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

Mr. Prafull Tayshete*, Er. S.M.Bhosale R A Charate*** .Prof . N.N.Shinde***

**Department of Energy Technology, Shivaji University Kolhapur, India*
*** Department of Civil Engineering Shivaji University Kolhapur ,India*
****Principal SIT Polytechnic, Sangli,India*

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 Literite 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 = Extarnal Plastering (m2)
C = Specific Heat of Air (J/ kg-K)
D = Brick Mashnari (m3)
E = Internal Plasterig (m2)
F = Lawn (m2)
K1 = Thermal Conductivity of lawn (w/m2-K)
K2 = Thermal Conductivity of soil (w/m2-K)
K3 = Thermal Conductivity of Extarnal Plastering (w/m2-K)
K4 = Thermal Conductivity of Brike wall (w/m2-K)
K5 = Thermal Conductivity of Internal Plasterig (w/m2-K)
kj = Thermal Conductivity of its Material(W/m2-K)
L= Latent Heat of Evaporation (j/kg-k)
Lj= 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)
Qventilation = 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 = Temperctur of Outside of Earth Berming (K)
T2 = Temperctur of Lawn (K)
T3 = Temperctur of Soil (K)
T4 = Temperctur of External Plaster (K)
T5 = Temperctur of Brick wall (K)
T6 = Temperctur 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 = Tikanes of Lawn (m)
X2 = Tikanes of Soil (m)
X3 = Tikanes of Extarnal Plastering (m)

X4 = Tikanes of Brick wall (m)
X5 = Tikanes of Internal Plasterig (m)
U = Thermal Transmittance (W/ m2- K)
Vr = Ventilation Rate (m3/ s)
a = Base of Earth Berming. (m)
b = Hight of Earth Berming (m)
c = Digonal lenth of Eath Berming (m)
h = Heat Transfer Coefficient (W/m2-K)
hi = Inside Heat Transfer Coefficients(w/m2-K)
ho= Outside Heat Transfer Coefficients (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).
ΔT = Temperature difference (To – Ti) (K)
αs = Mean Absorptive of the Space
ε = Emissivity of the Surface (m2).
ρ = Density of air (kg/ m3)
T*i* = transitivity 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.

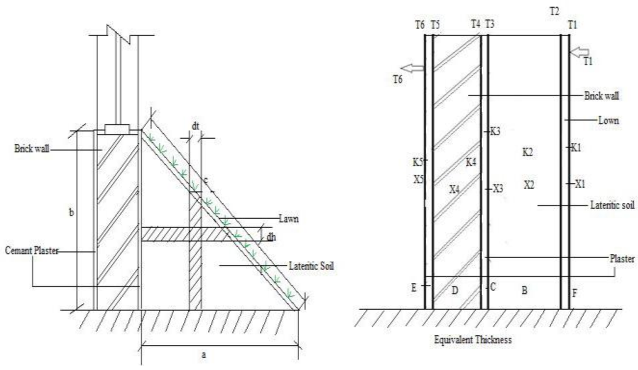


Fig no: 2 Lawn plus black cotton soil, brick wall with plaster on both side and equivalent wall thickness.

