Technology, 12(4), 283-290, (2009)

TECHNOLOGY

FUEL CONSUMPTION AND INFLUENCES OF EXTERNAL WALL OPTIMUM INSULATION THICKNESS TO OWNING COST OF ENERGY

Emrah DENİZ[*], Ali Etem Gürel[**], Ali DAŞDEMİR[**], Doğu ÇAMUR[**]
[*] Karabuk University, Faculty of Engineering, Karabuk/Turkey
[**] Karabuk University, Graduate School of Natural and Applied Sciences, Karabuk/Turkey

Abstract

In our country, still being keep up to date, the most important problem is energy saving. Especially, heat insulation application in indoors like housing and working, places has an important role in being reduced the waste gas issue to protect the environment, in spite of being supply an significant energy saving. In this study, it has been counted to take into consideration of the optimum insulation thickness of two different insulation material (rock wool and extruded polystyrene) for external wall, energy saving and payback periods, rate of interest and inflation by method of degree day, in using coal in building as an heat source in the city of Muğla. When using rock wool as of an insulation material, optimum insulation thickness in external wall, annual energy conservation and payback periods have been fixed respectively as 0.06 m, 43% and 2.29 year. When using extruded polystyrene, these values are 0.05 m, 23% and 4.41 year.

Keywords: Insulation, Optimization, Energy Saving

1. Introduction

Both in our country and all around the wall, the demand of energy has been increasing day by day. This situation makes some international association and corporations seek for researches about the consumption of fuel, its usage and new energy resources. However, the last researches show that the fossil sources of energy will have been consumed by 2030 [1, 2]. In this respect, the efficient usage of limited sources of energy throughout the world gain more importance.

In the worldwide, energy consumption has increased for only per person nearly 5% in the last 25 years. However in our developing world, this rate has gone up over 100%. While about 50% of energy need were supplying from our own production in 1990 in our world. But today this rate dropped back to 30%. When taking into consideration to all of these, both increasing the energy generation, and using energy in an efficient way become obligatory. Being utilized the energy in an efficient way is a cheapest method than energy generation. Decreased the heat loss and used the produced energy in an efficient way in housing where 30% of final energy consumption, will supply a big gain to country’s economy. When examined the insulation technologies which decreased the heat loss, come into consideration. Although insulation thickness seems a solution that will decrease to heat dissipation and will decrease fuel cost, in the applications that chosen insulation thickness more than needed, insulation costs and depending on total cost increases. This means that, in the identification of insulation thickness, on economic optimum point exists that is the best production. In the surveys of insulation, a different survey has been done an oriented of identification of optimum insulation thickness to energy costs.

Hasan (1999) has made applications to four different wall models in his studies and identified the optimum insulation thickness [4]. Bolattürk (2003), through his studies in Isparta, has calculated the optimum insulation thickness when polystyrene is used as an outer insulation material for the walls and identified that 60.2% energy saving can be provided under these circumstances [5]. Comakli vd. (2003), in their studies in Erzurum, Kars and Erzincan, have assessed the time span of optimum insulation thickness, energy saving and refunding; and identified that the optimum insulation thickness is 0.1048 m., 0.1073 m. and 0.085 m by turn

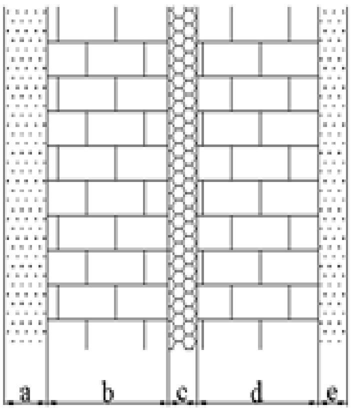
Corresponded Author; edeniz@karabuk.edu.tr

[6]. Aytac vd. (2006), has identified for Elazig the refunding time and annual savings by using 5 different types of fuel and 2 different types of insulation materials [7].

However in this study, the time span of optimum insulation thickness, energy saving and refunding are identified for rock wool and extrude polystyrene (XPS) as long as coal is used as a source of energy in Muğla.

