Investigation of Water Absorption by Expanded Polystyrene Slabs

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Article gives analysis of experimental results of water absorption by expanded polystyrene slabs. The investigation was carried out applying different test methods. It was established that the most precise results of water absorption by expanded polystyrene are obtained when method of increased pressure is applied. Results obtained applying this method show that the water absorption of expanded polystyrene considerably increases when its density decreases. When the specimen is immersed, the largest amount of water is accumulated between the pores. Due to an even pressure distribution around the walls of the specimen, water does not push out the air, which is between the pores, and, therefore, a part of the specimen does not soak through. Moreover, spaces between expanded polystyrene pores usually interact, and, depending on the density of a product, the diameter of them may be up to few millimetres. When the specimen is withdrawn from water, all of a sudden the greatest amount of water retires from the spaces between the pores.

Keywords: expanded polystyrene (EPS) slabs, water absorption, vacuuming, water pressure.

INTRODUCTION

Closed-cell polymer foams are used in thermal insulation, buoyancy aids, packaging and structures. Their low production costs and simple techonologies enable wide application of expanded polystyrene (EPS) [1 – 4].

The most significant indicator of expanded polystyrene application for thermal insulation is the coefficient of thermal conductivity, which increases when EPS soaks water [5]. The characteristics such as water absorption vapour permeability, resistance to water action and resistance to watering and drying show the influence of humidity upon the material. Water absorption is one of the most influential characteristics. In [6] it is argued that the process of estimation of water absorption is very complicated due to many variable factors, which affect quantity of absorbed water.

The material has the ability to absorb water by immersion. Ratio of mass of fully absorbed water and volume or mass of the material shows water absorption. If all pores were open and interconnected, water absorption of the material would be equal to that of porous one. Pores of porous material, however, are partly closed and watertight for water; therefore, their water absorption is lower than the porosity. Ratio of pores volume and whole volume of the material is called assumed porosity, exposed by water absorption. Absorption of building materials may be determined by several methods, namely, simply immersion, boiling in water, applying high pressure, vacuuming [7, 8].

Speed and degree of water absorption of the materials depend on their state and time spent in water. Suddenly submerged material absorbs lower amount of water than slowly immersed one, because as a result of gradual dipping water soaks in through capillaries and pushes air out.

Expanded polystyrene comprised of closed pores produces the best quality. On the contrary, polystyrene with open and interconnected pores demonstrates the worst features. Furthermore, density and technological criteria of expanded polystyrene have a great impact on water absorption. Insufficient agglomeration of granules increases vacuum among granules in the process of making products [7]. The lower is EPS density the lower quantity of closed pores in polystyrene and consequently higher water absorption.

Water absorption of expanded polystyrene depends on watering time at initial and changes insignificantly later [14].

Water absorption of expanded polystyrene may be determined by typical methods. Therefore, expanded polystyrene is not exploited at the temperature of 60 ºC. Therefore, the above mentioned boiling method is unsuitable Furthermore, water absorption of the material increases if two other methods, namely, boiling and raising water pressure, are applied [9].

Long-lasting water absorption by applying completely submerged method has been recognised as an appropriate condition for experiment of certain products without direct dependence of their exploitation conditions [10]. Referring to [11] products of expanded polystyrene fall into classification of those products, which water absorption has been defined by the completely submerged method.

Interaction of expanded polystyrene and humidity mostly depends on the structure of polystyrene. Water absorption depends on quantity and size of pores. Small-porous material usually absorbs more water than large-porous material [12, 13].

The most important factor among many those that characterise EPS structure is the ratio of two phases, namely polymeric and gaseous expressed by density indicator. Interconnected granules with larger or lower vacuum comprise EPS, which consists of 98 % gaseous phase and 2 % polymeric phase [1].

Water absorption of expanded polystyrene has been identified in 28 days by holding in water, vacuuming and applying cyclical frost-defrost method [8]. Findings of water absorption in this experiment are significantly lower than given in written sources due to differences in sample forms and methods of sample preparation.

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In order to define water absorption of small EPS samples laboratory experiments were carried out in many countries. Quality and results of these experiments varied. Results of experiment achieved in investigation of operated EPS block in road construction match laboratory findings. Samples of 18 – 26 kg/m^3 density were extracted of the block after 30 years of its use from three diverse places and diverse depth: over groundwater, they were covered by water periodically and held submerged persistently. Water in blocks located over groundwater comprises less than 1 % by volume. Water in blocks covered by water periodically comprises up to 4 % by volume. Water in persistently submerged blocks comprises over 10 % by volume [15].

Used standard methods for determination of water absorption by expanded polystyrene slabs are insufficiently exact. The purpose of this work is to find more exact method for determination of water absorption and maximum to reduce time of experiment

EXPERIMENTAL

Expanded polystyrene slabs made at Lithuanian enterprises by foaming in a closed space hard granules of 0.9 mm – 2.5 mm in diameter supplied by the companies “Styrochem” (Finland) and BASF (Germany) were used for the experiment. Density of the slabs ranges from 11 kg/m^{3}to 34 kg/m^3, types of the products are EPS30 to EPS200. Rectangular specimens (200×200×50) mm were made out of the slabs for all test methods. Samples from the slabs were cut by a hot wire.

