Compression tests for EPS blocks used in geotechnical engineering

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Keywords: Geosynthetics, geofoam, expanded polystyrene (EPS), unconfined axial compression

ABSTRACT: Expanded polystyrene (EPS) has been recently introduced in Brazil as lightweight material for geotechnical use. 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 compressive laboratory tests. The samples used had density of 10, 14,5, 17, 20, 30 and 40 kg/m³ with virgin material and 10 kg/m³ for recycled material. A research with different specimen's dimensions was carried out. It was also performed compressive tests with different speeds of execution (5, 10, 15, 50 and 200 mm/min), and with different elevated temperatures in a range from 30 to 72°C. The tests showed that the EPS geofoam may be better characterized through three parameters instead only one (strength at 10% strain). The tests showed too a great compression resistance dependent from density and the temperature, but not significantly dependent from the test speed execution and the specimens size.

1 INTRODUCTION

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).

In almost all use, the EPS-geofoam is influenced by the compressive strength. Thus, the need to study and characterize the material and its behavior on this loading becomes necessarily to obtain design parameters.

Duskov (1997) performed compressive tests on two samples of EPS-geofoam with different densities (15 and 20 kg/m³) with cylindrical shape (300 mm tall and 150 mm diameter). In his study, the author limited the test to a deformation of 10%. The EPS strength values (defined for 10% strain) obtained are relatively high, despite the low density of the material. The author also suggests a correlation between the initial modulus of elasticity and the density.

Duskov (1997) also verified the speed of execution influence on EPS-geofoam strength. The tests were carried out with speeds of 0.2, 1, 10 and 100 mm/min. The author concludes that with the increased execution speed, there is an increased on the strength. However, this strength increase is not significant.

Horvath (1994) studied the behavior of cubic specimens of EPS-geofoam in axial compression. He noted a large influence of density on the compressive strength. The author proposes a correlation between the modulus of elasticity and the density, and compares different suggestions of correlations of other authors.

Bueno (2005) performed compressive tests on EPS-geofoam (10 and 20kg/m³) using cylindrical shape specimens, with ratios height/diameter of 3:1 (h = 150 mm and d = 50 mm). The author concluded that the samples did not reach the rupture with the traditional patterns. In this configuration, the samples showed a rupture similar to a lateral instability (buckling). Thus, there is evidence that the use of samples in a cylindrical shape can masquerade the real compressive strength due to other sources of rupture possible.

In another research, Stark et al. (2004) mention that specimens of cylindrical shape tend to show a lower modulus of elasticity and yield strength value when compared with cubic specimens. About the specimen's size, the authors mentioned that, in general, with its increase size there is also a significant increase of its modulus of elasticity. However, the authors cite that the results are not conclusive, requiring further analysis.

Yeo and Hsuan (2006) performed unconfined axial compressive tests at different elevated temperatures. The authors used five temperatures ranging from 30°C to 58ºC with 7ºC intervals. The authors observed a decrease in resistance with increasing temperature and a bi-linear behavior with the pronounced change of slope at 44°C.

Filling a gap of these studies, this research explored the behavior of EPS-geofoam of a wide range of density in the compressive tests. The analyses extrapolating the mere compressive strength set by other authors (for a 10% strain), with the suggestion of a new characterization. For more details on this test program and other mechanical and hydraulic tests performed EPS-geofoam, it is recommended to consult Avesani Neto (2008).

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. All tests specimens were cubes of 100 and 50 mm dimensions.

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
14,5	15,50	14,00	14,68	0,37	2,49
17	20,00	16,60	18,79	0,61	3,26
20	25,50	20,70	22,18	1,18	5,34
30	38,60	30,30	33,19	1,95	5,88
40	43,70	38,60	41,03	2,03	4,95

2.2 *Unconfined axial compression test*

The simple compression testing in cell plastics is normalized by ASTM 1621, 2000. For the standard, the test consists in compress the samples with predetermined dimensions and masses. This test determines the material stress - strain behavior.

These tests were performed in a universal testing machine with control of deformation rate. In addition of different samples sizes tested, the compression was performed with different speeds of execution. The rates of deformation velocity were: 5, 10, 15, 50 and 200 mm/min. Five replicates were tested for each situations.