2. Method

In this building, areas where loss of heat occurred most are its outer walls. So, the structure of the outer walls of the building plays a very important role in the upcoming calculation of outer walls. Loss of heat and thus fuel consumption proves more in a building that is built with classical construction materials (such as air brick, concrete, wood etc.). Besides, as a place having this kind of outer walls would be uncomfortable in terms of heat both in summer and in winter, more consumption of fuel would be needed as well. Under these circumstances, the outer walls are designed as having outer insulation, inner insulation and sandwich in order to get the necessary standards of comfort in summer and winter months by decreasing the amount of energy consumption.
In scope of our study, the structure of sandwich walls made up of 2 cm-thick inner plaster, 2 units of 13 cm thick horizontal air brick and 3cm thick outer plaster are used as is shown schematically diagram and material properties in Fig. 1. Rock wool used in the construction of the walls and the optimum thickness of XPS materials are designated through these studies done.



	Materials	**Gauge** (m)	**Coefficient Of Heat Transmission** "k" (W/mK)
a	External rendering	0.03	0.87
b	Horizontal coring brick	0.13	0.45
c	Insulation materials		
	Rock wool	*	0.04
	XPS	*	0.03
d	Horizontal coring brick	0.13	0.45
e	Interior rendering	0.02	0.87

* These Properties will be Optimized According to the Results of This Study.

Figure 1. Features of Wall Model and Utilized Materials which were Used in the Works

Building features, (loss of heat materialized by way of conveyance and convection), characteristic features of heat system, climatic conditions, outdoor air temperature, intensity of solar warm up and inner heat profits are situated among the factors which effect the necessity of building's heat energy. In the work, optimum insulating thickness is counted by considering only the losses formed on the outdoor walls, temperature backbends are neglected.

Heat losses formed on the outdoor walls from the unit area,

$$q=U.\Delta t \qquad (1)$$

was counted with. "U" (W/m^2K) is coefficient of heat transmission. Annual heat loss in the unit area which is given as in the Equation 2, can be counted with "U" and degree day number (DDN).

$$q_{yıl}=86400.DDN.U \qquad (2)$$

Because of the loss of heat formed by the surface of the outer wall, the annual amount of energy "E_A" needed for heating is obtained by the rate of annual loss of heat to the efficiency of fuel system [8]. In annual amount of energy needed for heating, dissipation system such as pipe etc. would be as effective as the efficiency of fuel system.

$$E_A=(86400.DDN.U)/\eta \quad (3)$$

Total heat transition for a typical wall is calculated as:

$$U=1/(R_i+R_w+R_{ins}+R_d) \quad (4)$$

Here, "R_i" and "R_d" in turn stand for inner and outer surface heat resistance whereas, "R_w" stands for the heat resistance of insulated wall parts and "R_{ins}" for the heat resistance of insulation material and the equality is calculated with 5.

$$R_{ins} = x/k \quad (5)$$

"x'' expresses insulation materials thickness and "k" expresses coefficient of heat transmission as in the equation 5. if total thermal resistance of a wall layer without insulation accepted in total R_d, R_w and R_i, equation 4 turns into equation 6.

$$U = 1/(R_{wt} + R_{ins}) \quad (6)$$

As a consequence, annual energy amount which utilized for warming can be counted with equation 7.

$$E_A = \frac{86400.DDN}{(R_{wt}+R_{ins}).\eta} \quad (7)$$

Energy cost which was used for warm up the unit area is being acquired to use the equation 8.

$$C_{yıl} = \frac{86400.DDN.C_f}{(R_{wt}+R_{ins}).H_u.\eta} \quad (8)$$

"C_f" expresses fuel cost and "H_u" expresses lower heating value in here. While counting optimum insulation thickness, working life's cost analyze (LCCA) was used and was being evaluated with total cost of warming, life time (N) and present worth factor (PWF). PWF depends on rate of inflation (g) and rate of interest(i).when rate of interest and rate of inflation take into consideration, value of real rate of interest (r) and present worth factor (PWF) are counted with respectively the help of equation 9 and 10. [8].

