Insulation of Exterior Structural Walls

by Using Engineering Insulation Materials:

PONZA and EPS

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Abstract

Because of the rapidly growing world population and also rapid development at Technology ,
Energy is being much valuable and we need it at every stage of our lives.
Because of energy resources are limited and production of energy is expensive, forcing Researchers to find different kinds of materials for optimum usage of existing energy Subject .
Heat energy is the most fundamental and the most needed type of energy. In Spite of the fact that, technology development at cooling is very high recently, energy Needed for cooling is three times more than that of heating. Exterior walls are the Construction elements that has maximum surface area with direct touch of exterior Environment and because of this, heat difference in between sides are great and this may Result great heat loss.
And also at structures in time, diffusion of heat and vapor
Resulting durability problems other than energy loss problem. Because of this, when planning exterior walls, vapor diffusion has to be taken into account. In this study, vapor diffusion, wall thickness and their economical values are examined at opaque details of exterior walls constructed by using block structural elements made of pumice which is a type of volcanic rock and expanded polystyrene (EPS) gathered from polymerization of styrene resin. From the opaque details of found exterior wall, applicable, positive and practical results are gathered.

Key Words: Exterior wall of buildings, heat isolation, vapor diffusion, pumice brick, expanded polystyrene.

١,٠ INTRODUCTION

Today, the level of technological improvements reached making us more dependent on energy at every stage of our lives. But because of the fact that fossil energy sources are limited, makes people find new energy sources and also makes people use energy optimum. A larger part of the energy consumed is the energy used for heating. World has limited sources of fossil energy but, it has also rich sources of heat insulation materials that may be used for construction materials. By appraising these sources in structures not only heat losses will be prevented, but also health of structure and comfort condition will also be provided. By this way, energy will be consumed less and economy will be provided.

Today, insulation projects applied are not enough for needs. In order to get more economic results, exterior wall members have also to be used and profited. In order to achieve this, heat bridges in the insulated exterior walls have to be prevented [١]. Materials used at the exterior walls are related directly with the interior comfort and heat losses. Saved energy with heat insulation is more than that of traditional heat gathering methods [٢]. The most important reason of heat losses at structures are exterior walls. With applying heat insulation to those, ٦٠-٧٠٪ of total heat losses may be prevented [٣, ٤]. Hygrometric behavior of crust of structure depends on climatically data, condensation and wall material. Hygrometric performance of the crust may be increased with airing exterior walls [٥].

٢,٠ MATERIAL

٢,١ Polystyrene Hard Foam

Polystyrene hard foam boards are insulation materials obtained by spraying and folding polymerization of styrene resins under pressure (Extrude Polystyrene-XPS) or by pressing and expanding polystyrene grains with the help of vapor or hot water into folds (Expanded Polystyrene-EPS). These two materials may be used in combination with each other at structures [٦].

Motionless air is a material that has a low heat. Foam materials produced from polystyrene forms from ٩٨٪ air. Foam skeleton that conduct the heat forms the ٢٪ of the total volume. Also the polystyrene material that forms the skeleton of foam is a low conductive material. Because of the fact that, polystyrene foam material is formed from so little closed cells ٠,٠١-٠,١ mm in diameter, (٣-٦ milliard number of cells in ١ m٣ EPS Polystyrene Hard Foam) conducted heat losses with moving air is decreased with every more little volume. So, this material is a very appropriate material from the insulation technique point of view. Heat rays can be prevented best by more number of laminated layers. First of all, specific weight of polystyrene foam material is very low. Heat conductivity value of foam materials produced by pre inflation processes are changing according to produced densities. Generally, standard foam material of ١٠-٣٠ kg.m-٣ density is used in constructions [٧].

Heat isolation of wall, ceiling, roof and prefabricated construction elements in constructions is the biggest usage area of foam material made of polystyrene. Other usage areas may be said as noise isolation, decorative ceiling plates and void elements in concrete folding. Pre swelled polystyrene is also used in production of lightweight concrete and lightweight bricks.

Today, raw-material of EPS is produced ٢,٢ million ton/year in the world and,

The heat isolation products and quantities consumed in Turkey and Europe are shown in Figure ١.

