Water Permeability Tests for EPS Blocks used in Geotechnical Engineering

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ABSTRACT
Expanded polystyrene (EPS) has traditionally been used in many areas in the civil engineering such as building construction because its high thermal capacity, acoustic insulation and absorption of impacts and settlements. In Brazil, it has been recently introduced as lightweight material for construction of embankments on soft soils and bridge abutments. Despite this fact there is no consolidated experience in testing of this product from a geotechnical point of view in this country. This paper presents the first research data on water permeability laboratory tests, conduced in a rigid wall permeameter with constant or variable water head. The samples used had densities of 10, 20 and 30 kg/m³ for virgin material and 10 kg/m³ for recycled material. The water permeability tests show that the samples have a significant wide range of permeability, appreciably variable with the density and with the composition (virgin or recycled).

1. INTRODUCTION

Expanded polystyrene (EPS) and extruded polystyrene (XPS) have recently been used as geosynthetics with many applications in geotechnical engineering. They have traditionally been used in others areas in the civil engineering such as building construction because its high thermal capacity, acoustic insulation and absorption of impacts and settlements.

In geotechnical engineering, this material is currently manufactured in prismatic blocks called geofoam. These blocks have dimensions in accordance with the needs of each situation, reaching sizes with dimensions of meters. EPS manufacturing is very simple, using the raw material (polystyrene polymer – PS) and a blow agent.

EPS geofoam has a variety of properties that allow their use in many applications. The very low density (about 100 times lower than the soil, a result of its manufacturing process), relatively high mechanical strength, and biological resistance of EPS are great advantages that favor its use in applications like embankments. These blocks are especially applied in areas with low capacity soils foundation (soft soil). Besides this "classic" application, the EPS geofoam can also use as a sub-base of roads pavements, alleviate stresses on walls and slopes, infrastructure protection and bridges seat.

In these applications, EPS blocks are solicited of varied kind of solicitations. Thus, it is necessary to study the response of the material front of these solicitations, both mechanical and hydraulic (STARK et al, 2004).

The mechanical tests and behavior of EPS geofoam have been exhaustively explored in many papers and can be seen in publications like Avesani Neto (2008), Horvath (1994), Duskov (1997) and Stark et al. (2004). In the hydraulic tests, the water absorption was frequently studied. However, the water permeability hasn't received special attention.

Thus, an experimental program was performed. The response of EPS was assessed through water permeability tests. With this procedure, there was a comparative study of the permeability behaviour with the density with the objective of determining possible relationships to predict the behaviour of the material, expanding its study and help in understanding the behaviour of EPS.

2. LABORATORY TESTS

2.1 Samples

The chosen EPS blocks density used in this research had been in accordance with its density used in the practical ones of design (generally between 10 and 30 kg/m³) in a form to enclose most of the values. It was carried out testing with EPS blocks containing recycled materials (30% of recycled EPS) to study materials with properties that may have future utility.

Before the tests, all samples were placed in a acclimatized room with temperature of 23 °C and relative humidity of the air of 50% for a not inferior period the 24 hours. After this acclimatization, all the samples had been weighed in a scale of precision of thousandth of gram and duly measures for the determination of the volumes and densities in accordance with 1996 norm ASTM C 303. Table 1 displays all statistics of the measurements made in all samples tested. Note that the values of density have a small variation between samples. This variation is perfectly acceptable in the conduct of the tests.

Table 1. Statistics of EPS samples.

Nominal density (kg/m³)	Measured density (kg/m³)			S. D.	C.V. (%)
	Max.	Min.	Aver.		
10 (30% recycled)	15.40	12.00	13.03	0.58	4.42
10	13.10	10.30	11.69	0.65	5.58
20	25.50	20.70	22.18	1.18	5.34
30	38.60	30.30	33.19	1.95	5.88

The samples were cylindrical with 75 mm in diameter and 50 mm in height (1 : 1.5 proportion).

2.2 Water Permeability Test

The water permeability test was carried out in similar to soil tests describes in the Brazilian norms (NBR 14545, 2000 and NBR 13295, 1995), with some changes to the equipment and methodology.

The sequence of chamber test preparation can bee seen in the Figure 1.

