POWDER FILLERS FOR POLYMER COMPOSITES: GROUT, SAND AND KAOLIN

CARGAS NA FORMA DE PÓ PARA COMPÓSITOS POLIMÉRICOS: REJUNTE, AREIA E CAULIM

RELLENOS EN POLVO PARA COMPUESTOS POLIMÉRICOS: LECHADA, ARENA Y CAOLÍN

10.56238/edimpacto2025.063-004

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ABSTRACT

New development trends and the demand for materials that meet market and technological demands result in the widespread consumption of natural resources, along with the significant production of waste. Therefore, the development of new materials that meet current demands and aim to reuse waste or expand the applicability of existing materials becomes important. Therefore, composites emerge as a possible alternative to solve this problem. These composites are generated from the mixture of different components, generally arranged with phases called matrix and reinforcement. Therefore, this research aims to evaluate the mechanical behavior of polymer composites with the inclusion of fillers widely used in different industrial sectors: grout, sand, and kaolin. Mechanical characterization was performed through tests on specimens with dimensions defined by ASTM D638. Unsaturated terephthalic polyester resin was used as the matrix phase of the composite, and the MEK (Methyl Ethyl Ketone) V388 catalyst was applied to accelerate curing. Tensile strength tests were carried out, the average maximum stress values obtained were, respectively: 8.05 (± 1.38) MPa, 14.48 (± 1.70) MPa and 10.76 (± 1.47) MPa, using grout, sand and kaolin fillers.

Keywords: New Materials. Waste. Mechanical Behavior.

RESUMO

Novas tendências de desenvolvimento e demanda por materiais que satisfaçam exigências mercadológicas e tecnológicas acarretam no amplo consumo de recursos naturais juntamente com a produção considerável de resíduos. Logo, o desenvolvimento de novos materiais que atendam às demandas da atualidade e que visem o reaproveitamento de resíduos ou a ampliação da aplicabilidade de materiais já existentes se torna importante.

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Diante disso, os compósitos surgem como uma possível alternativa para solucionar tal problemática, estes são gerados a partir da mistura de componentes distintos, geralmente dispostos com as fases denominadas de matriz e reforço. Portanto, esta pesquisa visa avaliar o comportamento mecânico de compósitos poliméricos com a inclusão de cargas que são amplamente utilizadas em diferentes setores da indústria, rejunte, areia e caulim. A caracterização mecânica foi realizada por meio de testes em corpos de prova com dimensões definidas pela norma ASTM D638, foi utilizada como fase matriz do compósito a resina poliéster terefitálica insaturada e para acelerar a cura dos corpos de prova foi aplicado o catalisador MEK (Metil Etil Cetona) V388. Foram realizados ensaios de resistência à tração cujos valores médios de tensão máxima obtidos foram, respectivamente: 8,05 (± 1,38) MPa, 14,48 (±1,70) MPa e 10,76 (± 1,47) MPa, utilizando as cargas de rejunte, areia e caulim.

Palavras-chave: Novos Materiais. Resíduos. Comportamento Mecânico.

RESUMEN
Las nuevas tendencias de desarrollo y la demanda de materiales que satisfagan las demandas del mercado y tecnológicas resultan en el consumo generalizado de recursos naturales, junto con la producción significativa de residuos. Por lo tanto, el desarrollo de nuevos materiales que satisfagan las demandas actuales y tengan como objetivo la reutilización de residuos o ampliar la aplicabilidad de los materiales existentes se vuelve importante. Por lo tanto, los compuestos surgen como una posible alternativa para resolver este problema. Estos compuestos se generan a partir de la mezcla de diferentes componentes, generalmente dispuestos con fases llamadas matriz y refuerzo. Por lo tanto, esta investigación tiene como objetivo evaluar el comportamiento mecánico de los compuestos poliméricos con la inclusión de rellenos ampliamente utilizados en diferentes sectores industriales: lechada, arena y caolín. La caracterización mecánica se realizó mediante ensayos en probetas con dimensiones definidas por ASTM D638. Se utilizó resina de poliéster tereftálico insaturado como fase matriz del compuesto, y se aplicó el catalizador MEK (metil etil cetona) V388 para acelerar el curado. Se realizaron ensayos de resistencia a tracción, obteniéndose valores promedio de tensión máxima, respectivamente: 8,05 (± 1,38) MPa, 14,48 (± 1,70) MPa y 10,76 (± 1,47) MPa, utilizando como rellenos lechada, arena y caolín.

