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INFLUENCE ON THE MECHANICAL PROPERTIES OF TRACTION IN POLYMERIC MATRIX COMPOUNDS WITH MINERAL LOADS

Fernanda Beatriz Aires de Freitas

LMEst - Structural Mechanics Laboratory, Federal University of Uberlândia, School of Mechanical Engineering, Av. João Naves de Ávila, 2121, Uberlândia, MG, 38408-196, Brazil.

fernanda.beatriz@ufu.br

Evans Paiva da Costa Ferreira

Federal University of Rio Grande do Norte, Natal, Brazil.

evans@ct.ufrn.br

Erick Ramon Medeiros do Nascimento

Ana Claudia de Melo Caldas Batista

Daniel Freitas Freire Martins

Federal Rural University of the Semi-Arid, Caraúbas, RN, Brazil.

erickiramon@gmail.com

ana.batista@ufersa.edu.br

dffm@ufersa.edu.br

Abstract. *Due to recurring environmental impacts, the current engineer works for solutions that minimize environmental degradation. For example, using waste to develop new materials. In the western region of Rio Grande do Norte, stands the solid waste generated by the quarries (stone powder), which cause several problems in the environment. Therefore, to minimize environmental degradation, this work aims to propose the use of these wastes as cargo in a particulate polymer composite. For this, four materials were developed using these tailings (limestone powder and granite powder) in different proportions (10% and 30% by mass) as a filler and the polyester resin as the matrix. The mechanical properties were evaluated using the uniaxial tensile test, based on ASTM D638. Using the results obtained, it was possible to notice that the granite material had better stiffness and limestone had better strength, when compared 10% and 30% of stones, respectively. Therefore, it is suggested that these waste tailings in quarries can be reused in the manufacture of new materials, reducing their quantity, and avoiding damages to the environment.*

Keywords: *Residues, composite, mechanical properties.*

1. INTRODUCTION

The waste generated by industries is a worrying problem for the environment due to its negative impacts. For this reason, new solutions are sought for the reuse of these wastes so that they can be removed from the environment, thus reducing their impacts and helping to restructure the environment.

In the western region of Rio Grande do Norte, there is an example of this problem, which is the solid waste generated by the quarries that cause environmental degradation, since the powder of the stone, which is not used in other processes ends up accumulating in every area creating numerous problems in water, soil, air, and the local population. Hence the need to seek an alternative to reuse this powder.

Thus, this work proposes the use of stone powder (limestone and granite) as a filler in a particulate polymeric composite material. Which consists of a material formed by the combination of two or more materials to present better properties than the materials initially used; among which one can cite improvements in stiffness, strength, weight reduction, corrosion resistance, thermal properties, fatigue and wear resistance (Reddy, 2004). When it comes to composite particles, the particles are generally used to improve properties such as stiffness, resistance to high temperatures, resistance to surface wear, machinability, increased hardness, reduced costs (Berthelot, 2010, Mendoza, 2005).

To perform this work, plates with limestone and granite powder were made in different proportions and X-ray fluorescence spectrometry (FRX) and uniaxial tensile tests were performed to evaluate their properties. Seeking to minimize the environmental problems generated by the accumulation of these residues. Since in a study carried out by

Nascimento *et al.* (2017) and Freitas *et al.* (2017), it presented that granite and limestone shows good results as loads in polymeric composites when compared to pure resin composite. Therefore, the objective of this work is to compare the two stone powders (granite and limestone) and to verify which of the two have better mechanical properties and in what proportion (10% or 30%).

2. EXPERIMENTAL PROCEDURE

For the accomplishment of this work a new material was developed with the percentages of 10% e 30% of granite and limestone (as reinforcement) and resin Orthophthalic Polyester (5061) as the matrix. The particles of stone powder (granite and limestone – Fig.1) were obtained in the quarry of the county of Caraubas - RN. The powders were used in the granulometry between # 100 and # 200 and were analyzed by the X-ray fluorescence test to obtain its composition, and thus understand better which causes in the final material.