If $i>g$, $r = \frac{i-g}{1+g}$; if, $i<g$, $r = \frac{g-i}{1+i}$ (9)

$$PWF = \frac{(1+r)^N-1}{r(1+r)^N} \quad (10)$$

"N" expresses the time in here and in this work it was accepted as 10 years. If value of "i" equal to value of "g", expression that is in the 10 equation turns into expression that is in the Equation 11.

$$PWF = \frac{1}{1+i} \quad (11)$$

Insulation cost will be counted with the expression that is in the Equation 12.

$$C_{ins}=C_m.x \quad (12)$$

"C_m" gives the unit price of insulation materials (TL/m^3) and "x" gives insulation material's thickness (m). Consequently total cost of warming is counted with using equation 13 for the building which is being isolated.

$$C_{t,ins}= C_{year} . PWF + C_m \quad (13)$$

Optimum insulation thickness that decreased the total cost into minimum is counted with equation 14.

$$x_{op} = 293.94 \cdot \left(\frac{DDN.C_f.PWF.k}{H_u.C_m.\eta}\right)^{1/2} - k.R_{wt} \quad (14)$$

3. Result and Discussion

In this study, the optimum insulation thickness of various insulation materials that are utilized in regards to energy saving are determined in accordance to degree day method. The values, pertaining to parameters to be used principally to this end were defined. The parameters employed and their values are given at Table 1.

Table.1. Parameters and Their Values Which Were Used in Calculating.

Parameter	**Value**
DDN	2276
Fuel	Coal
H_u	$29.302x10^6$ J/kg
η	0.65
Insulation (Rock wool)	
k	0.04
C_m	136 TL/m^3
Insulation (Extruded polystyrene)	
k	0.03
C_m	250 TL /m^3

The heat loss will be reduced when the insulation thickness is increased and this situation would lessen the heating loss and therefore also the fuel cost. Nevertheless, the total cost, constituted of sum of the insulation and fuel expenditures would also increase as the accrued insulation thickness will heighten the insulation cost too. The impact of optimum insulation thickness, upon the total cost, fuel cost and insulation cost is demonstrated at Figure 2 and Figure 3 when rock wool and XPS are utilized as insulation material. When the graphics on Figure 2 is analyzed, it is being observed that the accrued insulation thickness lowers the fuel cost until the optimum point, while rock wool is used as insulation. Yet the insulation gauge unnecessarily augmented after this point has heightened the insulation cost and increased the total costs in such a case. The costs ensuing when XPS is used as insulation material is given out at Figure 3. Both the two graphics are displaying curves similar to one another. But it is openly observed that XPS has a high insulation cost and a high total cost in consequence because of its costly unit price.

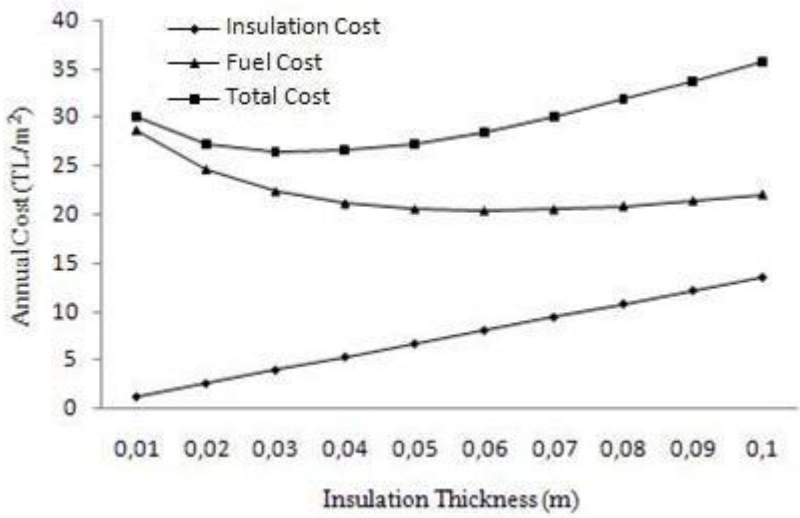


Figure 2. Influence of Different Insulation Thickness on Annual Cost for Rock Wool.

