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Economic optimization of Wall's Insulation Thickness on Energy Performance of Green buildings

G.R.K.D. Satya Prasad[1], Manas ranjan Panda[2], Hirok Jyoti Sarmah[3], Nishant Ku. singh[4], Hailendra Prasad[5]

[1]*Asscoaite Professor, Department of Electrical Engineering, GIET, Gunupur,* Orissa, INDIA
[2]*Asssiant Professor, Department of Mechanical Engineering, GIET, Gunupur,* Orissa, *INDIA*
[3,4,5]*Final Year UG student, Dept. of Mechanical Engineering,* GIET, Gunupur*, Orissa, INDIA*

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Abstract:

Heat losses of a building envelope are mainly depends on the heat penetration of the buildings. These heat losses can be minimized with proper insulation thickness of the walls. The insulation thickness and energy savings are calculated by using the life span of the building. Passive energy technologies will plays a vital role in deciding the insulation thickness of the buildings.

In this paper, a study has been done on energy saving in different types of building walls by using optimum insulation thickness with suitable insulation material.

Key words: *Insulation thickness, Life-cycle cost analysis, Sustainable homes, Energy consumption.*

1. INTRODUCTION

Buildings wall insulation thickness plays an important role in buildings energy consumption. The majority of the building designers are not aware of the importance of walls insulation thickness and to optimize the size of insulation thickness.

Inappropriate insulation thickness of the wall leads to a bad design of the building and hence consumes more energy by air-conditioning equipment of the building.

Insulation materials are preferred in terms of geographical area of the building, local weather conditions, number of floors, wall to window ratio, capacity of the air handling units etc.,

1.2 How insulation works

Insulation material of the wall depending on its thickness will depend on radiation, convection and conduction.

Radiation: This type of heat penetration depends on indirect contact heat process.

Conduction: Conduction type of heat penetration directly depends on direct contact of the heat process.

Convection: This type of heat process is by using an intermediate agent like air or fluids to transfer the heat in to buildings.

1.3 Performance

Insulation material performance mainly depends on the flow of heat energy in to the buildings. They are closely associated with the materials R-values and U-values. In other words; insulation material thermal resistance may resist the transfer of heat in to the buildings with proper optimization of the insulating material.

Thermal conductivity:
Thermal conductivity of the insulation material is an important parameter to decide the heat penetration in to the building. It is a constant measured in W/mK. The higher the thermal conductivity of the material the better the thermal conductivity of the building.

Thermal resistance:
Thermal resistance of the material is a product of thermal conductivity and insulation thickness. It is expressed in m^2K/W.

U-value:

This value is applicable to any type of building material; like roofs, walls, basement, window glasses, doors etc.,
It is a measure to calculate the transmission of heat through any material. It is measured in W/m^2K and gives an insight in to heat transfer through any medium.

2 Thermal insulation:

Thermal insulation in buildings is major causes for the excess energy consumption and increased electricity bills. A proper design of the thermal insulation of the building not only reduces the unwanted heat loss or gain and also it will cause thermal comfort of the occupant with less installation costs. Some good insulating materials are rock wool, polystyrene, glass wool, cellulose, wood fiber, cotton denim etc.,

Many of these insulating materials are cheaper in cost and results in good thermal reflectance of the heat in to the buildings.

2.1 Planning

The design of the insulation material, how much material required will depend mainly on design of the building, location, energy usage, schedule of usage, personal preference, aesthetics of the building, active and passive energy systems etc.,

Insulation material is to be selected with careful choice and the mode of heat transfer with season to season variations. Hence, the type of the material will be selected with a combination of material which has to suit to all seasons.

A qualified energy auditor has to assess the initial conditions of the building and according to his final report, a decision has to make to plan for insulation material thickness by considering all technical parameters.

In cold climatic areas, the main concentration is on to reduce heat flow out of the buildings. Similarly in hot climatic conditions, the heat to be removed from the building and at the same time heat is restricted to penetrate in to the building.

2. 2 Orientation - Passive Solar Design

Optimal planning of building essentials like windows, doors, roofs, basement are the main sources for buildings excessive energy consumption. A passive design building will be more effective in insulation

Building envelope

The thermal envelope of the building is depending on the living space of a building as well as the orientation of the building. Sun path will plays a crucial role in insulation thickness. Depending upon the buildings orientation in some directions the insulation material provided will be less and in some directions the insulation material requires more material.

The airflow will also play a crucial role while designing the walls insulation thickness. A better cross ventilated building will much lower impacts on buildings thermal load.

The lesser cross ventilated building requires much more active systems to increase the thermal comfort of the building.

2.3 Building Insulation Materials

There are two types of insulation materials are available for the walls insulation thickness. Bulk insulation thickness and reflective insulation thickness are the important insulation classifications are available in the market. The type of insulation is based on conduction, convection and radiation.

