Experimental analyses of the poly(vinyl chloride) foams' mechanical anisotropic behavior
Assessing a full set of mechanical properties is a rather complicate task in the case of foams, especially if material models must be calibrated with these results. Many issues, for example anisotropy and heterogeneity, influence the mechanical behavior. This article shows through experimental analyses how the microstructure affects different experimental setups and it also quantifies the degree of anisotropy of a poly(vinyl chloride) foam. Monotonic and cyclic experimental tests were carried out using standard compression specimens and non-standard tensile specimens. Results are complemented and compared with the aid of a digital image correlation technique and scanning electron microscopy analyses. Mechanical properties (e.g., elastic and plastic Poisson’s ratios) are evaluated for compression and tensile tests, for two different material directions (normal and in-plane). The material is found to be transversely isotropic. Differences in the results of the mechanical properties can be as high as 100%, or even more depending on the technique used and the loading direction. Also, the experimental analyses show how the material’s microstructure behavior, like the evolution of the herein identified “yield fronts” and a “spring back” phenomenon, can influence the phenomenological response and the failure mechanisms as well as the hardening curves. POLYM. ENG. SCI., 52:2654–2663, 2012. © 2012 Society of Plastics Engineers

INTRODUCTION

The current acknowledgement of foams as a new option for structural projects has drawn attention to the understanding of their mechanical behavior [1–5]. However, foams usually show an anisotropic behavior that complicates the evaluation of their phenomenological mechanical behavior. One of the reasons is the influence of the micromechanisms of failure seen in these materials. The shape of the cells and their elastic buckling and plastic micro mechanisms affect the mechanical behavior of the foam and impose hurdles on the exact determination of mechanical properties. This correct determination is very important, because the mechanical properties are used in phenomenological material models to predict structural failure under different loading paths [6, 7].

To determine the mechanical properties of foams, first, its relative density ($\rho_{rel}$), which is the ratio between the final material density and the density of its base material, is checked. For relative densities above 0.3, the material is considered porous, otherwise the material is assumed cellular [1]. Light cellular materials ($\rho_{rel} < 0.10$), like foams processed from a polymeric material, are often more sensitive to their manufacturing processes. Such dependence can increase the anisotropy and heterogeneity within this type of material [1, 8]. Therefore, to account for the microstructural influence and properly determine the mechanical properties, as well as to understand the mechanical behavior of cellular materials (e.g., foams), standard tests, when available, should be followed. Nevertheless, it is recommended to complement these tests with other experimental approaches owing to the influence of the material’s microstructure in the results.

Frequently, it can be found in the literature, important studies concerning the collection or even the estimation of material properties for cellular materials, mainly under compression loading, using standard procedures [2, 9, 10]. However, an issue rarely discussed in the literature concerns the hardening behavior of these cellular materials. Brittle, perfect plastic, and hardened responses may be identified in the same cellular material depending on the loading path. Of particular interest is the hardening of foams under compression, mainly for impact events. Low relative densities make cellular materials attractive for structural applications under impact loadings, because their voids allow large strains in compression and consequently these materials can absorb a great deal of strain energy. Thus, to properly incorporate this behavior in any

Correspondence to: Volnei Tita; e-mail: voltita@sc.usp.br
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material model, the hardening curves must be carefully obtained by experimental tests. Depending on the cellular structure, the material may either exhibit a perfect plastic behavior or a minor hardening throughout its densification process (which occurs with crushing of the micro cells). Currently, such cellular materials may often be found in fuselage of aircrafts or in hulls of sportive boats, always seeking to optimize parameters such as weight, cost, or mechanical features [11, 12].

Through regular and special experimental procedures, this article shows a deep investigation of the foams’ mechanical behavior. Thus, a polymeric cellular material, a poly(vinyl chloride) (PVC) rigid foam, was investigated. A digital image correlation (DIC) technique [13–17] and scanning electron microscopy (SEM) analyses were used to complement direct measurements from universal testing machines (UTMs). Mechanical properties (e.g., elastic and plastic Poisson’s ratios) were evaluated with compression and tensile tests for different material directions (mainly normal and in-plane). These experimental analyses provided a fair understanding of how the microstructure, the phenomenological anisotropic response, and the failure mechanisms are related to each other. For example, the material is found to be transversely isotropic. Thus, differences in the results of the mechanical properties can be as high as 100%, or even more depending on the loading direction. Also, the experimental analyses show how the material’s microstructure behavior, like the evolution of the herein identified “yield fronts” and a “spring back” phenomenon, can influence the phenomenological response and the failure mechanisms as well as the hardening curves. Therefore, the greatest contribution of this article consists on discussing the particular issues involving the assessment of mechanical properties of rigid PVC foam. In the text, one can find discussions on: the difference between yield and strength stresses for tension and compression loads, hardening curves, Poison’s ratios, elastic and plastic anisotropic responses, as well as errors and difficulties when performing experimental tests on PVC foams. Also, from this investigation of specific rigid PVC foam, conclusions on how to approach other polymeric foams, which present a significant degree of anisotropy, can then be withdrawn.