Figure 1. (a) Granite powder; (b) Limestone powder.

Then, glass plates were manufactured (shown in Fig. 2) for use as a mold in the manufacture of composite materials. The dimensions and quantities of plates used were:

- 02 plates of 40 cm x 02 cm, with 03 mm of thickness;
- 01 plate of 38 cm x 02 cm, with 03 mm of thickness;
- 01 plate of 40 cm x 40 cm, with 08 mm of thickness;
- 01 plate of 35 cm x 40 cm, with 08 mm thickness.

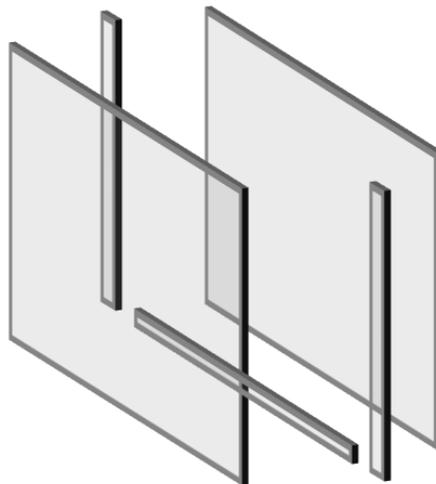


Figure 2. Illustration of glass plates used as mold.

Thus, the manufacturing procedure of the proposed composite materials can be started. The composite plates were made with granite and limestone powder. To this end, the resin and 2% monomer was placed in a plastic reservoir and

brought to the vacuum pump for 10 minutes to remove bubbles, and then 0.5% catalyst was added and the granite and limestone powder in the proportions of 10% and 30%, manually mixed for 2 minutes and again vacuum pump for 10 minutes. After this time the material was poured into the mold, where it remained for 24 hours, for the cure to occur. After the cure, the material was unmolded.

Finally, the test specimens were made (Fig. 3) for the tensile test, named as shown in Table 1. This test was performed in Mechanical Engineering Laboratory of the University of Federal Rural University of the Semi-Arid (UFERSA) based in the ASTM D638 (Standard Test Method for Tensile Properties of Plastics), in which an increasing uniaxial tensile load was applied to the specific specimen until it ruptured with a speed of 5 mm / min. This being one of the most used tests in the mechanical components industry due to the fact that it provides important quantitative data of the mechanical characteristics of the materials.

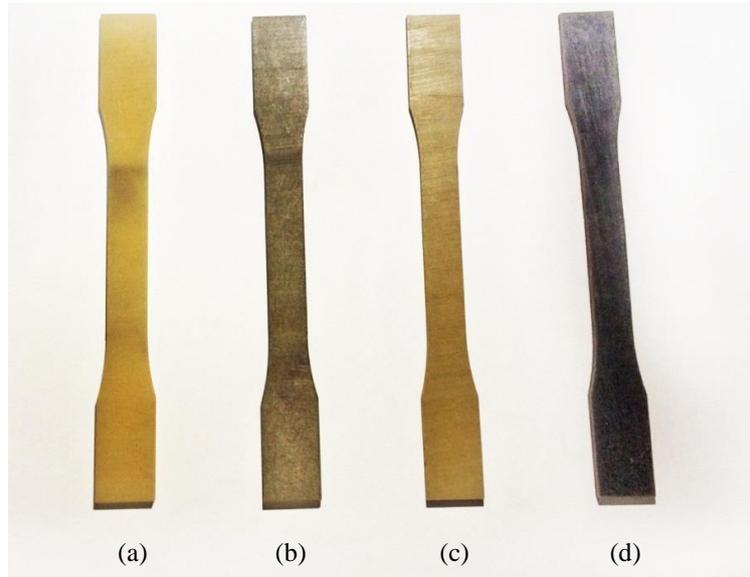


Figure 3. Tested specimens: (a) C_10; (b) G_10; (c) C_30; (d) G_30.

Table 1. Nomenclature used for the samples.

