Laboratory Research on EPS Blocks Used in Geotechnical Engineering

J.O. Avesani Neto, B.S. Bueno

Abstract. Geosynthetic geofoam has a cellular structure made of expanded polystyrene (EPS) and has been used as a lightweight material for geotechnical use in embankments, bridges seat, base and sub-base of roads pavements and infrastructure protection applications. This paper presents research data on EPS laboratory tests aiming to characterize Brazilian EPS for geotechnical use. The mechanical tests comprised unconfined axial compression (with variation of temperature, specimens dimensions and rates of deformation velocity), interface shear friction (EPS – EPS) and creep under compressive load. A simple loss weight test by mice attack was also conducted in an attempt to quantify the damage in samples of EPS by biological attack. Samples of 10 kg/m^3, 14.5 kg/m^3, 17 kg/m^3, 20 kg/m^3, 30 kg/m^3 and 40 kg/m^3 densities with virgin material and 10 kg/m^3 with recycled material were used. The results have shown that EPS has a great strength in compression and creep solicitation and high interface friction strength despite its very low density, and good geotechnical properties for applications in geotechnical engineering works. In the weight loss test it was found that the mice only attach the material mainly for a specific situation.
Keywords: geofoam, EPS, compression strength, shear friction, creep, mice attack.

1. Introduction

The use of expanded polystyrene (EPS) and extruded polystyrene (XPS) in civil engineering has already a recognized application in buildings due to then high thermal capacity, acoustic insulation and absorption of impacts and settlements. However their use as geosynthetic has only recent applications.

In geotechnical engineering this material, manufactured in prismatic blocks named geofoam, has properties that allow its use in many applications. The low density EPS (approximately 100 times lower than the soil, a result of its manufacturing process) and a relatively high mechanical strength give the EPS geofoam larger applicability in embankments as a lightweight fill – especially in areas with low bearing capacity soils and mainly as a base and sub-base of road pavements and bridge seat (Horvath, 1994, Beinbrech & Hillmann, 1997, Piana, 1997 and Stark *et al.*, 2004), thermal insulation (Horvath, 1995) and compressible inclusion to alleviate pressures on walls and slopes and infrastructure protection (Horvath, 1996, 1997, Murphy 1997 and Ikizler *et al.*, 2008).

In these applications, EPS blocks are submitted in varied solicitations. Thus, it is necessary to study the response of the material when subjected to these solicitations, both mechanical and hydraulically (Stark *et al.*, 2004).

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

Duskov (1997) performed compression tests in two EPS-geofoam samples of 15 kg/m^3 and 20 kg/m^3 densities and cylindrical shape (300 mm height and 150 mm diameter). The EPS strength values (defined for 10% strain) obtained were relatively high, despite the low density of the material. The author also suggested a correlation between the initial modulus of elasticity and the density. The speed of tests also seemed to influence the EPS-geofoam strength. This speed was also investigated by Duskov (1997 who concluded there was an increase in the strength in function of increased velocity. However, this strength increase was not significant.

Stark *et al.* (2004) observed that specimens of cylindrical shape tended to show a lower modulus of elasticity and yield strength value when compared with cubic specimens. They also tested samples of different sizes and the results showed that increasing the sample size there was a significant increase in its modulus of elasticity. However, the results were not conclusive and still require further investigations.

Bueno (2005) conducted compression tests in EPS-geofoam (10 kg/m^3 and 20 kg/m^3) using cylindrical-shape specimens, with height/diameter ratios of 3:1 (h = 150 mm and d = 50 mm). The author concluded that the samples did not reach rupture with the traditional patterns. In such a configuration, the samples showed a lateral instability (buckling), which is evidence that the use of samples

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of cylindrical shape can mislead the real compressive strength of the material.

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

Hazarika (2006) suggested a constitutive model based on various compression tests of EPS blocks of different shapes – cylindrical and cubic – and dimensions. The author concluded that EPS geofoam applications can be broadly divided into two categories: small-strain and large-strain, in which the desired constitutive (stress-strain-time) properties vary depending on each application.

Sun (1997) performed creep tests in 50 mm cubic samples of 18 kg/m^3 density EPS. The stress levels ranged between 30% and 70% of compressive strength at 5% strain (85 kPa). The author observed that the creep deformation effects were negligible at stress levels up to 30% of compressive strength (at 5% strain).

Duskov (1997) reported creep test results of cylindrical samples of EPS geofoam. He verified that the immediate strain (occurred on the first day) could represent values above 50% of the total strain. The same behavior was observed by Sheeley (2000) with cubic specimens of 50 mm.

According to Horvath (1994), there are two shear modes that are important to EPS blocks. The internal blocks shear, that there is no apparent collapse of the samples and are not frequent, and the shear of interface between blocks (joint), which is an important factor of stability in works with horizontal solicitations.

Sheeley & Negussey (2000) conducted interface shear tests in EPS blocks (EPS – EPS) with no connection and with a barbed connector plate. They observed that barbed connector plates did not cause any increase in the shear strength of EPS – EPS interface and concluded that the difference in the shear strength between different foam densities was only marginal.

Barrett & Valsangkar (2009) performed shear strength tests in EPS geofoam blocks with no connections and connected with barbed connector plates and with polyurethane adhesive. The authors found that the friction coefficient between blocks was consistent with the values reported in the literature and conservative in terms of commonly used design values. Furthermore, they concluded that the barbed connector plates did not provide any additional interface shear strength, but the polyurethane adhesive connector worked very well making the individual blocks act as one large mass.

This paper introduces data on lab tests performed in various EPS blocks with large density variation. The main objective is to compare engineering data of the various EPS bocks according to their density.

2. Laboratory Tests

2.1. Samples

The nominal densities of the EPS blocks used in this research ranged between 10 kg/m^3 and 40 kg/m^3. Prior to the tests, all samples were placed in an acclimatized room with temperature of 23 °C and relative air humidity of 50%, for a period up to 24 h. The densities were then determined in accordance with ASTM (2007). Table 1 summarizes the data obtained. The variations of densities were small, showing a standard deviation (S.D.) smaller than 2.0 with an average value of 1.10 and coefficient of variation (CV(%)) smaller than 5.9% with an average value of 4.60.

2.2. Unconfined axial compression tests

In the axial compression (ASTM, 2000) test all densities showed in Table 1 were used in cubes of 100 mm and 50 mm dimensions. The influence of speed was also verified. The rates of deformation tested were 5 mm/min, 10 mm/min, 15 mm/min, 50 mm/min and 200 mm/min.

