http://dx.doi.org/10.22161/ijeab/4.1.27 ISSN: 2456-1878

SBR-Based Light Cimental Compositions for use in Sustainable Constructions

Carolina Pereira Dantas[1], Ana Carolina Feitosa de Vasconcelos[2], Antônio Farias Leal[3]

[1]Researcher at Federal University of Campina Grande, Brazil.
Email: carolinapdantas@yahoo.com.br
[2]Corresponding author. Post-doc researcher at Federal University of Campina Grande, Brazil.
Email: ana3carol@yahoo.com.br
[3]Federal University of Paraiba, Brazil, Email: antoniofleal@gmail.com

***Abstract*— *The practice of sustainable development is a reality present in various segments of society. In this sense, buildings must be ecologically correct, socially just, culturally accepted, and economically viable. Seeking sustainability, the use of non-conventional building materials is increasing, especially for works of social interest. The aim of the present work was to develop light SBR - based composites based on industrial waste from the footwear sector, aiming at the elaboration of construction elements for the thermal protection of masonry.For the production of the composites, Portland cement type CP II F - 32 and a residue from a footwear industry based on SBR were used. For this, the composition of the granulometry of the light aggregate and the appropriate water / cement ratio were defined, and adequate values of resistance to compression, bending and absorption were considered.Therefore, the composition of the granulometry of the light aggregate and the appropriate water/cement ratio were defined, and adequate values of resistance to compression, bending and absorption were considered. Then, the influence of the incorporation content of the lightweight aggregate and the molding pressure to be used in the composites was evaluated, where flexural strength, absorption capacity, bulk density and visual analysis were performed.In addition, the thermal conductivity was determined in the optimized traces aiming the use of these composites as constructive elements for thermal protection of masonry. The lower values of absorption factors and voids index were reached when molding using the pressure level N1 (0.16 MPa). The bulk density factor of the pressure-molded composites reached the lowest values also under the pressure level N1 (0.16 MPa). The composites with higher contents of incorporation of molded waste without pressure showed no results resistance to bending and absorption.*

Keywords*— *industrial waste, thermal insulation, construction elements, sustainability, rural constructions.

I. INTRODUCTION

Man is increasingly exploiting the natural resources of the planet in an undisciplined way, causing the possibility of their scarcity and consequent degradation of the environment. As in the most diverse areas of science, in search of the development of eco-friendly technologies, research in the construction sector has been intensified in order to obtain high-energy efficiency materials, manufactured with industrial solid waste, that perform well and meet current expectations durability and strength.

Silva (2012) characterized the rubber based butadiene styrene (SBR) residue from a footwear industry in Campina Grande, Brazil, and concluded that this residue is classified as CLASS I - DANGEROUS, as it presents, in its leached extract, heavy metals with values above what are established in standard. In addition, the author considered that because it is coated with a layer of cement paste, the residue has the potential to remain isolated, making it feasible for use in rural and urban construction applications.

Soares et al. (2008) used eight types of mixtures to produce light mortars containing waste from the shoe industry and ceramics: four containing only shoe residue and cement; and another four containing footwear residue, cement and 30% of waste from the ceramic industry in substitution of cement. They concluded that the composite obtained can be used as a safe, ecological and low cost alternative for the manufacture of masonry panels, flat and corrugated boards for use in rural buildings, among other applications.

Rios et al. (2009) found that the composite cement matrix and polymeric reinforcement (SBR) is technically feasible, with a modulus of rupture and compression consistent with the minimum resistances established and validated in the market by similar products. These authors stated that when submitted to low pressure energy, the composite shows excellent degree of packaging, lower porosity, better ductility and resistivity.

Thus, this study aimed to elaborate lightweight composites using solid residues based on SBR, originated from the manufacture of footwear, for using in sustainable and low cost constructions.

II. MATERIALS AND METHODS

This study was carried out in the Laboratory of Recyclable Materials of the Rural Constructions area of the Department of Agricultural Engineering of the Federal University of Campina Grande, Campina Grande, Brazil. Different levels of incorporation of solid residues based on SBR from the manufacture of footwear were tested in a cementitious matrix under different molding pressure levels for the development of lightweight plate - shaped construction elements intended for use as insulation thermal, in rural and urban constructions.

For the production of the composites, Portland cement type CP II F - 32 and a residue from a footwear industry of the city of Campina Grande, based on SBR, were used. Table 1 shows the main physical characteristics of the cement.

