CARACTERISTICI TEHNICE ALE UNOR PANOURI DE IZOLAȚIE PRODUSE DIN MATERIALE NATURALE

TECHNICAL CHARACTERISTICS OF BUILDING ISOLATION PLATES PRODUCED FROM NATURAL MATERIALS SUCH AS: PERLITE, PUMICE MICASCHIST AND ARENITIZED GRANITE

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The development of materials that provide thermal comfort in buildings have become popular in recent years.The investigation of the technical characteristics of these products and the development on these characteristics have been accelerated in line with this trend. In this context, as well as the specifications of the materials used, the sensitivity to environment and economical processing are also important. In this study, particularly due to the low thermal conductivity of muscovite, mica schists were used as one of the components of the composites together with well-known natural isolation materials such as perlite and pumice. On the other hand, for the first time, the arenitized granite was used for this purpose. The physical and mechanical tests were performed on blocks (40x40x160 mm in size) prepared from the combination of the materials mentioned above and final products (isolation panels) produced after the application of the mixtures on Expanded Polystyrene foam (EPS), Extruded Polystyrene foam XPS and Mineral wool. Both blocks and plates provide the expected technical satisfaction for the physical and mechanical characteristics, according to ASTM and Turkish standards.

Keywords: *Natural materials · Isolation plates · XPS · EPS · Mineral Wool*

1. Introduction

Throughout history, in order to prevent the negative effects of the external world, mankind has tried to take measures for not to be affected by the climatic conditions. Buildings are usually constructed and planned to supply their occupants comfort in many aspects such as climatic and aesthetic points of views. Approximately 70% of building energy consumption is related to Heating Ventilating and Air Conditioning (HVAC) Systems. So, savings from HVAC will be very important if their designers take in account the energy efficiency. The buildings can help energy saving and the designers can be one of the important elements of energy saving policy by selection and integration of suitable building components. Thermal insulation term emerged in the 19th century with the industrial revolution in order to be protected from temperatures that occur and to increase the efficiency of steam boilers [1].

Thermal insulation in buildings is an application that positive impacts on the environment, health, comfort and economy. Investment in the insulation, in addition to the long-term recoup its costs, shows positive effects in earnings and provides mitigation of environmental pollution due to the reduction of fuel consumption. In recent years, a variety of exterior thermal insulation materials have been developed, with the research and development (R&D) activities carried out in this regard, new materials are also continuing to come out. On the development of thermal insulation materials, not only the performance, but also easy availability and production costs play an important role. Although they show difference in terms of cost due to the method applied and type of material, when compared with a building, the costs for the external insulation are about 4-5 %.

External Thermal Insulation Composite Systems (ETICS) have been applied to the facades of the buildings in Europe since 1960s and different terms in different locations of the world are used for this system [2]. The systems have started to be used in Turkey at the end of 1990s [3]. Because of the increasing importance, the systems' materials and effectiveness have changed in time [2,4 - 8]. Both organic and inorganic isolation materials have some negative aspects, for that reason the new kinds of materials are always in demand that eliminating one or more negative aspects [9].

For the improvement on the isolation materials, a wide variety of components from different fields have been tested for possible use in

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this sector. Thanks to their thermal efficiency (low thermal conductivity), high heat capacity, high moisture sensitivity, comfort and having mostly fibrous structure, the agricultural materials contributed an important improvement of the building thermal isolation [10].

Geological materials always find place for the usage in building sector. In this study, the different combinations of four different natural raw materials are used as building insulating material: Pumice and Perlite are well-known thermal isolation materials that have the potential to satisfy all characteristics can be expected from a building insulation material [9,11]. Pumice is a pyroclastic glassy igneous rock with low density and high porosity ranging grey to white in colour. It has wide spectrum of usage area such as health, art, beauty and especially construction sector as both decorative materials and blocks [11]. Perlite is a siliceous amorphous volcanic glassy unit that can be used as a raw material for production of geopolymer in construction sector. When heated above 870 ^{0}C, its volume increases from 4 to 20 times of the primary volume [9,12]. The final product after geopolymerization process can be used in industrial and construction-related applications thanks to its high capacity of thermal insulation, performance on reducing the noise, pore space volume (porosity), lightweight, extremely high resistance to fire, and being non-toxic [13].