The influence of temperature was also checked using axial compression tests when EPS samples were incubated in an environmental chamber for twelve hours. Temperatures in the range of 30 °C to 72 °C with 7 °C intervals (starting from room temperature of 23 °C) were used.

2.3. Joint direct shear tests

It was used the equipment of direct shear testing in soils (ASTM, 1998). EPS samples of 10, 20, 30 and 40 kg/m^3 densities with virgin material and 10 kg/m^3 with recycled material were tested.

Figure 1 shows the main steps of the sample preparation.

Normal stresses of 10 kPa, 20 kPa, 30 kPa, 40 kPa, 50 kPa and 60 kPa were chosen since in most application they can represent field situations.

2.4. Creep in compression tests

The creep in compression tests has been standardized by ASTM (2001) and ASTM (1995).

Table 1 - Densities of tested samples.

Nominal density (kg/m^3)	Measured density (kg/m^3)			S. D.	CV (%)
	Max.	Min.	Aver.		
10 (30% recycled)	15.4	12.0	13.0	0.6	4.4
10	13.1	10.3	11.7	0.7	5.6
14.5	15.5	14.0	14.7	0.4	2.5
17	20.0	16.6	18.8	0.6	3.3
20	25.5	20.7	22.2	1.2	5.3
30	38.6	30.3	33.2	2.0	5.9
40	43.7	38.6	41.0	2.0	5.0

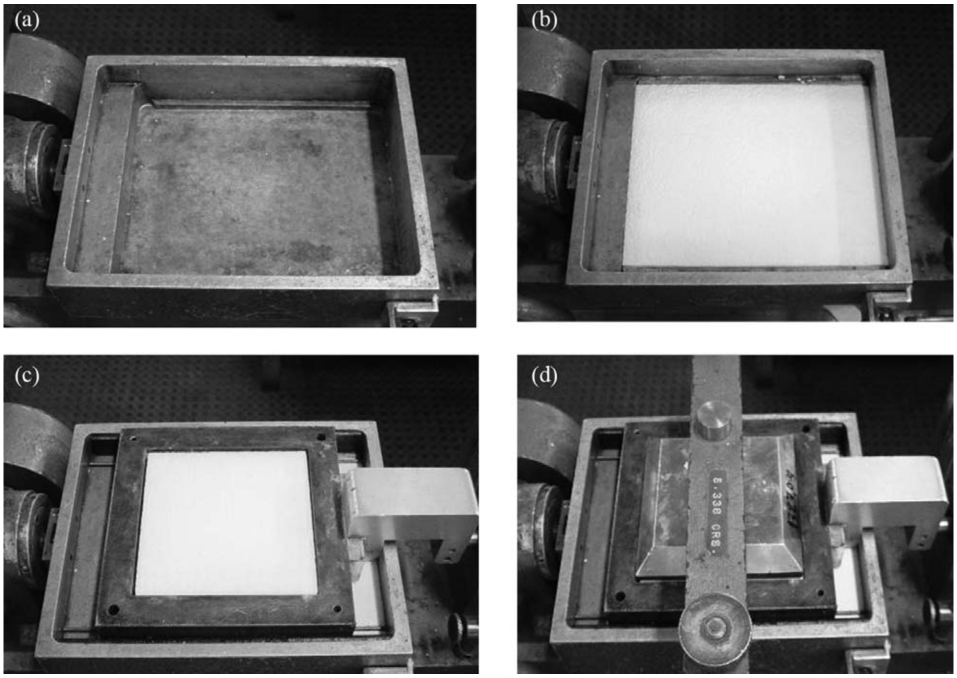

Figure 1 - Steps of sample preparation for direct shear tests of EPS joints: (a) shear box; (b) bottom sample of EPS placed in the box; (c) top block of EPS placed into the shear box; (d) top plate and system to apply the normal load already placed on top of the sample.

The EPS specimens were cubes of 50 mm dimensions. Table 2 presents the densities used and the compression loads applied. Figure 2 shows the test performed.

2.5. Loss weight test by attack of mice

As the EPS material is used in works it may be in contact with animals and various biological agents, not just in construction time but also in its lifetime, it was subjected to a test to evaluate the loss weight of samples with contact with mice.

Figure 3 shows a typical mouse (of *Mus musculus* specie) used as the agent of damage to the EPS samples.

Two control variables that influence mice actions were considered: the presence of food (food and water) and straw for building their nest. The mouse can bite the specimens for feeding itself and extract material for the construction of its nest. There were three groups of tests to determine the worst case in which the individual bites the samples as much as possible: In the first case the mouse is deprived of food and water and forced to nibble on the EPS

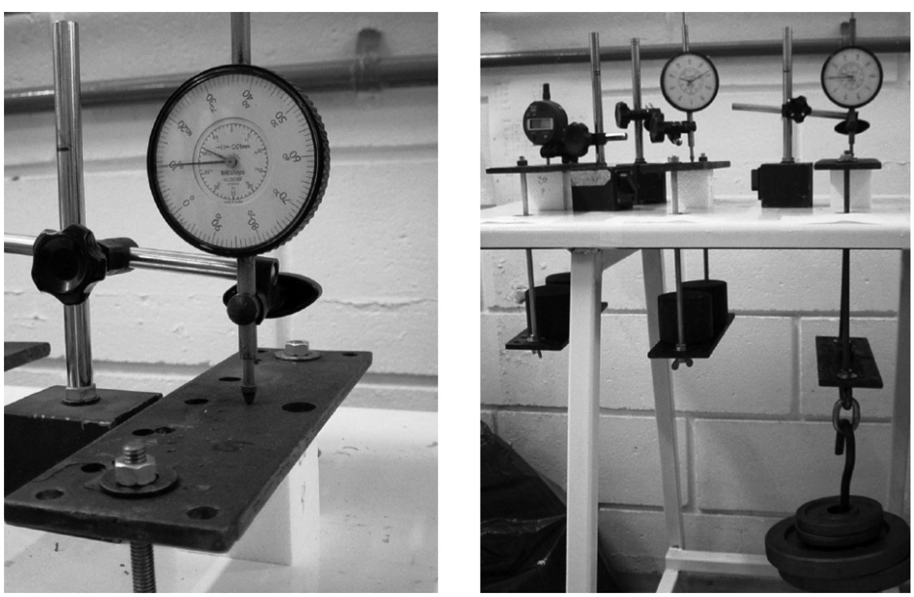

Figure 2 - Creep in compression tests.

Table 2 - Densities and applied loads used in the creep in the compression tests.