Table.1: Physical characteristics of Portland cement CP II F-32

Features	Unit	Value
Fineness of the Mesh n° 200	%	$\leq$12
Specific Area (Blaine)	cm^2g^{-1}	$\geq$ 2600
Cement handle start	h:min	$\geq$1:00
End of cement handle	h:min	$\leq$10:00
Simple Compressive Strength at 28 days	MPa	$\geq$32

Silva (2012) evaluated this residue and mentioned that it is hydrophobic, presenting difficulty of interaction with the cement; is very porous, with voids index of 57.06% and pores with a mean diameter of 3.6413µm; however, is not permeable. According to Rios (2008), the composites cement:SBR presented resistance to combustibility, characterized by the absence of flame or incandescence until the fastener, not being perfect fuels, because the presence of the retardant (cement) inhibits the burning.

With the objective of evaluating the incorporation of residues and the pressure levels of molding, the work was divided in three parts.

In the first one, the composition of the granulometry of the light aggregate and the appropriate water/cement ratio were defined. Thus, in the cement matrix, three compositions of light aggregate granulometry (SBR) and two water / cement content were tested. According to the objectives of thisstudy, adequate values of resistance to compression, bending, and absorption were considered.

In the second phase, the influence of the incorporation content of the lightweight aggregate and the molding pressure to be used in the composites was evaluated. In this way, three contents of light aggregate were tested in cement matrices: 25%, 50% and 100% in relation to the amount of binder.

In order to evaluate the appropriate molding pressure, four levels were considered:

- Zero level (N0) - No pressure(0 MPa);
- Level one (N1) – 1.6 $Kgfcm^{-2}$ (0.16 MPa);
- Level two (N2) – 4 $Kgfcm^{-2}$ (0.4 MPa);
- Level three (N3) – 8 $Kgfcm^{-2}$ (0.8 MPa)

Tests of resistance to flexion, absorption capacity, bulk density and visual analysis were carried out.

The tests of resistance to simple compression were realized in the equipment SHIMADZU AUTOGRAPH AG IS 100KN; and those of flexural strength in the SHIMADZU AUTOGRAPH AG-X 50KN electronic press, following the standards of the Brazilian Association of Technical Standards (ABNT) 5739.In order to determine the absorption capacity, an adaptation of standard NBR 9778 (2005) was used, according to Silva (2012).

In the third and final part, the thermal conductivity was determined in the optimized traces, aiming the use of these composites as building elements for thermal masonry protection. In this sense, the thermal conductivity of the composites was determined using the K30 Conductivity Meter, which is based on the protected hot plate method. The results obtained were compared with each other and with already validated thermal insulators in the market.

The physical-mechanical properties of the studied composites were evaluated through the adaptation of Efficiency Factor calculations (Rossignolo, 2003), which defines as a fundamental parameter for the evaluation of

http://dx.doi.org/10.22161/ijeab/4.1.27 ISSN: 2456-1878

light concrete, the calculation of the efficiency factor, which takes into account the specific mass dry and the simple compressive strength of the material, expressed mathematically by Equation 1:

Fef = fc/ λ (Eq. 1)

Where:

fc - compressive strength, MPa;

λ – specific dry mass of concrete, kg dm^{-3} (g cm^{-3})

Adapting the calculations, these factors were determined for other properties of the composites. Aiming at the preparation of lightweight composites, mainly intended for the thermal protection of masonry, low values of some properties and respective efficiency factors are required, such as absorption capacity, voids index and density. Thus, for this study, these parameters were denominated Absorption Factor, Empty Index Factor and Density Factor.

The analysis of variance of the results was done by the Tukey test at 5% of probability.

III. RESULTS AND DISCUSSIONS

Table 3 presents the results of the study for the composition of the particle size of the SBR residue and the a/mc factor, for use in the preparation of the composites.

Table.3: Results of the study for the composition of the granulometry of the SBR residue and the a/mc factor for use in the preparation of the composites.

Granulometry Trace 1:1	a/mc	Simple compression strength (MPa)	Flexural strength (MPa)	Absorption (%)	Void Index (%)
34567	0.3	0.54 b	Did not shape	-	-
3456		0.51 c			
345		0.55 a			
34567	0.4	0.66 c	0.013 c	20.22 a	17.86 a
3456		0.80 b	0.055 b	21.28 b	19.03 b
345		1.02 a	0.073 a	21.97 c	19.40 c

Means followed by the same letters (a, b) do not differ by Tukey test.

When the Tukey test was applied, all values of Flexural Strength, Bulk Density, Absorption and Void Index were statistically different, with 95% confidence.

When using the a/mc content of 0.4, it was noted that the less fines in the particle size composition, the greater the resistance to simple compression. Changingthe granulometryfrom 34567 to 3456, the compressive strength increased by 21.2%. When SBR with 345 granulometrywas used, there was an increase of 54.5% in relation to 34567, and 27.5% in relation to 3456.