Nomenclature	Samples
C_10	Polymer composite with 10% limestone powder
G_10	Polymer composite with 10% granite powder
C_30	Polymer composite with 30% limestone powder
G_30	Polymer composite with 30% granite powder

3. RESULTS

3.1 Chemical characterization of Granite and Limestone by X-Ray– FRX Fluorescence

The results obtained by the X-Ray Flowchart analysis, which determine the composition in the stone powder, are presented in Fig. 4. In which nine elements were identified for the granite: Silicon dioxide (SiO_2), Iron oxide (Fe_2O_3), Aluminum oxide (Al_2O_3), Potassium oxide (K_2O), Calcium oxide (CaO), Zirconium dioxide (ZrO_2), Titanium dioxide (TiO_2), Oxide of magnesium (MgO) and Manganese oxide (MnO), which are displayed in descending order in percentage terms. And six elements for the limestone: CaO , SiO_2 , Fe_2O_3 , Al_2O_3 , K_2O and MnO , also presented in descending order in percentage terms.

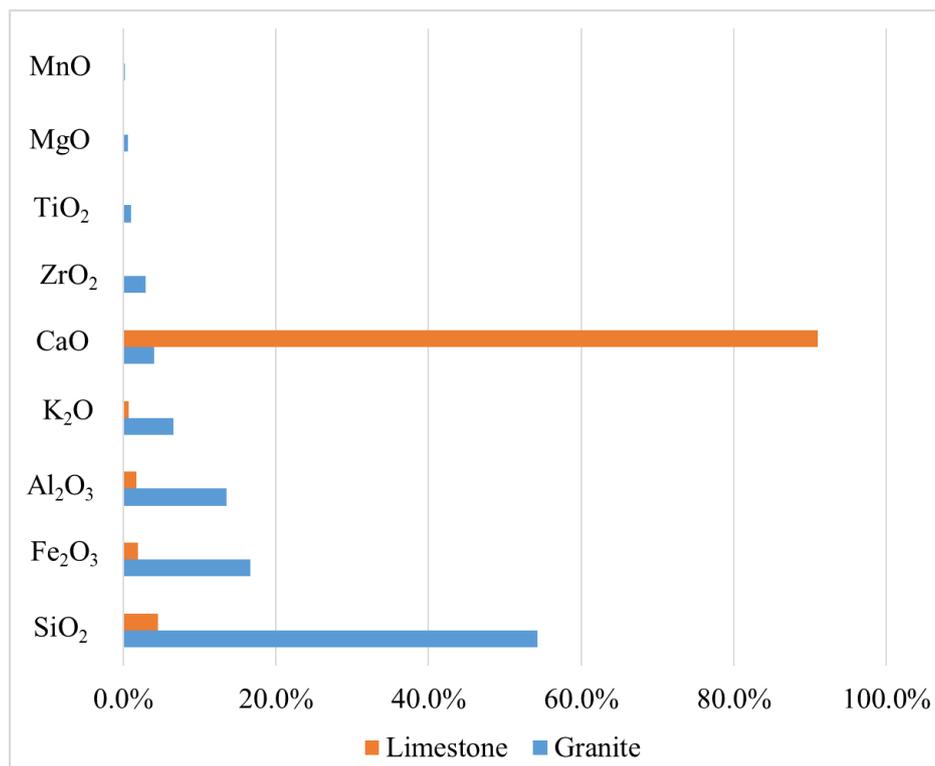


Figure 4. Composition of granite and limestone powder.

It is interesting to observe that some elements present in the two stone powders are the same, although in the limestone the ZrO₂, TiO₂ and MgO in their composition were not found. Still in relation to limestone, it is possible to notice that the presence of MnO is very small (0.07%), which makes it difficult to visualize the graph, while its CaO percentage is well above all other constituents, with a value of 90.97% and higher than the amount found in granite, which was 4.00%.