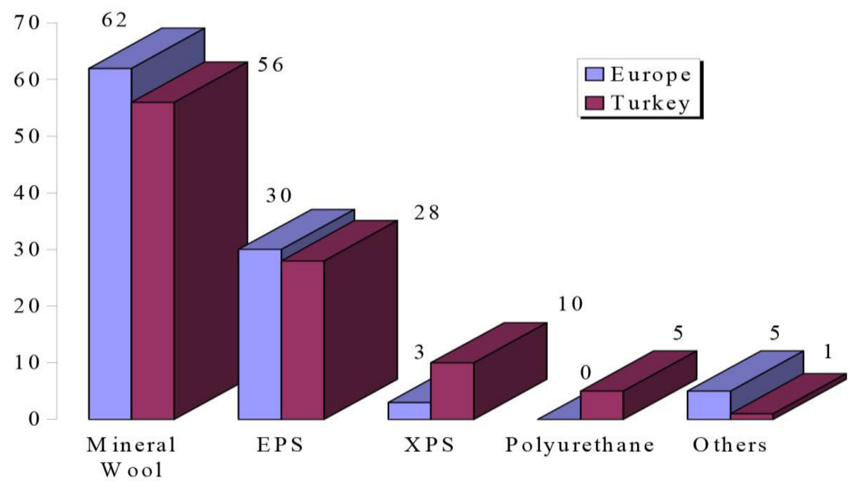

Figure 1. Place of EPS amongst heat insulation products [8].

Heat conduction coefficients of polystyrene hard foam boards used in this study produced in Isparta region is determined using TS ٣٨٨ “Determination of Heat Conductivity with Plate Method” [٩] and TS ٤١٥ “Calculations value of the Thermal Conductivity and Thermal Resistance for Architectural and Building Use (with Plate Method)” [١٠] for five main density group (١٠, ١٥, ٢٠, ٢٥ and ٣٠ kg.m-٣). Found results and data related with other standards are given in Figure ٢.

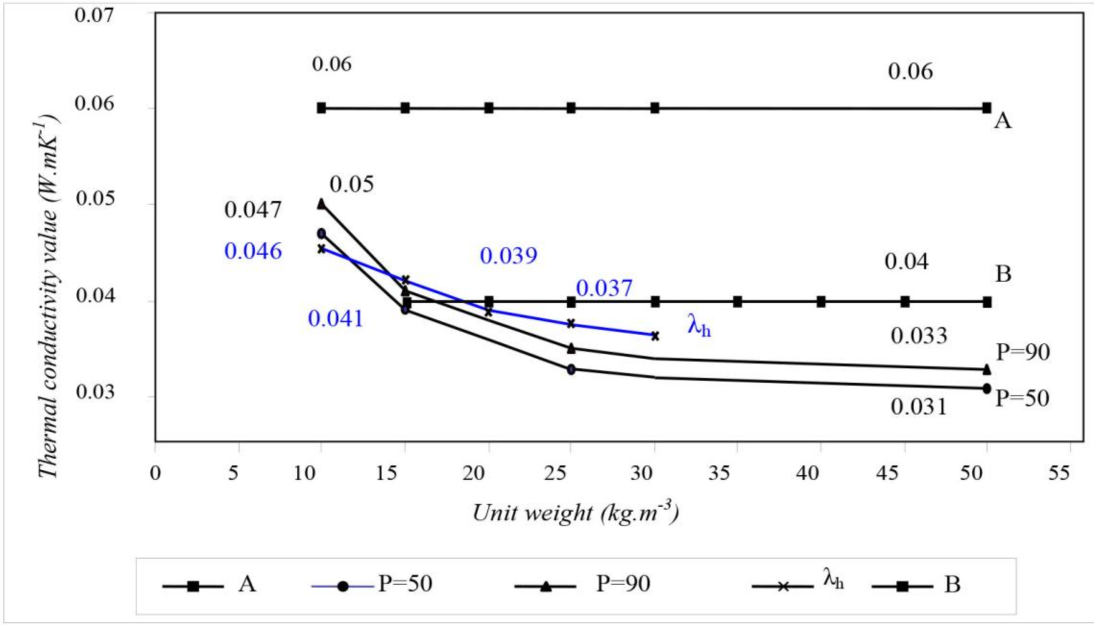

Figure 2. Calculation value of heat conductivity coefficient for EPS [11]

A: Heat conductivity coefficient that will be used for non experiment performed products according to PrEN ١٢٥٢٤ [١٢].
B: Heat conductivity coefficients that will be used according to TS ٨٢٥ [١٣] and DIN ٤١٠٨ [١٤].
P=٥٠ ve P=٩٠: Heat conductivity coefficient that will be used for ٥٠٪ and ٩٠٪ reliability levels according to PrEN ١٢٥٢٤ [١٢].
λh : Heat conductivity coefficient that is found at the experiments [١٢].