Nominal density (kg/m^3)	Average density (kg/m^3)	Normal load applied (kPa)	Normal load applied / stress at 2% deformation (%)
10	11.7	10	30
		20	60
		40	115
		60	170
17	18.8	20	25
		40	50
		60	75
		80	100
20	22.2	20	15
		40	35
		60	50
		80	70
30	33.2	20	10
		40	20
		60	30
		80	40

as it is very hungry; in the second case the mouse can access the food, but the straw is removed (deprivation of straw). It is forced to bite the EPS sample to build its nest. In the third case the mouse is deprived of both straw and food (total deprivation). Figures 4a and 4b show, respectively, an individual with total deprivation and straw deprivation.

The specimens used in the animal attack tests were blocks of 100 mm x 100 mm x 50 mm dimensions and all densities showed in Table 1. The exposure time of all tests was 48 h.

Figure 3 - Mouse used in this research.

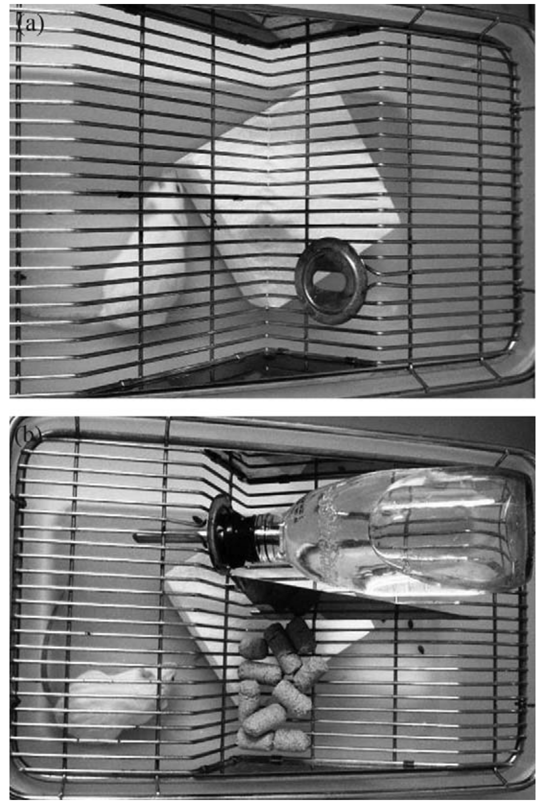

Figure 4 - a) total deprivation; b) straw deprivation.

3. Results

3.1. Unconfined axial compression tests

Figure 5 shows the compression test result of the 30 kg/m^3 density specimen in which the sample was a 100 mm cube.

According to several authors, the compressive strength of the EPS-geofoam is determined at the strain value of 10%. However, the typical behavior of the material, characterized by only one point (compressive strength

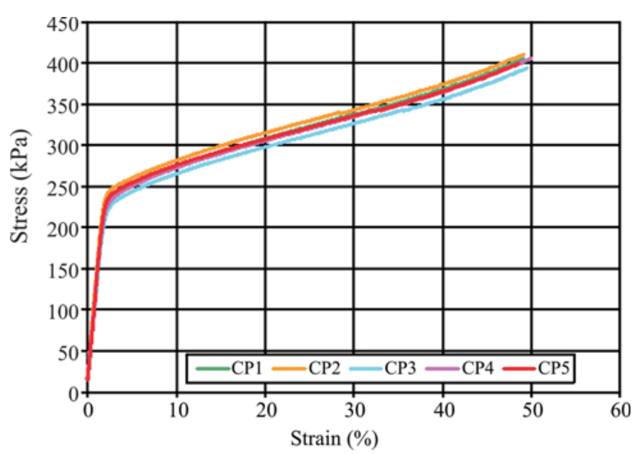

Figure 5 - Compression test result of 30 kg/m^3 EPS-geofoam sample.

at 10% strain), as seen in Figure 5, does not express its behavior adequately. The stress at 10% deformation is a parameter in the second straight-line just above the transition point that is around 2% of deformation.

Therefore, based on Fig. 5 that can be considered a typical stress x strain EPS-geofoam curve there is an elastic region from the beginning of the curve and extending to a 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, in a compression curve of EPS-geofoam one three distinctive points can be observed: (a) a tangent modulus of the elastic phase taken at 1% of deformation; (b) a transition stress adopted as the stress value at 2% of deformation – at this point there is a change in the slope of the curve; (c) a tangent modulus of the hardening stage for a strain above 2% (Fig. 6).

From about 350 compression tests performed, Figs. 7, 8 and 9 show the relationship between tangent modulus of the elastic phase, transition stress and tangent modulus of the hardening phase, respectively, varying with the density of EPS blocks. These figures show a good relationship between density and modulus and stress. Based on these data an EPS curve characterization by three key parameters is proposed, as shown in Fig. 6.

Correlations between the tangent modulus of the elastic phase and the density of EPS blocks were proposed using data from other researchers (van Dorp, 1988; Eriksson & Trank, 1991; Negussey & Sun, 1996; Duskov, 1997; Horvath, 1997; Elragi *et al.*, 2000; and Hazarika, 2006). Figure 10 shows these correlations and compares them with the one of this paper.

The curves obtained by Eriksson & Trank (1991), Duskov (1997) and Avesani Neto (2008) are a nonlinear power function of densities and elastic modulus in low-density cases. All the other curves are expressed as a linear expression. The higher curve of modulus was obtained by Elragi *et al.* (2000), followed by Duskov (1997) and the minor modulus was suggested by Negussey & Sun (1999).

The temperature influence on the compressive strength can be visualized in Fig. 11. The strength value is the average of three tests for each temperature.

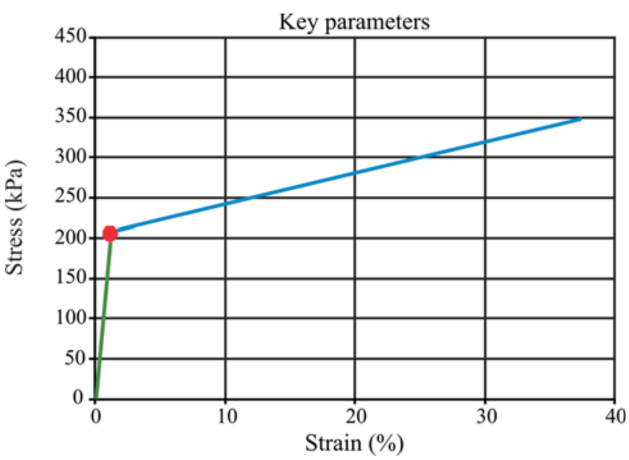

Figure 6 - Three key parameters of compressive behavior.

