

Absorbent Properties of Polystyrene with Closed Outer Structure in Case of Failure of the External Surface of the Board

Ondřej Pilný¹, Lubor Kalousek¹

¹ Institute of Building Structures, Brno University of Technology, Faculty of Civil Engineering, Veverří 331/95, 602 00 Brno, Czech Republic

pilny.o@fce.vutbr.cz

Abstract. Thermal insulation is an integral part of almost all modern buildings. An important aspect in this process is the elimination of thermal bridges and insulation of all structures which are exposed to adverse environmental conditions. We are increasingly encountering thermal insulation solutions for elements that have been neglected in the past. One of these constructions is the substructure, which means not only the foundations, but underground floors and plinth. These constructions must be insulated with a material which not only has suitable thermal-insulating properties, but also has to withstand the effects of moisture in the long term. Nowadays, expanded polystyrene with a closed outer structure has become one of the most commonly used thermal insulators for these purposes. However, it is clear that, when built-in, the outer structure of the envelope is often damaged. This is often neglected phenomenon, which has a negative effect in the amount of diffusion flow and moisture propagation in the material. This paper describes a laboratory experiment, in which the outer structure of the EPS samples was broken in various ways. The samples were then fully immersed in water, changes in mass and volume absorbency over time were recorded and results were reciprocally compared.

1. Introduction

Thermal insulation as a protection of structures against heat leakage and its proper design is today, besides ensuring a static balance of structures and interior protection against the influence of moisture, one of the main duties of each designer and contractor. As a result of the stricter thermal standards in Europe [1], we are increasingly encountering thermal insulation of structures that have been neglected in the past due to technical difficulty when performing insulation or because of their apparent lack of importance for the overall heat loss. For example, these are not only penetrations through constructions in the form of installations, but mainly constructions of substructure, foundation structures, walls of underground floors, or, last but not least, a plinth.

Modern computational methods for the simulation of heat flow and conduction using the MESH and CFD methods, together with thermal imaging techniques, however shows us the influence of these thermal bridges on structures that seemed immaterial in past [2]. Construction nowadays takes the protection of these structures almost as a matter of course. However, the problem often arises in choosing a suitable thermal insulator.



In this environment, i.e. the substructure, the materials must meet several properties. In addition to a suitable thermal conductivity coefficient λ [$\text{Wm}^{-1}\text{K}^{-1}$], the materials must resist mechanical damage, be dimensionally stable and be effectively resistant to the effects of moisture over time. The longer the thermal insulator is exposed to moisture, the more it deteriorates its heat-insulating property, which depends on the thermal conductivity coefficient λ . It is therefore necessary to choose materials that are as non-absorbent as possible. One of these materials is, for example, currently commonly used expanded polystyrene (abbreviation in civil engineering EPS) with a closed outer structure, i.e. a thermal insulator, which obtains its resistance against humidity by outer structure of the envelope of individual boards and which is designed for structures in direct contact with moisture and high loads. It is however clear that when installed in a conventional building process, said board envelope mechanically breaks down either by mistake or for the purpose of cutting and subsequently gluing + anchoring to the structures in question.

The main object of this paper is to describe a laboratory experiment in which samples of expanded polystyrene with closed outer structure of the board were subjected to various surface treatments commonly found on the building site, i.e. cutting wire (hot-wire cutter) and polystyrene saw. The individual surface treatments were then compared with the conventional unmodified board structure.

2. Used method, materials, boundary conditions and samples measurements

2.1. Used Method

Within the complexity of measurement, standard methods were used to compute the volume absorption capacity for thermal insulation products for use in the construction industry according to ČSN EN 12087 [3] and weight absorption according to the standard ČSN 72 2603 [4]. These methods are used to determine the long-term absorption of materials during immersion. The method of immersion was considered as complete with upper surface of sample about 50 mm below water level for 28 days.

2.2. Materials and Samples

A total of 12 samples were prepared for the laboratory experiment in the selected method with dimensions of the sides of the base about 200 x 200 mm. The expanded polystyrene with a closed outer structure as a material was used due to very low water absorption. The material is intended for environments with direct contact with moisture. Since it is not normally possible to get samples of these exact dimensions needed for the method, the samples were made from larger boards. The samples were prepared so that the dimensions of the base correspond with the standards prescribed. This gave rise to cubes of the prescribed dimensions, which were suitably adjusted from 4 sides to achieve the required criteria and the two opposite sides (see Figure 1) were left as the sides on which the effect of surface treatments was measured.