The most important basic thermal characteristics of the thermal insulation materials are the thermal conductivity coefficient and the thermal resistance. These parameters show difference depending on the bonding force between the atoms of the material, texture, the amount of pore space and moisture content. Due to its thermal conductivity performance, for the first time, the micaschist is used as one of the compound of isolation panels mixtures in this study. The room temperature values for muscovite 4.05 W/mK for conductivity parallel to the planes, and 0.46 W/mK perpendicular to the planes [14]. When the mixture including micaschist is applied on the panels, it is expected that the planar surfaces of the micas in micaschist will lie on the planar surface thanks to its cleavage. That process will result in the lower thermal conductivity on the final product. On the other hand; the layered silicates (mica minerals, especially muscovite and flogopite) have special characteristics to delay the time taken for ignition of and reduces the heat release rate [15].

Due to their aesthetical view of the textures formed by different minerals, become robust to physical and chemical alteration, the granitoid family has always been sought and desired as a natural material in construction sector. With the technological improvements, the life standards and expectations of the humankind change too. In the light of those improvements, the environmental awareness also increases, so the people try to live more natural environments. In recent years, the interior and exterior natural stone usage in architecture shows a significant increase.

In this study, it was investigated the possibilities of developing a new product which has superior performance in terms of environmental sensitivity, fire resistance, economical efficiency, especially thermal conductivity of composites obtained by using various geological materials, which may be alternative to cement based mortar, which is used as plaster in the outer layer of existing exterior insulation plates. In this context, the production of exterior facade insulation panels obtained from natural materials (micaschist-arenitized granite, pumice and perlite) and their different combinations with the application on commonly used exterior insulation materials such as Expanded Polystyrene foam (EPS), Extruded Polystyrene foam (XPS) and Mineral wool were investigated by means of thermal, physical and mechanical characteristics such as thermal conductivity, bending resistance, On the other hand, in addition to these properties, some other characteristics such as compressive strength, water absorption and specific gravity values were investigated on the block samples to point out the mortar's properties.

2. Materials and Methods

2.1. Materials

The natural raw materials used in this study for producing the building exterior insulation panel were mainly composed of geological units such as micaschist, pumice, perlite, and arenitized granite with different combinations as the main phase, and cement for stabilizing the final product. Micaschists were taken from Palaeozoic Malatya metamorphics cropped out northern part of Kahramanmaraş city. The rock show lepidoblastic texture and the main mineral assemblages are muscovite, biotite, quartz whereas the secondary minerals are represented by apatite, sphene, garnet and epidote (Fig. 1a,b). The acidic pumice samples with more than 65% SiO_2 are of Pliocene Cappadoccian Volcanic Province (CVP) cropped out in the vicinity of Kaymaklı county in Nevşehir in the Cappadoccia region. They have approximately 75-80 % pore space and exhibit glassy texture. Total porosity was determined by using the samples with regular geometry, measuring the volume and the weights of these samples, determining the density and specific gravity values and using the equation [Total porosity (n)= (Specific gravity (G_s)-Dry density (γ_{dry}))/(Specific gravity (G_s)) x100]. The perlite samples were obtained from Bergama-İzmir/Turkey

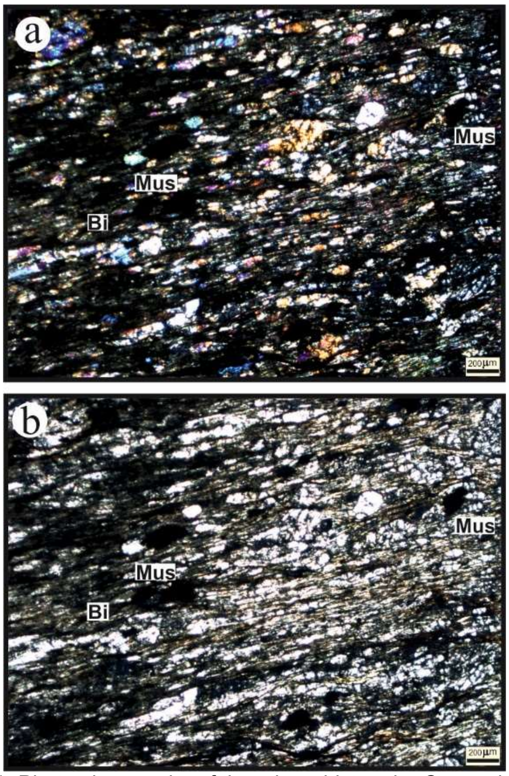

Fig. 1- Photomicrographs of the micaschist under Crossed Polarized Light a) and under Plain Polarized Light b) (Mus: Muscovite, Bi:Biotite).

