ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology (IARJSET)
National Conference on Renewable Energy and Environment (NCREE-2015)
IMS Engineering College, Ghaziabad
Vol. 2, Special Issue 1, May 2015

Potential for energy conservation in Mud Wall building

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Abstract: Energy conservation refers to efforts made to reduce energy consumption. Energy conservation can be achieved through using efficient energy sources, in conjunction with decreased energy consumption or reduced consumption from conventional energy sources. A considerable energy saving can be achieved by using proper thickness of insulation in building walls. This paper briefly discussed mud wall as a better option of energy conservation over conventional brick wall construction buildings. After calculating the Energy saving value for a representative room of size 5 m x 4 m x 3.5 m, it is found that there is potential of energy conservation up to 520 kWh/Year by using mud wall instead of conventional brick wall.

Keywords: Energy conservation, mud wall, optimum insulation, conductive heat transfer.

I.INTRODUCTION

Using proper insulation material is the most effective way of energy conservation in residential applications. The energy consumption is distributed among four main sectors: industrial, building (residential or commercial), transportation and agricultural areas. The building sector is the highest energy consumer among the other sectors. The energy conservation is achieved by the application of thermal insulation in buildings. Thermal insulation restricted the transfer of heat from both sides of walls and make the house heat proof.

It also is very useful to keep the temperature of the house independent from outside temperature. From economic point of view, it may be better to choose an insulating material with a lower thermal conductivity rather than increase the thickness of the insulation. By reducing the thermal conductivity, less insulation will be required. Proper insulation reduces energy consumption, emission, increases thermal comfort by minimizing heat losses and reduces the running cost of space heating. Insulation as single investment pays for itself many times over, during the life cycle of a building.

In this study, the heating/ cooling potential of mud brick construction and brick wall construction has been calculated by Degree -Day Method. This study focuses mainly
on the thermal performance of a traditional mud brick structure and sun dried mud-brick (mud wall) building construction. The objective was to search for affordable and energy-efficient construction techniques suitable for rural settlements.

II. STRUCTURE OF BUILDING AND ITS MATERIALS

Mud has a number of properties which makes it a perfectly suitable material for construction. Mud construction is used to achieve thermal comfort at a low cost. These houses were constructed without any mechanical means. Energy saving due to mud wall construction in rural region of India for a representative room size is 5m x 4m x 3.5m is considered. Timber, Bamboo, Clay, straw, cow dung and a special variety of grass is used to build houses. Mud is mixed with cow dung, chopped straw and gravel to make the raw material for the walls. Fibrous ingredient like straw is used to improve tensile strength of mud brick. The external wall is formed by applying a thin coating of mud plaster on both sides of mud brick. Mud is act as a insulation. The building material for walls is mud and roof material is straw and khapra. The structure of external wall of mud Wall is made by 2.5 cm internal mud plaster, 36 cm mud brick thick and 2.5 cm outer plaster without insulation. Mud house with pitch roof structure building are shown on Fig.1. The percentage distribution of the different materials used in construction of Mud House is 83.05% (Soil with clay), 8.15% (Cow dung) , 4.15% (Wood or Bamboo), 3.2 % (Straw Bale), 0.95 %(White wash)and 0.5% (Hydrophobizing agent)

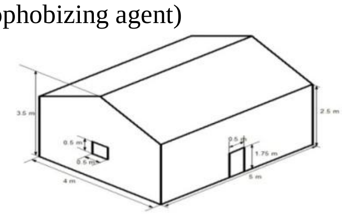

Fig.1. MUD WALL CONSTRUCTION WITH PITCH ROOF STRUCTURE

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III. OPTIMIZATION OF INSULATION THICKNESS AND ENERGY SAVING

Heat loss occurs from each wall, roof and building envelope because of temperature difference between indoors and atmosphere. The heat loss occurs in a unit of the surface of external wall is calculated by

$$Q_L = U \times (T_r - T_a) \quad (1)$$

The total cost is the sum of cost of insulation material and present worth of the cost of energy consumption over the lifetime of the building.

$$C_t = PWF\left[\frac{C_F}{H_u.\eta_s} + \frac{C_E}{COP}\right] \times \frac{T_a - T_r}{R_W + \frac{x}{K}} + C_i \times x \quad (2)$$

The optimum insulation thickness is obtained by minimizing the total heating cost and cooling cost. Hence the derivative of C_t with respect to x is taken as zero for finding the optimum thickness. The expression of optimum insulation thickness x_{opt}

$$X_{opt} = \left[\frac{K \times PWF}{C_i}\left(\frac{C_F}{H_u.\eta_s} + \frac{C_E}{COP}\right) \times (T_a - T_r)\right]^{0.5} - KR_W \quad (3)$$

