DETERMINING ENERGY SAVINGS IN BUILDINGS USING THE REDUCING COSTS METHOD

STAN IVAN F.E., MIRCEA I.
University of Craiova, Faculty of Electrical Engineering
ely_felicia@yahoo.com, imircea@elth.ucv.ro

Abstract - The paper is structured in four parts. The first part presents the importance of thermal insulation for buildings energy economy and some insulation properties. In the second part of the paper it is described the reducing cost method to determine the energy savings. The third part of the paper includes an analysis and a comparison for an exterior wall provided with different thicknesses of insulation layer in order to determine the average savings cost. The last part presents conclusions and discussion.

Keywords: insulation, economy, energy saving, optimal insulation, reducing costs.

1. INTRODUCTION

Insulations have a large economic impact in order to reduce energy consumption in buildings. The costs of the insulation placement are quickly recovered during the life cycle of a building. Reducing energy consumption also offers advantages in terms of environmental protection. Design of a safe isolation requires knowledge of all areas of physics buildings. Among the fundamental functions must meet insulation materials can remember: prevention of condensation, to minimize moisture in buildings is absorbing, be fire resistant, to minimize energy consumption in buildings. [1]

Saving energy [1]

Lately international regulations stipulate minimum requirements to limit the need for heating and energy saving in buildings. The goal however is to achieve energy savings.

A wear-efficient insulation, maintenance free and requires no replacement, for a period of time well established. The life time of the thermal insulation is normally considered to be 50 years. In practice, the life time of the insulation is unlimited. Therefore, the life cycle analysis for a well sized and placed insulation proves that it can be much higher than that provided for in the regulations.

Even if by placing a layer of insulation with a better quality than that required by regulation would increase costs, is a very effective measure, because the investment it is return within energy savings. The cost with a better quality insulation should consider the increase of energy prices, thus making further investments in additional insulation can be avoided in the future. It can be said that choosing a high standard of insulation is an insurance policy against future increases in energy prices.

Environmental concerns. How does the insulation influence the environment? [1]

The use of thermal insulation has a positive effect on the environment. Manufacture, including the extraction of raw materials, transportation and assembly has a negative environmental effect that is compensated for during the first year in which the insulation is used.

Totally overwhelming is the amount energy required for heat and hot water.

Choosing an optimal insulation [1]

Traditionally it can be calculate the optimum thickness for different economic structure of a building. In this case, the fact that the building costs will rise when insulation is increased is taken into consideration. But at the same time the annual energy consumption will decrease without there being any outlay for maintenance.

Buildings seen as an energy system [1]

If we were to build buildings that meet the requirements for achieving optimal energy savings it should be considered the whole assembly, not just individual private component surfaces.

For example, it must be appreciated that the various components in a building have different lifetimes. So, it is recommended to take into account the effects that different insulation standards have on the choice of heating system in the house process that must be examined in an early stage.

The savings achieved by placing insulation [1]

Heating and optimal operation of buildings contributes about 40% of total energy consumption in buildings (in Europe). Therefore, there is great potential to reduce energy consumption. Particularly important is that for new construction using appropriate insulation standards. Even when conducting renovation of buildings should take into account that construction should be further isolated.

Further it is presented an economic calculation in order to determine and estimate the optimum thickness of the insulation layer.

2. REDUCING COSTS METHOD (RC)

Method of reducing costs (RC) provides optimal insulation level determination leading to the lowest annual expense of calculation chosen premises. Minimum point is rather flat, which means that the annual costs increase only marginally if we chose a slightly higher standard insulation. [1]

Economic conditions [1]

By 2006, each EU member state had to implement a Directive on energy performance of buildings in the national legislation. This significant change in the first building regulations as regards the consumption of energy in buildings.

These regulations will be based on the total energy consumption of a building, taking into account the thermal losses in the tire, heat loss through ventilation intakes achieved by heat recovery: solar, the people, and making domestic water cooling using air conditioning systems, etc.