region and they are in the form of expanded perlite. The granitic arenites were taken from the arenitized section of Late Cretaceous Esence Granitoid located between Esence and Deveboynu villages in Afşin-Kahramanmaraş/Turkey. The main mineralogical composition of the granites in the region comprises quartz, plagioclase, K-feldspar, biotite, hornblende and secondary minerals [16]. CEM-1 42.5 R portland cement which chemical composition is given in Table 1 [17] was used for the production of mortars from the lithological units mentioned above.

In this study, two different forms of samples were prepared. The first form is 40x40x60 mm blocks and the second is three different kinds of isolation plates produced from the different combinations of natural materials. The materials of isolation plates are Expanded Polystyrene foam (EPS), Extruded Polystyrene foam (XPS) and Mineral wool. To improve the adhesion strength of the mortar during application, 160 g/m^2 4x4 glass fiber plaster mesh was used.

2.2. Methods

2.2.1. Mixing of natural raw materials

Before preparing samples that the physical and mechanical tests to be performed on them. The natural raw materials in appropriate proportions of three experiments mold ground (1350 g aggregates (1/3 fine, 2/3 of coarse aggregate), 450 g cement, 225 g of water) were mixed with the compositions in Table 2. Coarse aggregate is between 1-2 mm and fine aggregate is 0-1mm. The natural materials were used as the aggregate material and for each composition, the ratio of cement and natural aggregate material was applied as 25% and 75%, respectively. The compositions for each samples are Pumice (66.66%) + Cement (22.22%) + Water (11.11%) for MZK-1; Granite (66.66%) + Cement (22.22%) + Water (11.11%) for MZK-2; Perlite (66.66%) + Cement (22.22%) + Water (11.11%) for MZK-3; Micaschist (66.66 %) + Cement (22.22 %) + Water (11.11 %) for MZK-4; Micaschist (33.33%) + Granite (33.33%) + Cement (22.22%) + Water (11.11%) for MZK-5; Micaschist (33.33%) + Pumice

Table 1

Chemical composition of portland CEM-1 cement [17]

Oxides	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O + K_2O	SO_3	Free CaO	LOI
(%)	18.5	4.8	2.4	62.8	2.5	1.1	3.6	0.9	3,5

Table 2

The composition of the samples

Sample No	Ingredients
MZK-1	Pumice (66.66%) + Cement (22.22%) + Water (11.11%)
MZK-2	Granite (66.66%) + Cement (22.22%) + Water (11.11%)
MZK-3	Perlite (66.66%) + Cement (22.22%) + Water (11.11%)
MZK-4	Micaschist (66.66 %) + Cement (22.22 %) + Water (11.11 %)
MZK-5	Micaschist (33.33%) + Granite (33.33%) + Cement (22.22%) + Water (11.11%)
MZK-6	Micaschist (33.33%) + Pumice (33.33%) + Cement (22.22%) + Water (11.11%)
MZK-7	Pumice (33.33%) + Granite (33.33%) + Cement (22.22%) + Water (11.11%)
MZK-8	Pumice (33.33%) + Perlite (33.33%) + Cement (22.22%) + Water (11.11%)
MZK-9	Perlite (33.33%) + Granite (33.33%) + Cement (22.22%) + Water (11.11%)
MZK-10	Perlite (33.33%) + Micaschist (33.33%) + Cement (22.22%) + Water (11.11%)

(33.33%) + Cement (22.22%) + Water (11.11%) for MZK-6; Pumice (33.33%) + Granite (33.33%) + Cement (22.22%) + Water (11.11%) for MZK-7; Pumice (33.33%) + Perlite (33.33%) + Cement (22.22%) + Water (11.11%) for MZK-8; Perlite (33.33%) + Granite (33.33%) + Cement (22.22%) + Water (11.11%) for MZK-9; and Perlite (33.33%) + Micaschist (33.33%) + Cement (22.22%) + Water (11.11%) for MZK-10 (Table 2).