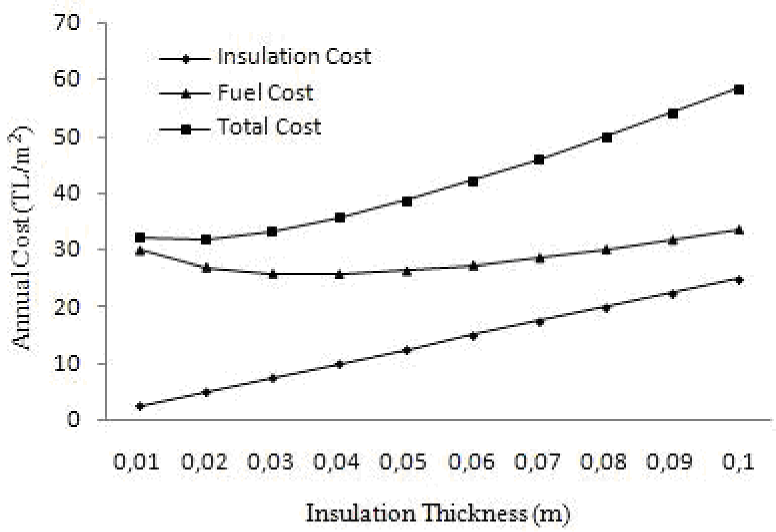


Figure 3. Influence of Different Insulation Thickness on Annual Cost for Extruded Polystyrene.

The impact of DDN upon payback period and insulation thickness in different types of insulation applications is shown at Figure 4 and Figure 5. The most important point, affecting the costs in insulation applications is payback period. The payback period may be described as the time the insulation expenditure committed, compensate its own cost and this time varies pursuing to the insulation material's unit price. The payback period would drop as DDN increases and, insulation thickness would rise. The reason that insulation thickness increases is that insulation thickness accrues at cold climates where DDN is high. As seen at Figure 4 and Figure 5, it is being observed that payback period is shorter, when rock wool is utilized as insulation material rock in comparison to utilization. The cause of this is that XPS is a more expensive material.

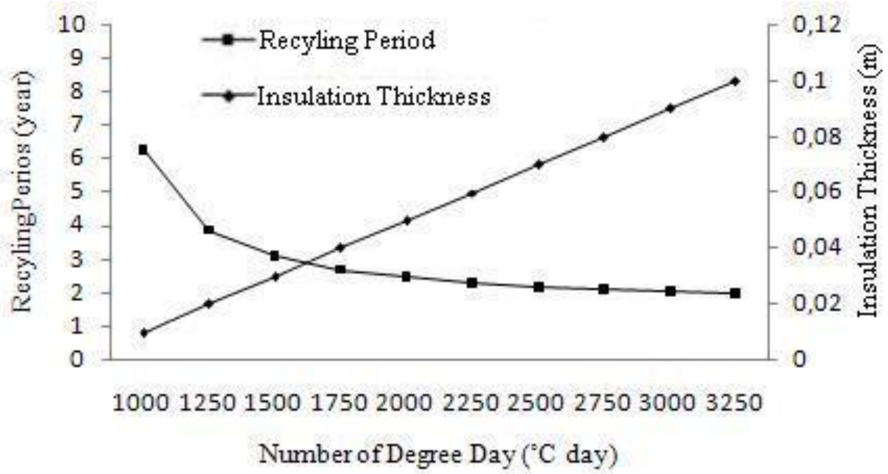


Figure 4. Influence of Number of Degree Day on Recycling Period and Optimum Insulation Thickness for Rock Wool.

