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The Impact of Climatic Factors to the Structure of Unprotected Expanded Polystyrene (EPS) External Insulation on Building

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The article describes the impact of climatic factors on expanded polystyrene slabs when the facade is not protected with external layers (plastered, painted). An overview of articles collected by different authors on climatic factors and their complex impact is provided. The publication also describes studies of the long-term impact of climatic factors in natural conditions of a facade made from expanded polystyrene slabs that are not protected with any coating. The following properties were studied: tensile strength, compression strength, water absorption; studies of the macro and microstructure were also carried out.

Keywords: *expanded polystyrene, climatic factors, mechanical properties, physical properties.*

1. Introduction

One of the most common thermal insulation methods both in Lithuania and in other countries is the mounting of thermal insulation layers on the external side of facades and the protection of the insulation material against environmental impacts with various coatings. By type of work and thermal insulation materials, facades are categorised as ventilated ("EXTERNAL VENTILATED THERMAL INSULATION SYSTEMS" STR 2.01.11:2012) and plastered ("External Thermal Insulation Composite Systems" STR 2.01.10:2007). Expanded polystyrene or stone wool slabs are used as the thermal insulation layer. The thermal conductivity coefficients of these materials are very similar, but the raw materials used for their production and their production technology are completely different. Particularly popular expanded polystyrene consists of polymerised polystyrol (1.5–2 %) and air (98–98.5 %) (Papadopoulos 2005).

With the arrival of the economic downfall in Lithuania, a number of construction projects, including facade thermal insulation work, were suspended. Currently several construction sites are still suspended. The abandoned thermal insulation layers are influenced by external factors (mostly humidity and temperature) for certain periods of time. Climatic factors include factors such as sudden fluctuations of temperature, long impact of high or low temperatures, ultraviolet radiation, changing humidity levels, and the complex impact of the aforementioned factors (Barkauskas and Stankevičius 2000).

Long-term impacts of various physical processes (usually called wear and tear) taking place. No regulation exists for studies of longevity or resistance to climatic factors of stone wool and expanded polystyrene slabs that are currently produced.

The true impact to the facade panels cannot be reflected in laboratory simulated conditions of temperature and humidity. Due to this, the aim of this research is to establish the complex natural climatic factors for exterior expanded polystyrene plates. Different sources of information provide different data about the values of the impact of the said factors on building envelopes in real operational conditions, depending on structure type and location where a given study was conducted. In one of the dissertations it is stated (Buska 2010) that measurements of temperature and relative air humidity in stone wool slabs of a building envelope of low slope roof comply in practice with normal (laboratory) testing conditions (LST EN 13162:2009 Thermal insulation products for buildings – Factory made mineral wool (MW) products – Specification). Normally, rising humidity levels result in considerable temperature drop.

Another publication (Endriukaitytė 2004) states that the humidity at the 'cold' side of the thermal insulation layer in the cold period of the year in Lithuania may reach even 100 %.

Interaction of expanded polystyrene and humidity mostly depends on the structure of polystyrene (Gnip and Kershulis 2004). Water absorption of thermal insulation materials is very complicated process (Vėjelis and Vaitkus 2006b, Hortvath 1999).

In the publications mechanical properties of polystyrene foams have been analysed (Mihlayanhar at al. 2008, Ramsteiner at al.2001, Lin Hong-Ru 1997, Gnip at al. 2006). The density of slabs has the greatest influence on durability at compression and steady-state moisture content have layer influence (Vėjelis and Vaitkus 2006 a, Duškov 1997).

Temperature has little or no impact on the compressive strength of polystyrene foam slabs (Duškov 1997). The compressive strength results received at a temperature of 15 °C were identical to the results obtained at room temperature. Another author (Chang 2000) carried out testing with temperatures ranging from –18 °C to +70 °C; the samples in those temperatures were kept for 6 days. The testing showed that during such a short period of time the impact of temperature on the compressive strength of the samples was not significant. The simulation of two climatic factors [70 °C temperature and 95 % humidity] in a climatic chamber for 28 days showed that the EPS 100 and EPS 70 boards mechanical properties did not suffer, and even in some cases increased, but in the result the density of the changed specimen‘s geometry [samples retreated] has increased. Two of several climatic factors simulated in the laboratory conditions do not reflect the actual effects in natural conditions where all factors may occur.

The purpose of this work is the analysis of the impact of the external environment on physical and mechanical properties of expanded polystyrene.

2. Methods

Testing was carried out with expanded polystyrene slabs taken from an unfinished apartment building which construction was suspended for more than two years (Fig. 1). A plastered thermal insulation system with expanded polystyrene slabs (dimensions: 1,000 x 500 x 150 mm) was used on the external side of the building. It can be seen in Fig. 1 that the foam polystyrene slabs were plainly glued and were not covered with any protective layer. In most places, the slabs had already fallen down or were otherwise removed from the facade. Samples for testing were taken from the bottom part of the facade, above the socle.