2.2.2. Sample preparation

2.2.2.1. Blocks

The mixtures obtained by the combinations of different natural materials such as micaschist, pumice, perlite and arenitized granite (Table 2) were used for preparing both block and isolation plate samples (Fig. 2a). The mixtures of fine and coarse aggregate were used for production of block samples, where as the fine aggregates were used for the isolation plates.

The mixture was stirred in the mixer until it received the homogenous slurry consistency by adding water (Fig. 2b). Prepared mortar was poured into molds that 40x40x160 mm in size specified in TS EN 196-1 standard [18]. The interior of the molds were lubricated with a special oil for not to be disturbed. When half of the molds were filled with mortar, it was subjected to shaking 60 times for filling the gaps. Then the mold was filled up and the shaking process was repeated. After the shaking, the upper surface of the mold was smoothed with the help of a spatula (Fig. 2c). Block samples left to dry were removed carefully after 24 hours without damaging (Fig. 2d).

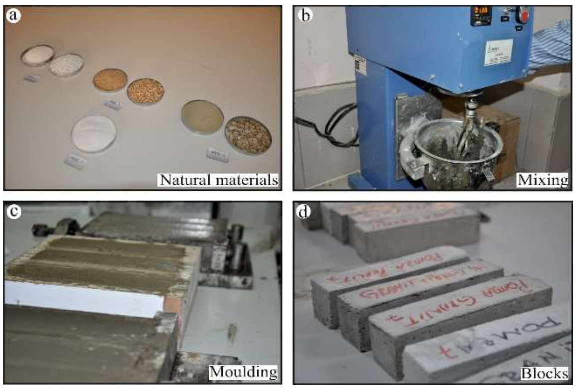

Fig. 2 - Preparation steps of the blocks.

Due to its low specific gravity, slurry consistency could not be achieved in the combination with perlite. So to obtain 40x40x160 mm block samples was not possible with the combination of cement+perlite. Even if the block sample from the cement+perlite combination couldn't be obtained, it is expected that the compressive strength of that combination would be out of measuring limits of the gauge. But, these samples could be applied on the isolation panels as a final product.

2.2.2.2. Panels

In this part of study, the isolation panel samples were prepared for observing the physical and mechanical characteristics of some natural raw materials (micaschist, perlite, pumice, arenitized granite) when applied the homogenous mortar prepared with the different combinations of those geological raw materials on some well-known isolation materials (EPS, XPS, Mineral wool) (Fig 3a). When plastering the first layer, firstly a gauge was used to control the thickness of it, so that the equal thickness was achieved on all the points of the plate's surface. As soon as finishing a thin (0.5-1 mm) first plaster layer, the plaster grid was applied to make the plaster fixed (Fig. 3b). Next, the second plaster layer was applied with a convenient thickness (Fig. 3c). Finally, the isolation plates covered by the natural raw material combinations were left to dry. The samples painted after drying were ready to be fixed to the outer surface of the buildings by the insulation anchors (Fig. 3d). Preferably, a layer of decorative plaster and painting can be applied (Fig. 3d). Plastering process was applied on the XPS (120x60 cm in size), EPS and Mineral wool (100x50 in size). The physical and mechanical tests were made after 28 days drying time.

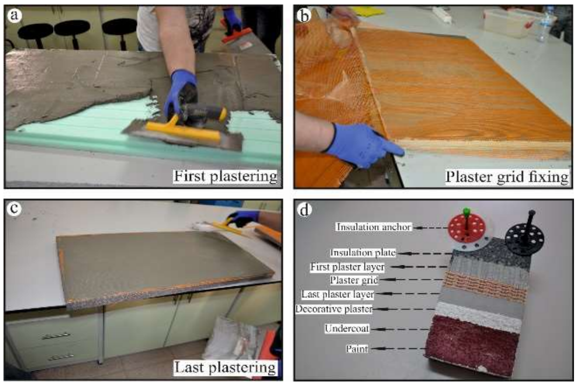

Fig. 3 - Preparation steps of the isolation plates.

