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CIRCULARITY PATHWAYS TO THE MATERIAL RECOVERY FROM BEGE BAHIA DIMENSION STONE

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Summary: Brazil is one of the world's largest producers of ornamental stones, with an annual production of approximately eight million tons. The large amount of waste generated has become one of the biggest problems in the stone sector. The reduction and reuse of industrial waste generated during exploration and processing is one of the major challenges to mitigate environmental impacts. In this way, the circular economy encompasses both the recovery of products, components and materialsthrough reuseand recycling. The objective of this work is to present preliminary suggestions such as operational routes and strategies to improve the circularity of the materials, aiming at the production of low-cost composites that can be used as piezoelectric floors, having about 80% of Bege Bahia marble waste, which treats It uses a low hardness limestone that is easy to cut and process; and its residues, generally, present ultrafine granulometry.

Key words: *circular economy 1, Bege Bahia 2, piezoelectric 3*

1. Introduction

1.1 Bege Bahia dimension stone

The stone commercially known as Bege Bahia marble in the dimension stone sector is abundant in the Salitre River region, which is characterized by the Caatinga formation, and comes from alterations of formation limestone. Its extraction is mainly concentrated in the city of Ourolândia, with mining, processing, and beneficiation activities (Figure I).

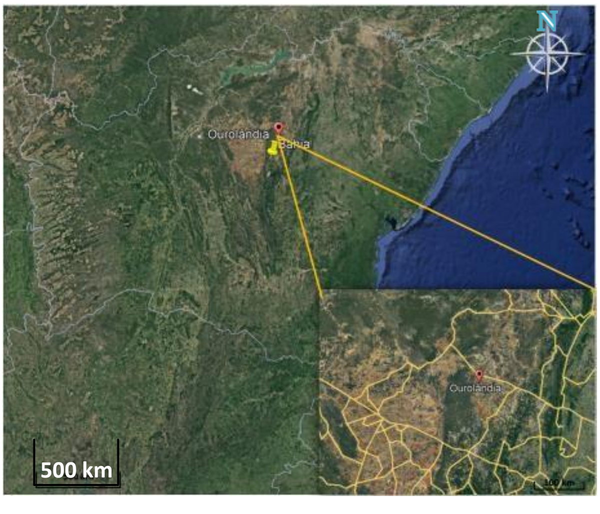

Fig. I. Location map of Ourolândia/ BA (GoogleEarth,2023)

According ABIROCHAS (2019), Brazil is one of the world's biggest producers of ornamental stones, with an annual production of approximately eight million tons, ranking among the top five global producers with a global participation of 5.4%, With a revenue of $1.34 billion, surpassing the historical record of $1.30 billion registered in 2013. There were found 78 existing processes in the Mining Registry and Sigmine/DNPM (2023) of Marble mining copanies in Ourolandia/BA, according to Figure II.

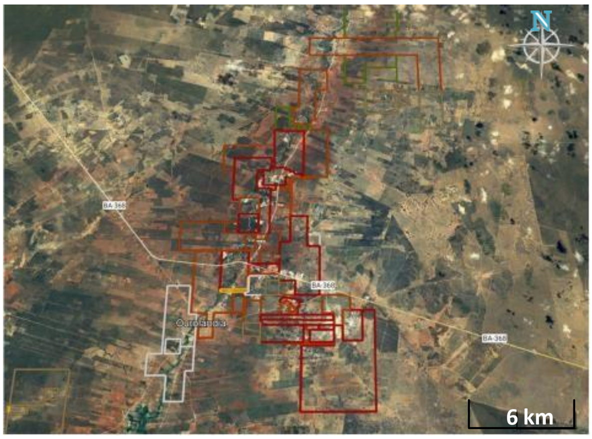

Fig. II. Area of Marble mining companies in Ourolandia / BA (GoogleEarth,2023)

The Brazilian industrial park is mainly composed of approximately 1,600 conventional cutting machines. Along with this production, a large amount of waste is generated. In the case of Bege Bahia reject, no abrasives are detected, as the process is essentially done with diamond-edged machines, which facilitates its use as a mineral filler (Ribeiro et al., 2012). Only about 30% of the extracted blocks from the mines are utilized, generatinga large volume of waste.