As with simple compression strength, flexural strength also increased when using finer grades. Altering the particle size from 34567 to 3456, this resistance increased by 323%, and from 34567 to 345 this increase was 461.5%. Regarding the grain size 3456, the increase in composition 345 was 32.7% in the flexural strength of the composite.

When comparing the absorption capacity, the less thin the material, the higher this characteristic. When changing from 34567 to 3456, the absorption increased only 5.2%. From 34567 to 345, this increase was 8.6%. When changing from 3456 to 345, the granulometry of the light aggregate, the increase in absorption capacity was 3.2%.

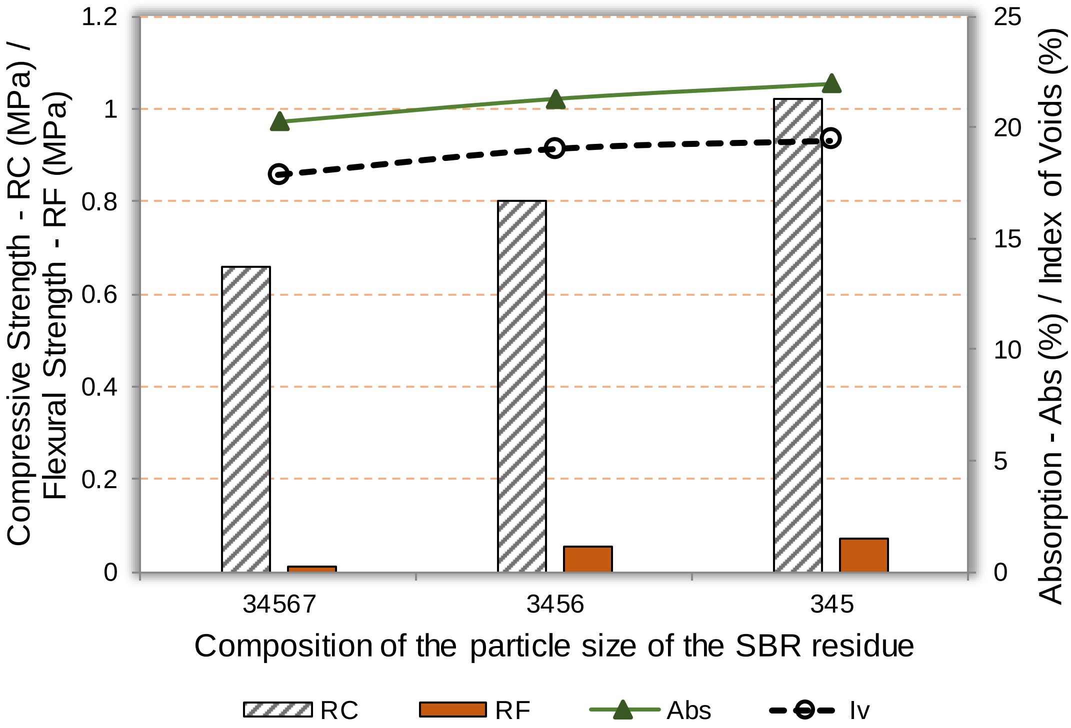
With the ratio a/ mc of 0.4, using the adjusted efficiency factor calculations, the best result for compressive and flexural strength was achieved with the particle size composition using particle sizes 3, 4 and 5, that is, retained in the sieves 4.8 mm, 2.4 mm and 1.2 mm, according to Table 4.

Table.4: Effectiveness factor (Fef) of the resistance to simple compression and bending to define the composition of the granulometry of the SBR residue.

Granulometry Trace 1: 1	Fef of Simple Compression Strength (MPa . cm^3/g)	Fefof Flexural strength (MPa . cm^3/g)
345	1.16	0.08