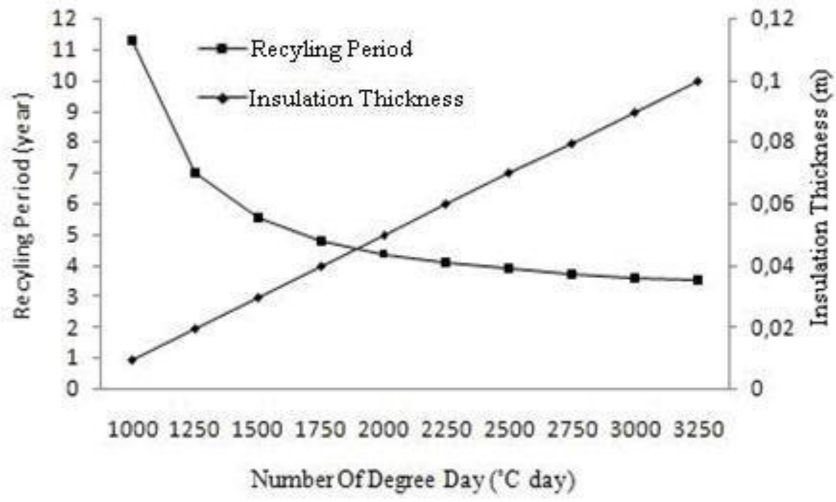


Figure 5. Influence of Number of Degree Day on Recycling Period and Optimum Insulation Thickness for Extruded Polystyrene (XPS)

It will be convenient to determine the cost difference of the building, in order to fully appreciate the benefit of fixing the optimum insulation thickness from economical point of view. The cost difference is being composed of divergence of heating expenditures of the building in insulated state and without insulation and is the most crucial indication of efficiency in applications of insulation. The graphics, reflecting the cost differences and the costs of insulated heating are displayed in Figure 6 and Figure 7. The increase of insulation thickness has reduced the insulated heating costs and thus, this situation has raised the cost difference, as observed on the figures. The yearly cost difference, that may be emanate per unit area at optimum insulation thickness point reached the highest level. The cost differences begin to decrease, in result of gauge, unnecessarily rising after this point. XPS, having high unit price is giving rise to a low cost difference because of this property.

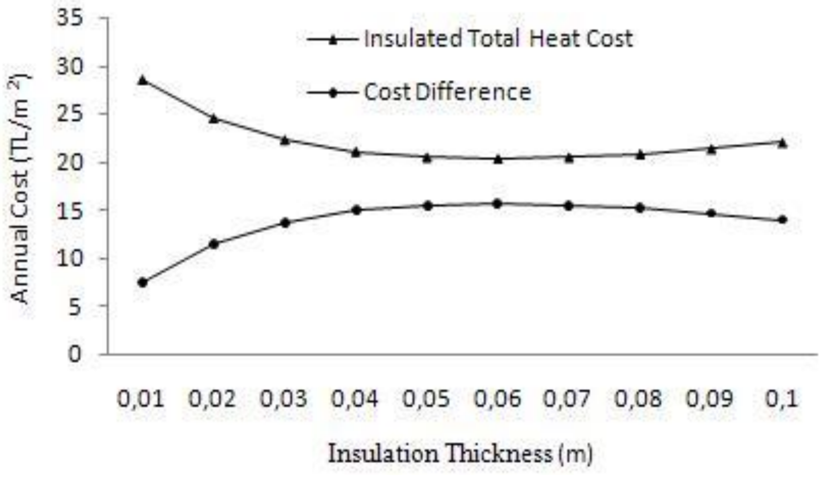


Figure 6. Influence of Insulation Thickness on Cost Difference for Rock Wool.

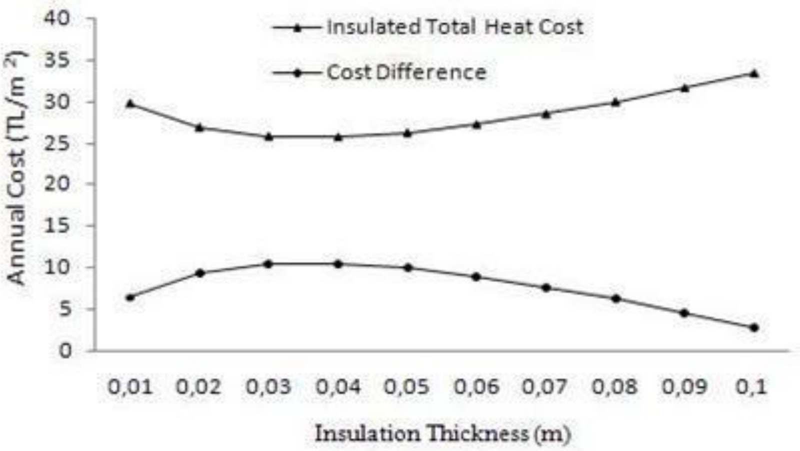


Figure 7. Influence of Insulation Thickness on Cost Difference for XPS

4. Conclusion

Today, as a result of rapidly increasing fuel costs studies on saving energy gained a huge momentum. Especially studies on optimum insulation thickness acts as an important guide on reducing unnecessary insulation costs. As a result of these studies it is ascertained that one of the two construction materials (rock wool and XPS) former provides the best energy saving. it is defined through calculations that optimum insulation thickness for rock wool is 0.06m, saving rate in a year is 43% and repayment period is 2.29 years, for XPS these values are orderly 0.05m, 23% and 4.41 year.