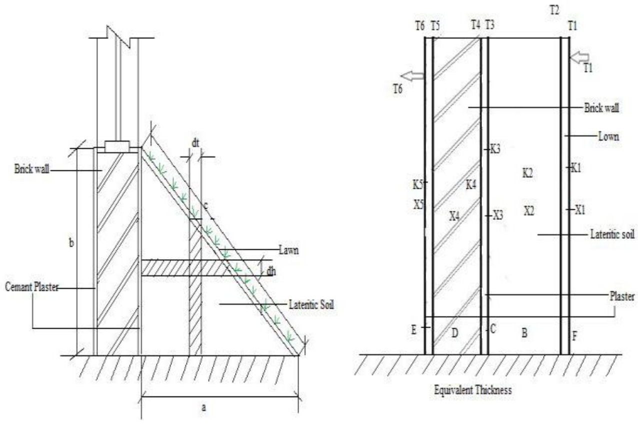
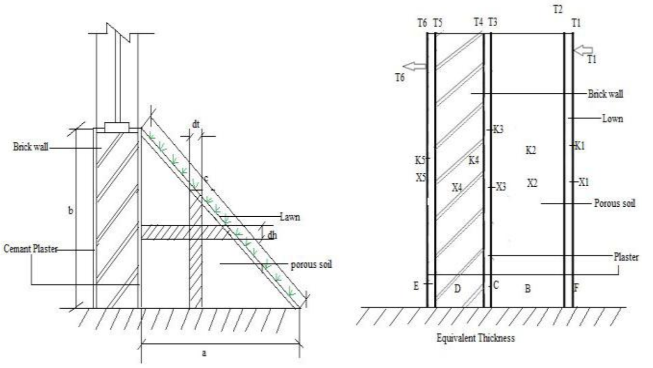


Fig no: 3 Lawn plus porous soil, brick wall with plaster on both side and equivalent wall thickness.



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

Heat Transfer by Thermal transmittance

Q conduction = A U ΔT -------------------- (1)

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

U=1/RT------------------------------ (2)

$$R_T = (1/hi) + (\sum_{j=1}^{m} Lj/kj) + (1/ho) \text{-------------(3)}$$

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 over al heat flow rate through the building envelope is expressed as:

$$Qc = \sum_{i=1}^{Nc} (Ai\ Ui\ \Delta Ti) \text{-------------(4)}$$

If the surface is also exposed to solar radiation then,

ΔT = Tso – Ti ------------------------------ (5)

$$T_{so} = T_0 + \frac{\alpha S_T}{h_0} - \frac{\varepsilon \Delta R}{h_0} \text{------------------(6)}$$

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:

$Qv = \rho \; Vr \; C \; \Delta T$ -------------------------- (7)

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

$$Q_S = \alpha_s \sum_{i=1}^{M} A_i \; S_{gi} \; \tau_i \text{------------}(8)$$

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

Qi = (No. of people × heat output rate) + Rated wattage of lamps + 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 evaporation = m x L ------------------- (10)

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

2.7. Heat balance equation ;

Q total = Q c + Q v +Q s + Q i + Q ev + Q equ – 11)

Q v , Q i , Q equ , this value are negligible in earth berming system.

Q total = Q c+ Q ev ------------------------ (12)

$$Q_{total} = \sum_{i=1}^{Nc} A_i \; U_i \; \Delta_i \; + \; mL - - - (13)$$

$$Q_{total} = \sum_{i=1}^{Nc} \frac{Ai(Tso - Ti)}{\frac{1}{hi} + (1/hi) + (\sum_{j=1}^{m} Lj/kj) + (1/ho)} + mL(14)$$

$$Q_{total} = \sum_{i=1}^{Nc} \frac{Ai\left(T_0 + \frac{\alpha S_T}{h_0} - \frac{\varepsilon \Delta R}{h_0} - Ti\right)}{\frac{1}{hi} + \frac{1}{hi} + \{\frac{x1}{k1} + \frac{\int_0^a da}{k2} + \frac{x3}{k3} + \frac{x4}{k4} + \frac{x5}{k5}\}}$$

$$Q_{total} = \sum_{i=1}^{Nc} \frac{\sqrt{a^2 + b^2}x1 + \sqrt{\int_0^a (da)^2 + \int_0^b (db)^2}\, x\,1 \; + 3b}{\frac{1}{hi} + \frac{1}{hi} + \{\frac{x1}{k1} + \frac{\int_0^a da}{k2} + \frac{x3}{k3} + \frac{x4}{k4} + \frac{x5}{k5}\}}$$