MATERIALS AND METHODS

The test specimens were cut from a larger foam plate, which is 1200-mm large, 850-mm wide, and 40-mm thick, discarding extra material on the edges (Fig. 1). The commercial reference of this foam is Divinycell™ H60, manufactured by Diab Group (DIAB) [18]. It is a rigid cellular material with closed cells. Its base material is the PVC polymer and it has a density of 60 kg/m³ and a relative density around 0.043 ($\rho_{\text{PVC}} = 1400$ kg/m³). Based on DIAB’s datasheet and on manufacturing processes of polymeric foams, the investigated material shows different mechanical responses according to the direction of loading. Thus, the first experimental tests were carried out for three loading directions (1-2-3) as shown in Fig. 1. Considering many preliminary experimental results and the literature information about manufacturing processes of foams [1, 8], the investigated material was assumed to be transversely isotropic. Hence, the compressive and tensile tests were performed for in-plane direction (1 or 2) and out-of-plane direction (3). Thus, the indexes 1(2) or 3 are kept throughout the text for the sake of brevity (Fig. 1).

For the compression tests, the guidelines within the ASTM D1621-04a standard [19] were followed and a UTM EMIC DL 10000 with a 10 kN load cell was used. All samples for compression tests were polished using a machine controlled by a qualified operator. The specimens were cut from the plane 1-2 (37.5 mm high with square section area of 40 mm $\times$ 40 mm), and from the plane 1-3 (35 mm high with square section area of 37 mm $\times$ 37 mm), owing to the geometry of the foam plate provided by DIAB. For each direction, some specimens were submitted to monotonic and cyclic loadings to investigate the unloading response of the foam. As the tests were quasi-static, the loading speed was set to 1.5 mm/min for both monotonic and cyclic tests. However, for impact loading applications, this article strongly recommends a separated investigation, considering the strain rate dependence of such material.

Considering mechanical tests, polymeric foams are more sensitive to experimental errors owing to aspects such as low relative density, low strength (~1 MPa), and their microstructural failure mechanisms. Besides, when a strain gauge is fixed on a cellular material specimen, the measurements from this device are dependent on their location on the specimen owing to the heterogeneity. Also, this problem occurs because the material surfaces are very irregular which was owing to the random shape of the cells. Therefore in this study, the strain fields on the compression and tensile specimens were obtained through the DIC technique, using a program named 

![FIG. 1. Polymeric foam and material coordinate system (1-2-3).](https://example.com/figure1.png)
A CANON (EOS 50D) camera was used, with a 400-mm lens, an aperture of f/4.5, and a focus distance close to 1.5 m. Light-emitting diode lights were used to illuminate the specimens during the tests, avoiding heat transfer.

Concerning the tensile tests, the ASTM D1623-03 standard [21] can provide some orientations, but in this study, the geometry of the sample plates did not match the cylindrical section area as recommended by the standard. Hence, a different geometry was proposed similar to the ones adopted by Viana and Carlsson [10]. Therefore, dog bone geometry with a rectangular section area and a flat side was utilized to favor the use of DIC technique coupled with the UTM EMIC DL 10000 having a 10 kN load cell (Fig. 2). All samples for the tensile tests were polished using a machine controlled by a qualified operator. The specimens were cut from both planes 1-3 and 1-2, and again, the specimens were submitted to monotonic and cyclic loadings. As the tests were quasi-static, the

loading speed was set to 0.2 mm/min for both monotonic and cyclic tests. Figure 2a and 2b shows the tensile specimens adopted for both planes.