A high standard of insulation for floors, walls, roof and windows it not only provide lower energy consumption for heating for shorter periods of time but also a free energy conservation improvement and creates appropriate conditions for using simple heating.

A high standard of insulation is an investment with a great return for a long time. There is no additional requirement in terms of operation and maintenance costs.

RC method allows comparing the cost of energy saving - cost-saving with current energy price. The method consists of progressively increasing thickness of insulation and determination by calculating the cost savings. [1]

Method of reducing costs - RC - can be calculated using the following formula:

$$RC = \frac{\Delta I}{B \cdot \alpha} \qquad \text{[euro/kWh]} \qquad (1)$$

where,

ΔI - increase investment cost, [euro/m^2];

B - energy consumption, [kWh/ m^2].

Energy consumption is determined using the relation:

$$B = \Delta U \cdot N_{12}^{\theta_i} \qquad \text{[kWh/ m}^2\text{]} \qquad (2)$$

where,

ΔU - improving thermal transmittance value [W/m2K];

$N_{12}^{\theta_i}$ -the number of heating degree days [Kh/year];

α - is the correction factor and is calculated using the following formula [1]:

$$\alpha = \frac{1 - t^n}{1 - t}, \; t = \frac{1+q}{1+r} \qquad (3)$$

where,

n – lifetime, [years];

t - the time period, [years];

r - discount rate of investment, [%];

q - real annual increase energy prices, [%].

3. EXAMPLE OF CALCULATION

For example, we chose an exterior wall building structure having the following characteristics: concrete layer with thickness d=0.30m, thermal conductivity λ=2.03W/mK, density ρ=2600kg/m^3, expanded polystyrene with thickness d=0.05m, the thermal conductivity λ=0.04W/mK and density ρ=20kg/m^3. Convection coefficient values for interior or exterior are: $\alpha_i = 0.13$, $\alpha_e = 0.04$.[3]

Next are presented the economic conditions and calculation assumptions taken into account for determining reductions in energy costs

Table 1. Calculation conditions taken into account when calculating energy cost reductions

Size	Value	Unit
The current price of thermal energy [4]	0.0423	euro/kWh
The discount rate, r	10	%
Real annual increase energy prices, q	2	%
Life time, n	50	years
The number of heating degree days, $N_{12}^{\theta_i}$	183.45	Kh/year
Investment growth insulation thickness, ΔI	5.22	euro/m^2
Correction factor, α	13.9064	-
The time period, t	0.93	years

In our case we started from an insulation thickness of 0.05m insulation. The cost per square meter of thermal insulation 1.74 euro/m^2 with a thickness of 0.05m. With an increase of insulation from 0.05 to 0.15 m, the investment increase by 5.22 euro/m^2. [1,6]

In our case we started from an insulation thickness of 0.05 m insulation The cost of a square meter of insulation with a thickness of 0.5 m is 1.74 euro/m^2, so for the case of a thermal insulation with a thickness of 0.15 m, the investment is 5.22 euro/m^2. To determine the investment growth of insulation will consider: the wall surface, the fixed costs and the thickness of the insulation. [1]

The total investment due to the location of an insulation layer thickness of 0.15 m is, [5,6]:

$$\Delta I = S * \Pr ice/insulation * \mathrm{d} = 12.5 \cdot (1.74 \cdot 3) \cdot 0.15 = 9.7875 \text{ euro/m}^2$$

where:

S- wall surface, [m^2];

Price/insulation - thermal insulation price depending on the thickness [euro/m^2];

d – insulation thickness, [m].

