M = Number of Transparent Elements
Nc = Number of Components
Q conduction = Rate of Heat Conduction (w)
Q evaporation = Rate of Evaporation (w)
Q ventilation = Heat flow Rate Ventilation (W)
Sgi = Daily average value of Solar radiation (including the effect of shading) on the ith transparent element (W/m²)
T1 = Temperature of outside of earth berming (K)
T2 = Temperature of lawn (K)
T3 = Temperature of soil (K)
T4 = Temperature of external plaster (K)
T5 = Temperature of brick wall (K)
T6 = Temperature of internal plaster (K)
Tf = Temperature of the fluid (K)
Ti = Indoor Temperature (K)
To = Daily average value of hourly ambient temperature (K)
Ts = Temperature of the surface (K)
Tso = Solar-air temperature
RT = Total thermal resistance
Ts = Daily average value of hourly Solar radiation incident on the surface (W/m²)
X1 = Tkanes of lawn (m)
X2 = Tkanes of soil (m)
X3 = Tkanes of external plastering (m)
X4 = Tikanes of Brick wall (m)  
X5 = Tikanes of Internal Plastering (m)  
U = Thermal Transmittance (W/ m²-K)  
Vr = Ventilation Rate (m³/s)  
a = Base of Earth Berming (m)  
b = Height of Earth Berming (m)  
c = Digonal length of Earth Berming (m)  
h = Heat Transfer Coefficient (W/m²-K)  
hi = Inside Heat Transfer Coefficient (W/m²-K)  
ho = Outside Heat Transfer Coefficient (W/m²-K)  
i = Building Element.  
m = Rate of Evaporation (kg/s)  
ΔR = Difference between the long wavelength radiation incident on the surface from the sky and the surroundings, and the radiation emitted by a black body at ambient temperature  
ΔT = Temperature difference between inside and outside air (K).  
αs = Mean Absorptivity of the Surface  
ε = Emissivity of the Surface (m²).  
ρ = Density of air (kg/m³)  
 Tmin = transmittivity of the ith transparent element  

2. THERMAL LOAD DESIGN CALCULATIONS.

Fig no: 1 Lawn Plus lateritic soil, brick wall with plasterer on both side and equivalent wall thickness.

Fig no: 2 Lawn plus black cotton soil, brick wall with plaster on both side and equivalent wall thickness.

Fig no: 3 Lawn plus porous soil, brick wall with plaster on both side and equivalent wall thickness.

2.1. Heat transfer and heat balance at Earth Berming by conduction, convection, and evaporation etc.

Heat Transfer by Thermal transmittance

\[ Q_{\text{conduction}} = A U \Delta T \]  

\[ U = \frac{1}{RT} \]  

\[ \Delta T = T_{\text{so}} - T_i \]

hi and ho respectively, are the inside and outside heat transfer coefficients of the and U indicates the total amount of heat transmitted from outdoor to indoor space through a given wall or brick wall 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 composite materials as described in above. The overall heat flow rate through the building envelope is expressed as:

\[ Q_c = \sum_{i=1}^{N_e} (A_i U_i \Delta T_i) \]  

If the surface is also exposed to solar radiation then,

\[ \Delta T = T_{so} - T_i \]

\[ T_{so} = T_i + \frac{\alpha S_T}{h_o} - \frac{\varepsilon \Delta R}{h_o} \]
2.2. Ventilation; The heat flow rate due to ventilation of air between the interior of a building and the outside depends on the rate of air exchange. It is given by:

\[ Q_v = \rho V r C \Delta T \]  

-------------------------- (7)

2.3. Solar Heat Gain; The solar gain through transparent elements can be written as:

\[ Q_s = \alpha_n \sum_{i=1}^{M} A_i \ v_{ei} \ t_i \]  

-------------------(8)

2.4. Internal Gain; Thus the heat flow rate due to internal heat gain is given by the equation

\[ Q_i = (\text{No. of people} \times \text{heat output rate}) + \text{Rated wattage of lamps} + \text{Appliance load} \]  

