ANALYSIS OF A HOUSE WITH MUD LAYER IN ROOF FOR SUMMERS

R. K. Pal[1*]

[1] Department of Mechanical Engineering
Panjab University SSG Regional Centre,
Hoshiarpur (Pb.)

ABSTRACT

The brick & cement-concrete houses are not comfortable to live in the extreme weather conditions in many parts of India. So an enormous amount of energy is needed for heating and cooling. Here an effort is made to discover the outcome of using mud layer in the roof of a house on indoor room air temperature in summer season. It was found that a lesser room air temperature existed in case of a brick & cement-concrete house with mud layer in the roof as compared to a brick & cement-concrete house without a layer of mud in the roof in May to September. A maximum temperature difference of 1.04°C, 0.97 °C, 0.78°C, 0.70°C and 0.72°C is achievable in a brick & cement-concrete house with mud layer in the roof as compared to a brick & cement-concrete house without a layer of mud in the roof in May to September respectively. Energy and money are also saved by using houses with a layer of mud in the roof. Energy savings are of the order of 506 units of electricity and money savings have a value of Rs. 2528 in summer seasons from May to September for houses with layer of mud in the roof as compared to houses without layer of mud in the roof. Therefore the houses with a layer of mud in the roof are slightly more suitable for living in comparison to houses without layer of mud in the house in summer season in addition to savings in terms of energy and money.

KEYWORDS: *Mud layer house; Room air temperature; Solar irradiation; Energy savings.*

1.0 INTRODUCTION

The brick and cement-concrete houses are not comfortable to live in the extreme weather conditions in many parts of India. The summers in northern parts of India are very hot and winters are very cold. Therefore the indoor air temperature rises above comfort level in summers and falls below the comfort level in winters. The indoor air needs to be conditioned in order to make it comfortable for living. So a huge amount of energy is needed for heating and cooling (Pal, 2012 & Harvey, 2009). Rapid urbanization is another factor which is increasing the energy expenditure. Urban population is increasing at a fast rate in India (WBCSD, 2009 & Pal, 2015). The overall population in India is also increasing (Pal, 2015). These two factors are too causing the consumption of energy to increase. The use of energy efficient buildings can reduce this energy expenditure. These energy efficient buildings are also environment friendly and help in reducing pollution (Jadhav, 2007). The amount of cooling load depends on the cooling degree days.

*Corresponding author e-mail: ravinder_75@yahoo.com

In northern India the cooling degree days are usually highest for the month of May and reduce gradually to the month of September. Cooling load can be reduced with a large mass in the walls and the roof and this can save energy expenditure by reducing the indoor temperature variation (Eben, 1990). The roof is main source of cooling or heating load. Therefore the amount of energy expenditure can be reduced by using a layer of insulating material in the roof. Thermal insulation of the buildings can also be done by applying appropriate methods of insulation along with insulating building materials (Naseer, 2013). Due to the insulating properties of the mud, the overall heat transfer coefficient for mud walls is lower as compared to red brick walls ("Handbook of functional requirements of buildings", 1987, p. 37). Therefore a layer of mud in the roof of a brick and cement-concrete house can help to reduce the cooling load. Also rammed soil naturally controls the relative humidity of inside air in house and thereby improves air quality (Uthaipattrakul, 2004). These methods can be used for reducing the heating and cooling necessity as it will keep the indoor air temperature within comfort level. The effect of mud roof needs to be evaluated for savings in energy consumption for creating comfort conditions.

The present effort is to find out the effect of mud layer in roof of a house on the thermal performance of the house in summer season. Parameters like thermal conductivity of building materials like plaster, brick, cement concrete mixture and mud & solar irradiation etc. were taken from the available literature. The parameters like indoor air temperature, indoor relative humidity, outdoor air temperature, outdoor relative humidity were either computed or noted down.

2.0 MATERIALS AND METHODS

The types of houses considered for the study are a brick and cement-concrete house with layer of mud in roof (Figure 1) and a brick & cement-concrete house (Figure 2).