3. TEST SET UP

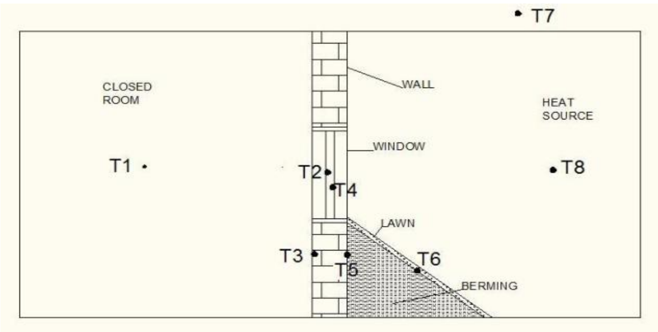
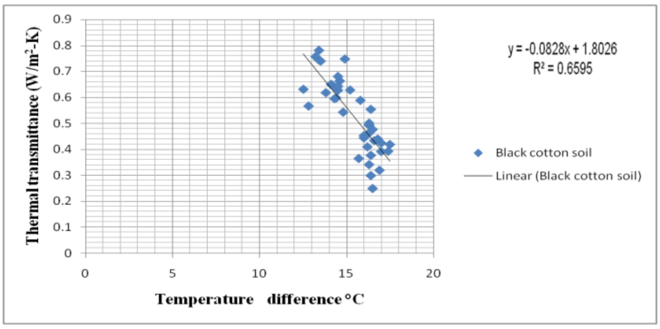
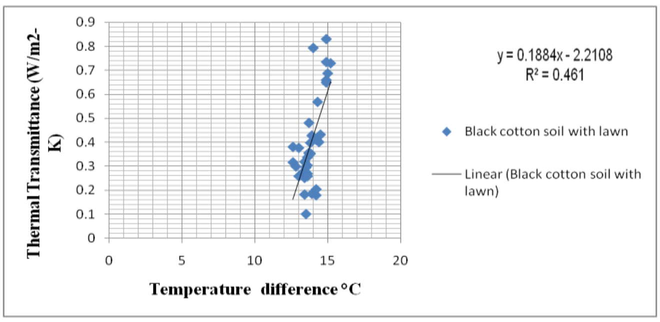


Fig no 4. Experimental Setup and measurements locations.

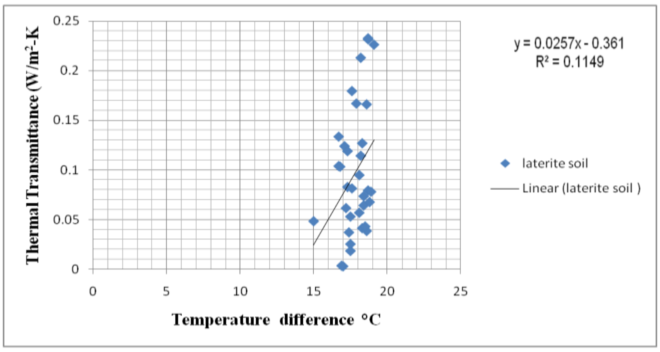
4. RESULTS –



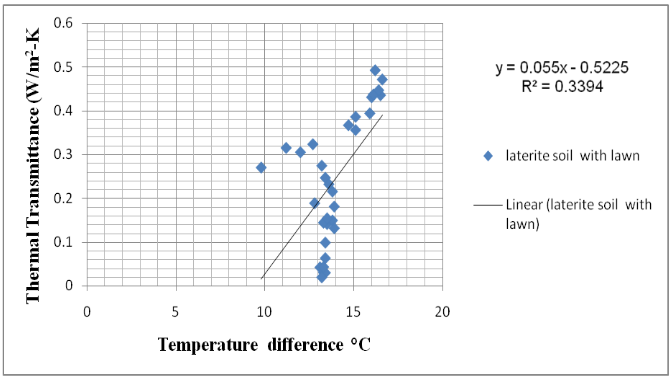
Graph no 1 Analysis for black cotton soil earth berming.