Limestone may be classified according to its MgO content in: calcitic, with less than 5% MgO; magnesium, with 5% to 12% MgO; and dolomite, with more than 12% of MgO (Primavesi, 2004). In the analyzed sample, no MgO was found in its composition, so we can consider that it is a calcitic limestone, which explains the high CaO in its composition. And these constituents are consistent with those shown in the literature, mentioning as an example the work done by Hagemann *et al.* (2019), it was obtained and in which approximate values for Fe₂O₃ (1.31%), Al₂O₃ (1.93%), K₂O (0.49%), MnO (0.06%) and the highest amount of CaO was also a constituent, with 44.30%.

In relation to granite, the percentages of SiO₂, Fe₂O₃, Al₂O₃, K₂O and MnO were higher than those found in limestone powder. And they are consistent with the results of the literature, as in a study by Godoy *et al.* (2019), they are analyzing different samples of granite and also found SiO₂, (57.85%), Fe₂O₃ (6.98%), Al₂O₃ (15.79%), K₂O (8.90%), CaO (6.08%), TiO₂ (0.54%), MgO (0.93%) and MnO (0.60%).

3.2 Mechanical performance of uniaxial traction for stone powder specimens

Before analyzing the properties of each of the materials, these properties were analyzed for a purely polymeric composite obtained in works done by Nascimento *et al.* (2017) and Freitas *et al.* (2017), which show the mean values and standard deviation of maximum tension, normal strain and modulus of elasticity of the material, (33.90 ± 5.23) MPa, (0.05 ± 0.01) mm / mm and (1.13 ± 0.04) GPa, respectively.

As explained by Nascimento *et al.* (2017) and Freitas *et al.* (2017) the deformation practically had no standard deviation, since its value was 0.01 mm / mm, whereas the resistance and modulus of elasticity presented values with the standard deviation of 5.23 MPa and 0.04 GPa, respectively. Probably, this standard deviation in the resistance occurred due to the bubbles/imperfections of the specimens from the manufacturing process, which end up acting as stress concentrators, making the material more fragile. While the modulus of elasticity, being an intrinsic characteristic of the material, was not influenced by the bubbles formed.

The mechanical performance for plates with granite and limestone in 10% and 30% proportions shown in Table 2.

Table 2. Mechanical properties - 10% and 30% of granite and limestone.

Mechanical properties	10% granite	30% granite	10% limestone	30% limestone
Tensile Strength (MPa)	29.84±1.51	23.92±0.93	36.01±0.88	29.09±0.71
Strain (mm/mm)	0.03±2.23 x 10 ⁻³	0.03±3.38 x 10 ⁻³	0.04±1.51 x 10 ⁻³	0.04±1.85 x 10 ⁻³
Elastic Modulus (GPa)	1.33±0.06	1.76±0.14	1.11±0.01	1.51±0.15

It is possible to see that all the properties showed small standard deviations, showing that the particles uniformly filled the spaces in the material. In relation to the resistance, much lower values are obtained in the composites made with 10% and 30% of granite powder and with 30% of limestone powder, which is probably due to the insertion of particles in the material that caused the amount of bubbles to decrease with the filling of some voids by these particles. Moreover, it can be seen that with increasing stone powder both granite and limestone the modulus of elasticity also increases in relation to that of the pure resin, which obtained a value of 1.13 GPa (Nascimento *et al.*, 2017 and Freitas *et al.*, 2017), making the material more rigid (except for the composite with 10% limestone).

3.3 Comparison between the two composites manufactured

After obtaining the data presented in the previous section for the plates of composites with granite and limestone in the two ratios studied (10% and 30%), a comparison was made between them to obtain the influence of the type of material for each percentage of stone powder in the composition. The results obtained in this analysis are shown in the following topics.

3.3.1 Composites with 10% of stone powder

Initially, the Tension x Strain graph was obtained (Fig. 5). Then, the graphs were plotted for each of the studied properties (Fig. 6).