3456	0.89	0.06
34567	0.76	0.01

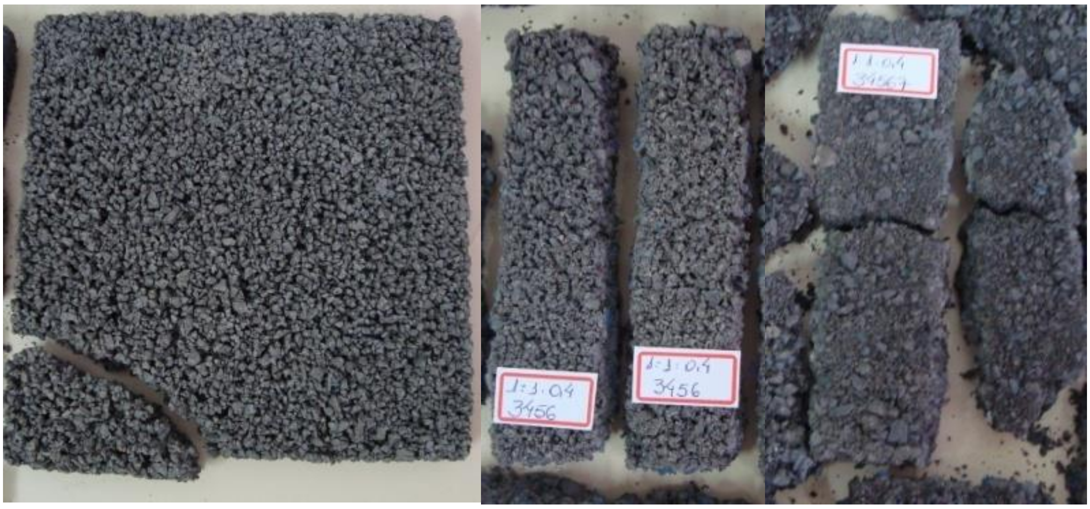
Figure 1 shows the results observed in the properties of the molded composites with a/ mc content of 0.4:



RC: Compressive strength; RF: Flexural Strength; Abs: Absorption: Iv: Index of Voids

Fig.1: Physical-mechanical properties of cement composites and SBR residues, molded with a/mc content of 0.4.

The molded plates with the three granulometries tested and with a / mc factor 0.4 are shown in Figures 2 (a) (b) and (c).Note that the respective granulometries of the lightweight aggregate (with finer ones) leave the material more fragile and brittle.



(a) (b) (c)

Fig.2: Prismatic specimens with trace 1: 1: 0.4 (a) particle size SBR 345 (b) particle size SBR 3456 (c) particle size SBR 34567

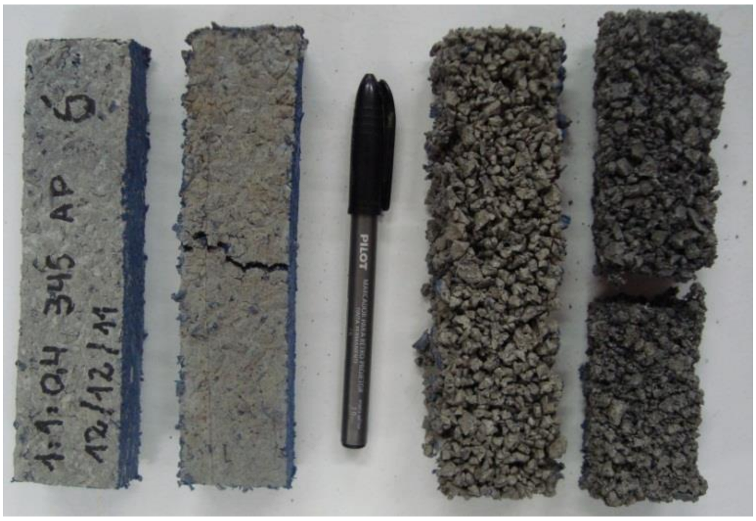
In addition to the best results for simple compression and flexural strength, the mixture of cement and SBR residue in grain size 345 showed better workability. Another advantage of this granulometry composition is the fact that it is not necessary to intensify the process of crushing the residue, reducing costs, since they are not fine granulometry.

After the evaluation of the granulometry of the SBR residue, traces and molding pressure levels were tested for cementitious matrix composites. The water content in relation to the binder (a/agl) was adjusted to 0.4

http://dx.doi.org/10.22161/ijeab/4.1.27 ISSN: 2456-1878

by varying the applied pressure level (N0, N1, N2 or N3) and the trace (1: 1, 1: 0.5 and 1: 0.25) as quoted in the methodology.

Figure 3 shows 1: 1 trace test bodies, subjected to the N3 level molding pressure and without molding pressure (N0), before and after the flexural test.



(a) (b)

Fig.3: Cement matrix test bodies with SBR residues of 1: 1: 0.4 (a) traces of grain size 345 subjected to molding pressure N3 and (b) without molding pressure (N0).

The observed results of the physical-mechanical properties of the composites cement: SBR are in Table 5.

Table.5: Results of the study of the cement composite and SBR residue for use in the elaboration of lightweight construction elements.