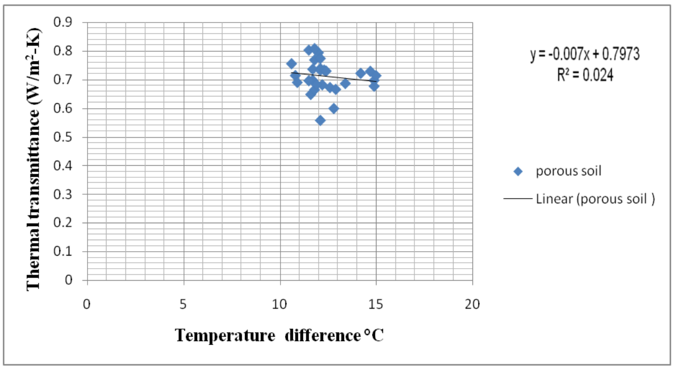
Graph no 2 Analysis of black cotton soil earth berming with lawn.



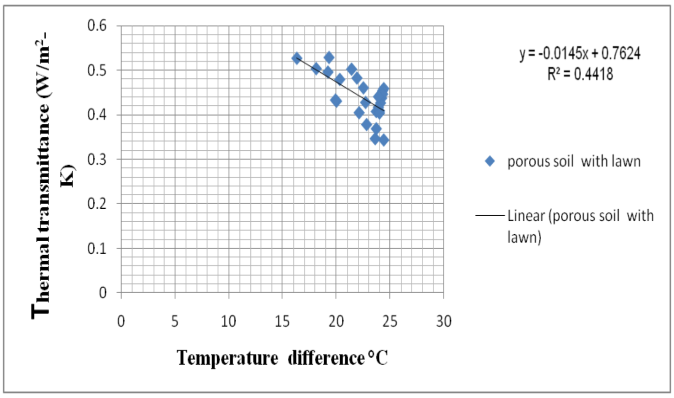
Graph no 3 Analysis of laterite soil earth berming



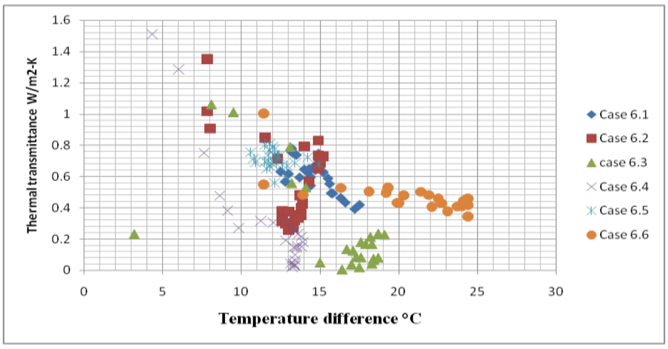
Graph no 4 Analysis of laterite soil earth berming with lawn.



Graph no 5 Analysis of porous soil in earth berming.



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

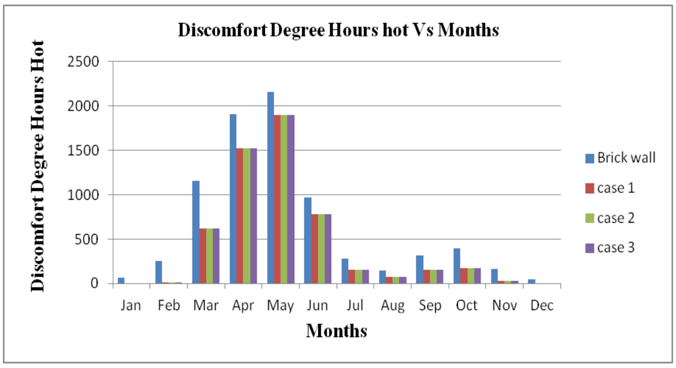


Graph no 7 Thermal transmittance (W/m²-K) for different types of soil with lawn against temperature difference.