Palabras clave: Nuevos Materiales. Residuos. Comportamiento Mecánico.

1 INTRODUCTION

Materials have been of great importance since the emergence of the first civilizations, global technological development is closely associated with the creation and improvement of materials and processes, envisioning new applications and practices of reuse and recycling. In this sense, it is verified that numerous sectors such as civil construction, which is of great importance for the economic prosperity of nations, produce large volumes of waste, many of which still do not have an adequate destination or possible reuse, the production of waste such as sand and gravel, for example, provide harmful environmental impacts (Brasileiro and Matos, 2015). Therefore, the present work aims to evaluate the tensile strength of polymeric composites using fillers of materials widely used in different sectors of the industry, namely: grout, commercial sand and kaolin.

Or Grout consists of a material for filling settlement joints, these are the gaps present between ceramic plates, being essential for the realization of ceramic coating. In addition to its aesthetic function, in terms of maintaining the color and appearance of the coating, grout also acts in the absorption of deformations, supporting expansion and contraction and providing resistance to microorganisms, avoiding the accumulation of waste (Valiati, 2009). There is a growing expansion of the use of ceramic tiles in the civil construction sector, among the main factors that motivate this use, there is the reduction in the occurrence of cracks, molds and blisters, verified in other types of tiles (Paes and Carasek, 2002).

Sand is also one of the components widely used in the civil construction sector, this can be defined as an aggregate, that is, mineral particles intended to increase the volume of the mixture, generating cost reduction. Sands are considered small aggregates, based on the dimensions of the diameters of their particles. Concrete, for example, is a construction material that has a portion of aggregates in its constitution, including sand (Pinheiro, 2007).

Kaolin is understood as a group of hydrated aluminum silicates, especially with the presence of kaolinite ($Al_2O_3.2SiO_2.2H_2O$), the main constituent, and halosite. Its largest reserves are found in the northern region of Brazil, in the states of Amazonas, Pará and Amapá. Kaolin is a mineral additive, among its characteristics, its hiding power as a pigment, low abrasiveness, low thermal and electrical conductivity and lower cost in relation to other competing materials stand out. Among its main applications, it is used as a filler and covering agent in the production of paper, as a pigment in the composition of paints and is present in compositions of ceramic pastes, rubbers, plastics, among others (Brasil, 2001; Murray, 2006; Andrade, 2019).

In this sense, based on the global trends in the development of new materials and intensified consumption needs, application tests aimed at combining various materials from different areas become valid. The study of composite materials values such an initiative, based on the combination of different elements. Tests with the reuse of waste and the use of existing and commercialized materials, aiming at the production of new materials, are of great relevance in this area (da Silva Fernandes *et al*, 2023; Mendonça *et al*., 2024; Izadi and Bazli, 2025). Composites can be understood as mixtures, having well-defined phases, and are traditionally called matrix and reinforcement. The purpose of such a union is to obtain specific properties according to the individual characteristics of each material present in each phase (Rodrigues and Fujiyama, 2010; Levy Neto; Pardini, 2021).

Therefore, the present research aims to evaluate the mechanical behavior of polymeric composites with loads of different materials, which are widely used in different sectors of the industry, the grout, commercial sand and kaolin, aiming at the production of new materials and envisioning the application of waste generated from the processing of these raw materials into composites. For the characterization, specimens were prepared according to the ASTM D638 standard for testing polymeric materials, the samples were submitted to tensile strength tests to acquire the mechanical property values of each composite configuration.

2 MATERIALS AND METHODS

2.1 MATERIALS

The materials used for the reinforcement tests on composites were provided by the Composite Materials Research Group (GPMAC) of the Federal University of Pará (UFPA). Fillers in the form of powder (particles) were used. Figure 1 shows the selected loads, in (a) grout, commonly marketed in Brazil as flexible, ivory in color in (b) commercial sand, traditionally commercialized, and (c) kaolin.