Trace Cement: SBR residues	a/agl	Molding Pressure Level	Flexural Strength (MPa)	Tenacity (KJ\cm^2)	Compression Resistance (MPa)	Bulk density (Kg/m^3)	Expelled a/mc	Specific dry mass (g/cm^3)	Absorption (%)	Void Index (%)
1:1	0.4	N0	0.073 ± 0.012 dC	0.07 ± 0.004	1.02	**652.3 ± 6.02**dC•	**0**	**0.91 ± 0.16**bB	31.1 ± 5.57 aA	28.1 ± 3.96 aA
		N1	0.75 ± 0.03 cC	0.67 ± 0.08		**721.1 ± 20.46**cC•	**0**	1.13 ± 0.009 aC	**21.0 ± 0.5**dA	**23.4 ± 0.49**aA
		N2	0.75 ± 0.01 bC	0.87 ± 0.17		947.4 ± 20.5 bC	+	1.10 ± 0.05 aC	22.9 ± 2.3 cA	25.2 ± 1.60 aA
		N3	**0.77 ±0.01**aC	**0.91 ± 0.07**		1062.6 ± 15.31 aC	++	1.11 ± 0.009 aC	23.7 ± 0.32 bA	26.3 ± 0.27 aA
1:0.5		N0	0.66 ± 0.05 cB	0.58± 0.03	1.71	**947.3 ± 42.91**cB	**0**	**0.94 ± 0.16**cB	28.7 ± 8.5 aB	27.0 ± 5.77 aB
		N1	1.30 ± 0.14 bB	0.94± 0.23		**1029.4 ± 15.53**bB	**0**	1.23 ± 0.10 bB	**14.5 ± 0.66** dB	**17.9 ± 0.79** dB
		N2	**1.47 ± 0.06**bB	0.92± 0.05		1058.5 ± 41.37 bB	++	1.22 ± 0.09 bB	17.6 ± 1.17 cB	21.4 ± 2.91 cB
		N3	1.30 ± 0.03 bB	**1.40 ± 0.13•**		1114.1 ± 45.9 aB	+++	1.37 ± 0.02 aB	18.5 ± 1.05 bB	25.5 ± 1.37 bB
1:0.25		N0	1.13 ± 0.15 dA	0.52± 0.07	**4.88•**	**1041.7 ± 8.42**dA	**0**	**1.03 ± 0.076**dA	21.1 ± 3.41 aC	21.8 ± 3.23 bC
		N1	2.02 ± 0.15 cA	0.63± 0.019		**1104.3 ± 29.99**cA	+	1.35 ± 0.04 cA	**13.2 ± 0.37**dC•	**17.8 ± 0.50** dB•
		N2	2.93 ± 0.24 bA	0.67± 0.009		1298.2 ± 21.18 bA	+++	1.43 ± 0.03 bA	14.9 ± 0.70 cC	21.2 ± 0.60 cB
		N3	**3.19 ± 0.34**aA•	**0.79 ± 0.14**		1331.2 ± 20.98 aA	++++	1.59 ± 0.008 aA	15.9 ± 1.01 bC	25.4 ± 1.60 aB

http://dx.doi.org/10.22161/ijeab/4.1.27 *ISSN: 2456-1878*

Means followed by the same lowercase letters (a, b, c, d) for the same trace do not differ by Tukey's test.
Means followed by the same capital letters (A, B, C, D) for the same molding pressure level in different traces do not differ by Tukey's test.
(•) Better results

By evaluating the properties of resistance to simple compression, it is noticed that the smaller the amount of SBR residues, the greater the resistance (Figure 4).

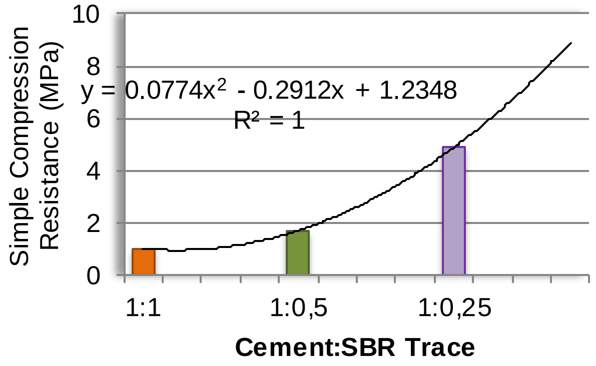


Fig.4: Resistance to Single Compression of the cement matrix with incorporation of SBR residue, in the granulometry 345.

When using the 1: 1 trace of cement and residue, a simple compressive strength of 1.02 MPa was achieved. When the amount of the incorporated residue was decreased by 50% (1: 0.5), the simple compressive strength increased by 67.6% (1.71 MPa). By decreasing the amount of the incorporated residue by 75% (1: 0.25), the increase in the simple compressive strength was 378.4% (4.88 MPa).