There can be made significant energy saves through this study which was made for the city of Muğla that can be applied all around in Turkey. Also this study which was made on the basis of outer walls can be made more complex and it’s applicability can be increased which is seen very beneficial.

5. Nomenclature

C_f	Fuel cost (TL/kg)
C_m	Unit price of insulating material (TL/m^3)
C_{ins}	Insulation cost (TL/m^2)
C_t	Total heat cost (TL/m^2)
$C_{t,ins}$	Insulated total heat cost (TL/m^2)
C_{year}	Annual heat cost (TL/m^2-year)
DDN	Degree day number (°C day)
E_A	Annual heating energy requirement (J/m^2-year)
g	Rate of inflation
H_u	Heating value for coal (J/kg)
i	Rate of interest
PWF	Present worth factor
r	Real rate of interest
R_d	Exterior surface thermal resistance (m^2 K/W)
R_i	Interior surface thermal resistance (m^2 K/W)
R_{ins}	Thermal resistance of insulating materials (m^2 K/W)
R_w	Thermal resistance of uninsulated wall layer (m^2 K/W)
R_{wt}	Total thermal coefficient of resistance of uninsulated wall layer (m^2 K/W)
U	Total Coefficient of heat transmission (W /m^{2}K)
x	Insulation thickness (m)
Z	Time (year)
k	Thermal Conductivity (W/mK)
η	Utilization factor of gain

References

1. Türker, M.,”Anaerobik Biyoteknoloji ve Biyogaz Üretimi Dünyada ve Türkiye’de Eğilimler”, VII. Ulusal Temiz Enerji Sempozyumu, İstanbul, s. 305-312, 2008.
2. Armağan, B., Yıldız, H., Arslan, A., Özgül, L., “Gap Bölgesi Çiftlik Atıklarından Biyogaz Üretme Potansiyelinin İncelenmesi”, VII. Ulusal Temiz Enerji Sempozyumu, s. 313-322, İstanbul, 2008.
3. Köse, B., Isıkan, O., İnan, T,A., “Isı Yalıtım Uygulamalarının Üç Bölge İçin Enerji Verimliliği Açısından İncelenmesi”, Makine Teknolojileri Elektronik Dergisi, s. 1-9, (3), 2006.
4. Hasan, A., “Optimizing Insulation Thickness for Buildings Using Life Cycle Cost”, Applied Energy, Cilt 63, s. 115-124, 1999.
5. Bolattürk A., “Binalarda Optimum Yalıtım Kalınlıklarının Hesabı ve Enerji tasarrufundaki Rolü”, 14. Ulusal Isı Bilimi ve Tekniği Kongresi, Isparta, s. 41-47, 3-5 Eylül, 2003.
6. Çomaklı K, Yüksel B. “Optimum Insulation Thickness of External Walls for Energy Saving”, Applied Thermal Engineering, Cilt 23, s. 473–479, 2003.
7. Aytaç, A., Aksoy, U,T., “Enerji Tasarrufu İçin Dış Duvarlarda Optimum Yalıtım Kalınlığı ve Isıtma Maliyeti İlişkisi” Gazi Üniversitesi Mühendislik Mimarlık Fakültesi Dergisi, Cilt 21, No 4, s. 753-758, 2006.
8. Gölcü, M., Dombaycı, A,Ö., Abalı, S.,”Denizli İçin Optimum Yalıtım Kalınlığının Enerji Tasarrufuna Etkisi ve Sonuçları”, Gazi Üniversitesi Mühendislik Mimarlık Fakültesi Dergisi, Cilt 21, No 4, s. 639-644, 2006.