For the first group of specimens which were cut from plane 1-3, there is a limitation in the manufactured specimens, owing to the low thickness of the foam plate. Hence, there is a short region in the center of the specimen which undergoes only uniaxial loadings. However, for the second group of specimens, cut from plane 1-2, the geometry obtained is adequate, because there is a long region in the center of the specimen that was subjected to only uniaxial loadings (direction 2). Thus, to measure strain fields on those nonstandard shapes, the use of a DIC technique was very strategic. The optical technique was capable of identifying the regions in the material with only uniaxial stress and the accuracy of the tensile experimental results was improved. Figure 3a and b show the dimensions of the specimens for both planes 1-3 and 1-2.

All tensile specimens were 38-mm thick and they were glued to rigid plates of steel and these plates were properly fixed on the UTM with clamps. The experimental setup for compression and tensile tests is shown in Fig. 4.

To investigate the microstructure of the Divinycell® H60 foam, nonloaded specimens, as well as specimens

![FIG. 2. Tensile specimens: (a) plane 1-3 (nonstandard); (b) plane 1-2.](image)

![FIG. 3. Dimensions of the tensile specimens: (a) plane 1-3; (b) plane 1-2.](image)
compressed in directions 3 (normal direction) and 2 (in-plane direction) were analyzed through SEM. The purpose was to find a link between the material’s microstructure and the phenomenological anisotropic response and failure mechanisms of this cellular material. The SEM specimens were cut with average dimensions of 10 mm \times 12 \text{ mm} \times 8 \text{ mm} and were polished using a machine controlled by a qualified operator. The SEM micrographs were obtained from the LEO equipment with an OXFORD detector, operating with an electron beam of 20 kV. The samples received a gold-based coating in a BALZERS metallizer model SDC 050 and were kept in a desiccator until the beginning of the analysis.

RESULTS AND DISCUSSIONS

Uniaxial Compression Results

Figures 5 and 6 show complete results (the stress–strain curves) for cyclic compressive tests in both loading directions 3 (normal) and 2 (in-plane), respectively. The PVC foam shows large plastic strains. In loading direction 2, logarithmic strains up to nearly 250% are registered for this material. Such high-strain levels arise owing to the densification of the material (after the stress plateau). The stress plateau is established and can be observed in the stress–strain curves when the “yield fronts” are formed. The stress plateau is considerably steady and it is possible to evaluate the material’s yield stress based on this stress level. The “yield front” phenomena will be discussed later as well as the difference between Young’s modulus and yield stress for both loading directions owing to anisotropic aspects.

The cyclic tests results can be used for the determination of hardening curves (Fig. 7), which are often requested to evaluate the strain energy absorption capacity of the material. Such curves comprise the densification regime where the failure mechanisms of the foam under compression loading play an important role. Prior to the plateau, the foam can be assumed as a linear elastic material.

As the stress increases, the weakest transversal within the sample section fails by rupture of the cells (edges and...
faces) along with the formation of plastic hinges owing to microbuckling of the cells (Fig. 8a). Once most of the cells have buckled, the strength and stiffness of the cellular material increase abruptly with the self-contact of cells’ faces and the results approach the response of the base material, in this case, the PVC polymer. If the loadings are removed, the cells exhibit a spring back phenomenon. This influences the phenomenological hardening curves, because the total elastic strain for this cellular material is higher than expected for a regular continuum solid material. Thus, although the actual permanent plastic strain might be evaluated experimentally, the inclusion of the spring back phenomenon in hardening curves is mandatory to correctly evaluate the strain energy of the foam. Therefore, the total elastic strain \( (\varepsilon_C - \varepsilon_A = \varepsilon_{el\,\text{Total}}) \) can be evaluated with a contribution from the elastic macro response \( (\varepsilon_C - \varepsilon_B) \) and from the portion related to the spring back owing to the buckled microstructure \( (\varepsilon_B - \varepsilon_A) \) as shown in stress–strain curves. It is important to note that the hardening curves also depend on the loading direction. Therefore, to plot actual hardening curves, microbuckling elastic strains must be incorporated in the total inelastic strain when the cellular material is under compression. This observation is essential to not underestimate the strain energy absorption capacity of the cellular material, especially when the hardening behavior is simulated by phenomenological material models.

To support the compression experimental results, SEM analyses were performed on some compressed specimens. Buckled and burst cells owing to compression of PVC specimens are shown in Fig. 8a and b. Microbuckling combined to the plastic hinge formation can explain the loops at the material responses, which are shown previously at stress–strain curves. Also, the burst of cells in different planes contributes to the complex material response, which was observed during the unloading of the foam from high strain levels (>50%). The microrupture of cells faces owing to the buckling phenomenon can explain the decrease in the stiffness and strength of the PVC foam under compression. These failure micromechanisms also depend on the loading direction, which can influence the determination of the material properties.