Three methods, namely, submerging sample in water, vacuuming of sample submerged in water and affecting submerged sample by raised water pressure, were applied in this investigation to identify water absorption of expanded polystyrene. By applying the first method water absorption was defined by [10] requirements. Dry sample was weighed to determine its mass m_0, kg, and then it was placed into the water in a position of complete submergence. Upper surface of the sample was (50 ±2) mm below water surface. Level of water was constant during the experiment. After 28 days the sample was removed from water, dehumidified and located vertically on the net leaned 45º for (10 ±0.5) min. The sample was weighed to determine its mass m_{28}, kg. Long-lasting water absorption (expressed in percents by volume) by applying complete submergence was calculated by the following formula:

$$W_t = \frac{m_{28} - m_0}{V} \cdot \frac{100}{pw}, \tag{1}$$

where V is the volume of the sample in cubic metres, pw is the density of water (1000 kg/m^3).

In the case of vacuuming of the sample, W_t was calculated by (1) formula, but instead of m_{28} we tried to determine m_v, where m_v means water absorption of a material after vacuuming. The sequence of this experiment is the following: we have calculated the mass m_0 of a dry sample, the sample then was placed to hermetic glass bowl with water and connected to pump, which made 0.15 atmospheric residual pressures. When new air foams have not appeared on the web of the sample, the experiment was completed, the sample was taken out and dehumidified and then its mass m_v was calculated.

In the case of application of the third method dry sample was weighed to determine its mass. The sample was then wrapped into thin fenestrate polythene sheet and its mass was determined again. The sample wrapped into the sheet was submerged into water and pressed by weight in order to hold it in water. There was a crotchet on the top of this mass connected to the scales (Fig. 1). The mass of the dry sample can be calculated. The sample was taken out and the sheet was removed. The sample with weight was placed in water again. Due to soft rubber close to webs of the bowl and weight, the sample was placed hermetically. Water pressure increased beneath the sample. Every 5 minutes the sample together with the weight was raised and tied to the scales. Each time the mass of the sample together with the attached weight was calculated.

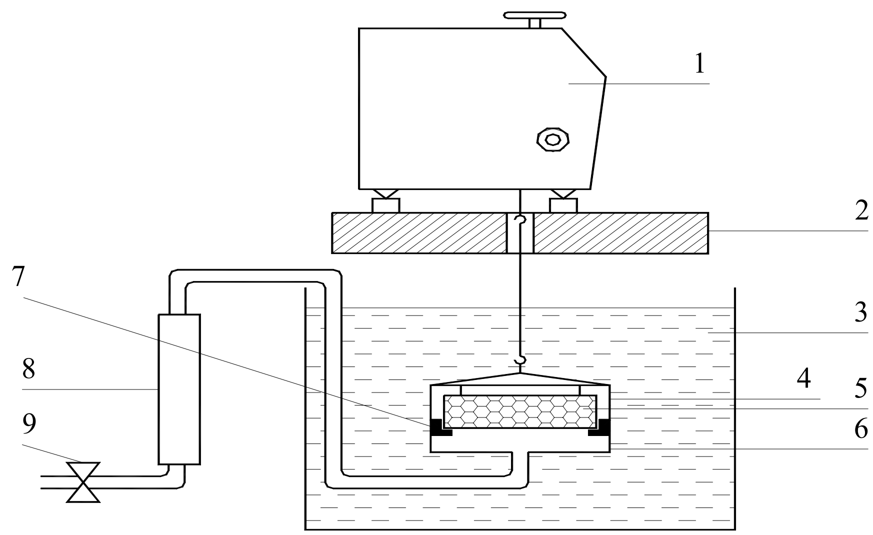

Fig. 1. Equipment for determination of expanded polystyrene slabs water absorption. 1 – weighing-machine; 2 – weighing-machine stand; 3 – water tank; 4 – weight for sinking specimen; 5 – specimen; 6 – metal frame; 7 – rubber interim; 8 – water flow meter; 9 – water-tap

When the mass of the sample have not change, the experi ment was finished and water absorption of the sample was calculated, outcomes were calculated according to the formula (1), but instead of m_{28} we determined m_{wp}, where m_{wp} means water absorption of material after application of water pressure. Specimens after using water pressure were dehumidified and located vertically on the net leaned 45º for (10 ±0.5) min. The sample was weighed to identify its mass by (1) equation.