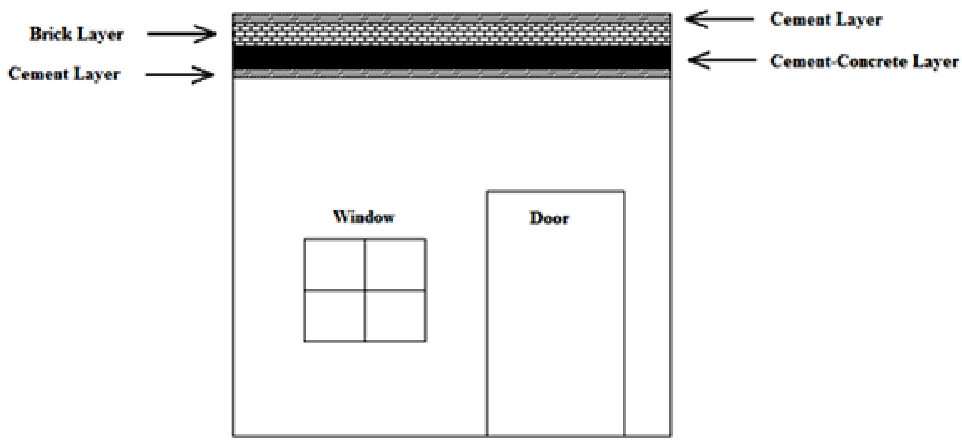

Figure 1. House without mud layer in roof

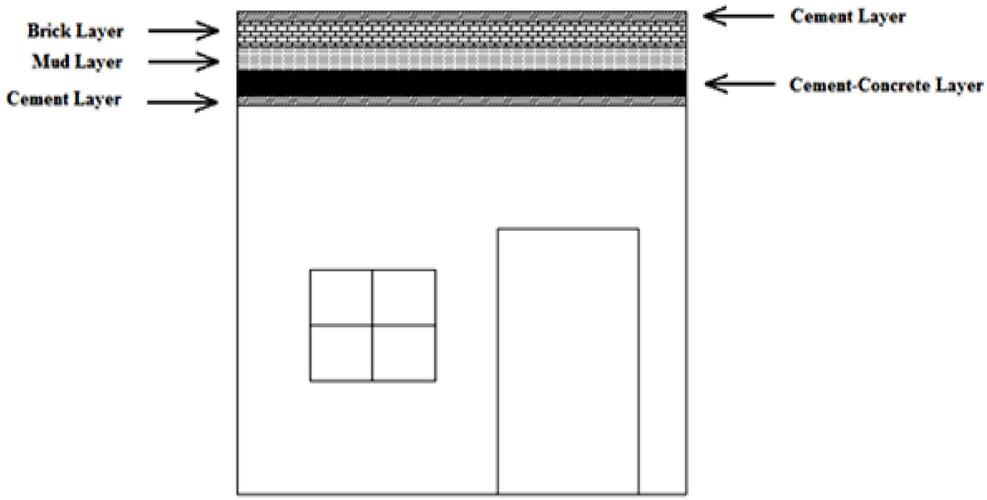

Figure 2. House with mud layer in roof

The exterior area exposed to the solar radiation is equal for both the houses. However lesser amount of heat will be transferred to the indoor air in case of mud layer house. The thermal resistance for brick cement-concrete and the house with mud layer is 0.010 °C/W and 0.065 °C/W respectively. The daily average temperature and solar irradiation was taken from the available literature and the room air temperature was computed. Following formulae (Equations 1-9) were used for calculations: -

The Sol-air temperature, T_{sa} (Chel & Tiwari, 2009) is given as;

$$T_{sa} = T_h + \frac{\alpha I_t}{h_o} - \frac{\varepsilon \delta R}{h_o} \tag{1}$$

The total heat gain by house, Q_{gain} is given as;

$$Q_{gain} = Q_{roof} + Q_{wall} + Q_{window} \tag{2}$$

The total heat loss from the house, Q_{loss} is given as;

$$Q_{loss} = Q_{venti} \tag{3}$$

The heat gain from the roof, Q_{roof} is given as;

$$Q_{roof} = U_{roof} * A_{roof} * (T_{sr} - T_{ra}) \tag{4}$$

The heat gain from the walls, Q_{wall} is given as;

$$Q_{wall} = U_{wall} * A_{wall} * (T_{swall} - T_{ra}) \tag{5}$$

The heat gain from the windows, Qwindow (Chel & Tiwari, 2009) is given as;

$$Q_{window} = A_{window} * \tau * I_t + U_{window} * A_{window} * (T_{swindow} - T_{ra}) \tag{6}$$