The large amount of waste generated has become one of the biggest problems in the stone sector, as the rejects are usually disposed in piles occupying large areas, together with the mining areas or are destined to landfills that are already saturated (Figure III) and may be subject to landslides and sediment transport by rainwater to watercourses, causing siltation, increased turbidity, and suspended particles. The reduction and reuse of industrial waste generated during the exploration and process is one of the major challenges to mitigate environmental impacts (Carmo,2020).

Figure III: Bege Bahia waste

1.2 The Circular Economy

The current linear economic and production model causes numerous negative impacts on the environment, due to the extraction of massive quantities of natural resources, resulting in a high generation of waste. The circular economy suggests a transformation of this linear model into a cyclical model where waste is reintegrated into the production chain (Freitas, 2022), adding value to a material that only has associated expenses. The principles of circularity establish requirements for valuing recovery routes based on sustainability and the generation of secondary material (Velenturf et al.,2021). This way, the circular economy encompasses both the recovery of products, components, and materials through reuseand recycling, presenting solutions for the identification and valorization of secondary materials, including waste treatment as a secondary resource. (Ellen MacArthur Foundation)

1.3 Utilization of Bege Bahia waste

The resources from dimension stones processing are an interesting source of material that meets the technical requirements for applications in different areas such as flooring, architectural composition elements, decoration, furniture, and others. The use of mineral fillers in the polymer industry aims to reduce costs for the sector. With the improvement of the use of these techniques, it is observed that these fillers could enable important transformations in the properties of polymer materials, such as density control, improvement in optical effects, thermal expansion control, flame retardation, modifications, electrical resistance, and magnetic susceptibility, as well as improvement of mechanical properties, such as hardness and tear resistance (Ribeiro et al, 2012).

According to (Ribeiro et al, 2012), the chemical analysis of Bege Bahia waste indicated that the main element in the residue is calcium (48.85%), which is naturally found as calcium carbonate, and that silica (5.13%) and iron oxides (0.34%) are extremely low, characterizing the high quality of the residue for application as a mineral filler. Bege Bahia marblesawmill residues generally have granulometry ultrafine and low levels of silica and iron, making it with high potential for application as a mineral filler, since there is no need for high costs with its beneficiation. (Vidal et al., 2009).

1.4 The use of the 3D Printer in the reuse of Bege Bahia waste

Technological advances have contributed to the manufacturing of different materials using 3D printers, which use overlapped layers of polymer resin. Therefore, taking advantage of this technology to generate piezoelectric floors could provide a response to the saturation of landfills, promoting circularity through the recovery of secondary waste and energy generation in pedestrian areas.

This energy could be used for low-consumption food devices such as lighting and security cameras, noting dependence on theelectrical grid and wanting to reduce greenhouse gas emissions.

The incorporation of residues in the polymeric matrix could also contribute to the reduction of the cost of the material, since the residue would serve as filler, replacing part of the polymeric resin without compromising the final properties of the material (.

Several studies such as (Cholleti,2018) admired that piezoelectric materials can generate electrical energy from mechanical stresses, such as pressure and vibration. When a piezoelectric material is subjected to mechanical stress, it generates an electrical potential difference on its surface. Thus, by using 3D printing technology to create piezoelectric floors with waste from Bege Bahia, it is possible to capture the energy of pedestrians' steps and convert it into electrical energy.

2. Objective

The objective of this work is to present preliminary suggestions such as operational routes and strategies to improve the circularity of the materials, aiming at the production of low-cost composites that can be used as piezoelectric floors having as 80% of Bege Bahia marble waste, transforming it into a potential solution to circularity.