Pay-back period (pp) is calculated by solving the equation

$$\frac{C_{Ins}}{A_s} = \frac{(1+r)^{pp} - 1}{r(1+r)^{pp}} \quad (4)$$

Where C_{Ins}/A_s is the simple pay-back period. Energy saving obtained during the life time of insulation material can be calculated as follow

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

At different thickness of insulation the total annual cost is represented as

TABLE I. TOTAL ANNUAL COST OF ROOF FOR MUD CONSTRUCTION

S.No	Insulation Thickness (cm)	Annual cost for heating(Rs)		
		Fuel cost(Rs)	Insulation cost(Rs)	Total cost(Rs)
1.	0	1543.4	0	1543.4
2.	5	954.3	137.5	1091.8
3.	10	690.7	275	965.7
4.	13.21	363.27	586.62	949.9
5.	15	541.2	412.5	953.7
6.	20	444.9	550	994.9
7.	25	377.7	687.5	1065.2

The optimum insulation thickness for Roof covered with straw for Mud wall constructions is 0.1321 m when straw is used as insulation. This investigation indicates the importance of the roof insulation, which results in a reduction up to 13 % of the heating load.

Fig.2. TOTAL ANNUAL COST FOR MUD WALL CONSTRUCTIONS VERSUS INSULATION THICKNESS (MUD DUNG SLURRY INSULATION)

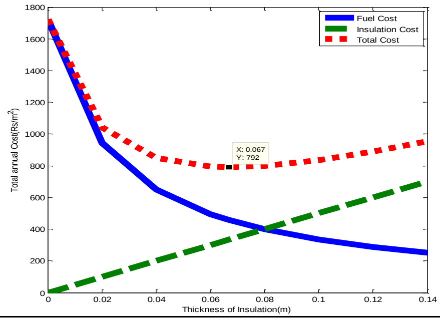

Fig.3. VARIATION OF TOTAL ANNUAL COST AND ENERGY SAVING VERSUS INSULATION THICKNESS FOR MUD WALL

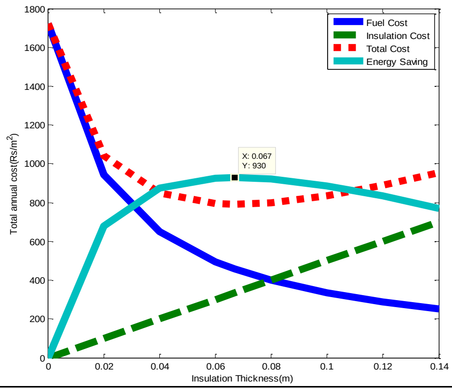

Fig.4. MONTHLY ENERGY SAVING FOR MUD HOUSE

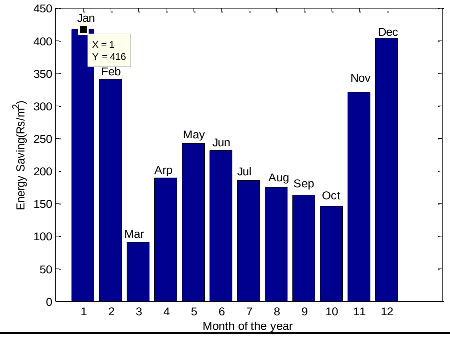

Fig.5. EFFECT OF THERMAL CONDUCTIVITY OF INSULATION ON ENERGY SAVING FOR MUD WALL FOR DIFFERENT FUEL TYPE

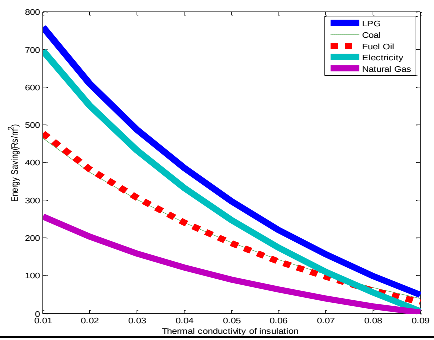

Fig.6. MONTHLY ENERGY REQUIRED FOR MUD HOUSE WITH AND WITHOUT INSULATION

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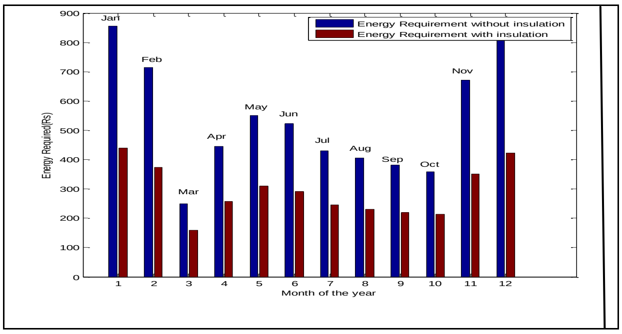