We calculate the correction factor α using the formula (3):

$$t = \frac{1+q}{1+r} = \frac{1+\frac{2}{100}}{1+\frac{10}{100}} = 0.93 \text{ years}$$

$$\alpha = \frac{1-t^n}{1-t} = \frac{1-(0.93)^{50}}{1-0.93} = 13.9064$$

Further we will determine the number of degree days. For Craiova town, the annual number of degree days calculation and duration of conventional heating period is determined according to the average annual temperature θ [°C], the annual number of degree days calculation, calculated average indoor temperature of the building heating period θ_i =+20°C and average daily outdoor temperature that marks the start and stop heating θ_a=+ 12°C, Dn the conventional heating period corresponding to a temperature θ_a =+12°C. [2]

Table 2. The annual number of degrees - days of computing and conventional heating period duration [2]

Town	θ_a [°C]	N_{12}^{20} [Kzile]	D_{12} [zile]
Craiova	10.6	3170	190

The annual number of degree day's calculation is determined by the provisions of SR 4839 -1997, with the relationship [2]:

$$N_{12}^{\theta_i} = N_{12}^{20} - (20-\theta_i)\cdot D_{12} \text{ [K·days]} \quad (4)$$

$$N_{12}^{\theta_i} = N_{12}^{20} - (20-\theta_i)\cdot D_{12} = 3170-(20-18)\cdot 190 = 2790 \text{ K·days}$$

$$N_{12}^{\theta_i} = (2790\cdot 24)/365 = 183.45 \text{ K·h/year}$$

It will be calculate the transmittances and heat resistance for the analyzed structure with insulation thickness of 0.05m.[3]

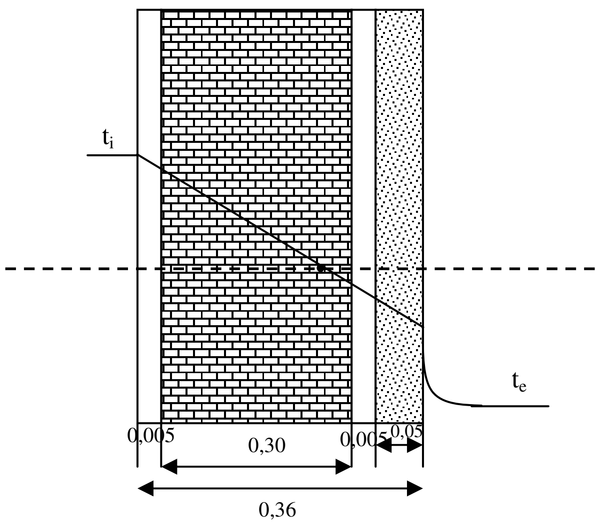

Fig. 1. Exterior wall with insulation thickness, d =0.05 m

Table 3. The calculation of the transmittances and heat resistance in the case of the isolation of 0.05 m

Material	d [m]	λ [W/mK]	cp [J/(kgK)]	ρ [kg/m³]	R [(m²K)/ W]
Internal plaster	0.005	0.37	840	1000	0.01
Reinforced concrete	0.3	0.27	1460	20	1.11
Cellular polystyrene	0.05	0.04	840	2600	1.25
Exterior plaster	0.005	0.93	840	1800	0.01
	0.36				**2.545**
				U_I[W/m²K]	**0.393**

For the case presented in figure 1 with an insulation layer d=0.05 m. the energy consumption is:

$$B_I = U_I \cdot N_{12}^{20} = 0.393\cdot 183.45 = 72.093 \text{ kWh/m}^2$$

For the case when the insulation thickness is 0.5 m the reducing costs will be:

$$RC_I = \frac{\Delta I}{B_I\cdot\alpha} = \frac{1.0625}{72.093\cdot 13.9064} = 0.0010 \text{ euro/kWh}$$

To determine the energy savings it will be considered the same structure design. But with an increase of the thermal insulation thickness from 0.05 to 0.15 m. [3]