Hot wire was used for removal of the samples. Eleven samples (200 x 200 mm) were cut out for long-term water absorption testing and 20 samples (50 x 50 ± 1 mm) for tensile and compression strength testing.

Long-term water absorption testing was carried out according to LST EN 12087 Thermal insulating products for building applications – Determination of long term water absorption by immersion.

Tensile and compression strength testing was carried out according to LST EN 826 Thermal insulating products for building applications – Determination of compression behaviour; LST EN 1607 Thermal insulating products for building applications – Determination of tensile strength perpendicular to faces.

Fig. 1. *Building from which samples were taken*

Samples for compression and tensile strength testing were cut out from a slab that was divided into two parts as shown in Fig. 2. The slab was divided into two parts – the upper part (damaged by external environmental factors) and the bottom part (undamaged). The bottom part served as control samples.

The compression surfaces of control samples were grounded. Compression strength testing was carried out using the computerised testing machine H10KS (Hounsfield, England). The load speed was (5 ± 1) mm/min (LST EN 826:1998 Thermal insulating products for building applications - Determination of compression behaviour).

Fig. 2. *A scheme of cutting out of samples*

Samples for testing micro and macrostructures were taken from mostly damaged in visual terms places. The testing of the macrostructure was carried out using an electronic microscope MOTIC. The testing of the microstructure was carried out using a scanning electron microscope ZEISS, EVO LS 25 with an OXFORD INCA microanalysis system. Testing conditions: voltage of 20 kV and cathode flow of 80 mA.

3. Results and discussion

With a view to determining the extent of damage of expanded polystyrene granules, studies of the macro and microstructures were conducted. The entry of water in deeper layers is visible with the naked eye.

The sample was first of all examined by visual evaluation: darker parts are visible in the upper part of the sample (Fig. 3 d). Further studies were carried out using optical and electronic microscopes.

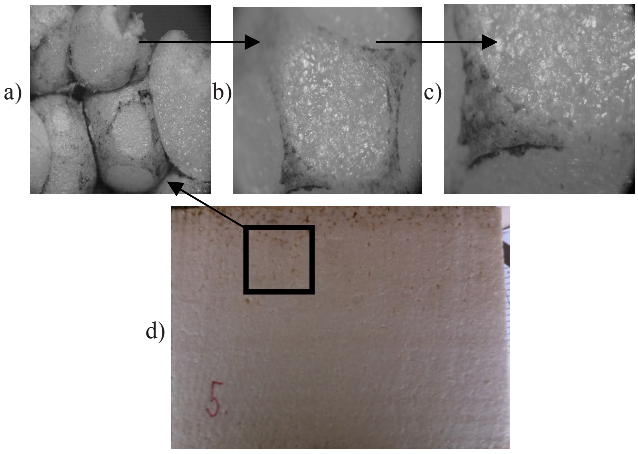

Fig. 3. Images of the macrostructure of the sample with and without an optical microscope: a) magnified 12 times, b) magnified 25 times, c) magnified 50 times, d) image without optical microscope

It can be seen in Fig. 3a that water is present between expanded polystyrene granules and its deep penetration inside the sample. Further magnification shows damaged granules of the expanded polystyrene. For more precise results, the structure was studied using an electronic microscope (Fig. 4). Damage to the surface of the granules was established.

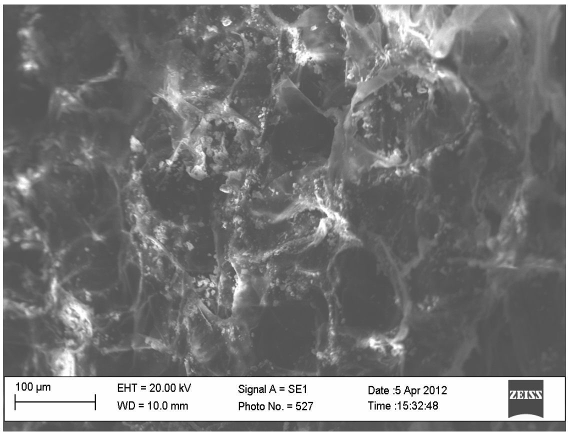

Fig. 4. An image of the microstructure of the sample (magnified 300 times)

Further long-term (28 days) water absorption testing was carried out. The results of water absorption testing obtained showed that water absorption of immersed polystyrene foam samples with damaged surface fluctuates between 1.4 % and 2.7 %, where density is relatively the same (Fig. 5). Samples, where earlier water absorption influence in natural conditions was voluminous, i.e. water absorption depth were higher, after test characterised bigger amount of water absorption, with the same density. In average 14.49 kg/m³ density water absorption values were 1.7 %, 2.7 % and 2.8 %. These results were obtained due to the depth of the damaged layer in the samples. The pores that merged in the damaged surface formed capillaries, through which water was absorbed into deeper layers (in this case water absorption should be higher).