٢,٢ Ponza (Pumice)

Ponza (or pumice) is with its porous structure, because of its lightness, high isolation capacity, resistance to atmospherical conditions and high puzzolanic activity, is the construction material used for centuries from the oldest periods of life. At the ages of Antique Greek and Roman periods, pumice is used widespread in amphitheaters, temples, aqueducts, baths, crypts and housing constructions. These structures are still resisting timing [١٥]

Pumice is a volcanic rock that is formed by acidic and basic characterized volcanic activities. When Volcano funnel congested, because of high pressure, gaseous materials in the magma goes outside quickly with acidic or basic materials with big explosions. The products that go outside with the effect of explosion by earning a permeable structure, strung according to their weights in an order horizontal and vertical form the pumice beddings. Pumice; divides into two according to type of volcanic material, acidic and basic pumice [١٦]

Pumice rock aggregate consists about ٧٠٪ voids. Fine grains are found in the nature more than enormous sizes. When we look generally to the chemical analyzes values of pumice of region Isparta, it is seen that, magma suspension has acidic characteristic. But physically, fine material rate is little and those rates do not exceed standard values. There is nearly no organic material and, because of the fact that it is a porous material, it absorbs a big quantity of water in a short time. Pumice aggregate has to be absorbed water when being produced and grain sizes bigger than determined value have to be used after cracking. Cracked pumices have to passed from pans in order to be classified made ready as block aggregate and transmitted to silos. Ready classified pumice aggregate in silos is mixed with binding-agent and water homogeneously folded into moulds with the help of vibrators and pressure. Pumice products are used in lightweight aggregate and have an average density of ٧٢٠-١٤٤٠ kg.m-٣ [١٧].

Heat conductivity coefficient of pumice blocks changes according to void ratio of ponza aggregate used in production, connection of voids with each other, grain size distribution of ponza aggregate used in production mortar, percentage of binding-agent and other materials, power used in pressing, deformation of ponza aggregate and density of ponza block. Generally, heat conductivity coefficients of produced blocks around region Isparta is given in Table ١.

Table 1. Production dimensions of ponza block and heat conductivity coefficients [18].

Product	Dimensions (cm)	Specific Weight ($kg.m^{-3}$)	Heat conductivity value ($kcal.mh^{\circ}C^{-1}$)
Hollow one row	15x39x18.5	0.7-0.8	0.21-0.23
	19x39x18.5		
Hollow two row	10x39x18.5	0.8-1.0	0.19-0.22
	15x39x18.5		
Hollow three row	19x39x18.5	0.9-1.0	0.17-0.21
	25x39x18.5		
Ponza brick	8.5x19x19	0.8-0.9	0.23-0.26
	13.5x19x19		

Parallel to the increase in importance to lightweight construction materials in recent years, because of the fact that low specific weight of pumice rock, high isolation of heat and voice, climatization property, can be easily plastered, acoustic property, elasticity against earthquake loads and behavior, and being more economic relative to alternatives, they have a wide range of usage range in construction industry. They are used in construction industry generally for producing full or hollow lightweight construction elements, prefabricated construction elements production, roof and decorative cladding element production, lightweight ready-made plaster and mortar production, lightweight concrete production and roof and floor isolation filling. Pumice rock is not used only in construction industry, but in Textile and Agriculture Industries and Chemical like sectors; in food, space technology and automotive sector like areas, usage of it is being researched [١٥]