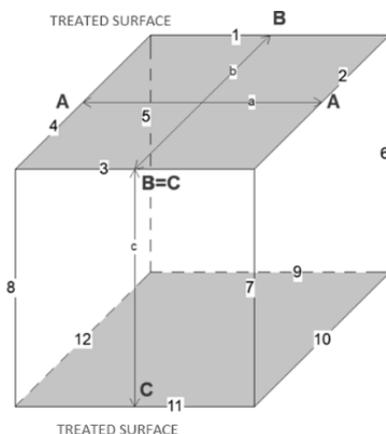


Figure 1. Sample Diagram [5].



Figure 2. Samples before Asphalt Dispersion Application [5].

2.3. Boundary Conditions

The boundary conditions on the laboratory corresponded to the prescribed values for the method during the course of the experiment. A water level of 50 ± 2 mm was maintained after immersion. A water temperature of $23 \pm 5^\circ\text{C}$ was maintained in the laboratory environment. Due to the creation of unsuitable boundary conditions on non-subject cutting surfaces (see Figure 2) in the creation of prescribed dimensions of individual samples, the effect of the mentioned shape and surface treatments was eliminated by coating the surfaces with dispersed asphalt mixture with modified synthetic rubber with thixotropic properties (hereinafter rubber-asphalt), which is intended for polystyrene. This coating (see Figure 3) was applied in two layers with a total thickness of approx. 2 ~ 2.5 mm. Individual samples were then allowed to dry for 3 days to eliminate residual moisture in the rubber-asphalt coating. After thorough drying, the samples were divided according to the test surface:

1. **Test Samples A** – 4 samples were treated in the subject sides with a cutting wire. Samples were numbered 1 ~ 4.
2. **Test Samples B** – 4 samples were treated in the subject sides with a polystyrene saw. Samples were numbered 5 ~ 8.
3. **Test Samples C** – 4 samples were left with the original board structure without any surface treatment on the examined subject sides. Samples were numbered 9 ~ 12.

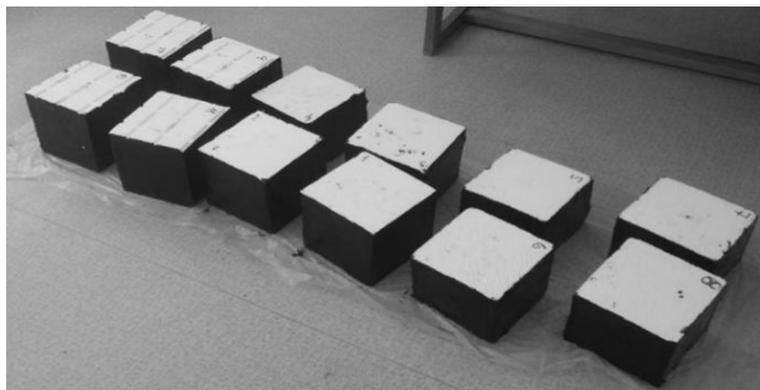


Figure 3. Samples after Asphalt Dispersion Application [5].

The intrinsic effect of the absorbency of rubber-asphalt has not been investigated in detail. For the experiment and results, the absorption of expanded polystyrene samples over time and the subsequent comparison of individual samples with different surface treatment methods A – C were decisive. The water absorption of asphalt waterproofing is not commonly stated by the manufacturer and can be found in other scientific publications [6].

2.4. Samples Measurements

The samples were measured using a digital calliper with an accuracy of 0.03 – 0.04 mm and weighted with a digital scales of 0.1 g accuracy before being immersed in water. Subsequently, the samples were suitably immersed in a container of water at the prescribed temperature, suitably burdened and placed in a laboratory environment with constant conditions prescribed by the standard. The samples were withdrawn every 24 hours, suitably dried only from surface moisture, re-measured in places designated as A-A, B-B and C-C and weighted to determine the effect not only on water absorption, but also on volume stability.