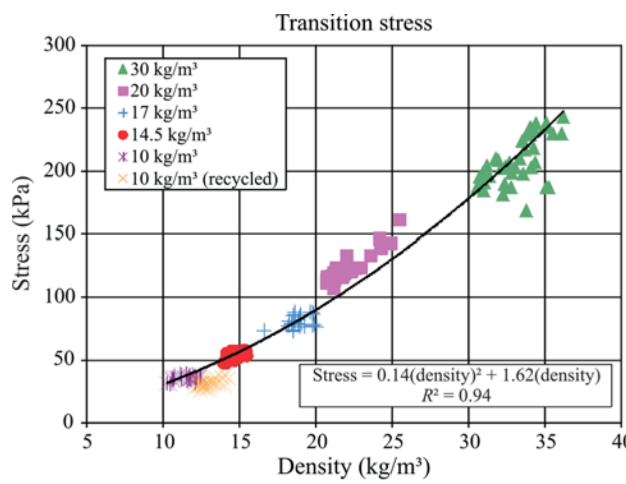

Figure 8 - Transition stress for EPS-geofoam samples.

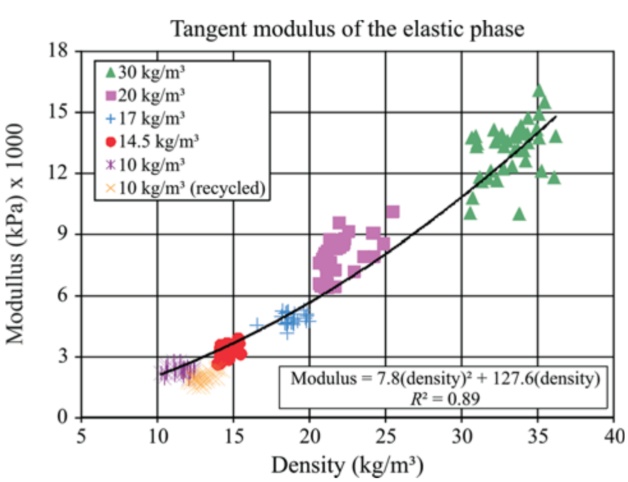

Figure 7 - Tangent modulus of the elastic phase for EPS-geofoam samples.

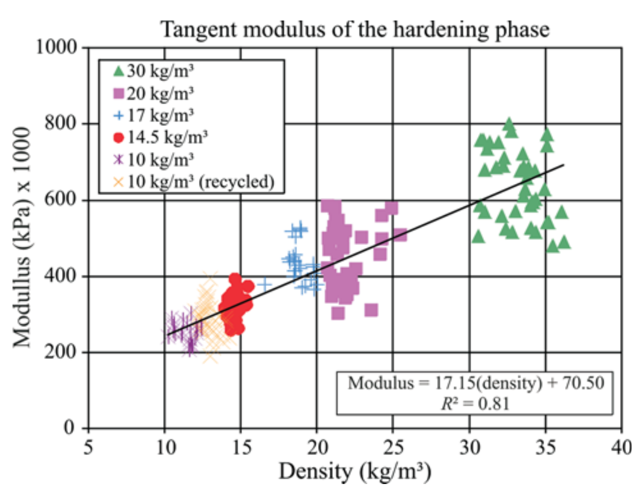

Figure 9 - Tangent modulus of the hardening phase for EPS-geofoam samples.

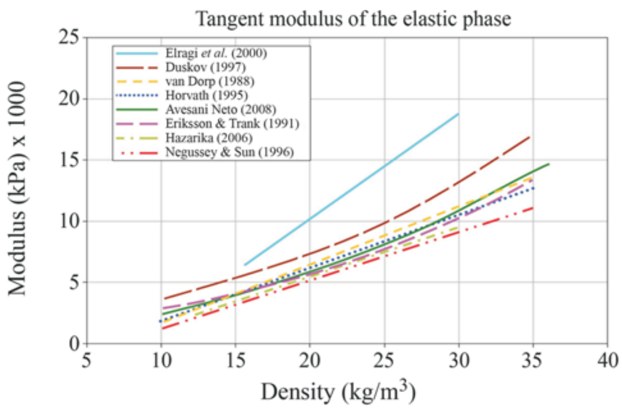

Figure 10 - Different relationships between density and tangent modulus of the elastic phase.

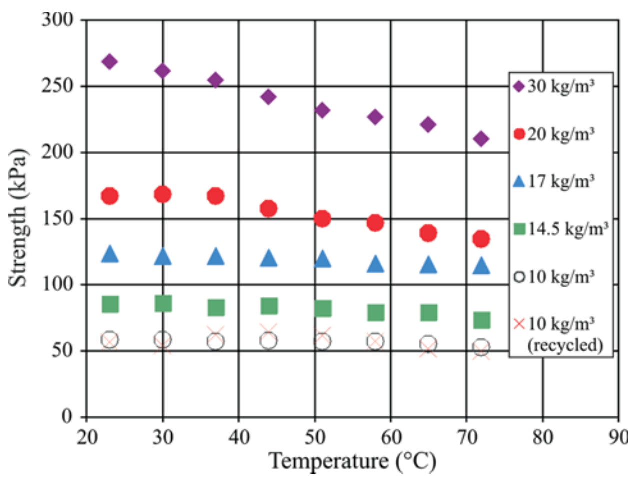

Figure 11 - Compressive strength *vs.* different temperatures.

Figure 11 shows a significant influence of temperature on the compressive strength of EPS-geofoam of higher density values (30 kg/m^3 and 20 kg/m^3) with strength 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 specimen density. Samples with higher density have a smaller amount of voids filled with air and a greater portion of polymer. This polymer portion is more significantly affected by the temperature change than the air in the voids, resulting in a strength reduction with temperature increase. A lower density has a greater amount of voids and a lower portion of polymer; consequently the specimen is less influenced by the temperature change.

Figure 12 shows the relationship between the strength obtained at each tested temperature and at the temperature of reference (in this case 23 °C) only for the densities that showed an appreciable loss of compressive strength (20 kg/m^3 and 30 kg/m^3).

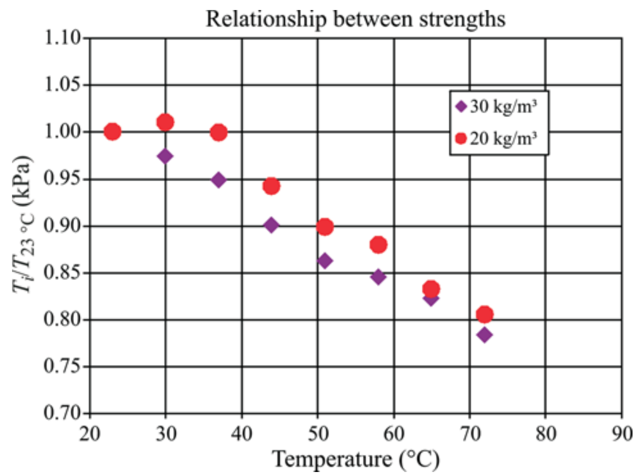

Figure 12 - Temperature influence in the 20 kg/m^3 and 30 kg/m^3 EPS-geofoams.