٣،٠ METOD

٣،١ Calculation of Thicknesses

Total heat conductivity resistance of exterior walls advised in third climatic region according to TS ٨٢٥ [١٣] is UD= ٠،٥٠ W.m٢K-١. Because of the fact that material thicknesses of pumice blocks are constant, insulation thicknesses are calculated from the total heat conductivity resistance of cross-section. From the comfort point of view, the difference between warmth of interior surface and warmth of interior volume is taken as ± ٣ °C. Plaster thickness is selected as ٠،٠٢ m, λ= ٠،٨٧ W.m٢K-١ and ١/αi = ٠،١٣ m٢ W.K-١, ١/αd = ٠،٠٤ m٢ W.K-١ [١٣] accepted as constant for all cross-sections. When selecting layering alternatives of opaque compound, minimum layers are unfolded. Other coatings (faience, paneling e.g.) that will be coated are not included into calculation. Found insulation and wall thicknesses at the result of calculations are given

in Figure ٣.
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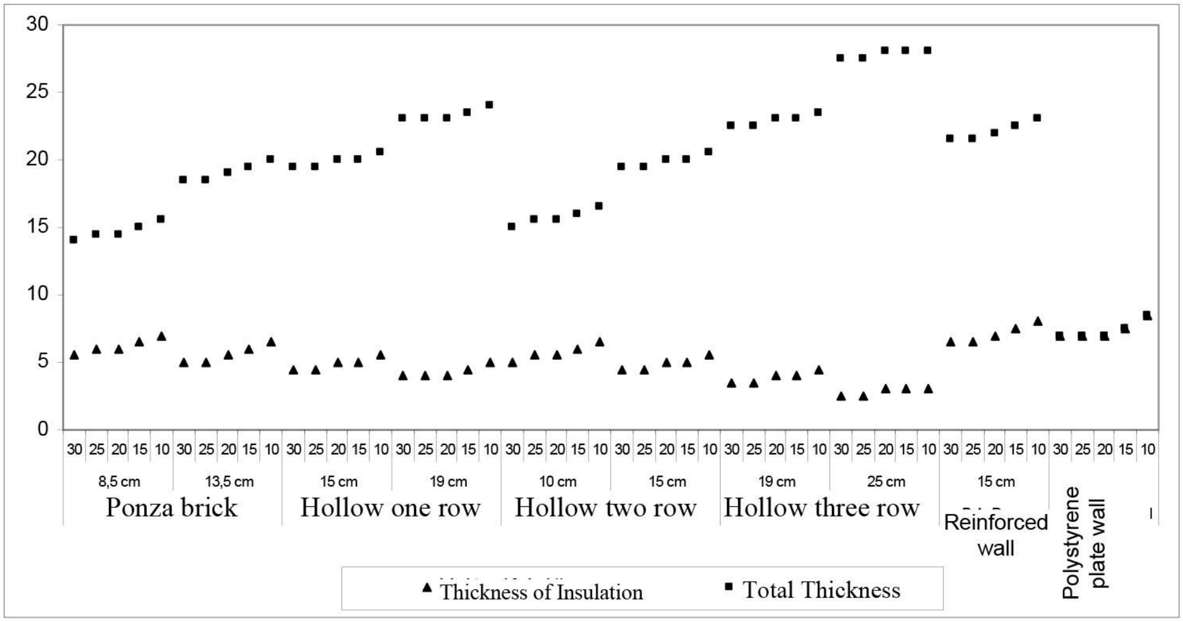

Figure 3. Insulation (EPS) thicknesses and total wall thicknesses

٣,٢ Diffusion of Vapor and Calculation of Condensation

Heat conductivity coefficients of different materials change with increase in humidity. For instance, in organic materials, a ١٪ increase in humidity according to weight causes a ١,٢٥٪ increase in heat conductivity coefficient. In inorganic basal materials, a ١٪ increase in humidity, causes an increase of ٣٢٪ in spite of the fact that, when humidity percentage increased, this value decreases to ٦,٢٪. So, without unfolding the effect of condensation in the building compound and without making necessary calculations, calculating only heat loss of materials may not give healthy results. Practically, most of the time if humidity and heat effects come together, construction materials are affected and frayed more rapidly [١٩].

Because of the fact that, change of heat causes termic strains in construction materials, it is one of the most determinant properties of the fray. Also because of the fact that, an increase in humidity of the cortex of structure is not wanted, water vapor penetrated into the construction material has to go out from the other side of the element. In the winter season, which is critical from the diffusion point of view, because of the fact that the direction of water vapor goes from inside to outside, vator wapor has to be obstructed in the inner side of the building crust whereas, it has to be simplified to go outside where possible [٢٠, ٢١]. Hygroscopic properties of structural walls have an important effect on ejecting vapor from interior in the period of evaporation and when forming condensation. Especially in the cross-section of wall, the heat transfer by radiating and convection after humidity forms to constitute are nearly the same [٢٢]. Calculations of vapor diffusion and condensation are performed according to TS ٨٢٥ [١٣].