3. Results

3.1 Used Equations

The following formulas for volume (1) and mass absorbency (2) were used to calculate and compare the absorbent properties. These formulas were derived from formulas given in the present standards:

$$n_v = \frac{m_n - m_s}{V_{28}} \times \frac{100}{\rho_k} \quad [\%] \tag{1}$$

where: n_v long-term volume water absorption [%]
 V_{28} volume of test sample after 28 days, $V_{28}=V_0$ [m³]
 m_s initial sample weight in time 0 [kg]
 m_n weight of the sample when exposed to moisture after 28 days of immersion [kg]
 ρ_k density of water [kg.m⁻³]

$$n_h = \frac{m_n - m_s}{m_s} \times 100 \quad [\%] \tag{2}$$

where: n_h long-term weight water absorption [%]
 m_n weight of the sample when exposed to moisture after 28 days of immersion [kg]
 m_s initial sample weight in time 0 [kg]

Individual equations were chosen with regard to the most accurate evaluation of the investigated properties. Formula (1) was corrected for the difference in the initial (V_0) and final (V_{28}) volume of the resulting values on the percentage comparison between these values. These values are based on the measurements of dimensions A-A = 0.52%, B-B = 0.34% a C-C = 1.08 %, where individual values were calculated from the minimum and maximum average values.

3.2 Resulting Graphs

The resulting values were summarized in graphs showing the course of water absorption over time.

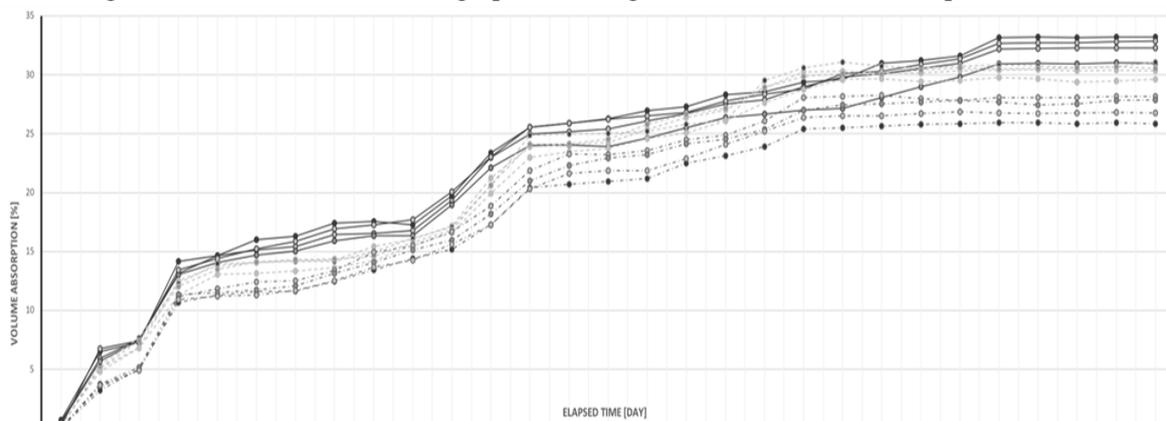


Figure 4. Graph of Volume Absorption of Polystyrene with Different Surface Treatment.

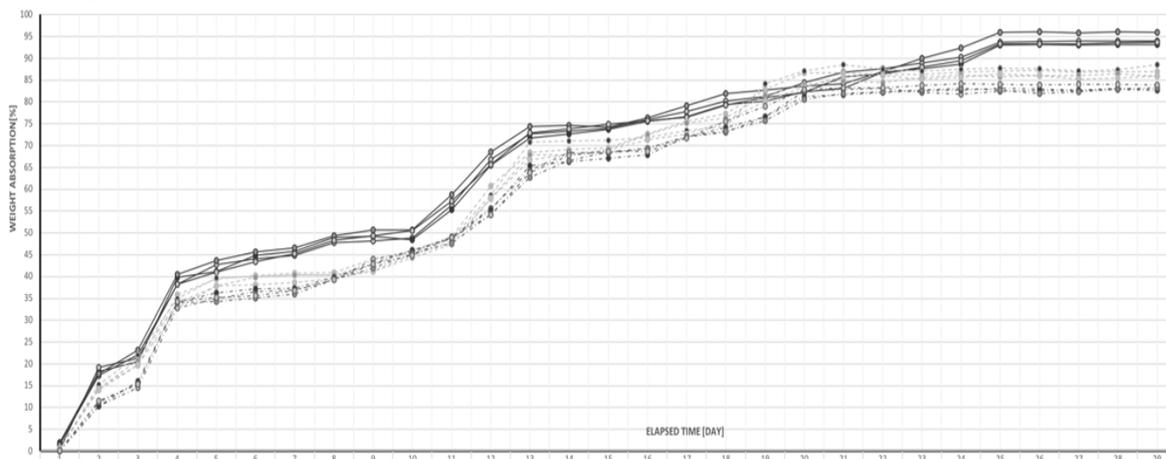


Figure 5. Graph of Weight Absorption of Polystyrene with Different Surface Treatment.

