International Journal of Advance Research and Innovation
Vol. 9(2), Apr-Jun 2021, pp. 108-114
Doi: 10.51976/ijari.922117

Article Info

Received: 07 Jan 2021 | Revised Submission: 28 Apr 2021 | Accepted: 05 May 2021 | Available Online: 15 Jun 2021

Energy Saving Analysis for Mud Wall Construction

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ABSTRACT

In building construction, the energy saving is very important for coming day. Energy saving is closely related with conservation of energy. The consequences of conservation of energy related to efforts reduce to consumption of energy. A certain amount of energy may be saved , when critical thickness of insulation is used in building walls. The purpose of thermal insulation is to keep the indoor temperature constant due to variation of atmospheric temperature. The main aim of mud wall construction is to save considerable amount of energy by providing a more stable temperature and reduces the heat losses through outer boundary of walls. Mud is act as a thermal mass due to it absorbs sun heat during day hours and keep the building warm during night. The energy saving by using mud insulation and straw material for the analysing the mud wall constructed room dimension (10 m x 8 m x 7 m) situated at Ghaziabad near Salimar Garden has been selected. The studies are carried out for varied thickness of insulation mud dung slurry. This study found that mud wall insulation is most economic insulation. In this analysis, it is observed that 51 % of energy is conserved by the application of mud dung slurry insulation for mud wall construction. In our result, 0.068 m optimum thickness of mud wall construction has been calculated, when insulation is used.

Keywords: *Energy saving; Mud wall; Heat transfer; Insulation; Thickness.*

1.0 Introduction

The energy requirement among four main sectors: industrial with any size from small scale industry to big scale industry, building construction, transportation and cultivation sector. Among the mention sectors, building construction region is highest energy consumption sector. In building construction, the most efficient method to save the energy is to use optimal thickness of insulation. The basic purpose of thermal insulation is minimizing the transfer of heat through outer boundary of building. Those insulation materials is more effective, whose thermal conductivity has less value. When use the suitable insulation material, then heat losses through building wall will be decreased and space heating cost of building has been also decreased. Therefore thermal comfort will be increased.

Durmayaz et al.[1] had used Degree-hours method to calculate the heating load requirement in building.Comakli and Yuksel[2] had observed that colder region require higher insulation as compaired to hotter due to higher value of Degree-dayse in cold climatic region.. Al-Sanea et al.[3] had investigate the significance of cost rate of electricity for different load condition in building wall after the application of insulation. IN this analysis the author used the economic model of heat transfer at the dynamic condition. Lu et al.[4] had determined the variation of outer boundary temperature and unsteady temperature in building by analytical method.Dombaycr et al.[5] had determine the critical insulation thickness of building construction for various fuels and different insulating materials for city Denizli (Turkey). Mahlia et al.[6] had established the relation between thickness and thermal conductivity of selected insulating materials for construction of building . Yildiz et al.[7]had determined the optimum thickness of insulation and heat energy for different construction of building.

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During analysis, the author considered two different climatic zone in turkey. In this analysis, Extruded Polystyrene and Rock wool was considered as insulation materials. Chel and Tiwari[8] had investigated thermal aspect of mud wall construction with vault roof. Mud wall building act as pollution free and has less energy consumption. The author show that the Energy requirement for mud wall construction at New Delhi(India) is less as compared to red brick construction. Daouas et al.[9] calculated the of insulation at which the heat loss is minimum for outer surface of building walls in Tunisia. Mishra and Usmani[10]had calculated the thermal resistance of mud wall and brick wall and conculed that less energy is required in mud wall as compared to brick wall .

On the basis of literature survey, it is observed that brick wall building has been analysed by most of the authors. But in India, there are many places at which there are occurrence of building constructed by stone, brick and mud wall. Optimum insulation thickness and Energy saving has been determined by many of the author at different region of world (Turkey and China). In this paper, I have analyses the effect of insulation on mud wall construction. Hence the present work based on thermal behavior of mud wall building in the term of Energy application. In this study, Degree-days Method is considering for determination of the heating/ cooling load of mud wall construction. This study primarily emphasis on the thermal performance of mud wall building construction. The study has been carried out to know the variation of monthly cost with different insulation thickness and result show that at optimum insulation thickness, energy saving has maximum value. The energy saving has been calculated for different month of year in India for mud wall construction.