Figure 1

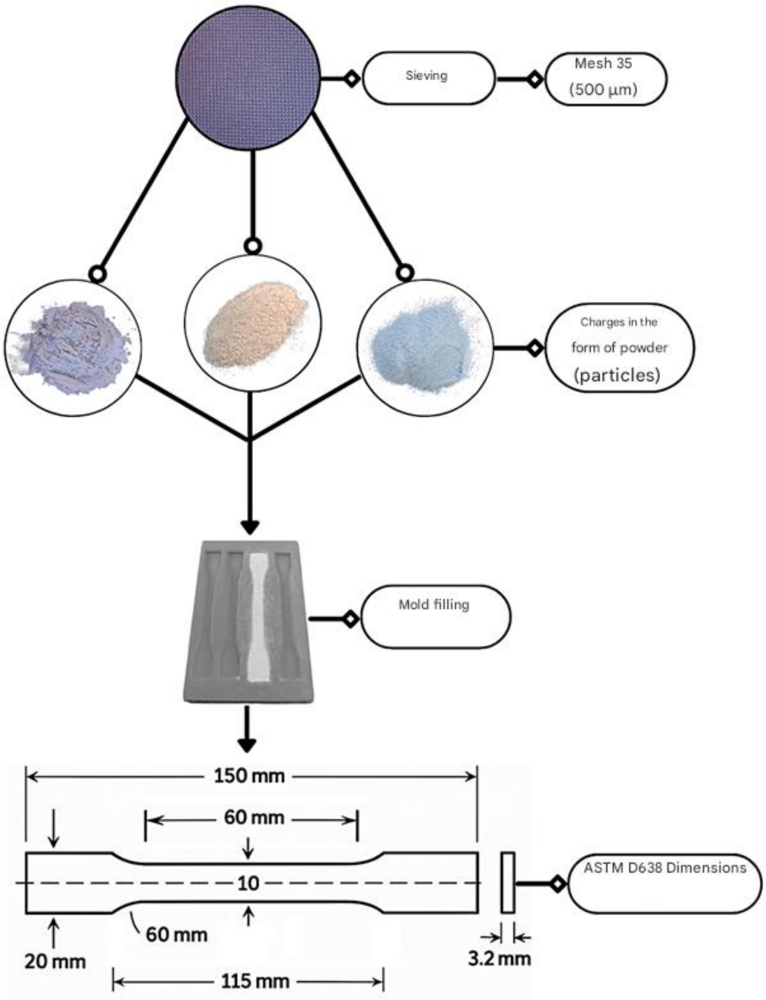
Particulate loads of (a) grout, (b) sand and (c) kaolin

Source: Authors (2025).

The specimens were manufactured using silicone molds with 4 cavities available with standardized geometry according to ASTM D638. The quantification of the masses necessary for the manufacture of the different composites was carried out by filling the gaps in the mold and then weighing the load volume obtained. For the homogenization of the particle size, sieving was carried out using a 35 mesh sieve, equivalent to 500 µm. Figure 2 presents an illustrative flowchart of the sieving process and quantification of the necessary masses, in addition to the dimensions of the standard.

Figure 2

Flowchart representing the processing of the loads to obtain the masses necessary for the preparation of the specimens

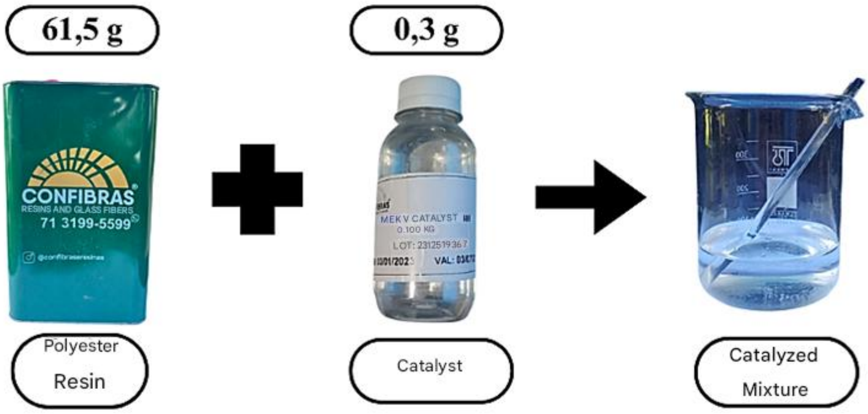


Source: Authors (2025).

After quantification, 24.74 g were obtained for grout, 40.59 g for commercial sand and 20.02 g for kaolin. The respective mass fractions were: 40.22%, 66% and 24.48%. The unsaturated and pre-accelerated polyester terephthalic resin was selected as the matrix phase, taking into account cost factors and ease of obtainment, together with the MEK (Methyl Ethyl Ketone) V388 catalyst, to accelerate the curing process of the specimens. The proportion used was 0.5%, by mass, of catalyst. Figure 2 presents a schematic of the addition of the catalyst to the resin. It is worth noting that the indicated matrix mass was obtained using the same technique used for the quantification of the shits.