Figure 12 shows that the strength reduction exceeds 20% for temperatures of 72 °C. There is also a linear trend towards decreasing strength with increasing temperature.

The influence of the test speed and the specimens size was verified in the compressive strength. However, in both cases no significant influence of these variables was found on the EPS-geofoam behavior. Since this influence was less than 5%, the results were not analyzed.

3.2. Joint direct shear tests

The results of the joint direct shear testing in EPS samples of 10 kg/m^3 (with virgin and recycled material), 20 kg/m^3, 30 kg/m^3 and 40 kg/m^3 can be seen in Figs. 13 to 17.

The EPS mechanical behavior in shear tes is similar to the behavior of soil samples, as seen in these Figures. There is a peak value to the shear stress, similar to overconsolidated soils, followed by a reduction of stress due to change in the contact surface area of the blocks for the sample with higher densities (20 kg/m^3, 30 kg/m^3 and 40 kg/m^3). However, for the samples with lower density (10 kg/m^3 vir-

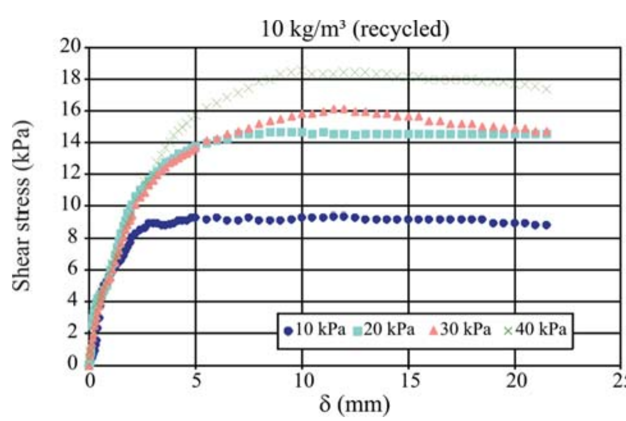

Figure 13 - Data of a direct shear test performed in the 10 kg/m^3 (recycled) EPS sample.

gin and recycled), the behavior is similar to normally consolidated soils, without a peak value.

Two failure envelopes were drawn from the tests data for each material: one with the peak friction angle, which was given the peak stress defined as the maximum shear stress, and another, called here "residual" friction angle, with a value of the shear stress corresponding to a displacement of 15 mm. Figures 18 and 19 show the failures envelopes for peak and residual friction angles for each density sample, respectively.

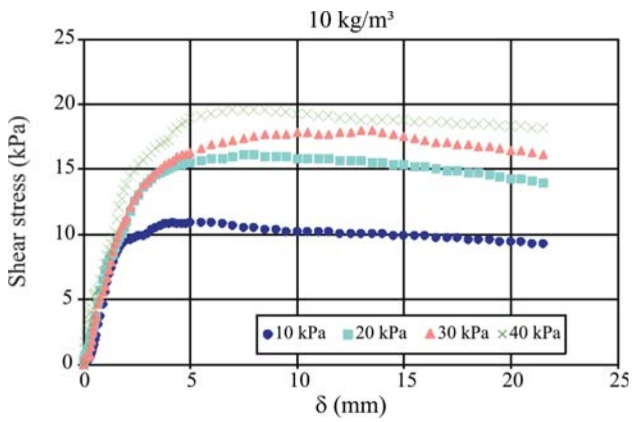

Figure 14 - Data of a direct shear test performed in the 10 kg/m³ EPS sample.

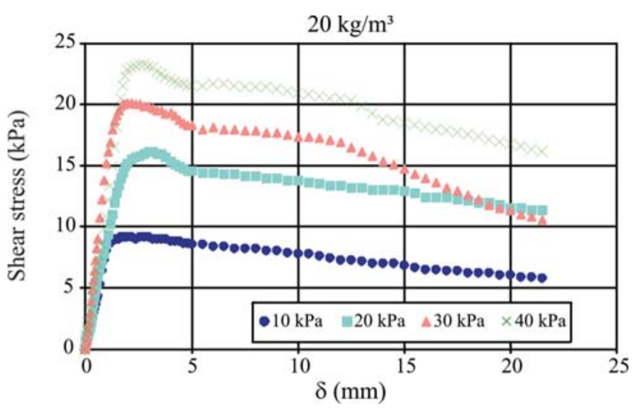

Figure 15 - Data of a direct shear test performed in the 20 kg/m³

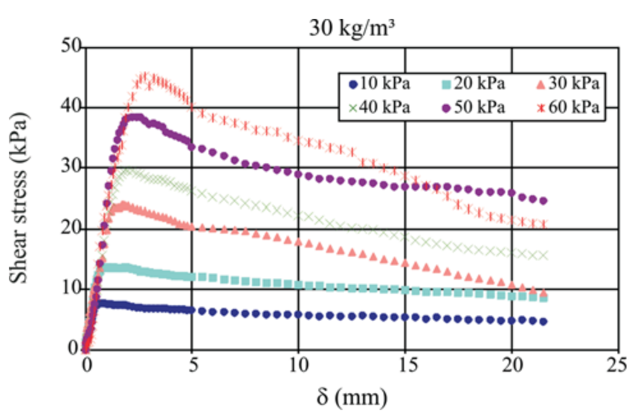

Figure 16 - Data of a direct shear test performed in the 30 kg/m³ EPS sample.

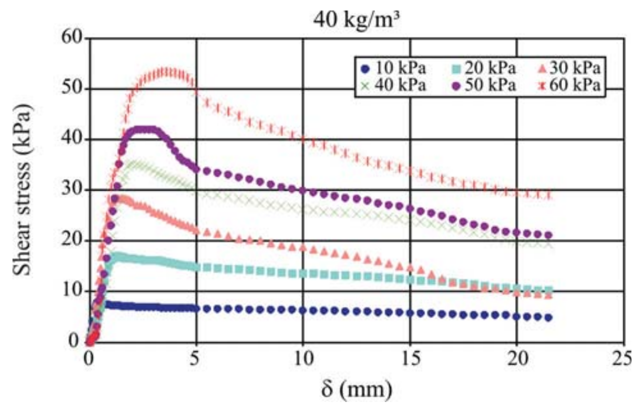

Figure 17 - Data of a direct shear test performed in the 40 kg/m³ EPS sample.