The heat loss due to ventilation, Q_{venti} (Chel & Tiwari, 2009) is given as;

$$Q_{venti} = \frac{\rho_a V_{ra} c_{ra} N(T_{ra} - T_a)}{3600} \tag{7}$$

Heat balance for the house, (Chel & Tiwari, 2009) is given as;

$$M_{ra}C_{ra}\frac{dT_{ra}}{dt} = U_{roof} * A_{roof} * (T_{sr} - T_{ra}) +$$

$$U_{wall} * A_{wall} * (T_{swall} - T_{ra}) + A_{window} * \tau * I_t +$$

$$U_{window} * A_{window} * (T_{swindow} - T_{ra}) + \frac{\rho_a V_{ra} c_{ra} N(T_{ra} - T_a)}{3600} \tag{8}$$

Energy saving potential of the house with mud layer in roof, E_s (Pal, 2015) is given as;

$$E_s = \frac{M_{ra}C_{ra} * (T_{ml} - T_{wml})}{3600} \tag{9}$$

3.0 RESULTS AND DISCUSSIONS

The room air temperature for brick & cement-concrete houses with and without mud layer is compared in the Figure 3 to Figure 7 for a very hot day in May to September respectively. Room air temperature was lower in case of house with a layer of mud in the roof as compared to a house without mud layer in the roof in the month of May to September. The lesser value of indoor room air temperature in a house with a layer of mud in the roof is because the mud has more heat capacity and lower thermal conductivity as compared to a house without layer of mud in the roof. The room air temperature is lower in case a house with mud layer as compared to a house without a mud layer throughout the day and night due to the reason explained. The maximum value of difference in room air temperature (Figure 3 to Figure 7) in a house with a mud layer in roof is 1.04°C, 0.97 °C, 0.78°C, 0.70°C, 0.72°C as compared to a house without mud layer in roof in May to September respectively. The difference in temperature for the two houses decreases from May to August due to fall in the outside temperature or in other words fall in cooling degree days . But the difference in temperature for two types of houses increases slightly in September as compared to that in August due to slight increase in outside temperature in September. Energy and money are saved by using houses with a layer of mud in the roof. Energy savings (Figure 8) are of the order of 119, 112, 99, 87, 89 units of electricity in the month of May to September respectively. A total of 506 units of electricity can be saved for the summer season per house. Money savings (Figure 9) have a value of Rs. 594, 561, 494, 435, 443 in May to September respectively for a house with layer of mud in the roof as compared to a house without layer of mud in the roof. A total of Rs. 2528 can be saved for the whole summer in case of a house with mud layer in the roof.