The determination of the foam’s mechanical properties was performed via two different approaches. Then, there was a comparison between the compressive strains obtained through direct measurements of the UTM’s crosshead displacement and the DIC technique. In Fig. 9, the data from DIC imply a stiffer response of the material in both loading directions (3 and 2). This result was expected, as the DIC technique is free from parasitic flexibilities found in the experimental setup. The difference between the data-collecting techniques is more evident for the stress–strain curves in loading direction 2 (in-plane). Still in Fig. 9, the anisotropic aspect of the PVC foam is clearly shown, because the strength values in both directions (3 and 2) are different by a factor close to 100%. It is important to mention that all the specimens rendered very consistent results, but only one specimen for each direction is plotted in this comparison to clearly represent the overall results.

Based on the results provided by the DIC technique, it is possible to evaluate the strain gradients during the load-
ing in both directions. Also, using the DIC technique, it is better understood the failure mechanisms as well as the influence of the anisotropy and the heterogeneity on the mechanical properties [22, 23]. Figure 10 shows the strain gradients of two specimens during the compression test. The PVC foam investigated presents a more homogeneous response when it is loaded in direction 2. For the loadings in direction 3, heterogeneous gradients are shown in Fig. 10 in which the dark shades represent an elastic regime and the clear shades are the “plastic” zones. The material initializes the yielding process after the formation of the first “yield front”, which is represented in the diagrams by the gray regions. Depending on the loading direction of this cellular material, there might be more than one yield front that separates the regions under mainly elastic strain or inelastic regime. It can also be seen that these yield fronts last longer and are more evident in loading direction 3 (normal) than in direction 2 (in-plane) owing to a larger heterogeneity in direction 3.

Going deeper into the anisotropic behavior, more specifically, into the highly heterogeneous strain gradient in plane 1-3 of the material when loaded in direction 3, SEM micrographs of nonloaded specimens of the PVC foam were taken. In Fig. 11a, elongated patterns are observed in plane 1-3 and “circular” patterns are observed in plane 1-2 of the material in Fig. 11b. These different patterns were originated in the manufacturing process [8, 24]. As the Divinycell™ H60 foam is rather light, with a low density of 60 kg/m³, the corresponding final microstructure was more sensitive to the gravity force imposed during the manufacturing process against the pressurization force. Consequently, in Fig. 11b, the plane 1-2 contains more edges and vertices, as well as, a larger concentration of material in the edges (greater transversal section areas), which increases the stiffness and strength of the foam in the direction 3 (out-of-plane). This microstructure can be analyzed as a bundle of hexahedron with one-dimension larger than the other two equal ones, stacked in a regular fashion.

Regarding Poisson’s ratios, different values according to the direction of loading were expected. Thus, caluli of Poisson’s ratios for the PVC foam were performed, in both loading directions (3 and 2), using strain results from the DIC technique. One must remember that the use of extensometers and strain gauges shows many limitations. It is very difficult to attach these sensors on the specimens of cellular materials without interfering in the results. The Correli program provides the strain gradients for planes 1-3 and 1-2, allowing the calculation of the Poisson’s ratios ($\nu_{31}$ and $\nu_{21}$) up to large strains, and

![FIG. 10. Strain gradients obtained from the Correli program and the respective average strain from the test machine EMIC. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]](image1)

![FIG. 11. Micrographs of the PVC foam, highlighting the pattern of the cells in each plane: (a) microstructure of the plane 1-3; (b) microstructure of the plane 1-2. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]](image2)
hence including plastic ratios. Figure 12 shows curves used to identify Poisson’s ratios, using linear regression based on the compression experimental results. It is clearly observed that there is a resemblance between Poisson’s ratios for plane 1-3 (Fig. 12a) and plane 1-2 (Fig. 12b). In both curves, there is a well-defined positive elastic Poisson’s ratio up to 4–5% of total strain, but there is a negative plastic Poisson’s ratio (very close to zero). In fact, the plastic Poisson’s ratios are often set to zero in plasticity models, and this simplification is reasonable and consistent. Such behaviors stem from the ‘‘yield fronts’’ formation, which delimits the elastic and plastic regimes as observed by strain gradients obtained from the Correli program.