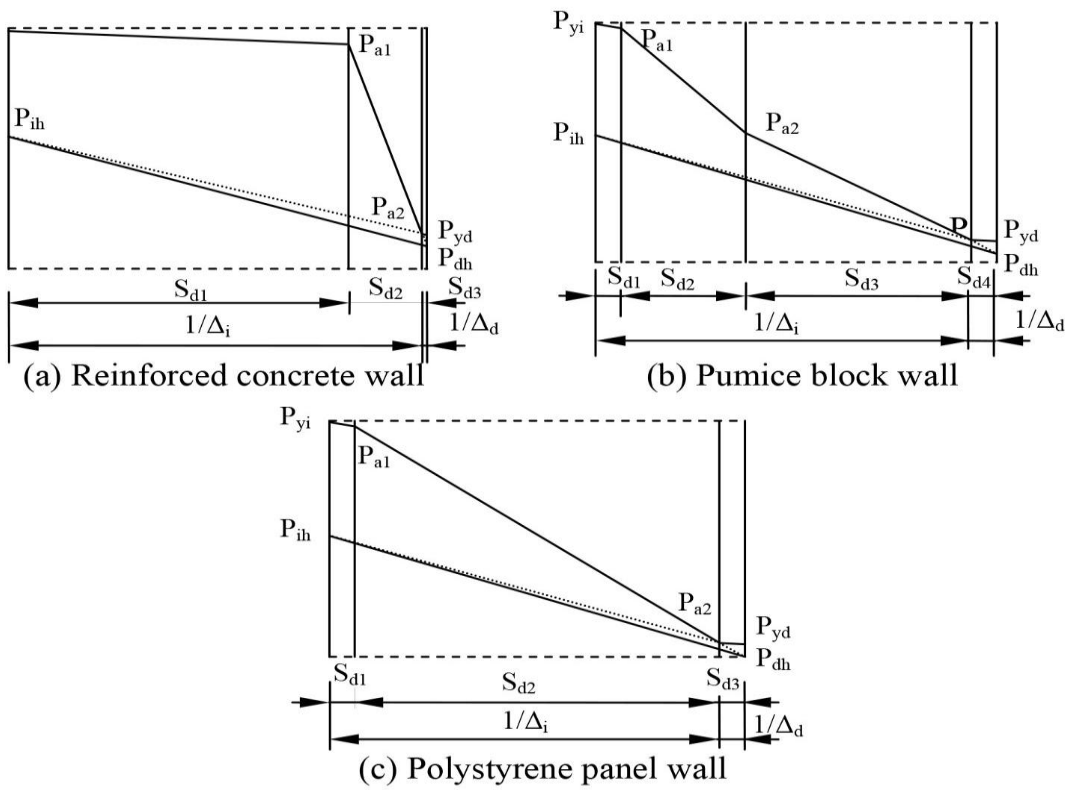

Figure 4. Condensation graphic for examined cross-sections

At the examined cross sections, all of the values of condensation period [WT (kg.m-٢)] are negative. Being negative of all those values show, there is no condensation and densening in the cross-sections. Values of vaporization period [Wv (kg.m-٢)] are positive. When densening is possible, because of the fact that WV > WT, its level is enough to be exhausted in the vaporization period (Cross-sections are in-between the limits as-specified in TS ٨٢٥ Item ٩,٢,٥).

٣,٣ Calculation of Heat Loss

Heat and humidity values used in the calculations are the data of ten years from ١٩٩٠ to ١٩٩٩ obtained from General Directorate of Meteorological Works. Method given in TS ٨٢٥ “Heat Insulation Rules in the Buildings” is used for the calculations of heat losses of example building. Because of the fact that TS ٨٢٥ unfolds the heat loss at all over the building, heat losses are so much high at the ceiling and slab that touches the ground when there is no isolation and insulation thickness is so high. Because of this, for insulated buildings, ٤ cm (١٠ kg.m-٣) polystyrene to the ceiling and ٣ cm (٣٠ kg.m-٣) polystyrene to the slab is added for calculation purposes. Totally not isolated building is notated as “A” whereas, slabs touching ceiling and soil isolated but exterior walls are not isolated building (partially isolated) is notated as “B”. Calculated and limited heat needs that belong to the building are given in Figure ٥.