2.0 Importance of Energy Conservation

It is compulsory to conserve energy for India due to energy demand gradually increases in its developing process. Whether a household or a plant, a small shop or a large commercial building, a farmer or a office worker, every uses the energy in different form. Every day use any kind of automobile for various purposes. In general for running of automobile any type of fuels like petrol, diesel or gas are used. Petroleum resources are gradually decreases due to increase demand. So it is necessary to efficiently use of fuel. For doing any activity depend upon any type of energy. For making our life comfortable and enjoyable, need any type of energy. If there is variation of temperature as compared to comfort temperature, then use air condition for cooling of the room. This incident is closely related with consumption of energy resources. Due to inadequate amount of energy resources, it is our duties to use the energy resources effectively.

One must uses energy efficiently, otherwiseenergy will not left for coming days. Energy conservation is also necessary when there is variation of climate condition. Presently, facing unpredictable climates changes. Hence there is need of energy saving. Benefit of energy saving are to wasting less money, wasting less primary fuel like coal, gas, oil etc. and producing less pollution.

3.0 Advantages of Mud Wall Construction

Mud wall construction has following advantages:

a) The mud wall house has been found to be superior then brick wall construction due to reducing large fluctuation of indoor temperature throughout the summer and winter season.
b) The mud construction has thick wall which provides excell thermal mass and it easily keeps warm in winter and cool in summer. Mud walls act as a thermal buffer inside the room due to high thermal mass.
c) By minimizing the heat losses from building walls, it conserved the energy.
d) Less cost is required for construction of mud wall as compared to other construction.
e) To minimize the emission of greenhouse gas through building construction due to use of Adobe, Mud, Cow Dung, Straw and other local byproduct material of agriculture i.e. low energy intensive material.

3.1 Drawback of mud wall construction

There are following limitation of mud wall construction;

a) Damage caused by insufficient strength foundations
b) Damage caused by the effect of exterior forces such as airstream and rain water

c) Problems caused by additional moisture or rain water or humidity at the outer surface of mud wall
d) High maintenance is required.

3.2 Insulation used in building walls

There is following insulations material used for residential and commercial insulation: Extruded polystyrene, Expanded polystyrene, polyurethane (PUR), and Glass wool. Each insulation has specific characteristics type for particular building applications. In general, thermal insulation for walls is using with high R-value insulation material.

There are following insulation, which is used in the construction of building:

a) Fiberglass
b) Expanded perlite
c) Expanded polystyrene(EPS)
d) Rockwool
e) Extruded polystyrene(XPS)
f) Polyvinyl chloride

3.2.1 Fiberglass

Fiberglass matting has following advantages:
High fire resistance

a) Can withstand higher temperature
b) Available in various forms (e.g. blankets, mats and boards)
c) Low thermal conductivity
d) High thermal resistance
e) Compressed fiberglass is used to made rigid board panel.

It has following disadvantages:

a) Poor compressive strength
b) Its permeability to moisture is higher

3.2.2 Expanded perlite

Expanded Perlite consist of silica and aluminium and it has impurities like Na2O, CaO, MgO and K2O. It is a chemically inert in nature. Its thermal conductivity is about 0.047 W m-1 °C-1.

It has good insulating efficiency when it is in dry or loose granular state. It has high resistance to fire, high heat resistance and low thermal conductivity.

3.2.3 Expanded polystyrene

When beads of polystyrene plastic or white pearls beads will expanded at suitable temperature and pressure, then expended polystyrene will formed. In general, expanded polystyrene are made by two methods i.e. (Extrusion method and moulding of slabs). Out of these methods, extrusion method is best method for manufacturing of expanded polystyrene. In extrusion process, the polystyrene plastic beads are mixed with solvent by adding gas at high pressure and finally required thickness of expanded polystyrene is obtained by extruding the mixture. It has high resistance to fire, high heat resistance and low thermal conductivity.