Figure 3

Schematic reproduction of the catalyzed mixture (resin + catalyst)



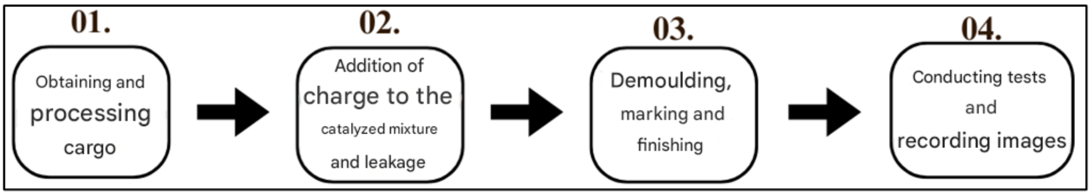
Source: Authors (2025).

2.2 METHODS

After mixing, the load is added, the mechanical homogenization of the system is carried out, and then the resulting mixture is poured into the mold. This process is carried out for each load (grout, commercial sand and industrial kaolin). Figure 4 presents a general flowchart of the process of preparation and mechanical characterization of the specimens. Step 01 mentions obtaining the loads, the sieving performed and the filling of the molds to quantify the masses necessary for manufacturing, step 02 concerns the addition of the catalyst to the resin for subsequent inclusion of the load and the leakage of the resulting mixture in the mold, step 03 presents the demolding, marking and finishing of the samples and step 04 the performance of tensile strength and registration tests of images of the specimens.

Figure 4

Flowchart representative of the process of making and testing the specimens



Source: Authors (2025).

Uniaxial tensile strength tests were performed on the 12 samples produced to acquire their mechanical properties. A universal EMIC testing machine model DL 10000 was used, with a load cell of 5 kN and a travel speed of 5 mm/min, stipulated by the ASTM D638 standard. The images were recorded using a Vedo 1000x USB LED digital microscope. Figure 5 (a) shows the testing machine and 4 (b) the microscope.

Figure 5

a) Universal EMIC testing machine b) Digital microscope

(a)

(b)

Source: Authors (2025).

3 RESULTS AND DISCUSSIONS

The manufacturing method proved to be satisfactory for the production of specimens with different loads, samples were produced without considerable geometric variations, following the dimensional guidelines of the ASTM D38 standard, attesting to the reproducibility of the process. The resin working time was sufficient for mixing and pouring in the mold, valuing the relationship between cost-benefit and availability of the resin with good workability.

From the tensile strength tests, the following mechanical properties were assessed: Maximum Stress (σ) (MPa), Maximum Strain (ε) (mm/mm) and Modulus of Elasticity (E) (MPa). Table 1 shows the average of the results obtained for each property. Figure 5 shows the Stress x Strain behavior of the composites manufactured from curves characteristic of each material, being generated from the average of the tested specimens.

Table 1

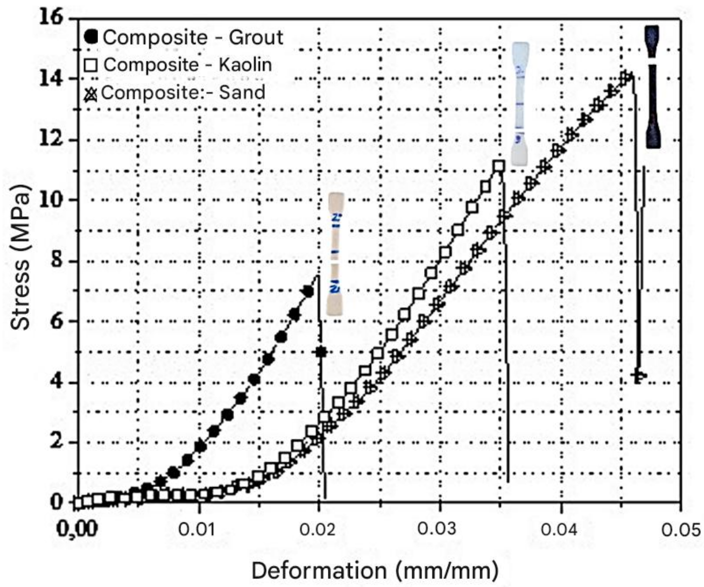
Mechanical properties of composites

Material	σ (MPa)	ε (mm/mm)	E (MPa)
Gtogether + Polyester	8.05 ± 1.38	0.026 ± 0.006	1159.04 ± 94.17
Areia + Polyester	14.48 ±1.70	0.046 ± 0.008	1041.90 ± 86.14
Caulim + Polyester	10.76 ± 1.47	0.038 ± 0.023	1224.62 ± 149.97
Polyester Matrix	26.94 ± 4.60	0.016 ± 0.003	1893.10 ± 151.82

Source: Authors (2025).