2.2.3. Testing Methods

2.2.3.1. Bending Resistance

To determine the bending resistance values of the mortar blocks, the mid-point method was used as desired in TS EN 998-1 standard [19]. In this context, the samples were kept at curing pool for 3, 7 and 28 days of curing and then tested. The bending resistance tests were made by "Zwick/ 2010 Universal Test" machine that has 20 kN capacity and capable of making bending, compressive and tenstile strength tests. The 50 N load was applied in a second and the span was

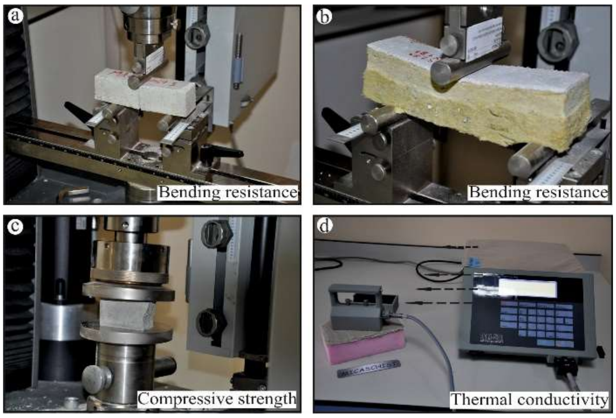

Fig. 4 - Testing methods.

determined as 100 mm (Fig. 4a). On the other hand, the isolation plate samples as the final products were prepared with 50x50x200 mm in size, and then the bending resistance tests were applied on those samples with 150 mm (2.5-3 times of the sample height) span (Fig. 4b)

2.2.3.2. Compressive Strength

The compressive strength tests were only applied to the block samples which were obtained from the two parts remained from the bending resistance tests at least 4x4x4 cm in size. As in the bending resistance test, the compressive strength tests were made by "Zwick/ 2010 Universal Test" machine. The compressive strength of hardened mortars were made in accordance with the test method stipulated in [18] (Fig. 4c).

2.2.3.3. Thermal Conductivity

The thermal conductivity coefficients of isolation plates were measured by KEM QTM-500 model thermal conductivity test instrument. The test was performed in accordance with the ASTM C 1113-90 standard [20] with the hot wire method (Fig. 4d).

2.2.3.4. Water absorption and Specific Gravity

The specific gravity and water absorption tests were performed according to ASTM C 67-03 standard [21]. To measure the water absorption of the blocks. The samples were immersed in the water tank and kept there 24 hours. The weight of the block was noted. The block was placed in a oven at 105 ^{0}C, then the weight of the block was noted. From these two values, the water absorbed by the entire block was calculated and noted

Water absorption (%) $=[(W_1-W_2) / W_1] \times 100$ (1)

W_1 = Weight of the saturated block

W_2 = Weight of the dry block

V = Volume of the block

The unit weight tests carried out by using ASTM C 67-03 [21]. The unit weights of the blocks were measured by dividing their mass values by their overall volumes.

Specific gravity $= [W_2/ V]$ (2)

3. Discussion and Results

The results of the experimental studies carried out for pointing out the characteristics of the new generation exterior isolation materials produced with the combination of some natural materials will be explained under two main subtitles. Firstly the physical and mechanical test results gained from the 40x40x160 mm blocks prepared from the different mixtures of the natural samples and then thermal isolation plates will be discussed.

Four different physical and mechanical characteristics (Bending resistance, Compressive Strength, Specific gravity and Water absorption ratio) were investigated on 40x40x160 mm blocks. On the thermal insulation plates, to obtain the final product, since it provides the ability to monitor its characteristic, primarily intended to measure the thermal conductivity coefficients of the plates. On the other hand, due to importance of the bending resistance on adhesive strength of the plates, the bending resistance values were also measured.

3.1. Blocks

The results of the physical and mechanical tests performed on the block are shown in Figs. 5 - 8. Bending and compressive strength values of the plaster mortar blocks were measured at 3, 7 and 28 days soaking time.