Expanded polystyrene foams have following disadvantages:

a) They are flammable
b) In presence of direct sunlight, it gradually break
c) They react with organic solvents like petrol, acetone, kerosene as well as solvents used in the installation of fiberglass- reinforced plastic

3.2.4 Rockwool

Rockwool is a mineral fiber. It is manufactured by melting basalt and coke in a cupola at about 14800c. For manufacturing of Rockwool, Phenolic binders are used. It is Suitable for high temperatures. It is used to insulate heat exchangers, driers, boilers, industrial ovens and high temperature pipes. It is available in matts, blankets, loose form or performed for pipe insulation. It has high mechanical strength, highly fire resistance, heat resistance and chemically inert.

Rock wool blanket can be placed under ceilings and floors to absorbed vibration and noise. Rock wool slab is mainly used for the thermal insulation of the roof of the building and building wall. Rock wool mattress is also used in building air conditioning pipe insulation, wall thermal insulation and sound absorbing.

3.2.5 Extruded polystyrene

It has better moisture resistance as compared to other insulation materials. There is serious effect on building material due to temperature fluctuations, above and below freezing, in the presence of moisture. But due to moisture resistance characteristic, it protect the building material to corrosion or any other types of damage.

It is not affected by the climate variation so it may be stored outside. The surface become dusty and pale, when it is kept in ultra violet radiation of sunlight. This will have no significant effect on insulating characteristic unless the surface is eroded or thickness is reduced.

3.2.6 Polyvinyl chloride

Polyvinyl chloride insulation is mainly used for wire and cable at the prescribed temperature. This insulation is generally used in power and control circuits at the specified thickness and voltage ratings and to dry locations. Polyvinyl chloride has a following advantages:

a) High shock resistance
b) High distortion resistance
c) High tensile strength and elongation for oil resistance test.

4.0 Method of Optimization for Insulation Thickness and Energy Saving

Heat loss will take place through outer surface of building wall and each wall surface due to temperature difference between atmosphere and inside room. For unit surface area, the heat loss through external surface is calculated by given equation,

$$\Delta Q = U \times (T_b - T_o) \quad ...(1)$$

Where U is overall heat transfer coefficient , T_b and T_0 is the wall and ambient temperature respectively.

The total cost is mainly depend upon insulation cost and Energy cost at the times of estimation. The total cost consumption over the useful life of the building can be calculated as

$$C_T = PWF\left[\frac{C_F}{H_{LH}\eta_H} + \frac{C_E}{COP}\right] \times \frac{T_o - T_b}{R_w + \frac{x}{K}} + C_i \times x \quad ...(2)$$

CT , CF , CE and Ci are the total cost, cost of Fuel, cost of electricity and insulation cost respectively. Rw, x and K is the thermal rasistance of walls, thickness of insulation and thermal conductivity of insulation material respectively. COP, PWF, and HLH is the coefficient of performance, present worth factor anf heating value of fuels respectively.

For obtaining the optimum insulation thickness(Xopt), the first derivative of total cost C_T with respect to x is taken as zero. The mathematical expression of xopt can be written as

$$X_{opt} = \left[\frac{K \times PWF}{C_i}\left(\frac{C_F}{H_{LH}\eta_H} + \frac{C_E}{COP}\right) \times (T_o - T_b)\right]^{0.5} - KR_W \quad ...(3)$$

The expression of Pay-back period (pbp) is written as

$$\frac{C_{Ins}}{A_S} = \frac{(1+R)^{pbp} - 1}{R(1+R)^{pbp}} \quad ...(4)$$

Simple pay-back period can be represented by C_{Ins}/A_s. Energy saving can be calculating as follow

$$E_S = C_T - C_{Ins} \quad ...(5)$$

Table 1: Total Cost (Yearly) for Mud Wall Constructions in Presence of Mud Dung Slurry Insulation