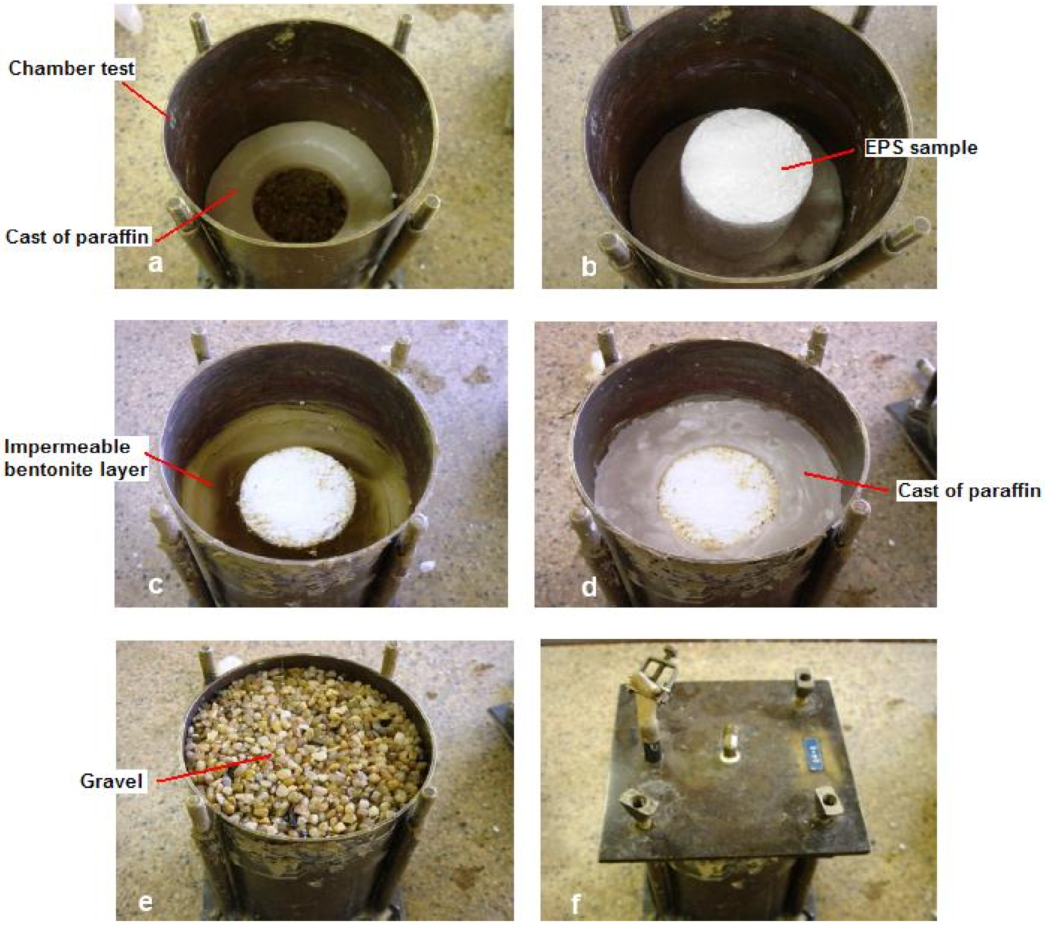

Figure 1. Water permeability chamber test preparation.

The chamber test used in these tests was in accordance with the specifications of the Brazilian norms NBR 14545, from, 2000 and NBR 13295 from 1995. The chamber test dimensions are 20 cm (about 8 in) of height and 15 cm (about 6 in) of diameter.

The bottom of chamber test was completed with draining material (pebbles) which has a high hydraulic conductivity. This layer has a function to drain and to equalize the water flow after passing through the EPS sample. Above this layer, was a cast of paraffin to serve to support the sample and to a basis for the bentonite layer. This hydrated bentonite layer was used to prevent a water flow out of the sample, like sample side flows and wall of the chamber flows. The bentonite layer was spread carefully on the wall of the chamber test and the side of the sample in order to prevent the water flow for these ways. Finally, another cast of paraffin and draining material layer was utilized above all layers to avoid contact between the gravel and bentonite and to promote a regularization of the water flow in the chamber test.

The Figure 2 shows the chamber test configuration and layers (in centimeter) for each test.