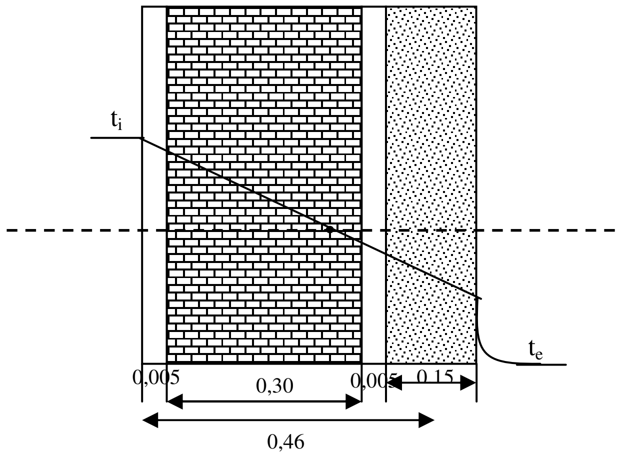

Fig. 2. Exterior wall with insulation thickness, d =0.15 m

Table 4. The calculation of the transmittances and heat resistance in the case of the isolation of 0.15 m[3]

Material	d [m]	λ [W/ mK]	cp [J/(kgK)]	ρ [kg/m³]	R [(m²K)/ W]
Internal plaster	0.005	0.37	840	1000	0.014
Reinforced concrete	0.3	0.27	1460	20	1.111
Cellular polystyrene	0.15	0.04	840	2600	3.750
Exterior plaster	0.005	0.93	840	1800	0.005
	0.46				**5.050**
				U_{II}[W/m²K]	**0.198**

The energy consumption obtained by locating an insulation layer with thickness ranging from 0.05 m (first case) to 0.15 m is determined as follows:

$$B_{II} = U_{II}\cdot N_{12}^{20} = 0.198\cdot 183.45 = 0.198\cdot 183.45 = 36.327$$
kWh/m²

For the case when the insulation thickness is 0.15 m the reducing costs will be:

$$RC_{II} = \frac{\Delta I}{B_{II}\cdot\alpha} = \frac{9.7875}{36.327\cdot 13.9064} = 0.0194 \text{ euro/kWh}$$

Considering the energy savings obtained by locating additional layer of thermal insulation the average energy consumption and the average reducing costs can be calculated using the formulas:

$$B_{average} = \Delta U \cdot N_{12}^{20} = (0.393 - 0.198) \cdot 183.45 = \text{ kWh/m}^2$$
$$= 0.195 \cdot 183.45 = 35.7727$$

$$RC_{average} = \frac{\Delta I}{B_{average} \cdot \alpha} = \frac{9.7875}{35.77 \cdot 13.9064} = 0.0197 \text{ euro/kWh}$$

The calculation to determine the average reducing cost. $RC_{average}$ can be made for each increase in the thickness of the thermal insulation. According to this calculation it can be determined the optimal insulation thickness depending on the climate zone considered, the number of degree-days, interior and exterior temperature.

In our case the average reducing cost was determined by calculating the total step gradually increasing insulation thickness from 0.05 m to 0.15 m

Measures are profitable as long as the average reducing costs $RC_{average}$ is less than the price of thermal energy considered: $RC_{average} < 0.0423$ euro/kWh.

In our case the average reducing cost $RC_{average}$ is 0.0197 euro/kWh and is less then 0.0423 euro/kWh.

Calculation algorithm can be continued until the average energy savings is achieving the value reaches the desired price for the consumers.

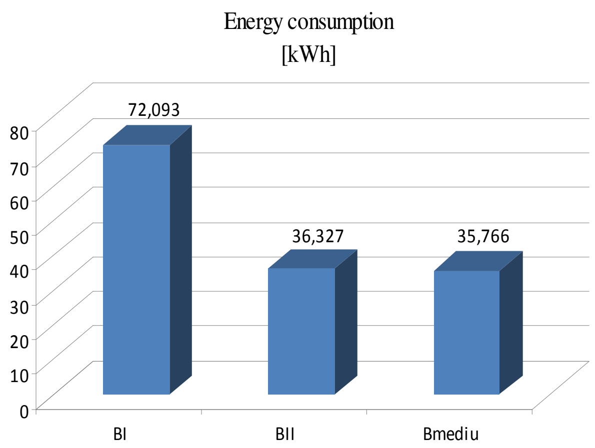

Fig. 3. Energy consumption for different thicknesses of insulation layer including the value of average consumption