3. Materials and Methods

The methodological approach sought, in an exploratory way, to collect and analysis secondary data. A literature review by authors in the area to consolidate aspects related to theuse of secondary materials as a productive institution and primary data provided by local union representatives and the Associação de Mármore Bege Bahia (ASSOBEGE)

3.1 Materials

The waste used in this work comes from the mining of Bege Bahia marble, in the city of Ourolândia – BA. Polypropylene has a melt index of 1.5g/10min and a density of 0.903 g.cm^{-3}

3.2 Composite processing

The processing consisted, in a first step of mixing polypropylene with limestone residue, and the composites were processed with 10, 20, 30, 40 and 50% by mass. Then, themixturewas extruded in a twin-screw extruder, model DCT 20. The final shape of the specimens was obtained by the Injector Battenfeld Plus 35 machine in Table I.

Table I: Percentage of waste in each composite

BB01	BB02	BB03	BB04	BB05	BB06
0%	10%	20%	30%	40%	50%

3.3 Chemical Analysis of the Waste

The determination of the composition of the residue was carried out by the coordination of mineral analysis (COAM) of CETEM.

3.4 Determination of Specific Mass

The specific mass of the composites was determined according to the ASTM D792-13 (2013) standard.

3.5 Mechanical Behaviour

The tensile test was performed using an Emic mechanical testing machine, according to ASTM D 638 (2010). The impact test carried out using the Izod test, according to ASTM D 256 – 05 (1993). The bending test was carried out using an Emic universal mechanical testing machine, in accordance with the ASTM D 790(1984).

3.6 Determining the Waste Class

The dangerousness of a waste is classified according to its physical, chemical, or infectious-contagious properties, which may present a risk to human health and the environment, when the waste is handled or disposed of improperly. The NBR 10.004/04 (2004) was used to classify Bege Bahia marble waste and composites into class I or II, based on their dangerousness and inertia. The residue was submitted to solubilization, and leaching tests and the resulting extracts were submitted to chemical analysis. The same procedure was performed with the composites. The results were compared with the maximum limits established in Annexes G and H of the standard.

3.7 Electric circuit generation

It will be necessary to carry out a future study for the construction phase of the electrical circuit for the piezoelectric floors.

4. Results and discussions

4.1 Characterization of Composites

Determination of Specific Mass

The specific mass values obtained for pure PP (0%) were around 0.9 g.mL^{-1}. It was also observed that there is little variation in mass specific with the percentage increase of residues, because with 10 and 20% the value of the specific mass was 1 g. mL^{-1} and with 30, 40 and 50% the specific mass increased to 1.1 g.mL^{-1}.

4.2 Chemical Analysis of the Waste

The evaluation of the residue by FRX determined contents of 43.5% of CaO, about 8% of MgO, 0.5% of Al_2O_3, 5.4% SiO_2 and about 43% loss on ignition since it is a limestone calcite.

4.3 Mechanical Behaviour

According to the tensile tests it is possible to obtain some parameters. The first to be analysed will be the Yield Stress of the material, as can be seen in Fig. IV. The yield stress is the maximum stress that the material supports still in the elastic regime of deformation. That way, it appears that the presence of this load is responsible for making the composites support less tension. In Fig. V it is observed that the specific deformation in the rupture of the free polypropylene of mineral load is high, reaching values around 300% and with the addition of waste mechanical stabilization of the material is verified, since the specific deformation decreases gradually reaching values around 10%.

In Fig. VI, the modulus of elasticity of the composites can be verified. Young's modulus or Modulus of Elasticity is a mechanical parameter that provides a measure of the stiffness of a solid stuff. In Fig. VII, corresponding to the Izod Impact test, it is also verified that the addition of the residue is responsible for the mechanical stabilization of the material, since with the addition of load the values of resistance to impact remain around 20 J/m.