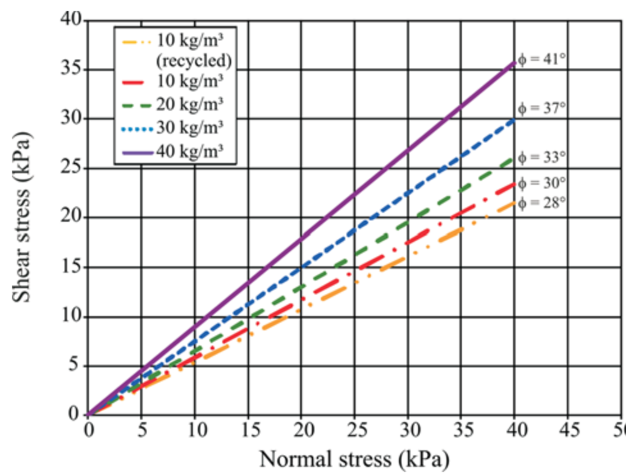

Figure 18 - Failure envelopes of EPS samples at the peak condition.

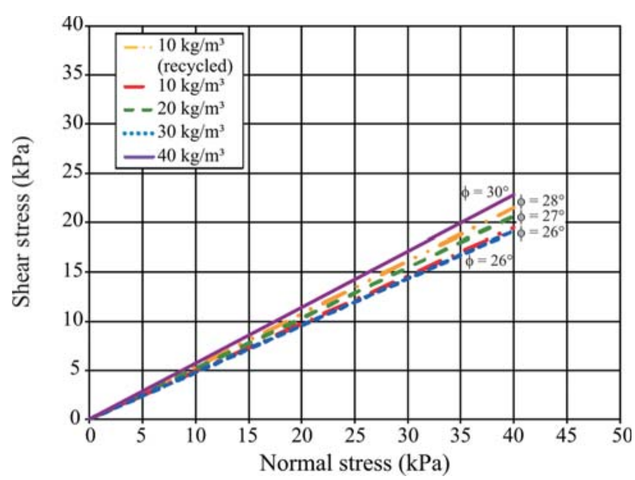

Figure 19 - Failure envelopes of EPS samples at the "residual" condition.

The friction angles obtained for all samples are relatively high for both peak and residual conditions, with values up to 41° (peak) and 30° ("residual"). Comparing the values of the friction angles of samples in each case a visible increase with density at the peak condition is noted. However, for the "residual" condition no significant change in the friction angle was observed with the density increase.

Comparing the results of the friction angles at peak and "residual" conditions, a considerable reduction is observed for samples with higher densities (Table 3).

Table 3 shows a greater reduction in the friction angle in the 30 kg/m^3 sample, lower reduction in the sample of 10 kg/m^3 virgin material, and conservation of the friction angle value in the sample containing recycled material. An explanation for this behavior is due to the contact surface of the material containing recycled EPS (and the sample of 10 kg/m^3 virgin material) which has a higher roughness on the specimens surface that prevent the formation of a lower friction efficiency region between the blocks and maintain the shear stress value at larger displacements.

The results allowed observing there is proportionality between the friction angle and the material density. For higher density values there is an increase in the friction angle at peak condition and reduction at "residual" condition. Thus, it is possible to establish a relationship between the average of friction angle (both for peak and "residual" conditions) with each sample for the average of density. These relationships provided a linear correlation between these two variables.

Figures 20 and 21 display the curves for the peak and "residual" conditions, respectively and the equation of better adjustment.

The figures show the proportionality between the friction angle and density. Although the recycled material has a higher density, it has poor mechanical characteristics if compared with the virgin material.

3.3. Creep in compression tests

The creep in compression tests were performed for a total time of 1000 h (about 42 days). The results of tests with specimens of 10 kg/m^3 (with virgin material), 17 kg/m^3, 20 kg/m^3 and 30 kg/m^3 can be seen in Figures 22

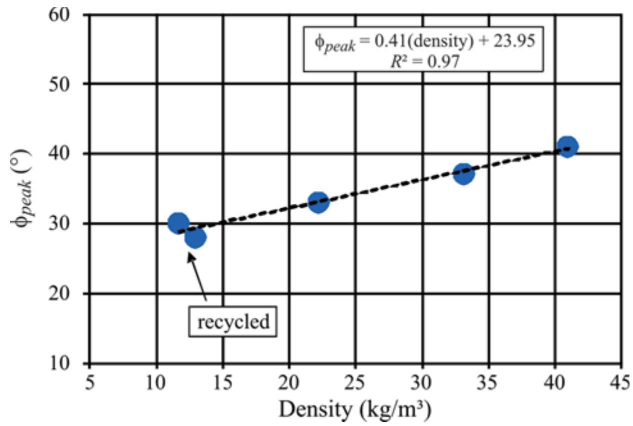

Figure 20 - Relationship between peak friction angle and density.

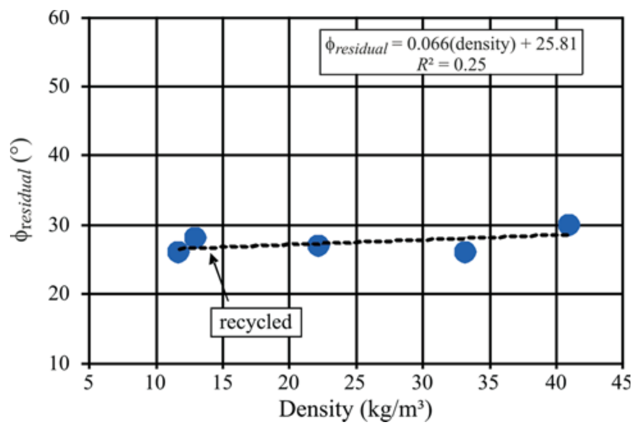

Figure 21 - Relationship between "residual" friction angle and density.

to 25, which indicate the nominal density, the average of measured density (in parentheses), the applied load and the relation between the applied load and the transition stress at 2% deformation.

Figures 22 to 25 allowed concluding that the tested EPS material practically does not exhibit creep in compression. However the EPS geofoam has a significant value of initial strain (over 80% of the total strain in all cases) independently of the density and percentage of load applied in relation to the transition stress. A limited creep was observed in the cases whose relation between load applied and

Table 3 - Comparison between data of peak and residual friction angles tests.