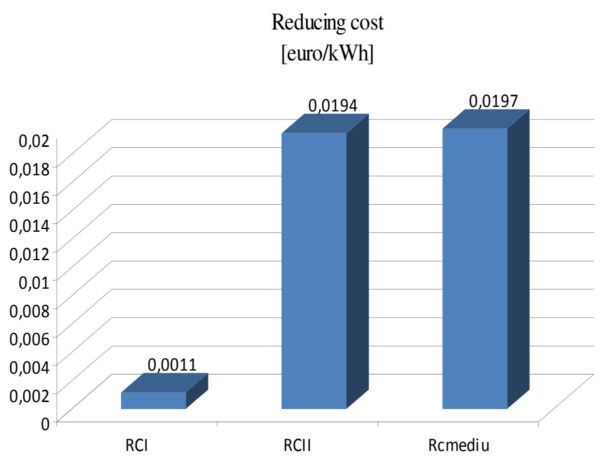

Fig. 4. Reducing energy costs for different thicknesses of insulation layer including the amount of the average costs

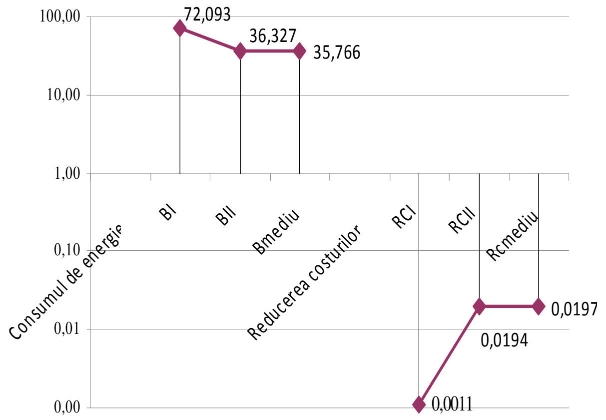

Fig. 5. Comparison and variation of energy consume and reducing cost for the analyzed cases

3. CONCLUSIONS

This article presents a calculation for determining the reduction of energy costs by placing insulation.

As insulation material it was chosen expanded polystyrene with thickness ranging from 0.05 m to 0.15 m. For the same structural outer wall design were calculated transmittances and heat resistance in order to determine the effectiveness of each thermal insulation layer.

According to tables 3 and 4 results that the outer wall with thermal insulation placed on the outside surface with a thickness of 0.15 m has a smaller loss coefficient $U=0.198$ W/m^{2}K than in the first case when the thickness of the thermal insulation is only 0.05 m and $U=0.393$ W/m^{2}K.

Based on these values were calculated energy consumption and cost savings by placing various layers of thermal insulation with different thickness.

For the first case, the insulating layer of 0.05 m the power consumption is 72.093 kWh/m^2 and cost savings are only 0.0010 euro/kWh.

In the second case, when the wall is provided with thermal insulation by 0.15m thickness energy consumption is 36.327 kWh/m^2 and cost savings are 0.0194 euro/kWh.

After determining the energy consumption and the cost savings for each of the two cases analyzed it can be determined the average cost reduction $RC_{average}$ as the ratio between the value of investments (ΔI) due to the location of insulating layers with different thicknesses and the product of energy consumption difference of the two structures analyzed $B_{average}$ and correction coefficient. α.

The method is considered to be efficient if the average energy cost reduction has a lower value than the price of energy considered. In our case the $RC_{average}= 0.0197$ euro /kWh and the price is lower than the thermal energy 0.0423 euro/kWh.

Based on calculation of energy savings B it can be determined the effects of the gradual increase insulation layers thickness

Even if investment increases with increasing thickness of insulation those investments are recovered fairly quickly in order to reduce the energy consumption.

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