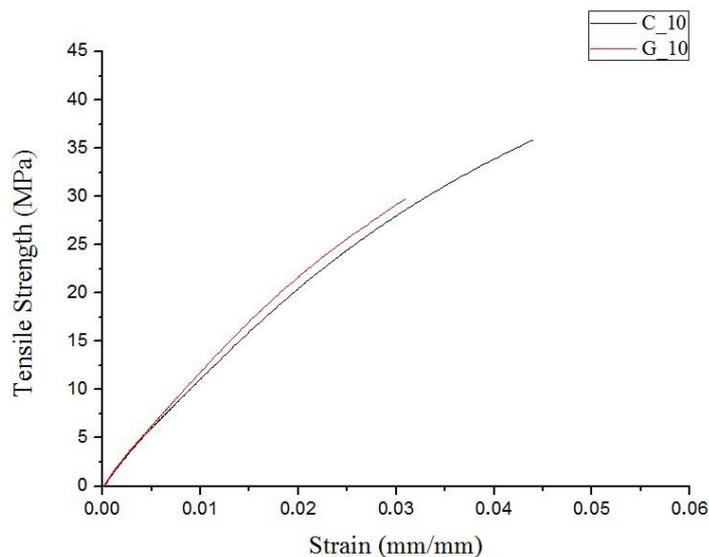


Figure 5. Tension vs. Strain graph of the comparison between the CP's of C_10 and G_10.