S. No.	Insulation thickness (m)	Annual cost(Rs)			Energy Saving (E_s) in Rs/m^2
		Fuel cost	Insulation cost	Total cost	
1	0	1700	0	1700	0
2	0.02	850	120	970	730
3	0.04	555	240	795	905
4	0.06	390	360	750	950
5	0.068	332	408	740	960
6	0.08	305	480	785	915
7	0.10	225	600	825	875
8	0.12	175	720	895	805
9	0.14	150	840	990	710

The total cost for different thickness of insulationin the case of Mud wall construction is represented in Table 1.

In presence of mud dung slurry insulation for mud wall building, the calculated value of optimum insulation thickness is 0.068 m. From the above Table 1., it can be concluded that Energy saving will gradually increase up to certain stage(at the point of optimal thickness) and then after decrease. Therefore insulation thickness installation is more useful at Optimum insulation thickness.

4.1 Energy saving in different month of year for mud house construction

In year 2019, there are eight months in the region of Ghaziabad (India) in which cooling are required for comfort condition and rest of four month heating is required.Energy saving can be defined as the total amount of energy cost saving in the term of money, when the building outer surface has been covered with suitable insulation material at its critical thickness In this year, March month has least energy required and june month has more energy required as compared to other month . In such type of construction, the amount of heating and cooling load saved as 213 Kwh and 330 Kwh respectively. During the year 2019, Month biased energy scenarios are

shown in Table 2. In this year, the energy requirement for such type of construction with and without the insulation is 484 Kwh and 1027 Kwh respectively. On the basis of above analysis, 51 % of the energy has been saved for such type of construction with mud dung slurry insulation.

Table 2: Month Biased Energy Saving Scenarios for Mud House With Insulation

S. No	Month	Energy potential (Kw) With insulation	Energy cost (Rs) With insulation	Energy Saving (Rs)	% Energy Saving
1	January(H)	40	200	325	12
2	February(H)	55	275	200	8
3	March(C)	25	125	100	4
4	April(C)	40	200	175	7
5	May(C)	45	225	275	10
6	June(C)	50	250	400	15
7	July(C)	52	260	165	6
8	August (C)	40	200	175	7
9	September (C)	35	175	130	5
10	October (C)	30	150	160	6
11	November (H)	42	210	290	11
12	December (H)	40	200	250	9

Table 3: Month Biased Energy Saving Scenarios for Mud House Without Insulation

S. No	Month	Energy potential (Kw) Without insulation	Energy cost (Rs) Without insulation	Energy Saving (Rs)	% Energy Saving
01	January (H)	105	525	325	12
02	February (H)	95	475	200	8
03	March (C)	45	225	100	4
04	April (C)	75	375	175	7
05	May (C)	100	500	275	10
06	June (C)	130	650	400	15
07	July (C)	85	425	165	6
08	August (C)	75	375	175	7
09	September (C)	65	305	130	5
10	October (C)	62	310	160	6
11	November (H)	100	500	290	11
12	December (H)	90	450	250	9

After analysis of energy saving for mud house, the heating andcooling energy saving is shown in Table 2. Thermal conductivity and thickness of insulating material has significant effect on Energy saving. When thickness of insulation material is increasing, then heat transfer rate will gradually decrease. But due to increase of thickness, insulation cost will increase. For compensation of increase of insulation cost, optimum thickness of insulation has been selected. It is observed that at optimum insulation thickness, energy saving has maximum

5.0 Results and Discussion

The intensity of solar radiation will be changed from morning to evening of the days in any season like winter or summer. Atmospheric temperature is also affected due to solar radiation. Mud has specific properties like high resistivity, high heat capacity and higher value of thermal mass. So temperature inside the room of mud house is less as compared to ambient temperature and variation of temperature is also less i.e uniform temperature. Fig. 1 shows the variation of different cost with insulation thickness for such type of construction in the presence of insulation.With increase of insulation thickness, heat transfers across surface of wall will gradually decreases so less energy sources will required for comfort condition.At this instant insulation cost increase. For compensation of increase of insulation cost, use optimum insulation thickness so that overall total cost is optimized. At optimum thickness, increase of insulation cost is balanced with decrease with energy cost.