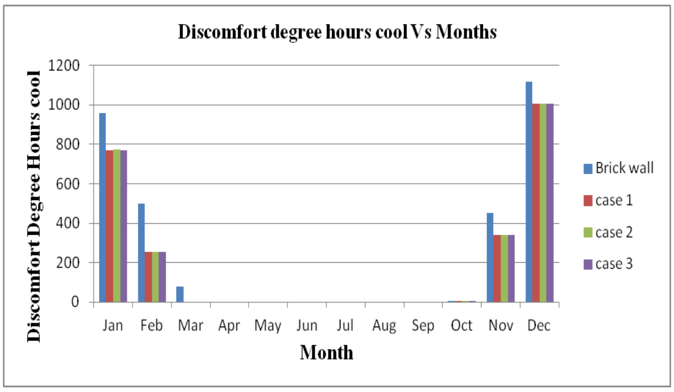
The thermal transmittance calculated varies from 0.334 W/m²-K to 1.0031W/m²-K.

4.1. Influence of Earth Bearming 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 content here.

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

1. Nayak J.K., Hazra R. and Prajapati J., Manual on solar passive architecture, Solar Energy Centre, MNES, Govt. of India, New Delhi, 1999
2. Sukhatme S.P., Solar energy, 2nd Edition, Tata McGraw Hill, New Delhi, 1996.
3. ASHRAE handbook: fundamentals, American Society of Heating, Refrigerating and Air-conditioning Engineers, Inc., Atlanta, GA, USA, 2001.
4. Ministry of non conventional energy sources, Government of India, New Delhi Manual on solar passive architecture: energy systems engineering IIT Delhi and Solar Energy Centre.
5. Nayak J K, Hazra R. Development of design guidelines by laws.
6. M. Staniec, H. Nowak; "Analysis of the earth-sheltered buildings"; Heating and cooling energy demand depending on type of soil Vol. XI 2011, P.P.1-15.
7. R.K.Rajput "Heat And Mass Transfer" S.Chand And Company Pvt Ltd.(An Iso 9001:2008 Company)
8. E.A. Rodriguez S. Alvarez, Ph.D. "Heat Transfer Analysis Of Ground-Coupled Structures"
9. Pawłowski Aleksander, Heim Dariusz Hensen Jan "Ground Source Heat Pumps Designed For Low-Energy, Earth-Sheltered Atrium Building" 9th polish conference of science and technology building physics in theory and practice'',pp.558-567
10. Xibin Mal,et al. "Finite Element Modeling of Coupled Heat and Moisture Transfer In Typical Earth-Sheltered Building Envelope" Eleventh International IBPSA Conference Glasgow, Scotland july 27-30,2009
11. Nayak & Prajapati by Handbook on Energy Conscious Buildings, 2006
12. Ravi Kapoor, Aalok Deshmukh and Swati Lal, Strategy roadmap for net zero energy buildings in India, USAID ECO-II Project, International Resources Group, AADI Building, New Delhi, August 2011.
13. Mani A., Handbook of solar radiation data for India, Allied Publishers, New Delhi, a. 1981.
14. Detailing of Concrete Masonry Vol-3, Published by Concrete Manufacturers Association, 2005.
15. Russil., "Thermal transmittance of walls of dwellings before and after application of wall insulation". Energy Saving Trust no. 222077, 2008.
16. Carroll D. Energy consumption and conservation in buildings: an international comparison. Proceedings of the Third International Symposium on Energy Conservation in the Building Environment, vol. 1A, CIB=AnForasForbartha, Dublin, 1982. p. 190–203.
17. Clark JA. Advanced design tools for energy conscious building design. Energy and the Environment into the 1990's, Reading,September
18. Wiki.naturalfrequency.com/ecotectcommunitywiki
19. www.autodesk.com/ecotectanalysis2011
20. www.accuweather.com