RESULTS AND ANALYSIS

Samples of various densities were used to define water absorption. As a result, it was found that water absorption of expanded polystyrene slabs depends on their density. Fig. 2 presents results of the experiment. This figure demonstrates that in the range of low density results are independent of used method. It is observed while the density of expanded polystyrene reaches about 20 kg/m^3. When density increases difference of results increases also. When water pressure is applied results are higher more than twice. This may explain that low density specimens fill up water very easy and run it out very easy too. When density increases water fills specimens up heavily but water runs out heavily too. It depends on structure of expanded polystyrene slabs. It is observed visually that low density specimens have got large size pores and spaces between them large too which reach some millimeters. The higher density pores of expanded polystyrene slabs are smaller and their spaces between pores are small too. Though spaces between pores of the higher density is present more (not on volume of spaces, but by their quantity), these emptiness too small that at a difference of small pressure water could penetrate. Using a method of the raised water pressure in a zone of 20 kg/m^3 specimen sharp reduction of water absorption intensity is observed. On this influence may have technology factors by manufacture EPS.

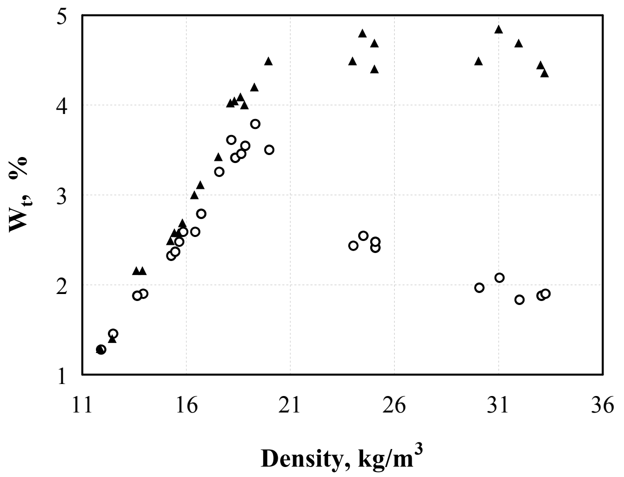

Fig. 2. The dependence of water absorption on EPS density: ▲ – according to [10] requirements; ○ – applying water pressure and location vertically on the net leaned at 45º for (10 ±0.5) minutes

Fig. 3 demonstrates that mass of specimens in the water is significantly higher. This difference is highest for law density of EPS. This proves above given facts about specimens filling up with water.

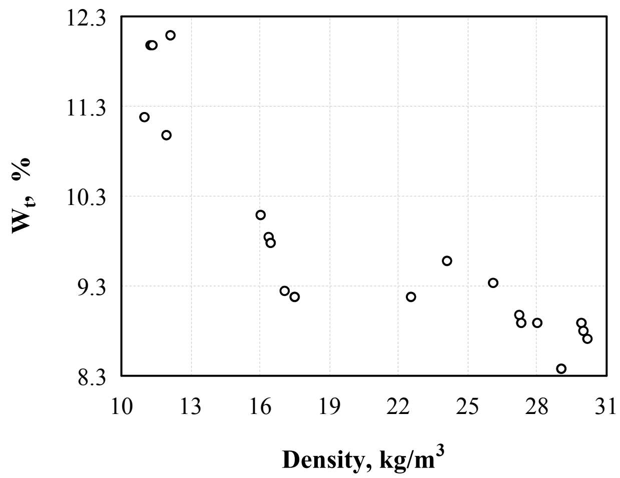

Fig. 3. The dependence of water absorption on EPS density when water pressure and weighting in water is applied

For comparisons of water absorption, results of other researchers [8, 14, 16] are given in Fig. 4. Visual differences between the results demonstrate that water absorption depends on the used test method.

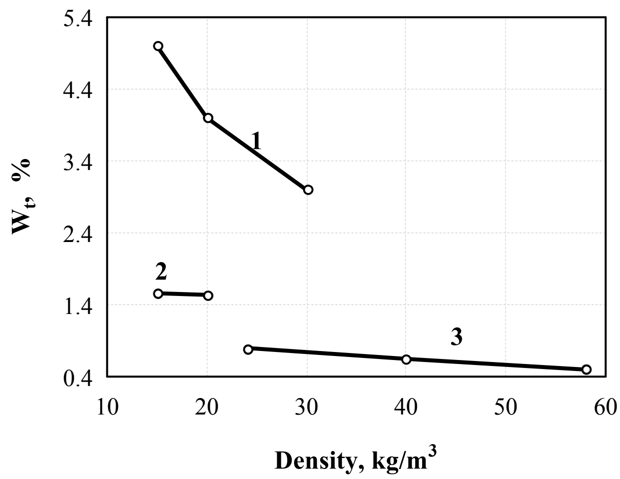

Fig. 4. Comparison of water absorption obtained by different investigations: 1 – [16], 2 – [8], 3 – [14]

CONCLUSIONS

1. Determination of water absorption of expanded polystyrene is a complicated process and obtained results may differ. The more open structure of expanded polystyrene slabs the lower water absorption. Furthermore, sample form, height and its preparation method have great influence on water absorption. This happens when applying standard method that produces immediate removal of water from the sample after its withdrawal from water.
2. Water absorption of expanded polystyrene is only partial when sample is submerged, because air inside the sample is affected by certain pressure around sample web and is not removed either in 28 days or significantly longer period of time.

3. Applying raised water pressure and weighting the sample of expanded polystyrene in water, real water absorption of the material may be found by showing structure of the material and significantly reducing duration of experiment.

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