Nominal density (kg/m^3)	Average density (kg/m^3)	ϕ at peak (°)	ϕ at 15 mm of displacement (°)	Reduction in function of tanϕ (%)
10 (recycled)	13.0	28	28	0.0
10	11.7	30	26	15.5
20	22.2	33	27	21.5
30	33.2	37	26	35.3
40	41.0	41	30	33.6

transition stress was over than 50%. For values for this ratio below than 50%, the creep is only marginal.

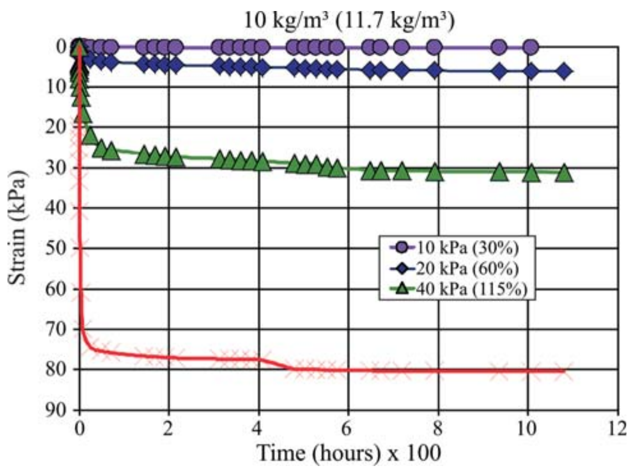

Figure 22 - Results of compression creep tests performed in the 10 kg/m^3 sample.

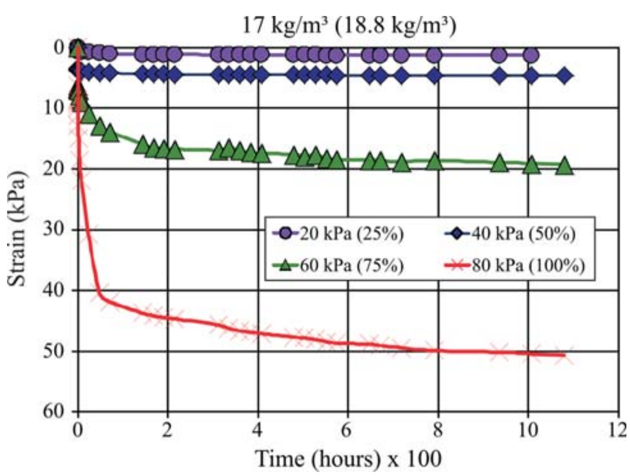

Figure 23 - Results of compression creep tests performed in the 17 kg/m^3 sample.

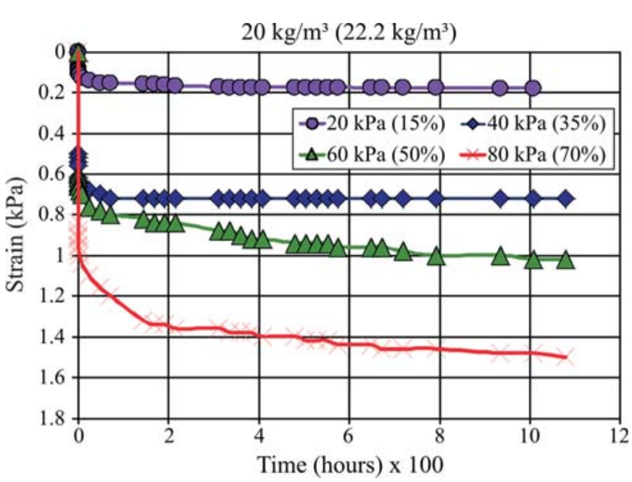

Figure 24 - Results of compression creep tests performed in the 20 kg/m^3 sample.

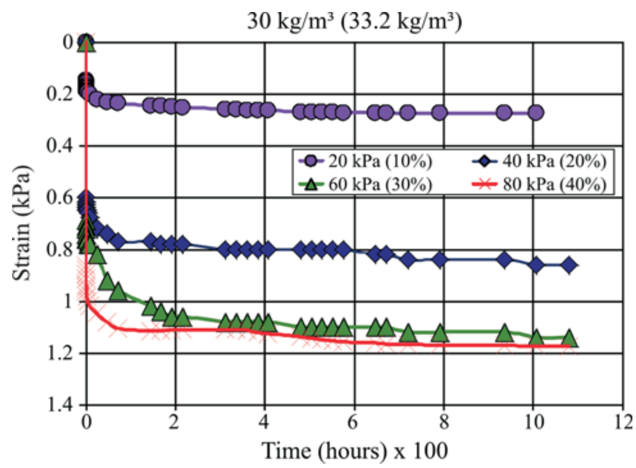

Figure 25 - Results of compression creep tests performed in the 30 kg/m^3 sample.

The creep with a very low value can be explained by the void reduction during the loading. After an initial deformation, the samples exhibit a void decrease, causing strength improvement and reduced specimens creep.

Figure 26 shows the relationship between the recorded strains and the density of all samples for different values of applied load in the same load exposure time (1000 h).

The 10 kg/m^3 sample exhibits a higher strain – almost 10% - for a load of 20 kPa (60% of the transition stress) after 1000 h of loading application. Moreover, the 17 kg/m^3 sample showed greater strain only for a load exceeding 40 kPa (50% of the transition stress). However even for a higher stress value such as 80 kPa, samples of 20 kPa and 30 kg/m^3 showed small strains.

3.4. Loss weight test by mice attack

Table 4 shows the result of loss weight test by mice attack on EPS. This value of weight loss is for a one mouse after 48 h of exposure with specimens.

Table 4 shows there are relatively high values of mass loss only in the case of straw deprivation. For a better view of the data, a chart with these values is shown in Fig. 27.

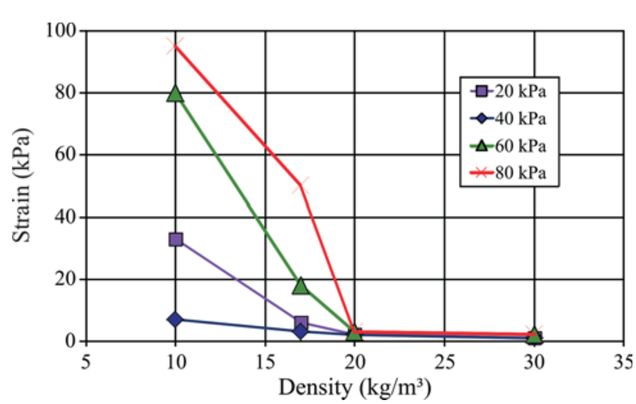

Figure 26 - Relationship between strain and density for each applied load.