Also the standard reference temperature (23°C), were performed compression tests at different elevated temperatures in a range from 30 to 72°C with 7°C intervals (seven different temperatures). To equilibrate the temperatures at the desired value, the specimens they were placed inside of an environmental chamber for twelve hours. Three replicates were tested at each temperature.

3 RESULTS

Figure 1 shows the compression test result of a 30 kg/m³ and 100 mm cube dimensions sample.

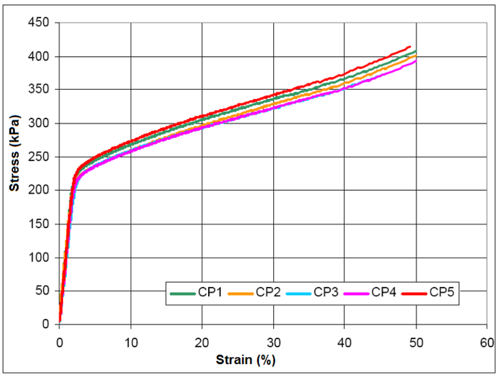

Figure 1. Compression test result of 30 kg/m³ EPS-geofoam sample

According several authors, the compressive strength of the EPS-geofoam was determined at the strain value of 10% strain. However, by the typical behavior of the material, that characterize it by just one point (compressive strength at 10% strain) do not express adequately its behavior. Further, the strength definition inside its plastic phase is no longer desirable. Thus, it is proposed a new characterization of EPS under unconfined axial compression.

Figure 1 shows a typical stress x strain EPS-geofoam curve in which there is an elastic region under the value close to 2% of deformation, and a plastic part (over about 2% of deformation). At this stage the material undergoes a hardening behavior. Consequently, the compression curve of EPS-geofoam can be characterized by three distinctive points: the tangent module of elastic phase, for 1% of deformation. The transition stress, adopted for 2% of deformation, the point where there is a change in the slope of the curve. And finally the tangent modulus of hardening stage for a strain over the 2%.

From about 350 compression tests performed, Figures 2, 3 and 4 shows the relation between tangent module of elastic phase, transition stress and tangent module of hardening phase, respectively, with the density of EPS blocks. Note in theses Figures a good relationship between density and modules and tension. Note also that this proposition of EPS characterization by three key parameters is applicable.

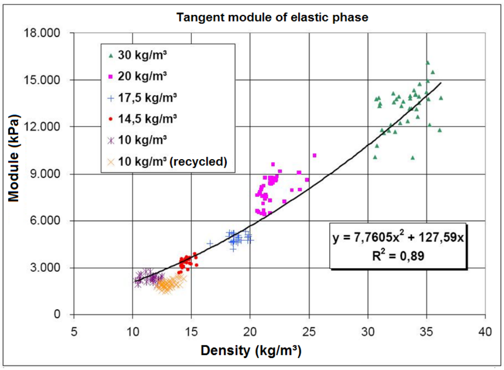

Figure 2. Tangent module of elastic phase for EPS-geofoam samples

The temperature influence on compressive strength can be visualized in Figure 5. The strength value is the average of three tests for each temperature.