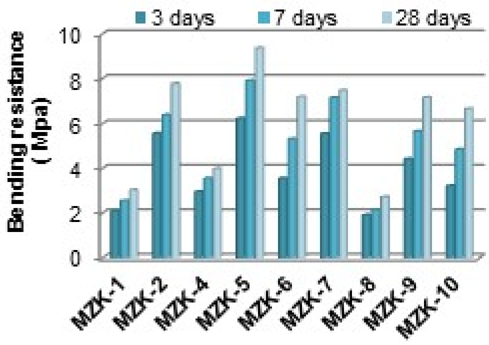

Fig. 5 - Bending resistance of the block samples.

If bending resistance test results of the block samples based on TS EN 196-1 standard [18] were evaluated in accordance with TSE K 113 [22] standard. The lowest values gained from MZK- 8 (pumice+perlite) as 1.91, 2.13 and 2.72, whereas the highest values were gained from MZK-5 (micaschist+arenitized granite) as 6.23, 7.91 and 9.37 MPa for 3, 7 and 28 days respectively. According to standard TSE K-113 [22], bending resistance values of the cement-based external plasters after 28 days curing in water should be at least 2 MPa. Block samples (except MZK-8) used in experimental studies reached this limit value in the first 3 days, and at the end of 28 days soaking, it has been reached to values higher than the limit values in all samples (Fig. 5).

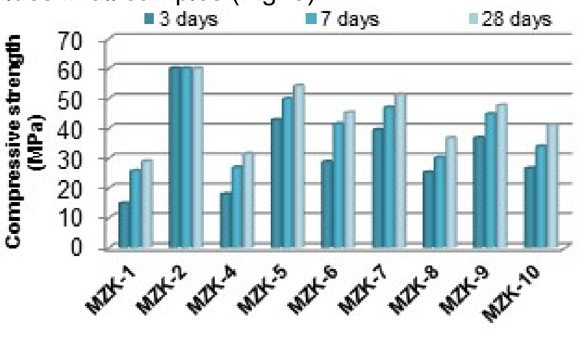

Fig. 6 - Compressive strength of the block samples.

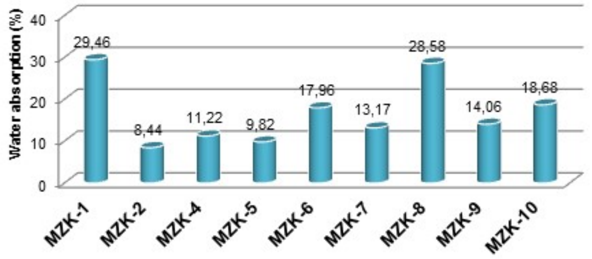

Fig. 7- Water absorption of the block samples.

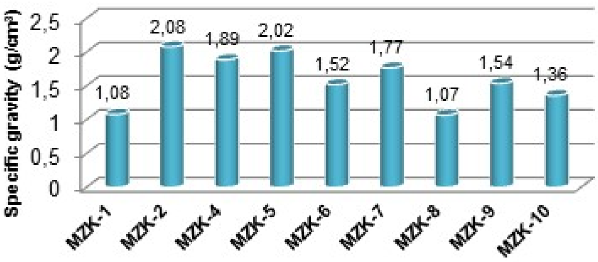

Fig. 8 - Specific gravity of the block samples.

Broken specimens having at least 40x40x40 mm dimensions were selected for testing compressive strength with the same standards as in bending resistance test. The lowest values yielded for 3, 7 and 28 days were 14.81; 25.74 and 28.94 MPa respectively from pumice block (MZK-1), whereas the highest values were more than 60 MPa for the three different soaking time on block sample produced from arenitized granite (MZK-2) (Fig. 6). According to TSE K-113 standard [22], the compressive strength should be at least 6 MPa at the end of the testing time. Our samples attained the limit value in 3 days soaking time (Fig.6)

The highest water absorption value was measured on pumice sample (MZK-1) as 29.46 % and the lowest value was gained on the block produced from arenitized granite (MZK-2) as 8.44% with the direct proportion to porosity (Fig. 7).

The specific gravity tests made in the produced blocks yielded maximum of 2.08 g/cm^3 which was obtained from arenitized granite (MZK-2); whereas the lowest value of the blocks was observed in pumice + perlite combination (MZK-8) as 1.07 g/cm^3 (Fig. 8). Thermal conductivity coefficient varies directly with the specific gravity, whereas it has a contrarily relation with porosity. For that reason the new generation thermal isolation materials tend to be lighter and porous. Due to its high specific gravity, rather than the usage of arenitized granite alone in external insulation, combination with the porous and low density components such as perlite and pumice will make improvements in this regard. Specific gravity values for the standard plaster must be more than 1.15 g/cm^3 [23]. All the samples (except pumice and pumice+perlite combination) have the specific gravity values higher than this standard value given above indicating the pumice and perlite must be used in a combination of some other natural materials rather than to be used alone for providing the standards on specific gravity.