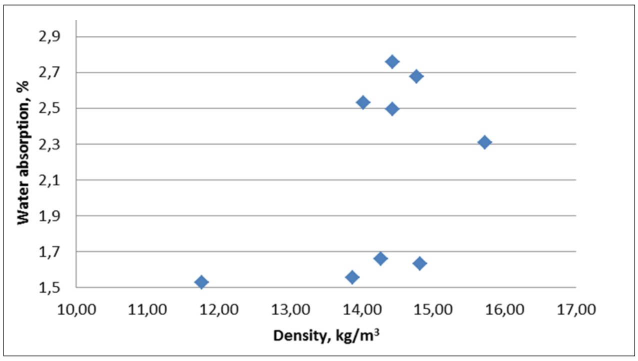

Fig 5. Water absorption dependence on density

The determination of the compressive strength of expanded polystyrene samples did not reveal any clear destruction of the samples or any precisely expressed value of compressive strength (Fig. 6 and Fig. 7). These parameters are determined in relative terms – as a load complying with the assigned material deformation level at 10 % relative deformation ("Thermal insulating products for building applications – Determination of compression behaviour" LST EN 826:1998 Thermal insulating products for building applications – Determination of compression behaviour).

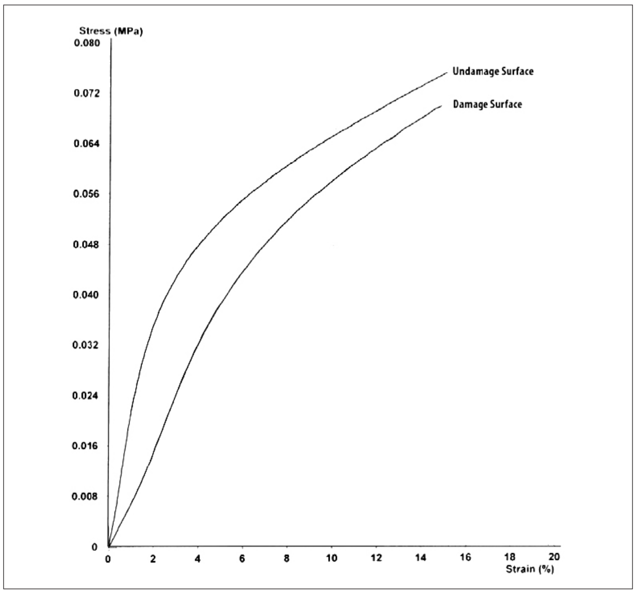

Fig. 6. Diagram of compression strength of samples

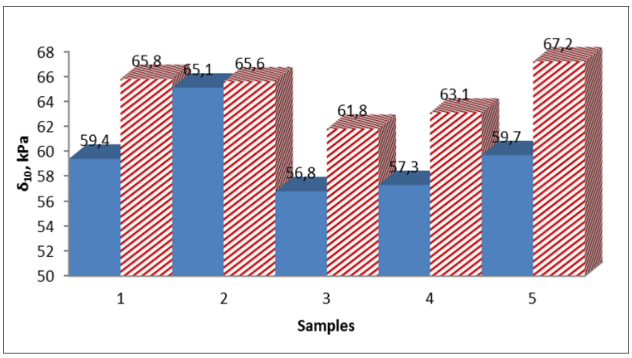

Fig. 7. Compression strength of samples at 10 % deformation (Damaged samples are portrayed in blue and control samples are portrayed in red)

Five samples with a damaged surface and five samples with even surface were prepared for determination the tensile strength (Fig. 8). Metal plates were attached to the surfaces of both types by means of epoxide resin; the samples were then left to dry for at least 24 hours. Tensile strength testing was carried out using the same equipment as in compression strength testing.

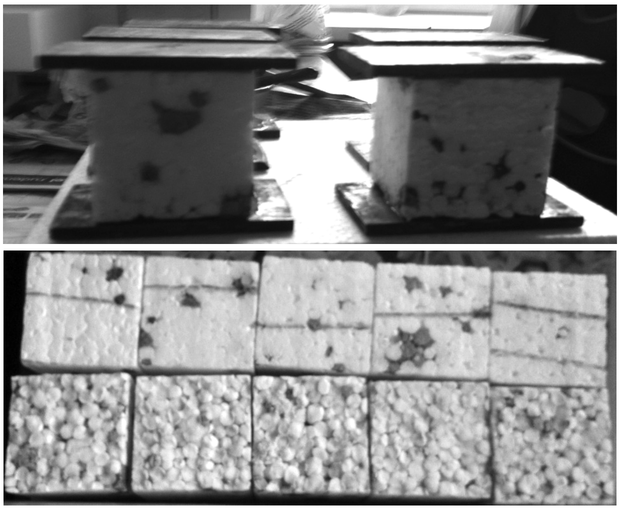

Fig. 8. *Expanded polystyrene samples for tensile strength testing*

The tensile strength of samples is impacted to a great extent by the degree of adhesion of the plates with the surface. For elimination of this impact, the damaged surfaces with small contact areas were additionally reinforced 24 hours later. For this purpose, an additional layer of epoxide resin with the same consistency was placed around the perimeter of the sample and the plate; this additional layer reinforced the contact area. The samples were tested after the resin became solid.