No satisfactory flexural strength was achieved using non-pressure molding (N0) for the highest contents of waste incorporation (1: 1 and 1: 0.5). With the application of molding pressure, the flexural strength was increased. The values were compatible with those found by Oliveira (2009), studying composites formed of gypsum or vermiculite and EVA; by Leal (2004) evaluating cement and EVA composites; and by Silva (2012) analyzing traces composed of cement, sand and SBR.

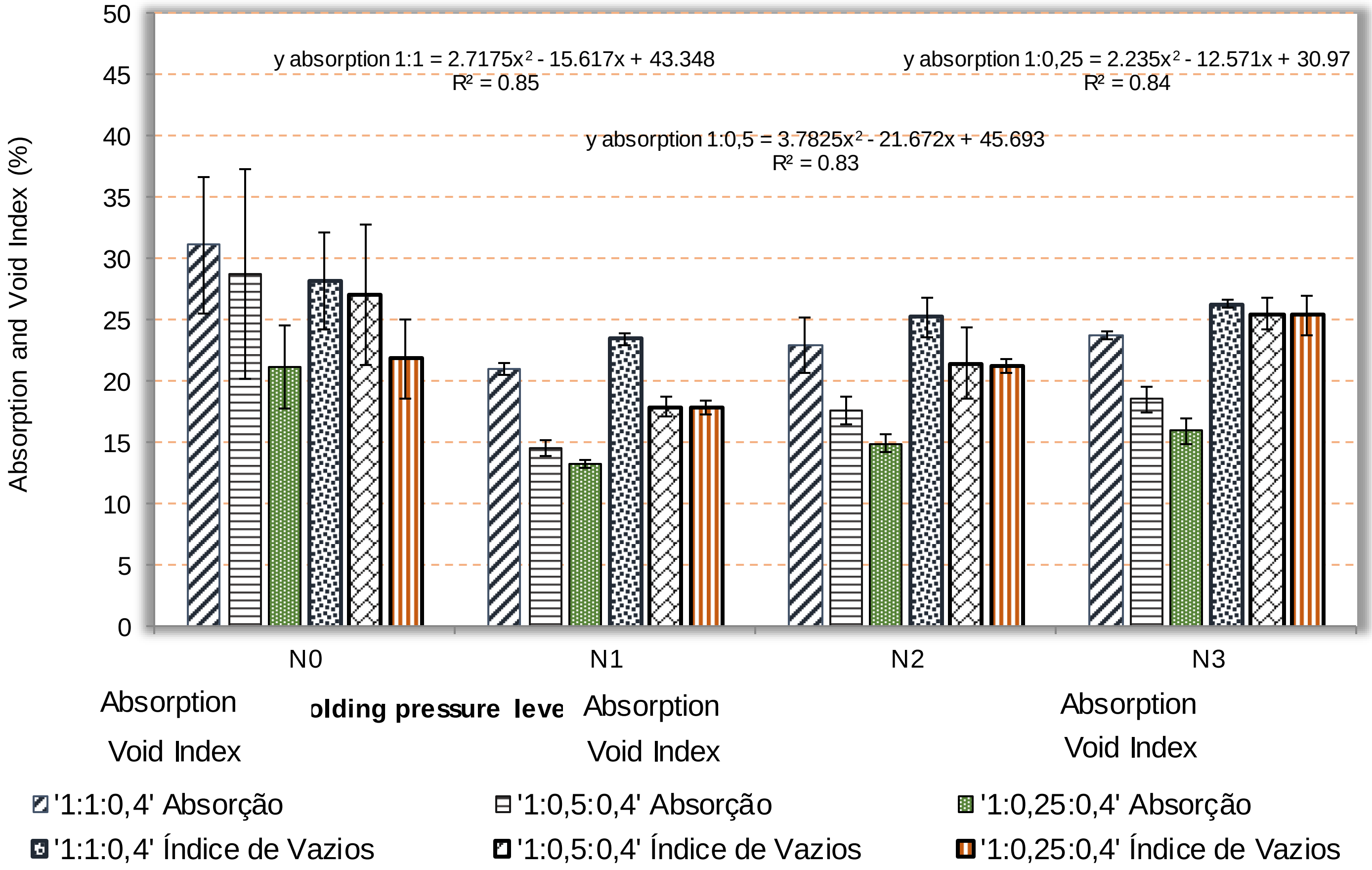


Fig.5: Absorption and Void Index of the cement matrix with incorporation of SBR residue, in the granulometry 345.

In relation to the specific dry mass, even though an increase occurred due to the application of molding pressure, all the composites could be considered light (910 to 1590 kg/m^3). The application of the molding pressure also caused an increase in the bulk density of the composites, which ranged from 652.3 to 1331.2 kg/ m^3.