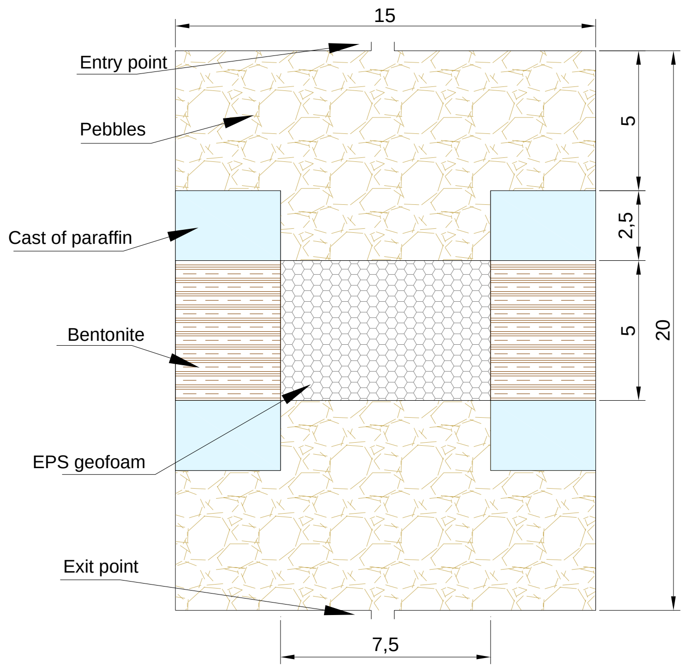

Figure 2. Water permeability chamber test configuration.

With the chamber test ready, all samples were submitted to a hydraulic gradient until the stabilization of the water flow to ensure the total saturation of the system. This procedure was performed in a time not less than 48 hours, even after the stabilization of the water flow. The equipment used to developing the hydraulic gradient and to take the readings during the performed tests is show in the Figure 3.

Figure 3. Water permeability equipment.

All the tests were analyzed by the constant and variable heads and a two replicates tests were made for all samples, with a total of three tests for each sample with a density. In all tests, the water gradient value was 30m/m.

3. RESULTS

The density is the most significant and important property of EPS geofoam. In addition to its importance, to obtain its value is very simple. Because of these characteristics, the correlation between the results of several tests (compression, shear, water absorption, and water permeability) with density is the best way to analyze the material and try to characterize and predict their behavior.

The results obtained with the water permeability testing in EPS samples of 10 (with virgin and 30% recycled material), 20 and 30 kg/m can be seen in Table 2.

Table 2. Water permeability results.

Nominal density (kg/m³)	Measured density (kg/m³)	k (cm/s)
10 (recycled)	13.0	1.4E-02
10	11.7	3.7E-03
20	22.2	2.2E-03
30	33.2	6.4E-06

Table 2 shows the influence of the density on the water permeability of the EPS. The density influence is inversely proportional and has a large range in the water permeability value. For example, the increase of density from 10 kg/m³ to 30 kg/m³ (3 times), the water permeability decrease from 3,66 x 10-3 to 1,32 x 10-6 (about 1000 times).

With this result, a graphic was made, and a relationship between these two properties has been obtained. The Figure 4 shows these results.

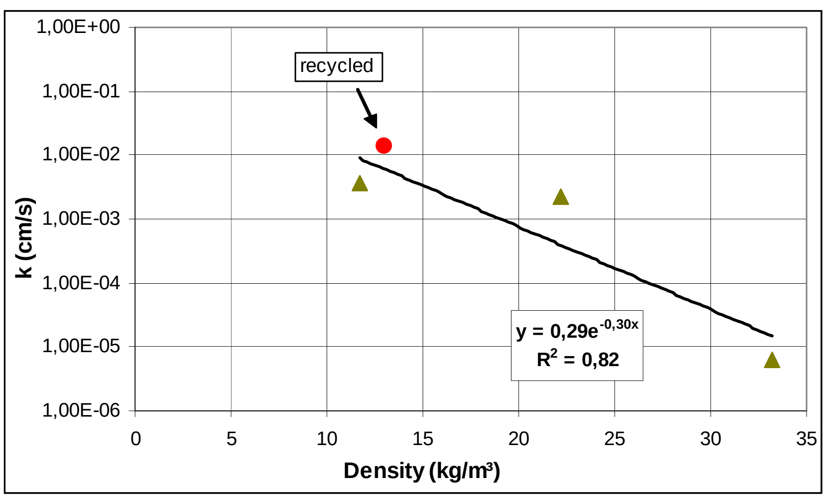

Figure 4. Water permeability results and relationship with density.

From Figure 4, and analyzing the 10kg/m³ samples (virgin and with 30% recycled EPS), we notice that the sample with recycled material, has a larger density than the sample with virgin material, and a water permeability much greater. This is a result of the material composition with a greater porosity. However, if considering only the virgin material water permeability, there is a valid relationship between this property with the density.

From these results, some different uses can be established, like application of impermeable and drainage layers.

4. CONCLUSIONS

Water permeability tests were made in with density of 10 (virgin and with 30% EPS recycled material), 20, and 30 kg/m³ aiming its applications for geotechnical use. The main conclusions are:

- The density has a significant influence in the water permeability propriety of the EPS samples;
- There is a large range of measured water permeability values, where the material has a behavior of impermeability or drainage layer ;
- There is a good relationship between the water permeability and density;
- The composition of the material (virgin or with EPS recycled) has great influence in the porosity and consequently in the water permeability of the samples.

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