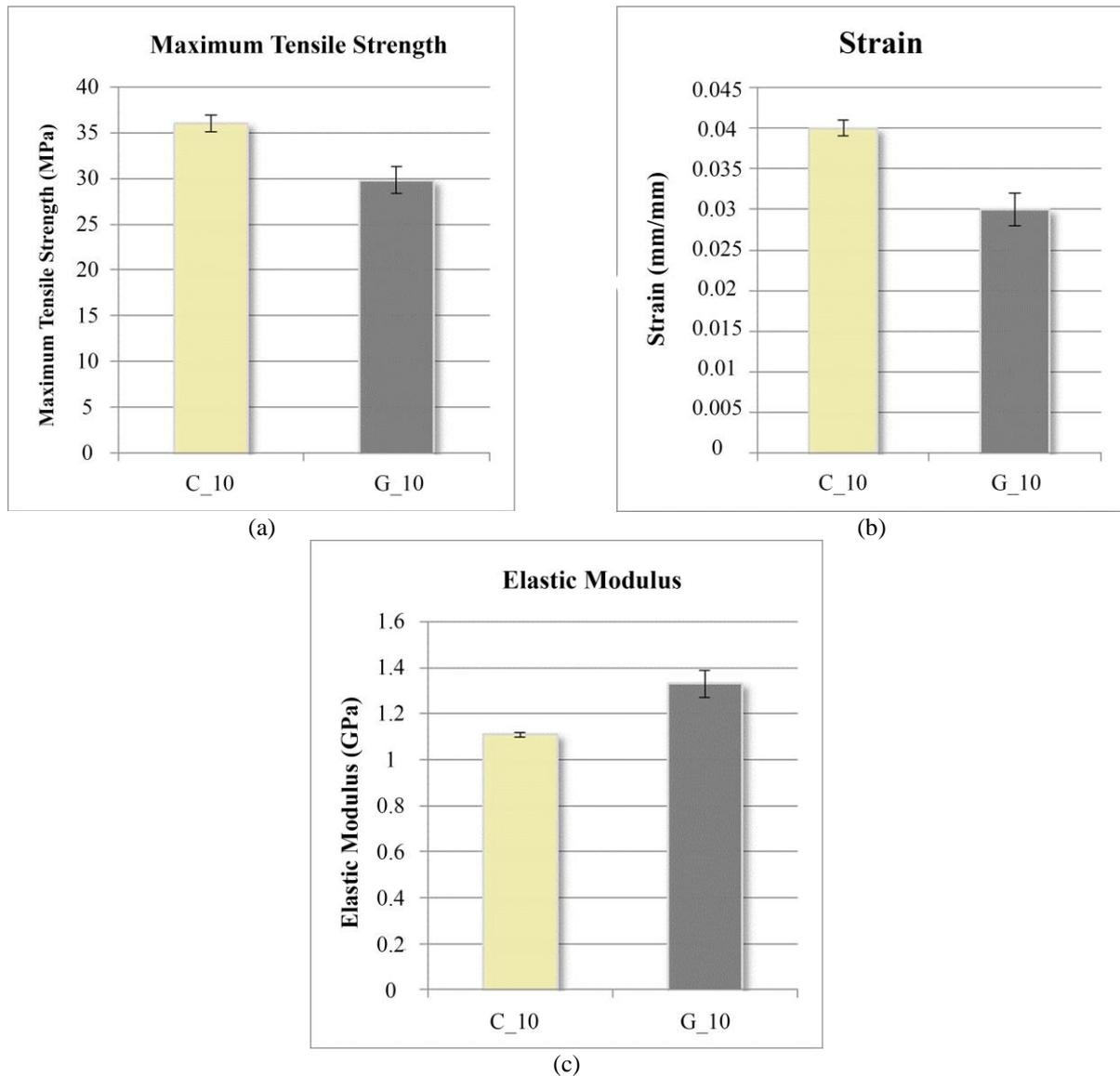


Figure 6. Comparison between CPs of C_10 and G_10: (a) Average tensile; (b) Strain; and (c) Modulus of elasticity.

According to figures 5 and 6, it can be observed that the C_10 presents increase of 20.67% in the resistance and of 33.33% in relation to the deformation when compared with the G_10. However, when granite is used, it has a gain of 19.81% in the modulus of elasticity in relation to the use of limestone, both with 10% of its composition. The result shows that the stone powder composition directly influenced the result.

3.3.2 Composites with 30% of stone powder

As in the composition of 10% of stone powder, the plot of Tension Strain (Fig. 7) was plotted for the composition of 30%. Then, the graphs were plotted for each of the studied properties (Fig. 8).

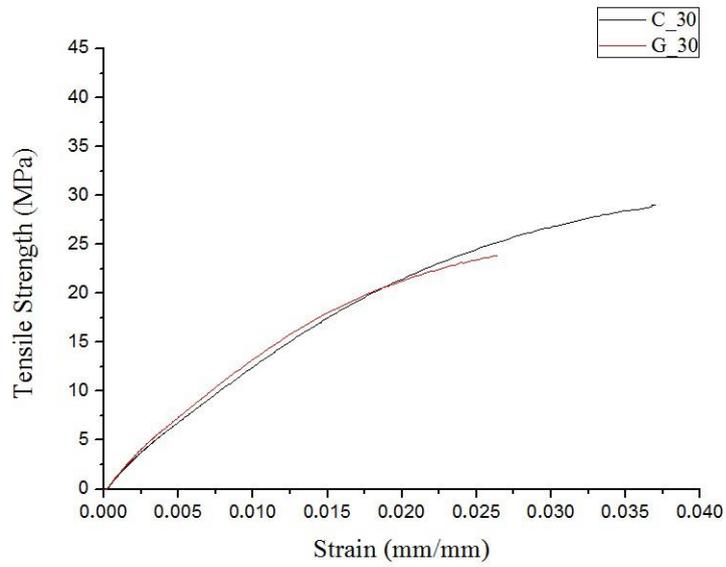
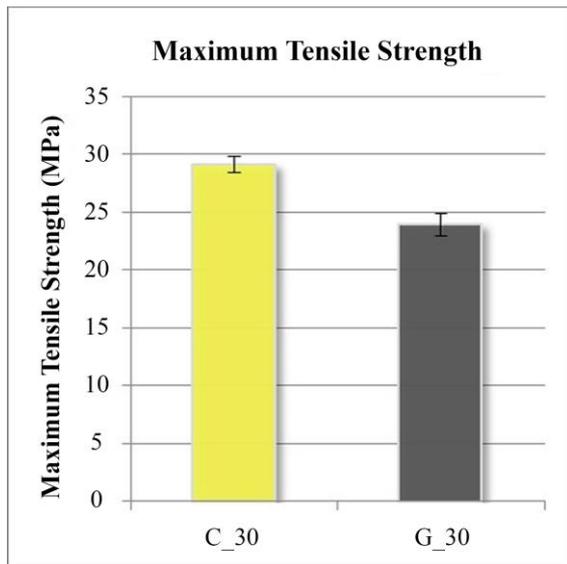
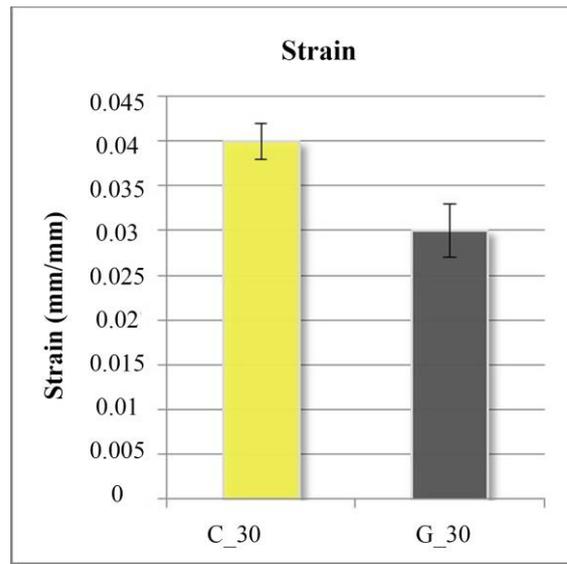