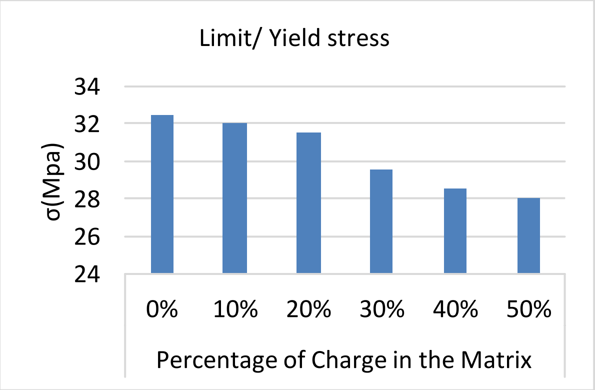

Figure IV: Yield stress

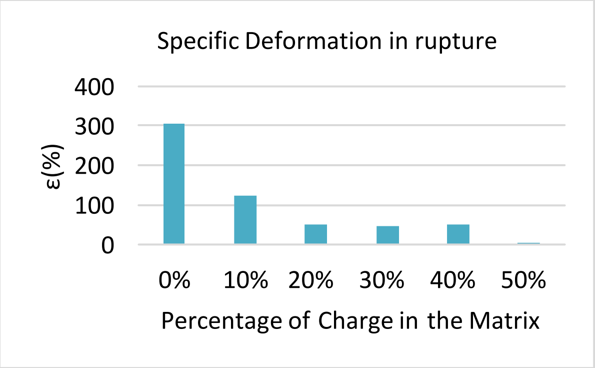

Figure V: Specific Deformation in rupture

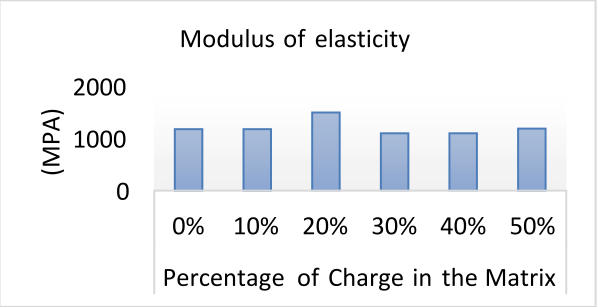

Figure VI: Modulus of elasticity

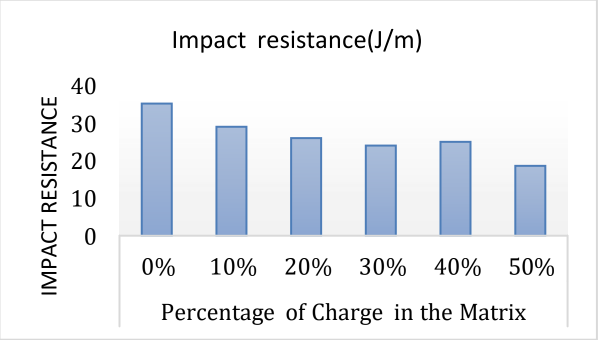

Figure VII: Impact resistance

4.4 Verification of dangerousness

After adding the residue to the PP matrix to form the composite and this composite being leached and solubilized, chemical analysis results did not indicate solubilization or leaching of any of its elements, classifying the material as Class II B – non-hazardous and inert.

5. Conclusion

It can be concluded that Bege Bahia limestone waste can be used as mineral filler in the production of polypropylene composite, reaching 50% by mass, capable of generating a floor.

In addition, it is possible to verify that the increase in load does not change its specific mass, the composite has high resistance and is not dangerous. This material showed good results that can be directly related to the durability of the product and great potential for piezoelectric use.

In general, the use of waste from Bege Bahia in the production of piezoelectric floors represents a sustainable solution for the management of waste generated in the stone sector, in addition to contributing to the generation of clean energy in urban environments.

For future work, it will be necessary to carry out the study of the assignment of piezoelectric tablets to form a system of 2 floor plates containing the Bege Bahia residues.

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