Taking into account the purpose of the proposed constructive elements it is necessary that the composites that will be part of its structure have the lowest absorption capacity possible. The lowest results of this property were achieved in the molded composites with N1 pressure level (13 to 21%, according to the residue content). The values of the absorption capacity of the molded composites with this level of molding pressure were compatible with those of Bezerra (2002), studying cement, sand and EVA composites; and by Soares et al (2008), working with cement, ceramic residue and shoe waste.

When N2 and N3 molding pressure levels were used, binder water was ejected from the interior of the composites (highlighted in Table 5), resulting in a higher void index, and consequently a higher absorption capacity. When these properties were applied, the 1: 0.5 and 1: 0.25 trace composites presented similar trend in relation to the void index (Figure 5).

Figure 5 shows the lower absorption capacity and the lower void index of the composites when the N1 (0.16 MPa) level pressure is used. With this level of pressure, there was also a greater uniformity in the results, represented by smaller values of standard deviation.

Figure 6 illustrates the observed trend of the properties of cement composites and SBR residues.

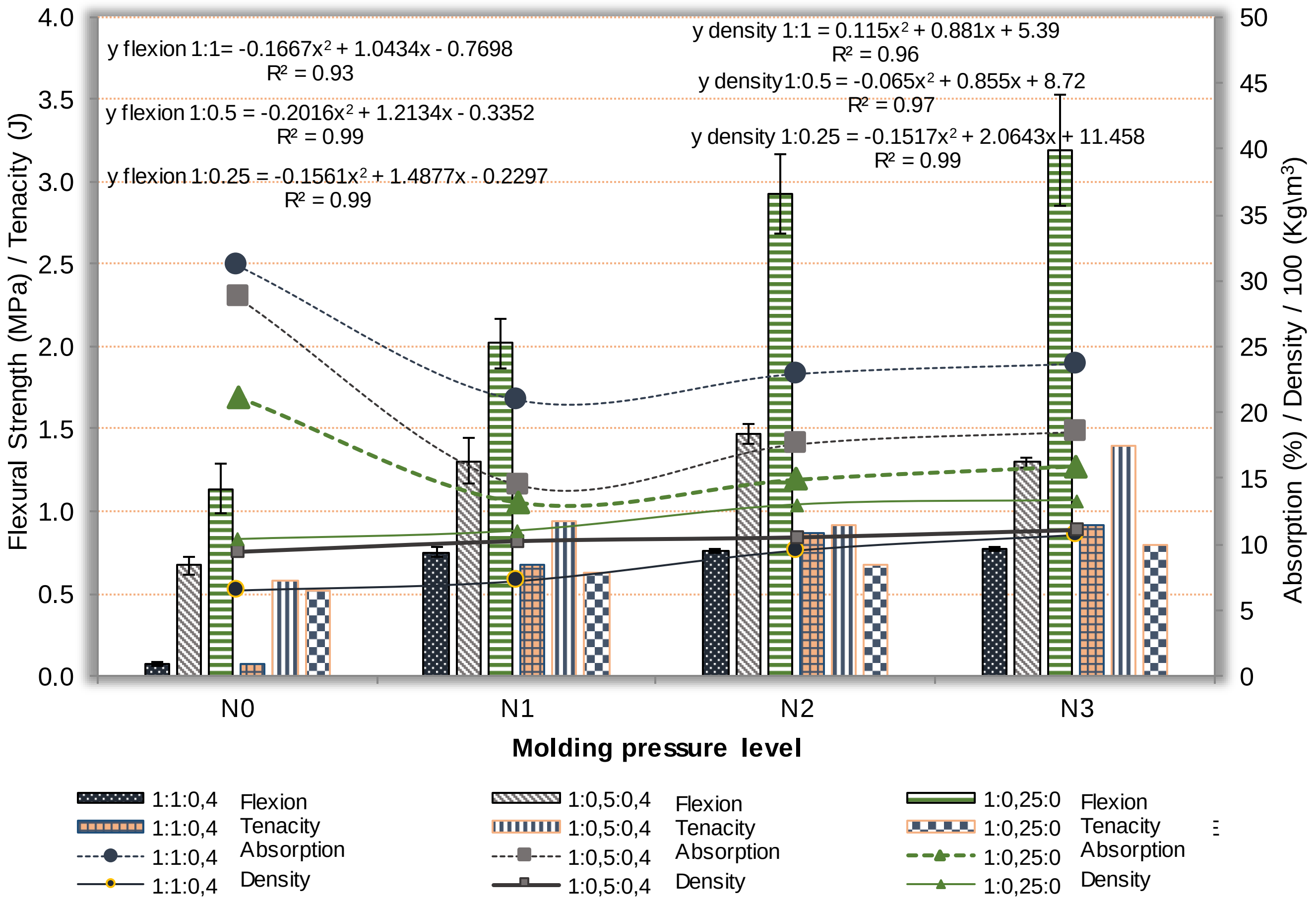


Fig.6: Resistance to flexural strength, Absorption, Tenacity and Bulk density of cement composites and SBR residues.