Figure 6

Graph of the behavior Stress (MPa) x Strain (mm/mm) of composites



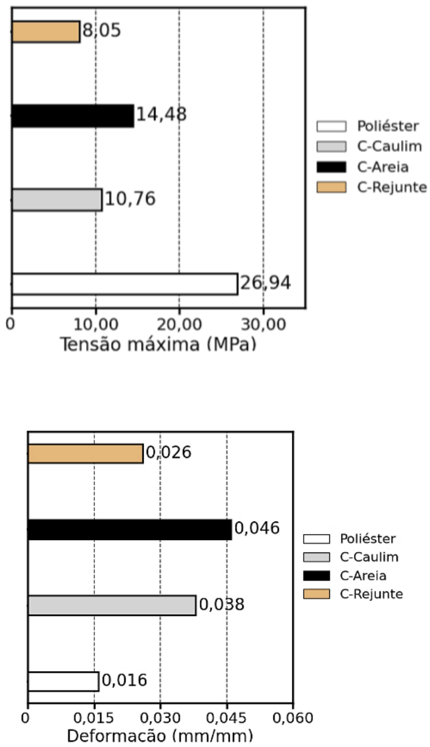
Source: Authors (2025).

Standard deviations of less than 15% also attest to the reproducibility of the manufacturing process due to the low variability of the properties between the test specimens. The data presented in Table 1 are validated based on the behavior of the characteristic curves shown in Fig. 6. After the adjustment region of the specimens to the test grip, a linear-elastic behavior is observed for the three materials.

In addition, the composites also showed lower stiffness than the pure matrix, but with higher maximum deformation. Figure 7 presents graphs that contrast the values of measured properties for a better visualization of the variations in relation to the pure matrix. Figure 8 presents the representation of a specimen of each composite configuration tested, with loads of (a) grout, (b) sand (c) kaolin, the term "C" included in the legend refers to the composite with the respective load.

Figure 7

Comparative graphs of the mechanical properties of composites in relation to the matrix



(a)

(b)

Source: Authors (2025).

Figure 8

Fracture of specimens with (a) grout load, (b) sand and (c) kaolin

(a)

(b)

(c)

Source: Authors (2025).

The fracture is verified in the region of the useful length of the specimens. When evaluating the fracture surface of the specimens, the presence of defects known as porosities or voids was verified. This occurrence is attributed to air bubbles that during the process of mechanical agitation and leakage in the molds end up not ascending to the surface of the mold and are retained during the curing process. The presence of these defects is detrimental to the mechanical performance of the materials because the regions of occurrence of porosities act as stress concentrating points, due to the fact that there is no physical matter resisting the mechanical loads, thus favoring the appearance and propagation of cracks, resulting in the early fracture of the materials.

4 CONCLUSION

The present work aimed to mechanically characterize polymeric composites with fillers of different materials, which are widely used in different sectors of industry, grout, commercial sand and kaolin. The manufacturing method used for the preparation of the samples to be characterized proved to be effective, allowing a coherent analysis of the mechanical performance of the specimens. The materials used in the polymeric matrix resulted in a decrease in its tensile strength, thus, they acted only as a load, without effectively reinforcing the composite, the rigidity of the polyester was also higher, presenting only lower maximum deformation compared to the composites generated. In addition, porosities were verified in the specimens, impairing the maximum mechanical performance to be obtained by the specimens. From the perspective of the production of new materials and the reuse of waste, such tests are valid, although the strength values obtained are lower than those of the pure matrix, applications are envisaged in structural components that need to support low levels of mechanical demands, promoting the application of waste from the processing of different raw materials.

ACKNOWLEDGMENTS

The authors thank PRODESP/UFPA and the Institutional Scientific Initiation Scholarship Program (PIBIC) for the scholarships granted to undergraduate students. They also thank CAPES, CNPq, and the Laboratory of Composite Materials of the Federal University of Pará for the experiments carried out in this work. The authors gratefully acknowledge the support of FEM/ITEC/UFPA and PPGEM/ITEC/UFPA.

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