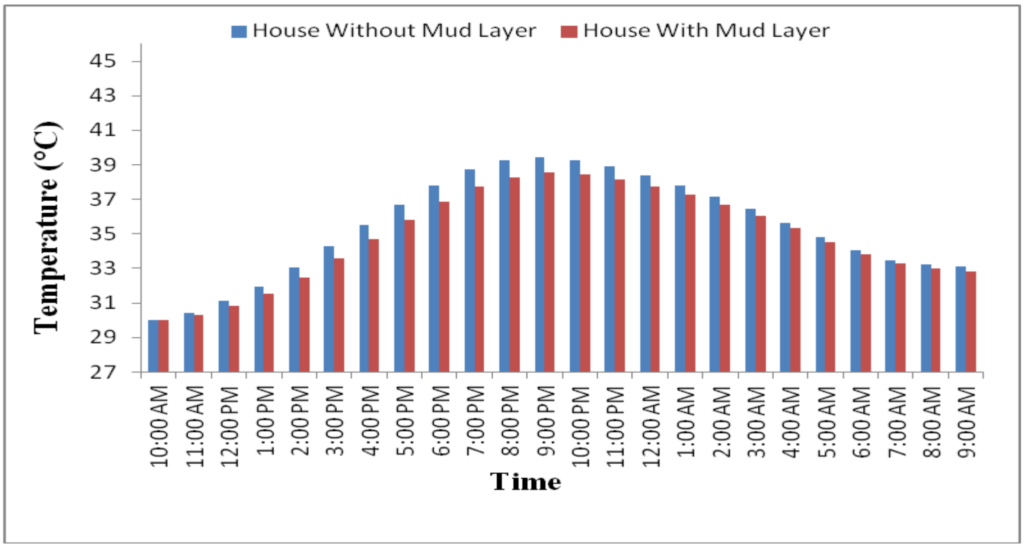

Figure 3. Room air temperature variation inside house in May

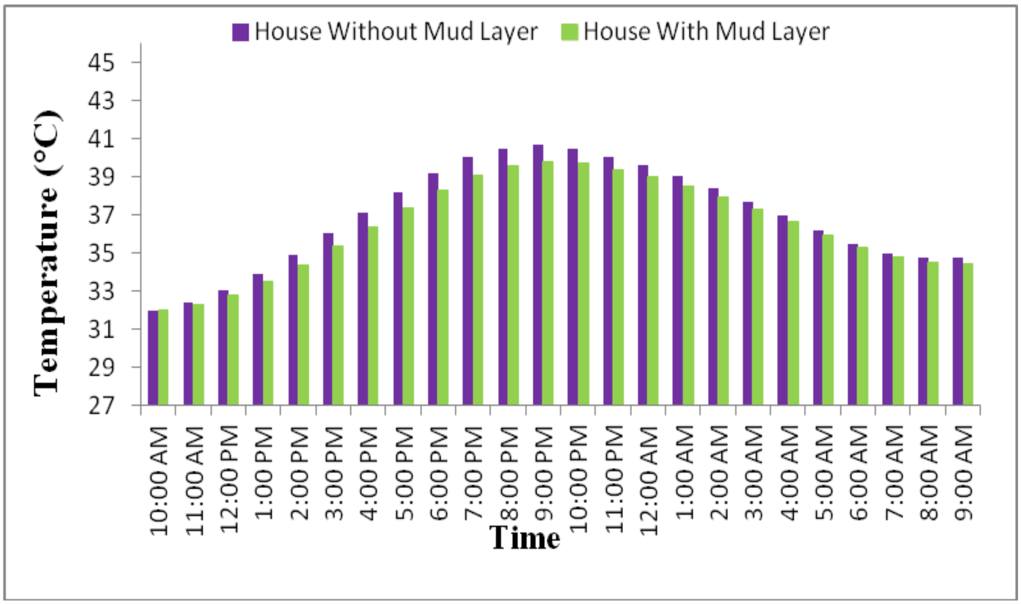

Figure 4. Room air temperature variation inside house in June

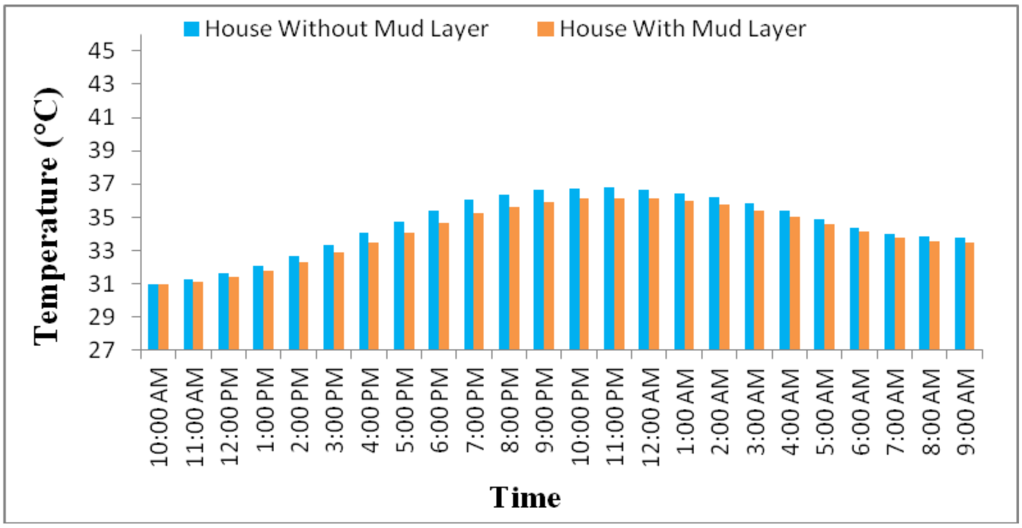

Figure 5. Room air temperature variation inside house in July

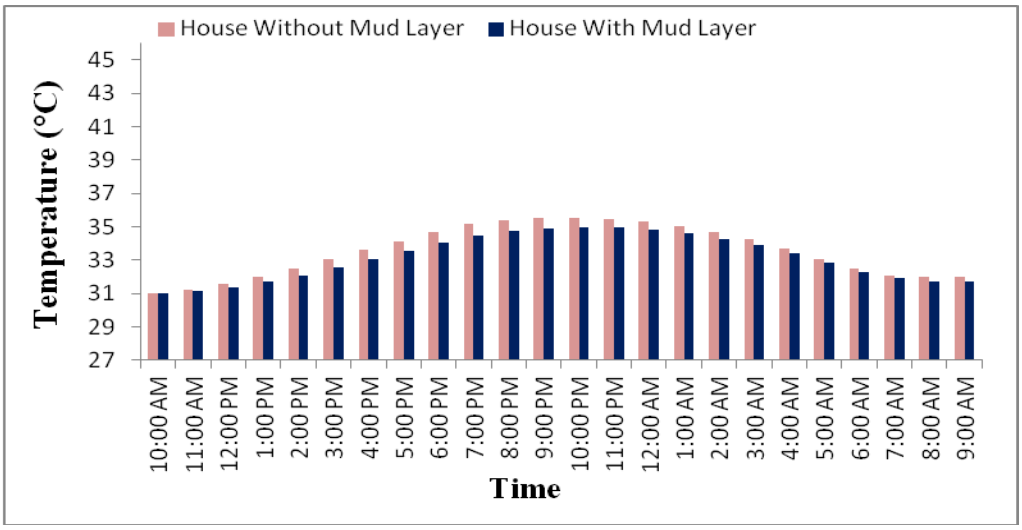

Figure 6. Room air temperature variation inside house in August

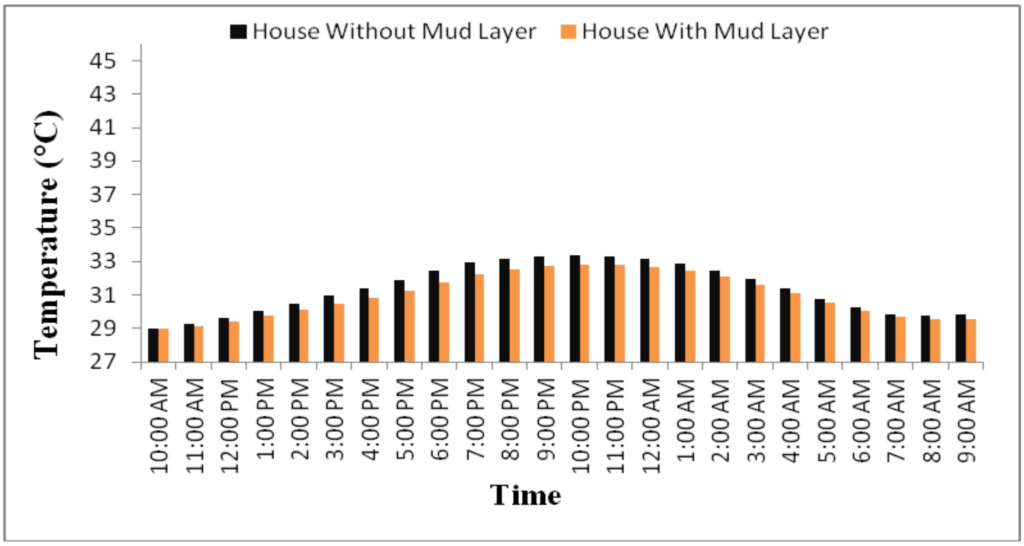

Figure 7. Room air temperature variation inside house in September

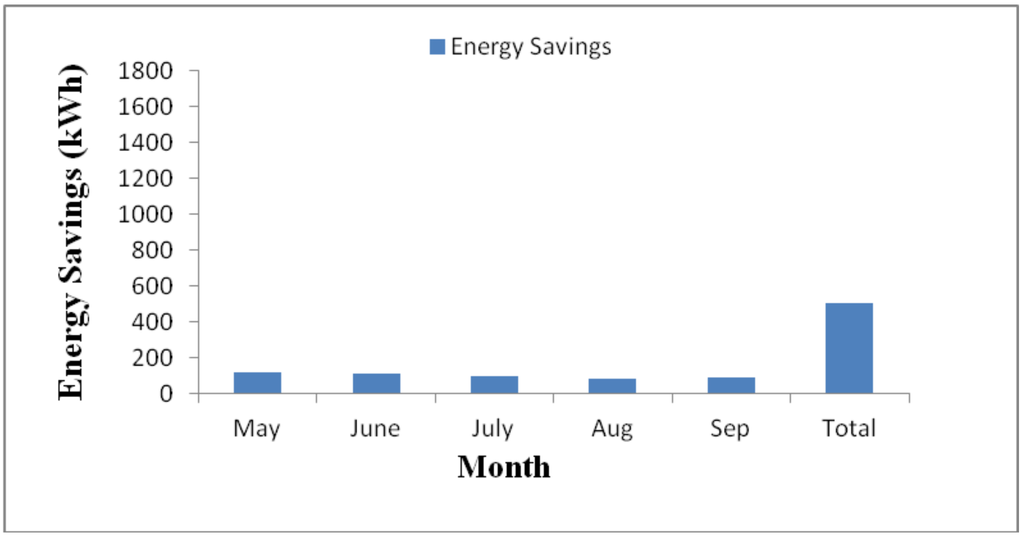

Figure 8. Energy savings for the mud layer house in summers

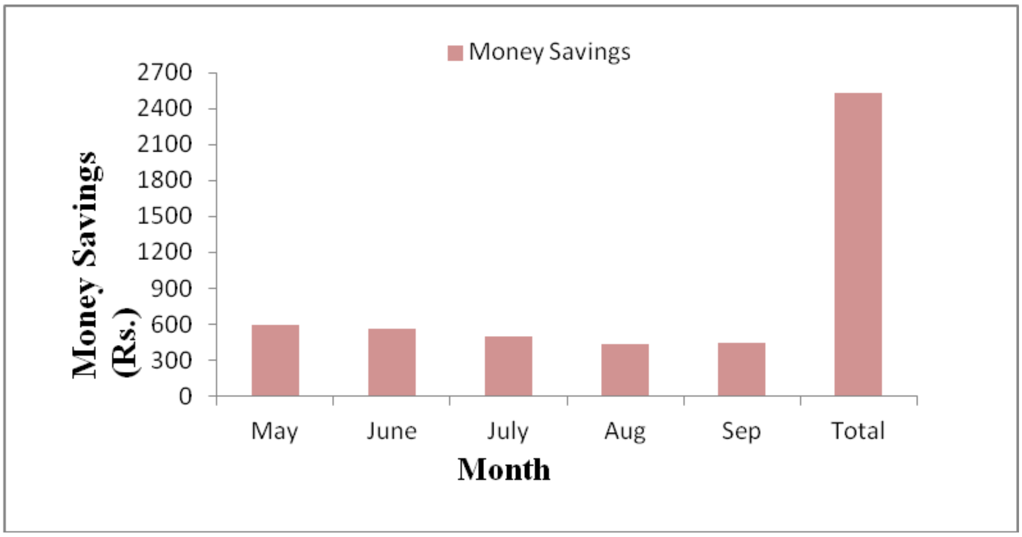

Figure 9. Money savings for the mud layer house in summers

4.0 CONCLUSIONS

Lower value of room air temperature exists in case of a brick and cement-concrete house with a layer of mud in the roof as compared to a brick & cement-concrete house without a layer of mud in the roof in May to September. A maximum difference of 1.04°C, 0.97 °C, 0.78°C, 0.70°C and 0.72°C in temperature exists in a house with a layer of mud in roof as compared to a house without a layer of mud in the roof. Energy and money are saved by using houses with a layer of mud in the roof. Energy