Uniaxial Tension Results

Stress–strain curves for uniaxial tensile cyclic loadings are shown in Figure 13a and b. First, a quasi-brittle behavior of the Divinycell™ H60 foam under tensile loadings is identified. For both loading directions (normal and in-plane), the investigated cellular material shows very low plastic strains under tension if compared to those obtained in compression. Based on these low values of inelastic strains for the PVC foam, the material can be assumed fragile with nearly linear elastic response, mainly for direction 3 and considering the DIC results. This mechanical behavior under tension can help explaining the reason why one calculates only strength values in the ASTM D1623-03 standard, and no yielding is evaluated for this rigid foam. Nevertheless, it is possible to set an elastic limit in tension if a criterion is established. The one herein proposed by the authors considers that, for the Divinycell™ H60 foam, 1% of total strain is a good choice for the elastic limit in tension, as it can be seen in the cyclic tests in loading direction 3 (normal) (Fig. 13a).

The results (obtained by the DIC technique in loading direction 3) show a stronger and stiffer material compared to the direct measurements from UTM EMIC. However, in loading direction 2 (in-plane), the curves swap their patterns and the EMIC data exhibit the stronger and stiffer response. The explanation lies in the nonstandard
geometries (Fig. 14). Owing to the shape of the purchased PVC plates, the samples were cut as explained earlier. Such forms for the tensile specimens resulted in different strain gradients on the two specimens designed for loading directions 3 and 2. For loading direction 3, the specimen had no unusual responses (Fig. 14a), but the curves for loading direction 2 presented a different outcome (Fig. 14b). It turns out that as the DIC results are solely averaged over the strains located at the very center of the specimens. To ensure uniaxial stress in the tensile analyses, only the regions with largest strains of the specimen designed for direction 2 were taken into account. In addition, the UTM EMIC results are calculated, assuming a homogenous strain gradient in the specimens. Thus, these two factors influenced the stress–strain results for in-plane loading direction. For loading direction 3, the low height of the respective specimens associated with the foam’s brittle behavior kept the expected differences between DIC and UTM EMIC results. Such strain analysis was possible only with the aid of the DIC technique. Thus, an optic approach is recommended to determine the actual Young’s modulus under tension for both loading directions along with the dog bone shape for the proposed specimens.

Regarding the Poisson’s ratios for the tensile tests (Fig. 15), different values are calculated according to the loading direction. For loading direction 3, the material exhibits a Poisson’s ratio close to zero (Fig. 15a), whereas for loading direction 2, the material shows a Poisson’s ratio with a high value, above 0.5 (Fig. 15b). In fact, Poisson’s ratios can exceed the value of 0.5 as long as the excessive deformation is compensated somehow (e.g., anisotropy). These high values of Poisson’s ratios are normally found for intricate structures or anisotropic materials, like cellular materials. Hence, the values obtained for the PVC foam agree with the literature, because it is a nonisotropic material.

As observed earlier, PVC foam is about twice stronger in direction 3 compared to direction 2 and it is precisely this difference that influences in tensile stress–strain curves. When the foam is loaded in direction 3, the lower stiffness in plane 1-2 associated with the brittle response identified leads to a minimum necking in plane 1-3. Also, edges and faces of the cells, aligned in-plane, deform very little through induced stresses, which explains the lower shrinking and the lower Poisson’s ratio. On the other hand, when loading is applied in direction 2 (or 1), the analyzed plane 1-2 presents a different response regarding the respective Poisson’s ratio. As the out-plane direction is normal to the section captured via the DIC technique, a higher Poisson’s ratio is expected for the plane 1-2. The greater stiffness in direction 3 minimizes the induced strain in this direction and allows the other direction to exhibit a larger induced strain. This explanation is confirmed by low value of Poisson’s ratio $\nu_{31}$ and the high value of Poisson’s ratio $\nu_{21}$. This analysis shows that equivalent or phenomenological Poisson’s ratios can be obtained from cellular materials without applying micromechanic theories. However, the material’s degree of anisotropy must always be considered.

Discussion of the Experimental Results

Finally, the set of mechanical properties obtained for the foam Divinycell™ H60 is summarized in Table 1.
Within the manufacture’s datasheet [18], the mechanical properties available are for the rise direction of the foam only, which is herein referred as direction 3 (normal direction). No Poisson’s ratios are provided by the manufacture’s datasheet. The lack of a complete set of properties in this datasheet jeopardizes any complex project calculus that seeks to predict structural responses of polymeric foams under different types of loadings. Not knowing Poisson’s ratios and that this material presents a much weaker strength in the in-plane directions (1-2) hinders any accurate identification of model parameters and calibration of material models concerning multiaxial loadings and/or plastic behavior. Also, the anisotropy effects tend to lessen with the increase of the foam density [2], but the specific base material and the manufacturing processes must be taken into account for every different cellular material. Therefore, a complete and proper set of mechanical properties is established.