IV.DISCUSSION

Fig.2. shows the cost variation for Mud wall, by using mud dung slurry, the fuel or energy cost decreases and insulation cost increases linearly with insulation thickness. The optimum insulation thickness (0.067 m for Mud wall) is taken at the lowest total cost. As insulation thickness increases the heating load decreases and also cost of fuel and total cost of heating is decrease. On the other hand, the insulation cost increases as its thickness increases. Heat loss through building walls will be decrease with increase of insulation thickness. But at the same time the cost of fuel will decrease. The initial investment will increased due to insulation cost and installation cost. From Fig.2. it can be seen that total cost decreased up to optimum insulation thickness, and after that total cost is increased. At this thickness, increase in insulation cost is compensated by decrease of fuel cost. Fig.3. shows the effect of insulation thickness on energy saving for Mud wall. The energy saving gets increased by increasing the insulation thickness up to optimum insulation thickness and vice-versa. The maximum energy saving point represents optimum insulation thickness. Fig.4. shows the substantial energy saving potential of this mud house. The highest and lowest energy saving is obtained for January (416 Rs/m^2) and March (90 Rs/m^2) month. The annual heating/cooling energy saving potential is estimated as 268 and 257 kwh/year respectively.Fig.5. shows effect of thermal conductivity of insulation on energy savings for different fuel. As thermal conductivity of insulation increases, then more heat is loss across the boundary. Adding insulation with less thermal conductivity to building not only reduces energy consumption but also increases thermal comfort. Figure reflects that It is beneficial to use LPG fuel with less insulation thickness Fig.6. shows the requirement of Energy for different month of year with and without insulation and energy saving. It is seen that the highest and lowest energy is required for January (856 Rs/m^2) and March (250 Rs/m^2) month respectively. Variation of temperature more frequently occurs in January month and being uniform in March month. So least energy saving occurs in March month.

V. METHOD FOR ANALYSIS

Optimum insulation thickness for residential wall (Mud house) has been calculated by implementing the Degree-Day method. Heating/cooling loads is required for finding the optimum insulation thickness. I have selected Degree-Day method for finding heating/ cooling load potential.

Degree-Days Methods

Degree-Days method is a well known and simple method for calculating the energy needs of buildings. The harshness of climatic conditions can easily be characterized in terms of degree-days. The annual heating requirement of building in different climates zones is calculated by Degree-Days methods. The number of Degree-Days is the difference between the base temperature and the mean outdoor ambient temperature. Degree-Days concept is based on constant indoor conditions during the heating or cooling season and assumes the efficiency of the heating or cooling equipment is not affected by the variation of outdoor temperature. Despite its simplicity accurate results can be obtained with the Degree-Days method for most houses and single-zone buildings. This method becomes too crude and unreliable for buildings that experience large hourly and daily fluctuations, such as crowded office buildings. The accuracy of Degree-Days method may be improved by using different base temperatures in different climate

S. No	Month	Energy potential (kw) With insulation	Cost of Energy (Rs) With insulation	Energy potential (kw) Without insulation	Cost of Energy (Rs) Without insulation	Energy Saving (Rs)
01	January (H)	80	440	155	856	416
02	February (H)	68	374	129	714	340
03	March(C)	29	160	45	250	90
04	April(C)	46	257	81	446	189
05	May(C)	56	310	100	551	241
06	June(C)	52	291	94	522	231
07	July(C)	44	246	78	431	185
08	August (C)	42	231	73	405	174
09	September (C)	39	219	69	382	163
10	October (C)	38	213	65	358	145
11	November (H)	64	352	122	672	320
12	December (H)	76	422	150	825	403
Grand total consumption cost			3515		6412	2857

zones.

TABLE IICOOLING/ HEATING LOAD REQUIREMENT IN MUD WALL IN DIFFERENT MONTH FOR LPG FUEL SOURCE FOR HEATING AND ELECTRICITY FOR COOLING

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In the above chart the heating is required during four month (November, December, January and February) and Cooling is required during rest of the month for Delhi and NCR region climate of India.

VI. STATISTICAL ERROR ANALYSIS FOR VALIDATION

If population consists of measurement of only one variable, the population is known as univariate population. But if we have the data on two variables, the population is known as bivariate population. If the data happen to be on more than two variables, the population is known as multivariate population. There is several method of determining the relationship between variable. For determining the correlation between variable correlation technique is used. In this analysis bivariate population is used. There are following method of determining the relation between two variables.