The results obtained with the calculations adapted from the Efficiency Factor (Fef) of properties according to Rossignolo (2003) are presented in Table 6. For the bulk density and absorption, this factor was denominated "Density Factor" and "Absorption Factor".

Table.6: Results of the efficiency factors of cement composites and SBR residue for use in the elaboration of lightweight construction elements.

Trace Cement: SBR residues	a/agl	Molding Pressure Level	Efficiency factor ofFlexural Strength (MPa.cm³\g)	Factor ofBulk density	Factor of Absorption (%.cm³\g)	Factor ofVoid Index (%.cm³\g)
1:1	0.4	N0	0.08↓	7.16	34.19	30.97
		N1	0.67	**6.38•**	**18.58•**	**20.77•**
		N2	**0.69•**	8.61	20.85	22.94
		N3	**0.69•**	9.57	21.35	23.71
1:0.5		N0	0.71↓	10.07	30.61	28.76
		N1	1.06	**8.37•**	**11.85•**	**14.56•**
		N2	**1.20•**	8.67	14.44	17.58
		N3	0.95	**8.13•**	13.55	18.63
1:0.25		N0	1.10↓	10.11	20.53	21.17
		N1	1.50	**8.18•**	**9.79•**	**13.22•**
		N2	**2.05•**	9.08	10.43	14.87
		N3	2.01	8.37	10.02	15.97

IV. CONCLUSIONS

The Efficiency Factor of the flexural strength of the 1: 1: 0.4 trace presented higher values with molding pressure levels N2 (0.4 MPa) and N3 (0.8 MPa); however, from N1 (0.16 MPa) this increase was not significant. For the 1: 0.5: 0.4 and 1: 0.25: 0.4 traces the N2 level molding pressure was more efficient for this property.

The lower values of absorption efficiency factors and void index were obtained when the composites were molded using N1 (0.16 MPa) pressure level. The bulk density factor of the pressure molded composites reached the lowest values when the pressure level N1 (0.16 MPa) was also used.

The composites with higher contents of incorporation of residues, molded without pressure, did not present satisfactory results of resistance to the flexion and absorption. Although the 1: 0.25: 0.4 trace presented better values of resistance factors to flexion and absorption, it did not provide a greater incorporation of residues, allowing a greater use of cement.

REFERENCES

[1] ABNT, ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. *"Ensaio de compressão de corpos-de-prova cilíndricos de concreto"*, NBR 5739. Rio de Janeiro, 1994.

[2] BEZERRA, A. J. V. *"Utilização do resíduo da indústria de calçados (EVA - etileno acetato de vinila) como agregado leve na produção de blocos vazados de concreto para alvenaria sem função estrutural"*. Dissertação (Mestrado) – Universidade Federal da Paraíba. Campina Grande, 2002. 115p.

[3] RIOS F. R. A., SILVA V. R. DA, SOARES E. A., LEAL A. F., NASCIMENTO J. W. B. do. "*Incorporação do sbr na confecção de compósitos de matriz cimentícia"* - Revista Educação Agrícola Superior - v.24, n.1, p.13-19, 2009.

[4] RIOS, F. R. A. "*Incorporação de resíduos de calçados (SBR) na produção de compósitos leves"*. Dissertação (Mestrado) - Universidade Federal de Campina Grande. Campina Grande, 2008. 71p

[5] ROSSIGNOLO, J. A.*"Concreto leve de alto desempenho modificado com SBR para pré-fabricados esbeltos. Dosagem, Produção, Propriedades e Microestrutura*". Tese (Doutorado) - Universidade de São Paulo, São Carlos, 211p. 2003.

[6] SILVA I. F. "Viabilidade de aplicação do resíduo sólido polimérico (sbr) da indústria calçadista na confecção de elementos construtivos". Tese (Doutorado) - Universidade Federal de Campina Grande. Campina Grande. 138p. 2012.

[7] SOARES A. E.; LEAL A. F.; CARDOSO J. A. F..*"Argamassas leves produzidas com resíduos de calçados e de cerâmicas*" – Universidade Federal de Campina grande, Relatório final PIBIC / CNPQ / UFCG, 2008.