Figure1, illustrate that with the variation of insulation thickness, the different cost will be changed. Insulation cost is balanced with fuel cost. Total cost (i.e algebraic sum of fuel and insulation cost) is minimum at optimum thickness of insulation.The outcome of Fig. 1 is the total cost is Rs 740 at optimum thickness of 0.068 m for mud house.

Figure 2, shows the amount of Energy saving with the change of insulation thickness for Mud house with Mud dung slurry insulation. The energy saving firstly increases, reached to maximum value and then after decreases with increase of the insulation thickness .

Figure 1: The Variation of Total Cost with Insulation Thickness for Mud Wall Construction in the Presence of Insulation.

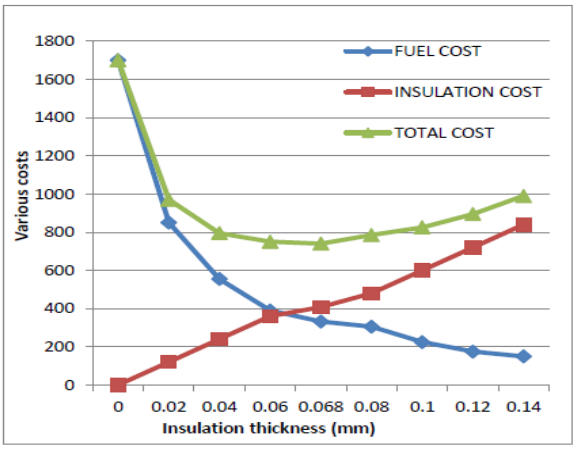
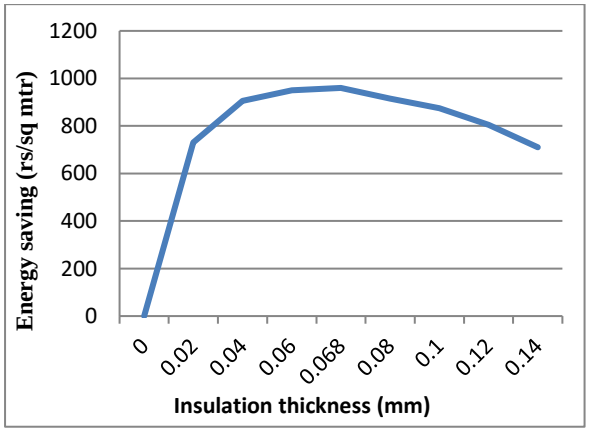


Figure 2: Variation of Energy Saving Versus Insulation Thickness for Mud House



From figure 2, it can visualized that at optimum thickness, energy saving has maximum value. As seen from the figure 2 , choosing a thickness other than optimum value, energy saving decreased. So it is benefited to apply optimum thickness of insulation across Mud wall. The outcome of Fig. 2 is the Energy saving is 960 Rs/m^{2}at optimum thickness of 0.068 m for mud house.

5.0 Conclusions

On the basis of results and discussion, there are following conclusions.

1. Mud has specific properties like high resistivity, high heat capacity and higher value of thermal mass. So it act as a insulation.
2. At 68 mm insulation thickness, the percentage of energy saving is 51%.
3. The study has been carried out to know the variation in annual cost by using variable insulation thickness and it is found that for mud house with 68 mm wall thickness, the maximum energy conservation is 51% approximately.
4. The Energy saving analysis was also carried out for the mud wall construction for different month of year 2019. And it is observed that 543 kWh/Year amount of energy conserved.
5. The heat transfer rate through wall surface is depending upon insulation material so for selection of insulation material, the cost and Thermal conductivity must be considered.

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