The results of the testing were unequal depending on the nature of breakage. Samples with even surfaces broke at the centre, average tensile strength was 84.3 kPa, while the nature of the breakage of damaged samples varied. It can be seen in Fig. 9 that the values for damaged expanded polystyrene samples were in the range of 65.2–99.1 kPa. The instances of sample breakage can be seen in Fig.11. In comparison with undamaged samples, the sample breakage through the sample lowest value (78.3 kPa) is higher than breakage through damage zone (65.2 kPa) (Fig. 9; Fig. 10). According to the control sample determination of the compressive and tensile strengths, we can maintain that expanded polystyrene should be EPS 70. The producers in Lithuania do not provide tensile strength in declarations of conformity. According to EN 13163 only one strength parameter should be declared. It is strange why producers only declare compression strength as the required tensile strength should be not lower than TR100 for all ETICS systems; therefore, the producers don not have any confirmation that their own system confirms to all required properties according to ETAG 004. According to the possible producers the samples do not meet the normative strength requirements for application. Tensile strength is lower than 100 kPa. Usually, for plastered facades not lower than EPS 70 is used.

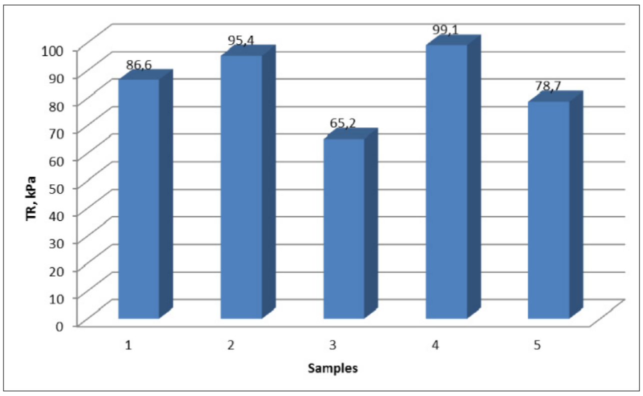

Fig. 9. *Tensile strength of damaged expanded polystyrene samples*

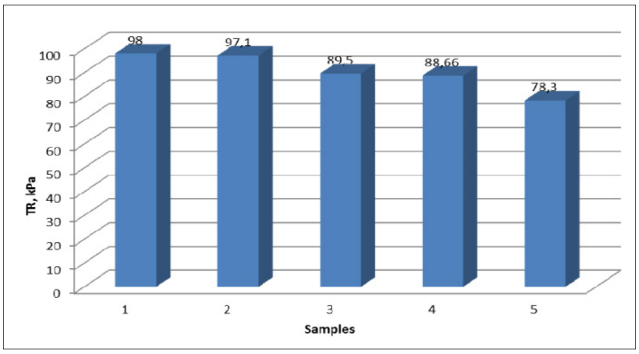

Fig. 10. *Tensile strength of undamaged expanded polystyrene samples*

a) b) c)

Fig. 11. *Instances of sample breakage: a) breakage next to the plate; b) breakage next to the area damaged by water, c) breakage through the sample*

4. Conclusions

1. Expanded polystyrene slabs that are left without protection against the impact of the external environment undergo certain change. Studies of the macro and microstructure show that granules are damaged.
2. Testing of compression strength of expanded polystyrene samples damaged by the environment showed that these samples are destroyed quicker. In this case, compression values are from 57,3 to 65,1 kPa.
3. Testing of tensile strength of polystyrene samples showed that the breakage nature of the samples varies. Breakages occur in the weakest areas, i.e. in the most damaged areas. According to the materials used in external system, tensile and compression strengths do not meet the normative strength requirements. According to EN 13163 EPS boards' tensile strength must be not lower than 100 kPa.
4. Expanded polystyrene boards' surface is over damaged and does not meet normative requirements. They must

be damaged by solar radiation and moisture-frost impact, which will affect very low adhesion with plaster. It is advised to remove all boards damaged by climatic factors and replace them with new ones or apply onto to the existing expanded polystyrene slabs the additional medium thin products slab, glues and fix to the wall base with the fasteners. The period of 2 years of these boards being outside without protecting layers is too long.

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