3.2. Thermal Isolation plates

The results of the physical and mechanical tests performed on the isolation plates produced with XPS, EPS and Mineral wool covered by the different composition of natural materials above mentioned are shown in Figs 9,10.

The bending resistance tests applied on the final product samples produced with well-known building external thermal isolation materials (XPS, EPS and Mineral wool) sized in 50x50x200 mm. The lowest bending resistance values for XPS, EPS and Mineral wool yielded as 0.58; 0.30 and 0.21 MPa in pumice+perlite combination (MZK-8), whereas the highest values was measured in the isolation plate prepared from arenitized granite as 0.90; 0.39 and 0.30 MPa for the same materials respectively (Fig. 9). The bending strength values obtained from XPS, EPS and mineral wool without mortar plaster were measured as 0.34, 0.12 and 0.20 MPa respectively. According to these values, the mortar plasters applied on the produced thermal isolation plates increase the bending resistance of the final products (Fig. 9). Due to their action under the load is very important, combination of base material with mortar will always give positive effects on resistance of the external cladding systems. Consequently, it is clearly seen that XPS with all the combinations show high bending resistance. On the contrary, the plates produced from the mineral wool is noteworthy that having the lowest bending resistance values. Despite its high specific weight, the mineral wool has low bending resistance due to its production process was pressing without binding.