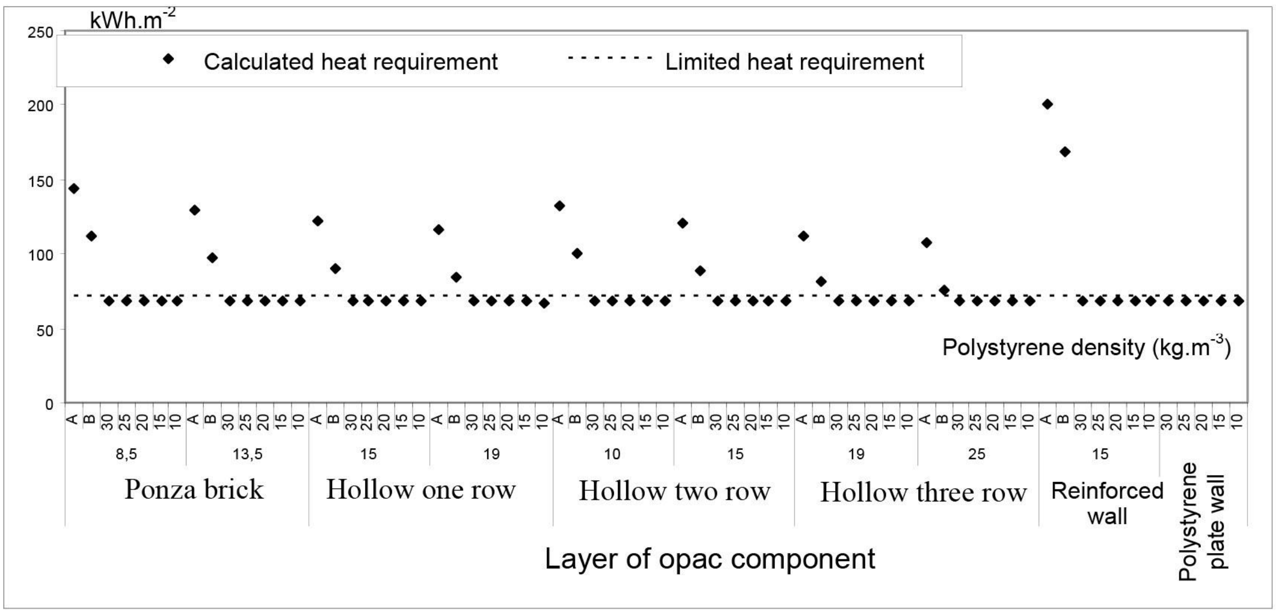

Figure 5. Calculated and Limited Heat Needs

Because of the fact that $Q < Q'$ at the isolated wall cross-sections, it can be seen that the calculated yearly heating energy need is less than the value that must be maximum. Inother-
words, because of the fact that the value is in-between the limit values stated in TS ٨٢٥, these cross-sections can be applied.

When heat consumptions of isolated and not isolated buildings are compared, it is assigned that, there are ٣٦-٥٣٪ decreases in the energy consumed at the cross-sections of walls constructed with pumice products whereas, there is a ٦٦٪ decrease in the reinforced concrete cross-section. At the building with no insulation and the building of which, slabs touching ceiling and soil isolated but exterior walls are not isolated

building (partially isolated), a heat loss of ٢٤~٣٩٪ is prevented at the structure constructed with pumice product whereas, prevention of heat loss is ٪١٦ at the reinforced concrete structure. A percentage of ١٥~٣٩٪ prevention of heat loss is obtained at the building totally insulated with using Expanded Polystyrene in the exterior walls compared to partially insulated building of wall cross-sections constructed with pumice products whereas, a heat loss prevention of ٥٩٪ is obtained at the exterior wall cross-sections with reinforced concrete.

It is determined that, for the consumption of heat between determined insulated crosssections,

there is a difference of ١,٦٦٪. For all of the cross-sections, minimum heat loss is obtained from the cross-section, one row hollow ١٩ cm pumice + ٥,٥ cm thickness and ١٠ kg.m-٣ density of polystyrene combination.

٣,٤ Economical Values of Cross-Sections

According to Close ١٩٦٦ [٢٣], minimum ٣٠٪ of first investment of cost-price can be earned back at every heating period. Taking this into consideration, the relation of costuse

has to be examined carefully and the investment done has to be less. For this aim, economic values of cross-sections are calculated by proportioning U values to crosssection

costs.