savings are of the order of 119, 112, 99, 87, 89 units of electricity in the month of May to September respectively. Money savings have a value of Rs. 594, 561, 494, 435, 443 in May to September respectively. Total energy savings are of the order of 506 units of electricity and money savings have a value of Rs. 2528 for summer season from May to September for houses with layer of mud in the roof as compared to houses without layer of mud in the roof. Therefore the houses with a layer of mud in the roof are slightly more suitable for living in comparison to houses without layer of mud in the house in summers in addition to savings in terms of energy and money.

NOMENCLATURE

T_{sa}	= Sol-air temperature (°C).
T_{sr}, T_{swall}, $T_{swindow}$	=Sol-air temperature for roof, wall and window respectively (°C).
T_h	= Current outside dry bulb temperature (°C).
T_{ra}	= Current room air Temperature (°C).
T_{ml}, T_{wml}	= Current room air Temperature for house with and without mud layer respectively (°C).
α	= Surface absorptance for solar radiation.
I_t	= Total incident solar load (W/m^2).

δR	= Difference of longwave radiation incident on the surface from the sky and surroundings and the radiation emitted by a black body at outdoor air temperature (W/m^2).
h_o, h_i	= Film co-efficient over the building and for indoor air respectively (W/m^2-K).
$\varepsilon\delta R/h_o$	= Longwave radiation factor.
U_{roof},U_{wall}, U_{window}	= Overall heat transfer coefficient for roof, walls and window respectively (W/m^2-K).
A_{roof}, A_{wall},A_{window}	= Area of the roof, walls and window respectively (m^2).
K_1,K_2,K_3, K_4 mud	= Thermal conductivity of cement, cement-concrete, brick and layer (W/m-K).
δ_1,δ_2,δ_3, δ_4	= Thickness of cement, concrete, brick and mud layer respectively (m).
Q_{roof},Q_{wall},Q_{window}	= Heat gain through roof, walls and windows respectively (kJ/s).
Q_{venti}	= Heat loss due to ventilation (kJ/s).
Q_{gain}, Q_{loss}	= Total heat gain and heat loss (kJ/s).
ρ_a, V_{ra}, C_{ra}, M_{ra}	= Density (kg/m^3), Volume (m^3) and Specific heat (kJ/kg-K) and Mass (kg) of room air respectively.
E_s	= Energy saving potential of the house with mud layer in roof.

REFERENCES

Handbook of functional requirements of buildings (other than industrial building). SP: 41(S&T) (1987). New Delhi: Bureau of Indian Standard. p. 37.

Chel Arvind & Tiwari, G.N. (2009). Performance evaluation and life cycle cost analysis of earth to air heat exchanger integrated with adobe building for New Delhi composite climate". *Energy and Buildings*, *41*, 56–66.

Eben, S.M.A. (1990). Adobe as a thermal regulating material. *Solar Wind Technology*, *7*, 407–416.

Harvey, F. (2009, April). Efforts increase to improve sustainability. Energy Efficient Buildings, *Financial Times*. 1-3.

Jadhav, R. (2007). Green architecture in India: Combining modern technology with traditional methods. *UN Chronicle*, *154* (2), 66-71.

Naseer, M. A. (2013). Energy Efficient Building Design: Revisiting Traditional Architecture. *The Asian Conference on Sustainability, Energy & the Environment, Official Conference Proceedings*, Osaka, Japan, 2013 (pp. 470-482).

Pal, R. K. (2012). Analysis of Geothermal Cooling System for Buildings. *International Journal of Engineering Sciences & Research Technology*, *1*(10), 569-572.

Pal, R. K. (2015). Thermal Performance of Mud Houses. *Research Journal of Engineering and Technology, 6*(4), 439-442.

Uthaipattrakul, Dh. (2004). *Mud-house construction technique. Building the house with mud.* Suan-ngarn-mena Press, Bangkok, 27-50.

WBCSD (2009). Energy efficiency in buildings: Transforming the market. A Report by World Business Council for Sustainable Development.