Table 4 - Result of loss weight test by mice attack.

Nominal density (kg/m^3)	Total deprivation			Straw deprivation			Food deprivation		
	Initial mass (kg)	Final mass (kg)	Loss (%)	Initial mass (kg)	Final mass (kg)	Loss (%)	Initial mass (kg)	Final mass (kg)	Loss (%)
30	0.016	0.015	9	0.016	0.0095	40	0.017	0.016	5
20	0.012	0.012	4	0.013	0.0070	44	0.012	0.012	1
17	0.0094	0.0089	6	0.0094	0.0076	19	0.0095	0.0094	1
14.5	0.0081	0.0079	3	0.0083	0.0051	38	0.0080	0.0079	1
10	0.0060	0.0057	5	0.0061	0.0047	24	0.0057	0.0056	1
10 (recycled)	0.0070	0.0066	5	0.0072	0.0049	32	0.0068	0.0067	2
		Average	5		Average	33		Average	2

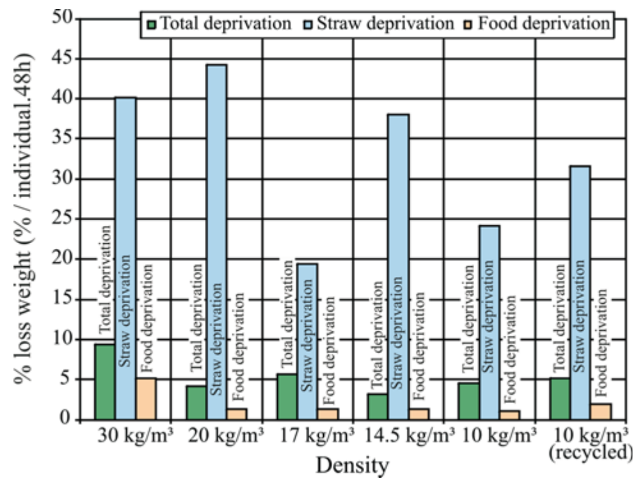

Figure 27 - Result of all loss weight tests by mice attack.

According the Fig. 27, the mass loss was small for two of the case (total and food deprivations) and extremely high in the case of straw deprivation because with the food deprivation the individuals enter in a low activity state to save energy. When there is no lack of food, the animal is in its state of normal activity and attacks the EPS samples to build its nest and generate physical comfort, as seen in Fig. 28. It was observed that there is not a relationship between the samples densities and the mice attack.

It should be considered in this study, for reasons of the available infrastructure for conducting the test, that the individuals were confined with the material, which may have aggravated the attack. However, it is important to observe that the value of mass loss was produced by only one laboratory mouse in a 48 h period. For a colony with larger and more aggressive wild rats and for a long period of time, the mass loss would probably be higher. The approach of this test, therefore, stands out for qualitative analysis of the attack, and not for a precise quantitative research of the mass loss value.

To visually quantify the attack of these animals in the samples, Fig. 28 shows the specimens tested in each case: a virgin specimen (before the test) and the specimens tested under food deprivation, total deprivation, and straw deprivation, respectively from left to right.

Figure 28 shows the elevated attack on the specimen tested under straw deprivation in comparison with the others deprivation. It must be emphasized that were used small size samples in the tests. There are reports that in large blocks – as occurs in real EPS apliccation – the rodents are installed inside them in order to form nests. However, by performing a correct cover of material with the soil in the works, avoiding exposing the EPS, risk of these animals attack the blocks can be reduced.

4. Conclusions

Several mechanical tests such as unconfined axial compression – with temperature variation, direct shear of

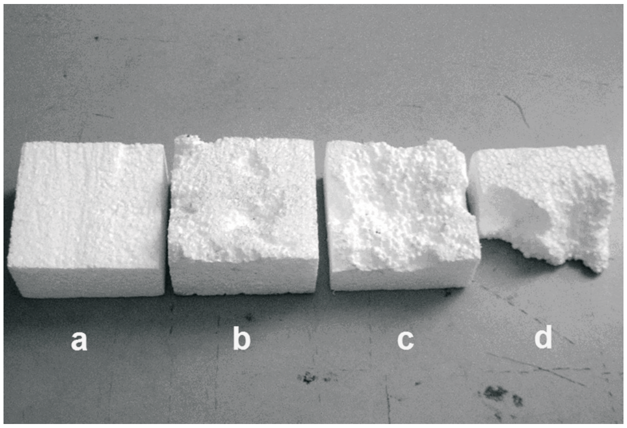

Figure 28 - Tested specimens: a) before the test; b) food deprivation; c) total deprivation; d) straw deprivation.

block joint and creep in compression – were performed in EPS geofoam samples with densities of 10 kg/m^3 (virgin and recycled), 14.5 kg/m^3, 17 kg/m^3, 20 kg/m^3, 30 kg/m^3 and 40 kg/m^3 aiming at their applications in geotechnical engineering. A simple mass loss test by mice attack was also conducted.

The main conclusions of this paper are:

- The current compressive strength definition (at 10% strain) does not express adequately its behavior;
- The material presents a well-defined elastic phase under 2% compression strain;
- The EPS-geofoam compression characterization by three key parameters (tangent modulus of elastic, hardening phases and transition stress) is relatively simple and effective and can be used in subsequent tests;
- The results from compression tests with temperature variation have showed a further influence on the EPS-geofoam strength of samples with densities of 20 kg/m^3 and 30 kg/m^3 with decreases of approximately 15% and 25%, respectively;
- The test speed and specimen size do not significantly affect the compressive strength results;
- The joint direct shear tests showed that the behavior of high-density EPS is similar to that of overconsolidated soils with a peak value of friction angle between 33° and 41°. For the lower-density EPS blocks, the behaviour was similar to normally consolidated soils, with a post-peak friction angle between 28° and 30°;
- The shear strength and consequently the friction angle and the failures envelope are directly proportional to the sample density;
- The reduction in the friction angle values from the peak to post-peak condition was high in EPS samples, reaching up to 30%. This reduction was more expressive at higher densities.
- The initial strain controls the creep in the compression of EPS;
- A limited creep was observed in the cases whose relationship between the applied load and the transition stress was larger than 50%;
- The result of mass loss test by mice attack showed a large loss in the specimen attacked. The most critical attack was recorded under the straw deprivation condition when the animal, in the presence of food, maintains the state of high metabolism and attacks the samples to build its nest and generate physical comfort;
- The values of the mass loss tests illustrate only a qualitative point of view of the phenomenon – proving the assertion of some practical cases – and not a quantitative analysis.

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