As seen in Figure ٦, in spite of the fact that the less amount of first investment values of cross-section from pumice bricks without insulation makes it appropriate at first look, insulated cross-sections are efficient from at long term from the energy saving and environmental health point of view. In the insulated cross-sections, it can be seen that, there is also the cross-section, two row hollow ١٠ cm pumice + ٥,٥ cm thickness and ١٠ kg.m-٣ density of polystyrene combination.

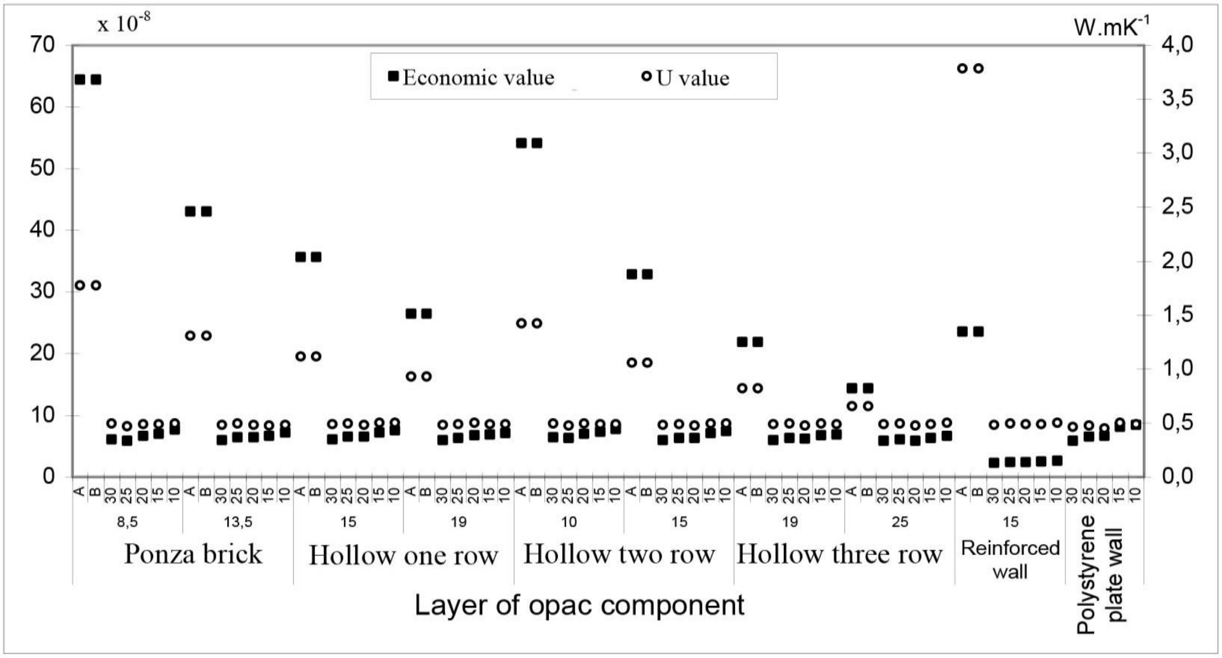

Figure 6. Economical value and U values of determined cross-sections.

٤,٠ DISCUSSION and RESULTS

Today, increasing population, industrialization and technological developments are resulting an increase in the need for energy that is growing day by day. Accordingly, fossil fuels of our world are decreasing day by day. Because of the fact that, we have limited reserves of fossil fuel resources, the difference between supply and demand is also increasing continuously. Another result of increasing energy consumption is the load on individuals-country economy and harms given to environment. Because of all these effects, in order to meet energy needs, economic, clean and renewable energy sources are needed. Meeting those energy needs with countries own sources will add to the economy of countries and will decrease the dependence on fossil energy sources. In this study, with the aim of minimizing fuel consumed in the buildings for heating purposes with using regional materials, it is seen that, heat loss in the not insulated building is twice as bigger than the heat loss of insulated building. This means that, when insulation is done, in order to obtain the same heat, we can obtain a ٣٦~٦٦٪ saving from the fuel consumed. Construction details obtained in this study are applicable from the building health and building technique points of view. With using this kind of materials in the buildings will not only make us save energy, but also spoils that may occur at the building may be prevented by obstructing the effects of heat and humidity.