Figure 7. Tension vs. Strain graph of the comparison between the CP's of C_10 and G_10.



(a)



(b)

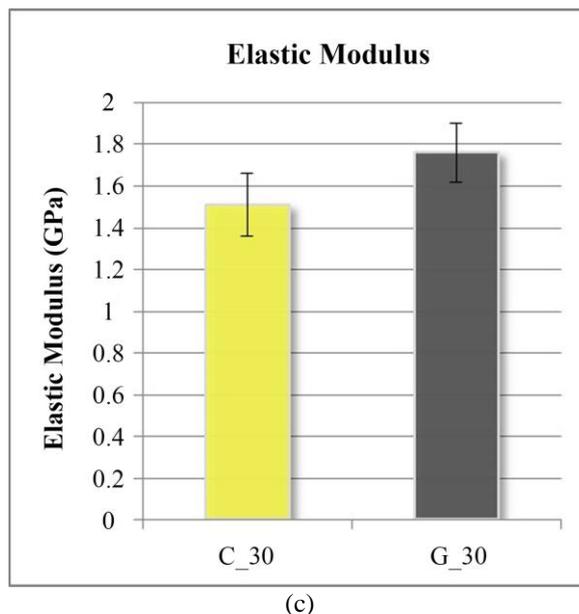


Figure 8. Comparison between CPs of C_30 and G_30: (a) Average Tensile; (b) Strain; and (c) Modulus of elasticity.

The figures 7 and 8 shown, it can be seen that as the compounds of fraction 10%, the C_30, in values, when using lime obtains an increase of 21.61% in the resistance and 33.33% in deformation, in relation to granite. However, the 30% granite composite obtained the best stiffness, an increase of 16.55% when changing the use of limestone by granite, in the percentage of 30%.

It can be seen that for the composition of 10% and for the composition of 30% the limestone presented greater strength and deformation while the granite presented the best modulus, showing that this is a characteristic acquired by the composition of the stone powder.

4. CONCLUSIONS

Thus, in addition, both G_10 and G_30 showed higher stiffness and lower resistance and deformation when compared respectively to C_10 and C_30. It was also observed that the elastic modulus was significantly higher in the compound with 30% of granite. Therefore, it is suggested that the waste of stone powder accumulated without use in quarries can be reused in the manufacture of new materials, reducing their quantity and avoiding damages to the environment, since they are advantageous in the mechanical point of view, like adjustment in the properties of the elastic modulus and strain and thus used in different applications.

5. ACKNOWLEDGMENTS

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