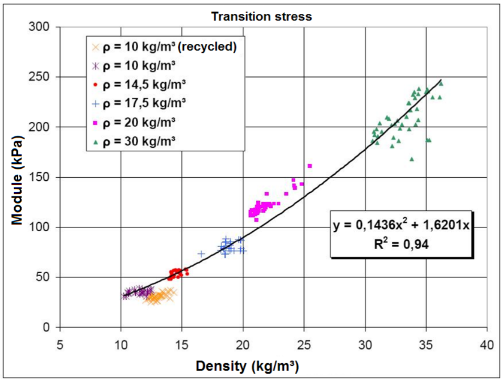

Figure 3. Transition stress for EPS-geofoam samples

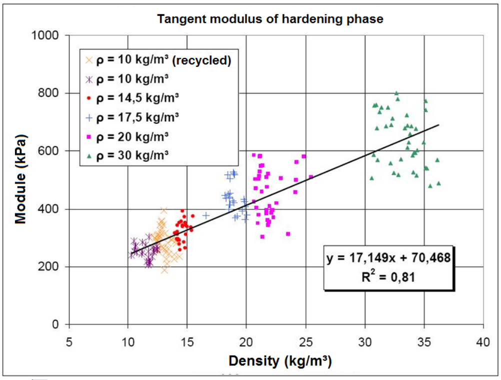

Figure 4. Tangent module of elastic phase for EPS-geofoam samples

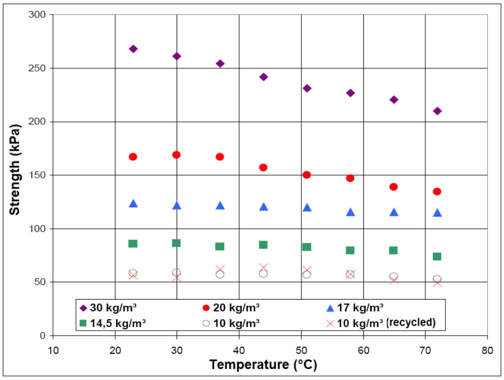

Figure 5. Compressive strength for different elevated temperatures

Figure 5 shows a significant influence of temperature on compressive strength of EPS-geofoam of higher density values (30 and 20 kg/m³), reaching reductions up to 20% for 50°C changes in temperature. However, the material with lower density is not significantly affected by temperature. This behavior can be explained by the density. Samples with higher density have a smaller amount of voids, filled with air, and a greater portion of the polymer. This polymer portion is more significantly affected by the temperature change than air in the voids, resulting in a strength reduction in a temperature increase. A lower density has a greater amount of voids and a lower portion of the polymer, consequently the specimen is less influenced by temperature.

Figure 6 shows the relationship between the strength obtained for each temperature by a temperature of reference (in this case 23°C) only for the densities that have appreciably loss of compressive strength (20 and 30kg/m³).

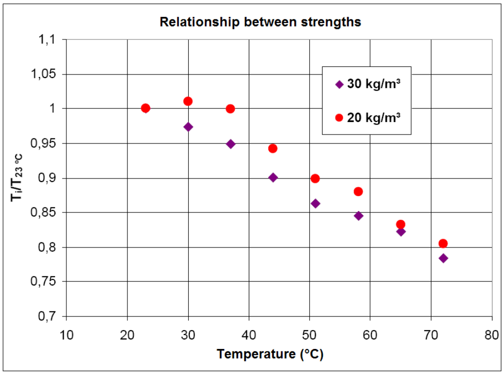

Figure 6. Temperature influence in 20 and 30 kg/m³ EPS-geofoam

From this Figure it is observed that the strength reducing exceeds 20% for temperatures of 72°C. There is also a linear trend of decreasing strength with increasing temperature.

It was verified the influence of execution speed and the specimens size in the compressive strength. However, in both cases was not found significant influence of these variables in the EPS-geofoam behavior. How this influence was less than 5%, their results have not been more analyzed.

4 CONCLUSION

Unconfined axial compression tests were made in EPS-geofoam samples of 10 (virgin and containing 30% of recycled material), 20, 14.5, 17, 20 and 30 kg/m³ aiming its applications for geotechnical use. The main conclusions of this paper are:

- The current compressive strength at 10% strain do not express adequately its behavior;
- The material has a good defined elastic phase under 2% strain;
- The EPS-geofoam characterization o by three key parameters (tangent modules of elastic and hardening phases, and transition stress) is simple and effective and can be used and allocated in subsequent tests;
- The results from compression tests with temperature variation was showed a further influence on the EPS-geofoam strength of 20 and 30 kg/m³, with decreases of about 15 and 25% respectively
- The test speed of execution and the specimens sizes do not significantly affect the compressive strength results;

ACKNOWLEDGMENTS

The authors thank the CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior) by financing this research and the Department of Geotechnical, especially to the Laboratory of Geosynthetics, both of the Engineering School of Sao Carlos of the University of Sao Paulo (EESC - USP) for the technical support and infrastructure.

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