3.3 Results Comparison

In comparison, a table was created for individual values from the graphs, in which the average values of water absorption after 28 days were compared.

Table 1. Comparison of Volume Absorption of Polystyrene Samples with Different Surface Treatment

Wire cutting			Saw cutting			Original surface		
Average	32.320	%	Average	30.385	%	Average	27.154	%
Average deviation	0.702	%	Average deviation	0.412	%	Average deviation	0.58	%
Minimum	30.958	%	Minimum	29.598	%	Minimum	25.836	%
Max.	33.189	%	Max.	31.072	%	Max.	28.143	%

Table 2. Comparison of Weight Absorption of Polystyrene Samples with Different Surface Treatment

Wire cutting			Saw cutting			Original surface		
Average	94.196	%	Average	86.776	%	Average	83.153	%
Average deviation	0.898	%	Average deviation	0.905	%	Average deviation	0.429	%
Minimum	93.120	%	Minimum	85.818	%	Minimum	82.699	%
Max.	95.991	%	Max.	88.463	%	Max.	83.937	%

As we can see in the graphs, from the very beginning the individual samples differ in their course in terms of both volume and mass absorption. Over time, these differences increase, especially after 96 hours from the start of the measurement. However, due to the formation of inhomogeneous samples, it is not possible to interleave the measuring process with a function describing the absorption for expanded polystyrene only, due to the use of rubber-asphalt.

4. Conclusion

Surprisingly, a cutting wire appears to be the least suitable surface treatment of the expanded polystyrene with a closed outer structure. On the basis of comparison, it can be said that, especially in the weight capacity, this treatment becomes problematic. When compared to each other (see Table 2) the difference from the untreated original board surface after 28 days is up to 11%.

The surface treatment with a hand saw for cutting polystyrene is similar in its properties to the absorbent properties of the original untreated surface of the boards. Thus, the weight absorption, together with the volume absorption, is about 3.5% higher than the untreated original surface of the boards after 28 days. It can be noted, however, that the course of individual curves shows the greatest deviation compared to the other investigated adjustments with the highest average deviation from the tested variants.

This process is explained by the view of the microstructure of the individual surfaces after the different surface treatments.

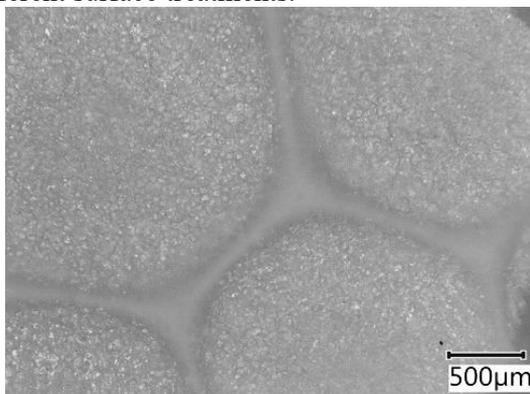


Figure 6. Original Surface of the Board [5].

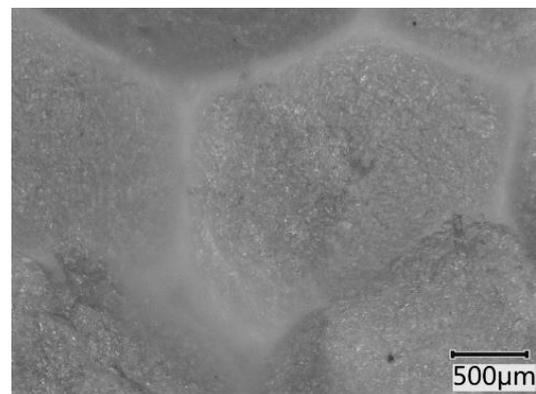


Figure 7. Saw Cutting of the Board [5].