1. Cross tabulation
2. Charles spearman's coefficient of correlation
3. Karl Pearson's coefficient of correlation

1. Cross tabulation: Cross tabulation approach is specially used when the data are in normal form. Under it we classify each variable into two or more categories and then cross classify the variables in these sub-categories. Then we took for interactions between them which may be symmetrical, reciprocal or asymmetrical. A symmetrical relationship is one in which the variable vary together. A reciprocal relationship exits when the two variables mutually influence or reinforce each other. Asymmetrical relationship is said to exist if one variable(the independent variable) is responsible for another variable(the dependent variable).

2. Charles spearman's coefficient of correlation: This correlation is also known as rank correlation. It is the technique of determining the degree of correlation between two variables in the case of ordinal data where ranks are given to the different values of the variables. The main objective of this coefficient is to determine the extent to which the two sets of ranking are similar or dissimilar. This coefficient is determined as under

$R_s = 1 – [6 \sum d_i^2/n(n^2-1)]$ (6)

Where R_s is the spearman's coefficient of correlation.Equation(vii) is taken from book of title " Research methodology method and techniques" by C.R.Kothari.

d_i = Difference between ranks of ith pair of the variables;

n = Number of pairs of observation

3. Karl Pearson's coefficient of correlation: This correlation is the most widely used method of measuring the degree of relationship between two variables. This coefficient assumes the following:

- There is linear relationship between the two variables
- The two variables are casually related which mean that one of the variable is independent and other one is dependent
- A large number of independent causes are operating in both variables so as to produce a normal distribution.

Karl Pearson's coefficient of correlation(r) =

$$\frac{\sum X_i Y_i - n\cdot \bar{X}\cdot \bar{Y}}{\sqrt{\sum X_i^2 - n\bar{X}^2}\sqrt{\sum Y_i^2 - n\bar{Y}^2}} \qquad (7)$$

Equation(viii) is taken from book of title " Research methodology method and techniques" by C.R.Kothari.

Karl Pearson's coefficient of correlation is also known as the product moment correlation coefficient. The value of 'r' lies between ± 1. Positive value of r indicate positive correlation between the two variable (i.e., changes in both variables takes place in the statement direction), whereas negatives value of 'r' indicate negative correlation(i.e., changes in the two variables taking place in the opposite directions. A zero value of 'r' indicates that there is no association between the two variables. When r=(+) 1, it indicates perfect positive correlation and when it is (-)1, it indicates perfect negative correlation. The value of 'r' nearer to +1 or -1 indicates high degree of correlation between the two variables.

In this analysis we have to use the Karl Pearson's coefficient of correlation. For verified the result of energy saving, the data of cooling/heating load for mud house with and without insulation is selected from the article " Thermal performance and embodied energy analysis of passive house-case study of vault roof mud-house in India, Applied Energy Journal by Arvind Chel and G.N.Tiwari. After that I have to compared the result of energy saving. And finding the variation of cooling/heating load potential. It is found that there is positive correlation between two results.

$$r = \frac{\sum X_i Y_i - n\cdot \bar{X}\cdot \bar{Y}}{\sqrt{\sum X_i^2 - n\bar{X}^2}\sqrt{\sum Y_i^2 - n\bar{Y}^2}} \qquad (8)$$

Where r is Karl Pearson's coefficient of correlation

$r = (4.07\text{-}4.0532)/(4.7096\text{-}4.367)^{0.5} \times (3.77\text{-}3.761)^{0.5}$

$= 0.0168/(0.5853 \times 0.094) = 0.0168/0.055 = 0.2362$

VII. CONCLUSION

To validate the results of mathematical model, analysis was carried out for mud wall on monthly basis, from January to December. Theoretically validation fromexperimental observations, statistical analysis data were presented by taken references to estimate correlation coefficient. The calculated value of Karl Pearson's coefficient of correlation for cooling load/ heating load potential for(mud wall construction) is 0.23. This statistical error analysis showed a good agreement between result of mathematical model and experimental results. After calculating the Energy saving value, it is

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found that there is potential of energy conservation up to 520 kWh/Year.

It was seen during analysis that highest value of energy saving is achieved by LPG for mud wall construction. The energy saving is maximum(44.55 %) at optimum insulation thickness of 67 mm. The above investigation also indicates the importance of roof insulation. A reduction upto 13% of the heating load is achieved by roof insulation. The analysis has been carried on monthly basis from January to December to validate the result of mathematic model. An approach has been made for selecting the most economic insulation material. Result show that Mud slurry is most economic insulation material (C_A Index 75) as compared to other insulation material.

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BIOGRAPHIES

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