Conductive and convective insulators are comes under Bulk insulation.

Eco-friendly insulation

Eco-Friendly insulation are one in which they will not harm the environment. The impact on insulation is prime concern in these types of insulation materials.

3. Case studies & simulation results

The energy performance of a building envelope is influenced by a number of factors. For example, these may include design elements such as the physical orientation of the building and the amount of sunlight that penetrates into the interior living or work spaces. Other factors may also include the heat transfer characteristics (both losses & gains) and the location of the building envelope components, including walls, windows, doors, floors and the roof.
The energy performance of a building may also be influenced by any natural air infiltration through the building envelope.

The RETScreen software has been validated in a number of ways. For example, RETScreen has been compared with HOMER simulation tool, which uses hourly solar Insolation data.

These software tools are compatible with local weather conditions and integrated with local temperature and updated regularly with NASA database.

3.1 case study with simulation results

The project type is of Energy efficient Measures, this is of institutional facility type and the analysis method is considered as method 1. The Heating value reference is considered as LHV. Higher heating value is typically used in Canada and USA, while lower heating value is used in the rest of the world. Hence LHV is selected. This is of International wide software hence we can get the currency what we required. The climatic data conditions are obtained for this location which is included in Site reference conditions.

For selecting climate location:
To access the RETScreen Climate Database click on the "Select climate data location" hyperlink or use the RETScreen menu or toolbar.

	Unit	Climate data location	Project location
Latitude	°N	17.0	17.0
Longitude	°E	82.2	82.2
Elevation	m	8	8
Heating design temperature	°C	20.0	
Cooling design temperature	°C	37.5	
Earth temperature amplitude	°C	7.7	

Month		Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
		°C	%	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January		24.5	74.2%	4.95	100.8	1.6	25.6	0	450
February		26.1	73.5%	5.74	100.6	1.4	27.4	0	451
March		28.4	72.2%	6.43	100.4	1.2	29.8	0	570
April		30.5	71.7%	6.71	100.2	1.3	30.3	0	615
May		32.0	70.0%	6.18	99.8	1.4	30.8	0	682
June		31.0	70.4%	4.65	99.6	1.7	29.9	0	630
July		29.2	77.1%	4.26	99.7	1.7	28.8	0	595
August		28.7	79.7%	4.34	99.7	1.7	28.6	0	580
September		28.8	81.0%	4.44	100.0	1.2	28.6	0	564
October		28.0	79.1%	4.49	100.3	1.5	27.8	0	558
November		26.3	73.6%	4.46	100.6	1.9	26.6	0	489
December		24.5	71.7%	4.56	100.8	1.8	25.6	0	450
Annual		28.2	74.5%	5.10	100.2	1.5	28.3	0	6,633
Measured at	m					10.0	0.0		

Fig.3.1: Gunupur climate data sheet

This is the extension of first window which show the data of climatic conditions of the considered location. While the latitude and longitude values are entered, the values of Air temperature, Relative humidity, Daily radiation-horizontal, Atmospheric, wind speed, Earth temperature, Heating Degree days, Cooling degree days are obtained for monthly basis. The data obtained is only for reference purpose not to run the model.

Energy Model

RETScreen Energy Model - Energy efficiency measures project

Fuels & schedules ☒ Show data

Fuel		Fuel type 1	Fuel type 2	Fuel type 3	Fuel type 4	Fuel type 5	Fuel type 6
Fuel type		Electricity					
Fuel consumption - unit		MWh					
Fuel rate - unit		Rs/kWh					
Fuel rate		4.000					

Schedule	Unit		Schedule 1	Schedule 2	Schedule 3	Schedule 4	Schedule 5	Schedule 6
Description			24/7					
				Occupied	Occupied	Occupied	Occupied	Occupied
Temperature - space heating	°C							
Temperature - space cooling	°C		25.0	24.0				
				Unoccupied				
Temperature - unoccupied	+/-°C			3.0				
				Occupied				
Occupancy rate - daily			h/d	h/d				
Monday			24	8.0				
Tuesday			24	8.0				
Wednesday			24	8.0				
Thursday			24	8.0				
Friday			24	8.0				
Saturday			24	8.0				
Sunday			24	8.0				
Occupancy rate - annual	h/yr		8,760	2,920				
	%		100%	33%				
Heating/cooling changeover temperature	°C	16.0						
Length of heating season	d	0						
Length of cooling season	d	365						

Fig.3.2: Energy model worksheet

Insulation thickness analysis:

RETScreen Tools - Energy efficiency measures project

Window properties

Base case See product database

	Orientation	Type	Width	Height	Unit cost	Number	Area	Centre glazing Ucg	SHGCcg	Rated window U-value	SHGC	Adjusted U-value	SHGC	Description
			mm	mm	Rs		m²	(W/m²)/°C		(W/m²)/°C		(W/m²)/°C		
1	East	Casement	900	1,210		5	5.4	2.83	0.76	2.67	0.48	2.70	0.54	
2	West	Casement	900	1,210		5	5.4	2.83	0.76	2.67	0.48	2.70	0.54	
3	South	Slider	900	1,210		3	3.3	2.83	0.76	2.67	0.48	2.56	0.28	
4	North	Slider	900	1,210		3	3.3	2.83	0.76	2.67	0.48	2.56	0.28	
5														

Fig. 3.3: Insulation thickness analysis

Facility characteristics ☒ Show data

Show:	Heating	Cooling	Electricity	Incremental initial costs	Fuel cost savings	Incremental O&M savings	Simple payback	Include measure?
Fuel saved	GJ	GJ	GJ	Rs	Rs	Rs	yr	☐
Heating system								
Cooling system								
AC	-	0	-	0	0	0	-	☒
Building envelope								
building	0	87	-	861,000	97,026	0	8.9	☒
Ventilation								
	0	7	-	20,000	7,700	0	2.6	☒
Lights								
	-	-	8	110,000	8,737	0	12.6	☒
Electrical equipment								
Hot water								
Pumps								
Fans								
Motors								
Process electricity								
Process heat								

Fig.3.3: Facility Characteristics of Building

Summary ☒ Show data

Fuel type	Fuel consumption - unit	Fuel rate	Base case Fuel consumption	Fuel cost	Proposed case Fuel consumption	Fuel cost	Fuel saved	Fuel cost savings
Electricity	MWh	Rs 4,000.000	97.6	Rs 390,555	69.3	Rs 277,093	28.4	Rs 113,462

Project verification Fuel type	Fuel consumption - unit	Fuel consumption - historical	Fuel consumption Base case	Fuel consumption - variance
Electricity	MWh		97.6	

Fuel consumption	Heating GJ	Cooling GJ	Electricity GJ	Total GJ
Fuel consumption - base case		334	17	351
Fuel consumption - proposed case		240	9	249
Fuel saved		94	8	102
Fuel saved - %		28.2%	45.5%	29.1%

☐ Show data See benc

Benchmark		
Energy unit	GJ	
Reference unit	m²	128

Benchmark Fuel consumption	Heating GJ/m²	Cooling GJ/m²	Electricity GJ/m²	Total GJ/m²
Fuel consumption - base case		2.61	0.14	2.75
Fuel consumption - proposed case		1.87	0.07	1.95
Fuel saved		0.74	0.06	0.80

Fig. 3.4: Summary of the results

Summary of the results:

As shown in the fig. 3.1; by selecting from the drop down list, Gunupur weather conditions can be loaded in to the software.

According to the selection of insulation material as shown in fig 3.3; material can be selected with base case and proposed case.

Complete results with technical and economical constraints are obtained based on local climatic conditions, insulation thickness building orientation etc.,

Financial Analysis and summary of results:

Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	30	
Debt ratio	%	74%	
Debt interest rate	%	6.50%	
Debt term	yr	20	
Initial costs			
Energy efficiency measures	Rs	991,000	100.0%
Other	Rs		0.0%
Total initial costs	Rs	991,000	100.0%
Incentives and grants	Rs		0.0%
Annual costs and debt payments			
O&M (savings) costs	Rs	0	
Fuel cost - proposed case	Rs	277,093	
Debt payments - 20 yrs	Rs	66,555	
Other	Rs		
Total annual costs	Rs	343,648	
Annual savings and income			
Fuel cost - base case	Rs	390,555	
Other	Rs		
Total annual savings and income	Rs	390,555	
Financial viability			
Pre-tax IRR - equity	%	23.5%	
Pre-tax IRR - assets	%	7.5%	
Simple payback	yr	8.7	
Equity payback	yr	4.8	

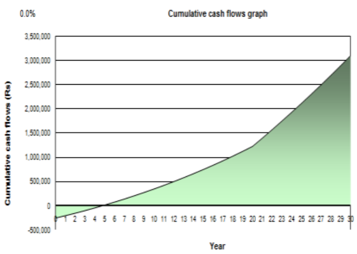

Fig. 3.5: Financial analysis and summary of results

As shown in fig 3.5; the financial viability of the project is with a payback period of 4.8 years.

4 Conclusions:

In financial analysis, the fuel rate for base case with proposed cases are compared even though the initial investment is high the payback period is very less by considering project life of 30years.

The results obtained by using RETSCREEN software are realistic and gives very promising results for Energy Efficient Buildings by considering walls insulation thickness.

The building simulation results found that; how various parameters like building envelope, insulation thickness will depend on buildings energy performance by optimizing the energy needs without compromising the consumers comfort.

However, as the consideration of equipments was done optimistically for the desired building load and net profits will be higher than the results in simulation by considering carbon credits and subsidies from government organizations.

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