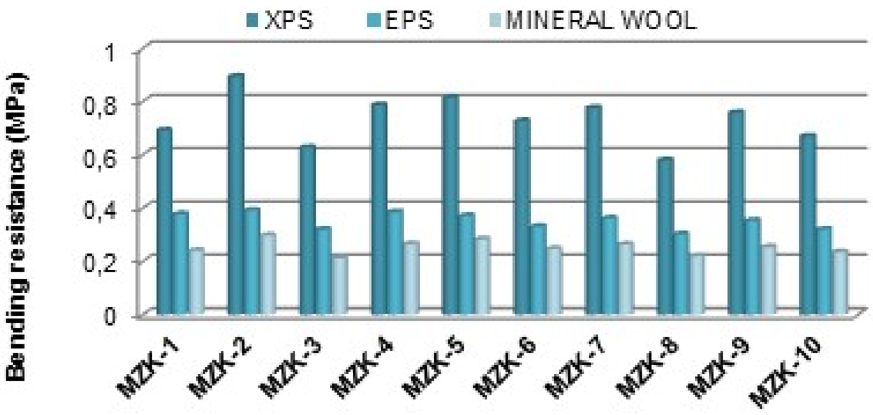

Fig. 9 - Bending resistance of the isolation plates

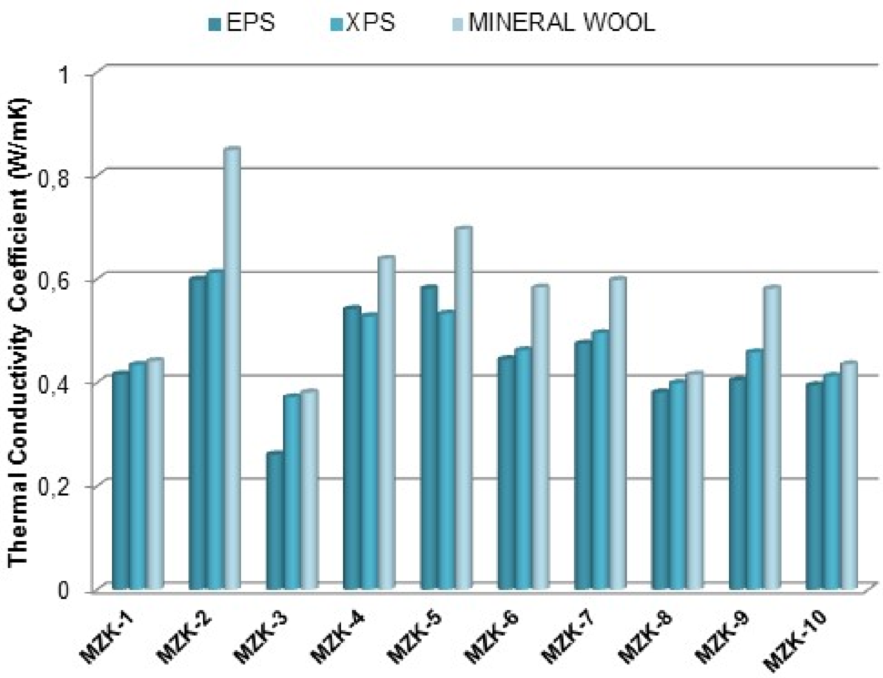

Fig. 10 - Thermal Conductivity Coefficients of the isolation plates

Thermal conductivity measurements made in the combinations given above with the XPS, EPS and Mineral wool; the lowest thermal conductivity coefficients were measured as 0.3722 W/mK, 0.2612 W/mK, 0.3813 W/mK respectively in perlite (MZK-3). Whereas the highest values were gained as 0.6123 W/mK 0.5990 W/mK, 0.8497 W/mK for same insulation materials respectively with the plate obtained with arenitized granite (MZK-2) (Fig. 10). All of the XPS, EPS and mineral wool materials give very low thermal conductivity coefficient values without plaster. However, when coated with a plaster in any composition, there is a clear increase in the thermal conductivity coefficients. According to TS 825, the thermal conductivity coefficients of building exterior insulation plates range from 0.4000 to 0.7000 W/mK [24]. The thermal conductivity coefficient measurement performed on the ordinary
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plaster applied on EPS, yielded 0.634 W/mK ,and all the thermal isolation plates produced on same material in this study gave more positive results than ordinary plaster (Fig. 10).

When high thermal isolation potential of the perlite combined with the fire resistance and retardant potential and heat dissipating characteristics of layered silicates such as biotite and muscovite in micaschists will allow to produce a material with superior thermal properties [15]. In such way, when a fire occurred in a building, the thermal isolation material from those natural raw materials will help the delay of fire and increase the evacuation time.

4. Conclusions

The following conclusions can be drawn from the test results gained in this study:

(1) As a result of compressive strength tests on the block samples; The lowest values were obtained from the blocks produced from pumice and micaschist, where as the highest values of the compressive strength were yielded from arenitized granite blocks. It was not possible to produce block from perlite due to its form and very low compression strength. Therefore, It is concluded that, in terms of compression strength, arenitized granite will give positive effects to the combinations which it is accompanied with.

(2) In terms of bending resistance, the pumice+perlite combination gave the lowest values, where as the micaschist+arenitized granite combination gave the highest values in block samples. Normally, only the blocks produced with arenitized granite are expected to have the highest bending strength, but the dimensional and structural form (sheet) of mica grains help to fill whole gaps in between arenitized grnite grains and increases the bending resistance. On the insulation boards; in each of the three types of insulation material (XPS, EPS, mineral wool), the lowest bending resistance values were obtained from pumice + perlite combination as in the block samples, but the highest values were obtained from plates formed from arenitized granite. The micaschist couldn't infiltrate into the mixing on application due to its thickness was not enough to give much resistance close to the plate from arenitized granite.

(3) Water absorption values are highest in pumice and perlite, whereas the lowest in the arenitized granite.

(4) During the engineering calculation of buildings, it must be taken into account that external insulation materials will affect the total load of the building. Therefore, the unit weight of isolation material can be reduced by using the compositons with the low density elements like perlite or pumice in this study.

(5) Although the two of well-known external thermal isolation materials are perlite and pumice or their combination; and give positive result in terms of thermal isolation [7], the combination of these two materials with micaschist give similar results. Also as a fire resistant and retardant mineral [15], mica minerals in micaschist will add positive properties to this material. The arenitized granite+micaschist combination has a very good properties in terms of water absorption (low) and bending resistance (high). It is expected that, if a third element having good thermal isolation characteristics such as perlite and pumice is added to the mixture of granite+micaschist; an economical and environmentally-sensitive new generation isolation material with much more superior characteristics can be produced.

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