Table 1 summarizes that the compression results from the direction 3 obtained through the DIC technique are closer to the manufacture’s data, as all the parasitic flexures any accurate identification of model parameters and calibration of material models concerning multiaxial loadings and/or plastic behavior. Also, the anisotropy effects tend to lessen with the increase of the foam density [2], but the specific base material and the manufacturing processes must be taken into account for every different cellular material. Therefore, a complete and proper set of mechanical properties is established.

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**Table 1.** Mechanical properties of the polymeric foam Divinycell® H60.

<table>
<thead>
<tr>
<th>Property</th>
<th>Compression</th>
<th>Tension</th>
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<tbody>
<tr>
<td></td>
<td>DIAB</td>
<td>Direction 3</td>
</tr>
<tr>
<td>$E_{\text{EMIC}}$, Young’s Modulus (MPa)</td>
<td>60–70</td>
<td>32 ± 1</td>
</tr>
<tr>
<td>$E_{\text{DIC}}$, Young’s Modulus (MPa)</td>
<td>53 ± 6</td>
<td>22 ± 2</td>
</tr>
<tr>
<td>$v_{\text{el}}$, elastic Poisson’s ratio</td>
<td>N/A</td>
<td>0.30 ± 0.01</td>
</tr>
<tr>
<td>$v_{\text{pl}}$, plastic Poisson’s ratio</td>
<td>N/A</td>
<td>–0.012 ± 0.001</td>
</tr>
<tr>
<td>$\sigma_y$, yield Stress (MPa)</td>
<td>0.7–0.9</td>
<td>0.75 ± 0.02</td>
</tr>
<tr>
<td>$\sigma_{RT}$, Strength (MPa)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
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</table>

* N/A: Not available.

inversion of results is owing to the nonstandard shape of the specimens used in the tension tests associated with the use of the procedure as explained earlier. However, regardless of the loading direction, the values obtained by the DIC are once again more accurate owing to the same reason stated for the compression results. The strength values in tension are in accordance with the material datasheet. Nevertheless, the results from the EMIC setup for the Young’s moduli in direction 3 are closer to the manufacture’s data, because the dimensions and the methods applied are closer to the one recommended in the standard used by DIAB.

Table 2 summarizes the direct comparisons of the results to emphasize the degree of anisotropy of this rigid PVC foam and how the DIC complemented and corrected some of the results. The results in Table 2 are separated in comparisons between loading directions and techniques applied (when applicable). The results summarize the facts stated so far: the material is stronger and stiffer when loaded in direction 3; the DIC technique shows more realistic values; and the foam is highly anisotropic, although there are only two sets of properties.

**CONCLUSIONS**

The heterogeneity and anisotropy of the rigid PVC foam have a great influence in predicting its structural responses under different types of loadings. Only direct measurements from UTMs were not enough to determine the mechanical properties of the PVC cellular material owing to its micro structure behavior. Besides, it was not possible to use extensometers and strain gauges owing to the high heterogeneity of this cellular material and its failure mechanisms, especially under compression. Moreover, a nonstandard geometry was required to perform some of the tests, mainly tensile tests. The DIC technique was of particular assistance at this stage, as it is an optic technique and free of parasitic strains. However, some difficulties arose, but they were properly handled and discussed.

As shown for polymeric foams, the failure mechanisms of the microstructures directly influence the strength and the plastic Poisson’s ratios, both required in structural
analysis. The DIC technique and SEM micrographs supported and explained how the mechanical properties were obtained without applying Micromechanics theories.

It is well known that the phenomenological properties of cellular materials are strongly dependent on the relative density. Depending on the relative density, the anisotropy of the foam might even be neglected. In fact, the authors recommend such evaluation for the same material herein discussed. Another investigation on the strain rate dependence was also recommended. Nevertheless, the purpose of this study was to show for anisotropic foam, the important issues about the determination of material properties and how the failure of micromechanisms can affect the material’s response.

All the issues contained in this article show that a proper use of rigid polymeric foams is not a straightforward and that both elastic and plastics anisotropy may significantly jeopardize structural projects.

REFERENCES