(9)

2.5. Evaporation; generally refers to the removal of water by vaporisation from aqueous solutions of non-volatile substances. It takes place continuously at all temperatures and increases as the temperature is raised. Increase in the wind speed also causes increased rates of evaporation. The latent heat required for vaporization is taken up partly from the surroundings and partly from the liquid itself. Evaporation thus causes cooling.

\[ Q_{\text{evaporation}} = m \times L \]  

------------------------- (10)

2.6. Equipment Gain; If any mechanical heating or cooling equipment is used, the heat flow rate of the equipment is added to the heat gain of the building.

2.7. Heat balance equation;

\[ Q_{\text{total}} = Q_c + Q_v + Q_s + Q_i + Q_{\text{ev}} + Q_{\text{equ}} \]  

(11)

\[ Q_v, Q_i, Q_{\text{equ}}, \text{this value are negligible in earth berthing system.} \]

\[ Q_{\text{total}} = Q_c + Q_{\text{ev}} \]  

------------------------- (12)

\[ Q_{\text{total}} = \sum_{i=1}^{N_c} \frac{A_i}{h_i} \frac{U_i}{A_i} \Delta_i + mL \]  

-------------------(13)

\[ Q_{\text{total}} = \sum_{i=1}^{N_c} \frac{A_i}{h_i} \left(\frac{T_{so} - T_i}{A_i} + (\sum_{j=1}^{N_c} \frac{L_j}{k_j}) - (1/h_o)\right) + mL \]  

(14)

3. TEST SET UP

Fig no 4. Experimental Setup and measurements locations.

4. RESULTS –

Graph no 1 Analysis for black cotton soil earth berthing.

Graph no 2 Analysis of black cotton soil earth berthing with lawn.
Graph no 3 Analysis of laterite soil earth berming

Graph no 4 Analysis of laterite soil earth berming with lawn.

Graph no 5 Analysis of porous soil in earth berming.

Graph no 6 Analysis of porous soil earth berming with lawn.

Graph no 7 Thermal transmittance (W/m²·K) for different types of soil with lawn against temperature difference.

The thermal transmittance calculated varies from 0.334 W/m²·K to 1.0031 W/m²·K.

4.1. Influence of Earth Berming on Comfort by Discomfort degree hours

The equivalent composite wall is considered for triangular earth berming shape and discomfort degree hours for hot and cool conditions are worked out for a moderate zone in India with 18°.32” North latitude and 73°.51” East longitude using Ecotech 11, simulation tools and results are compared with standard burned brick wall. They are represented in figs to.

Graph no 8 Discomfort degree hours --hot Vs Months

Graph no 9 Discomfort degree hours cool Vs Months
The laterite soil earth berming with lawn has been effective in reducing the discomfort hours as compared to that of burned brick solid wall. Lateritic soil with lawn results show that hot and cool discomfort degree reduced.

5. CONCLUSIONS

The thermal performance in terms of thermal transmittance using these materials are evaluated and analyzed as under:

1. Average U values of earth berming using black cotton soil of triangular shape for external wall are observed as 0.603 respectively.
2. Average U values of earth berming using black cotton soil with lawn of triangular shape for external wall are observed as 0.578 respectively.
3. Average U values of earth berming using Laterite soil of triangular shape for external wall are observed as 0.292 respectively.
4. Average U values of earth berming using Laterite soil with lawn of triangular shape for external wall are observed as 0.245 respectively.
5. Average U values of earth berming using Porous soil of triangular shape for external wall are observed as 0.709 respectively.
6. Average U values of earth berming using Porous soil with lawn of triangular shape for external wall are observed as 0.474 respectively.

Finally it is concluded that the U value of earth berming using Laterite soil with lawn is lowest 0.245 and is supported by reduction in discomfort hours over the year in a moderate zone in India, hence it is recommended for achieving comfort in building envelope.

6. REFERENCES

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