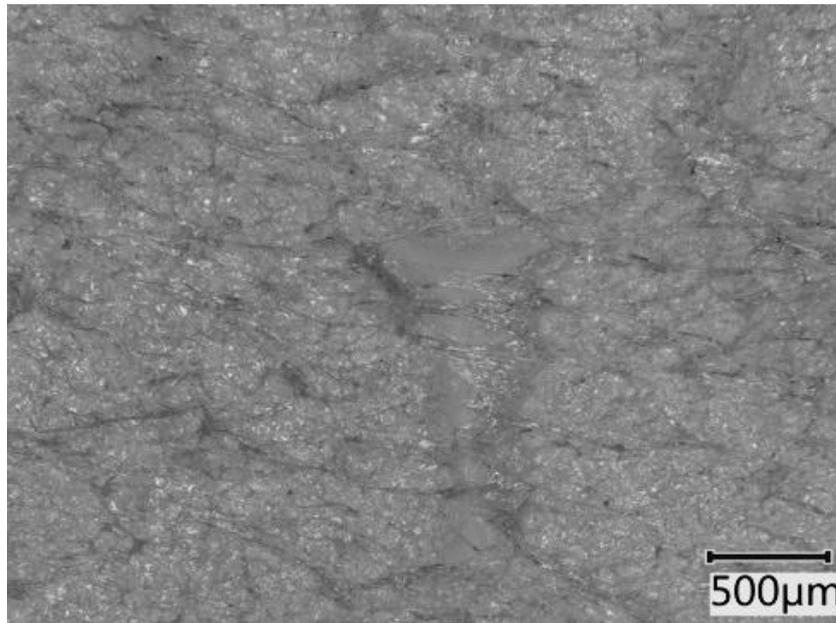


Figure 8. Wire Cutting of the Board [5].

When the surfaces are approached 100 times, individual differences can be seen, which explain with great probability the completely different courses of absorption over time. As we can see in Figure 6 and Figure 7, the individual surfaces are very similar. While using the saw for cutting, minor mechanical damage to polystyrene beads can be observed. However, the damage does not occur on the microstructure and to the extent that would be decisive. Thus, the higher absorbency over the untreated original surface is very likely due to the larger area exposed to the adverse environment, ie moisture. It is also necessary to note the intact microstructures of the bead surface itself. The surfaces thus have a low porosity.

However, the surface in Figure 8, which has been treated with a cutting wire, shows great differences at first glance when compared to others. Individual beads of polystyrene were divided in different parts of their profile, whereby the microstructure was melted and thus significantly disturbed. When the surface is treated or cut with the cutting wire, the coating of the individual beads is melted and the remaining residue is then left to cool on the surface. This fact is best noticed on the capillary in the middle of Figure 8. In general, a surface with a much higher porosity and an unclosed structure is formed, which results in higher surface absorbency properties of the treated surface of the boards. Thus, it can be expected that this treatment will accelerate the deterioration of the heat-insulating properties, namely the coefficient of thermal conductivity, which is moisture-dependent [7].

It is therefore necessary in the further investigation to determine the long-term effect of repeated soaking of the surface, which is commonly found in the environment in which the material is placed. This investigation and research must be focused not only on the weight and volume absorption, but also on the speed of this absorption and, last but not least, on the thermo-technical and insulating properties.

Acknowledgement

This paper has been worked out under the project No. LO1408 "AdMaS UP - Advanced Materials, Structures and Technologies", supported by Ministry of Education, Youth and Sports under the „National Sustainability Programme I" and under the project No. FAST-S-19-6045 “Studium fyzikálních procesů v kritických detailech obalových konstrukcí budov s téměř nulovou potřebou energie”.

References

- [1] Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings.
- [2] TZB - Info – Tepelná izolace soklu a spodní stavby – chyby v praxi [online]. Accesible from: <https://www.tzb-info.cz/4225-tepelna-izolace-soklu-a-spodni-stavby-chyby-v-praxi>.
- [3] ČSN EN 12087 Thermal insulating products for building application – Determination of long term water absorption by immersion, Praha ČNI, 2013.
- [4] ČSN 72 2603 Testing of brickwork products – Determination of mass, bulk density and water absorption, Praha ČNI, 1979.
- [5] Author's Archive
- [6] J. Plachy, J. Vysoka, R. Vejmelka, and Z. Caha, "Correlation of water absorption values of bitumen waterproofing sheets obtained according to CSN EN 14223 and CSN 503602," *Communications*, vol. 16, issue 4, pp. 118-122, 2014.
- [7] A. Lakatos, "Influence of the moisture in the thermal conductivity of Expanded Polystyrene insulators," *Contributions to Building Physics*, chapter 2.91, 2013.