

INFLUENCE OF THE VARIATION OF THE PERCENTAGE OF INCREASE OF BAUXITE RESIDUE ON THE PHYSICAL AND MECHANICAL PROPERTIES OF SYNTHETIC COARSE AGGREGATES AND THEIR USE IN STRUCTURAL CONCRETE OF NORMAL STRENGTH PORTLAND CEMENT

INFLUÊNCIA DA VARIAÇÃO DO PERCENTUAL DE INCREMENTO DE RESÍDUO DE BAUXITA NAS PROPRIEDADES FÍSICAS E MECÂNICAS DE AGREGADOS GRAÚDOS SINTÉTICOS E SUA UTILIZAÇÃO EM CONCRETO ESTRUTURAL DE CIMENTO PORTLAND DE RESISTÊNCIA NORMAL

INFLUENCIA DE LA VARIACIÓN DEL PORCENTAJE DE INCREMENTO DE RESIDUO DE BAUXITA EN LAS PROPIEDADES FÍSICAS Y MECÁNICAS DE AGREGADOS GRUESOS SINTÉTICOS Y SU UTILIZACIÓN EN CONCRETO ESTRUCTURAL DE CEMENTO PORTLAND DE RESISTENCIA NORMAL



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ABSTRACT

The present study is an integral part of an extensive cooperation project aimed at conducting research between the Federal University of Pará and the company Hydro Alunorte. The proposal consisted of producing synthetic coarse aggregates from bauxite residue (AGS) and

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their subsequent use in the production of conventional-strength structural concrete. This research refers to the study, which partially addressed the dynamics of the production cycles of synthesized aggregates. For this purpose, the AGS70 and AGS80 coarse aggregates from the third production cycle were used. The percentage discrepancy of residue in the aggregate composition was approximately 10%. Among the results obtained, the analyses of the physical and mechanical properties of the synthetic aggregates stand out. In this context, AGS80 showed a water absorption capacity 24% higher than that of AGS70. The results obtained in the composites with AGS70 and AGS80 aggregates indicated that, at an initial stage, the concrete with AGS80 showed better results regarding physical and mechanical properties.

Keywords: Synthetic Coarse Aggregate. Bauxite Residue. Concrete. Tests. Microstructure. Aggregate Modulus.

RESUMO

O presente estudo é parte integrante de um extenso projeto de cooperação para a realização de pesquisas entre a Universidade Federal do Pará e a empresa Hydro Alunorte. A proposta consistia na produção de agregados graúdos sintéticos a partir de resíduos de bauxita (AGS) e sua subsequente utilização na produção de concreto estrutural de resistência convencional. Esta pesquisa faz menção a um estudo, o qual abordou, em parte, a dinâmica dos ciclos de produção de agregados sintetizados. Para tanto, empregou-se os agregados graúdos AGS70 e AGS80 do terceiro ciclo de produção. A discrepância percentual do resíduo na composição dos agregados foi de aproximadamente 10%. Dentre os resultados obtidos, destacam-se as análises das propriedades físicas e mecânicas dos agregados sintéticos. Nesse contexto, o AGS80 apresentou capacidade de absorção de água 24% superior à do AGS70. Os resultados obtidos nos compósitos com os agregados AGS70 e AGS80 indicaram que, em um primeiro momento, o concreto com AGS80 apresentou melhores resultados em relação às propriedades físicas e mecânicas.

Palavras-chave: Agregado Graúdo Sintético. Resíduo da Bauxita. Concreto. Ensaios. Microestrutura e Módulo do Agregado.

RESUMEN

El presente estudio forma parte integral de un amplio proyecto de cooperación para la realización de investigaciones entre la Universidad Federal de Pará y la empresa Hydro Alunorte. La propuesta consistió en la producción de agregados gruesos sintéticos a partir de residuos de bauxita (AGS) y su posterior utilización en la producción de concreto estructural de resistencia convencional. Esta investigación hace referencia al estudio el cual abordó parcialmente la dinámica de los ciclos de producción de agregados sintetizados. Para ello, se emplearon los agregados gruesos AGS70 y AGS80 del tercer ciclo de producción. La discrepancia porcentual del residuo en la composición de los agregados fue de aproximadamente el 10%. Entre los resultados obtenidos, se destacan los análisis de las propiedades físicas y mecánicas de los agregados sintéticos. En este contexto, el AGS80 presentó una capacidad de absorción de agua un 24% superior a la del AGS70. Los resultados obtenidos en los compuestos con los agregados AGS70 y AGS80 indicaron que, en un primer momento, el concreto con AGS80 presentó mejores resultados en relación con las propiedades físicas y mecánicas.

Palabras clave: Agregado Grueso Sintético. Residuo de Bauxite. Concreto. Ensayos. Microestructura. Módulo del Agregado.

1 INTRODUCTION

The bauxite residue, formerly called red mud, is obtained through the Bayer process to refine bauxite and obtain alumina, a by-product of aluminum. For each ton of alumina produced, 1 to 2 tons of this waste are generated, which usually contains oxides of iron, titanium, silica, residual aluminum and other metals such as vanadium, nickel and chromium Miura, Yuuki Silveira (2015) and has a high pH increasing the environmental risk M. L. P. Antunes *et al.* (2010). Large containment deposits are built to store this waste. However, this condition ends up generating visual and ecological impact and can also degrade landscapes and hinder revegetation Miura, Yuuki Silveira (2015).

Research shows that some alternatives are already being applied to use bauxite residue with proper treatment, such as techniques for recovery and (or) reduction of the visual and ecological impacts of degraded areas Miura, Yuuki Silveira (2015). The use in construction materials with bricks or masonry laying blocks, cements, paving blocks, coarse and fine aggregates for concrete Antunes *et al.* (2010).

Based on the studies presented by Fernandes, *et al.* (2025), this research seeks to evaluate whether the amount of residue content used in the production of synthetic coarse aggregates through the third production cycle, specifically AGS70 and AGS80, influenced the results obtained from the physical, chemical and mechanical characterization tests. Thus, as in the physical and mechanical properties of Portland cement concretes of normal strength.

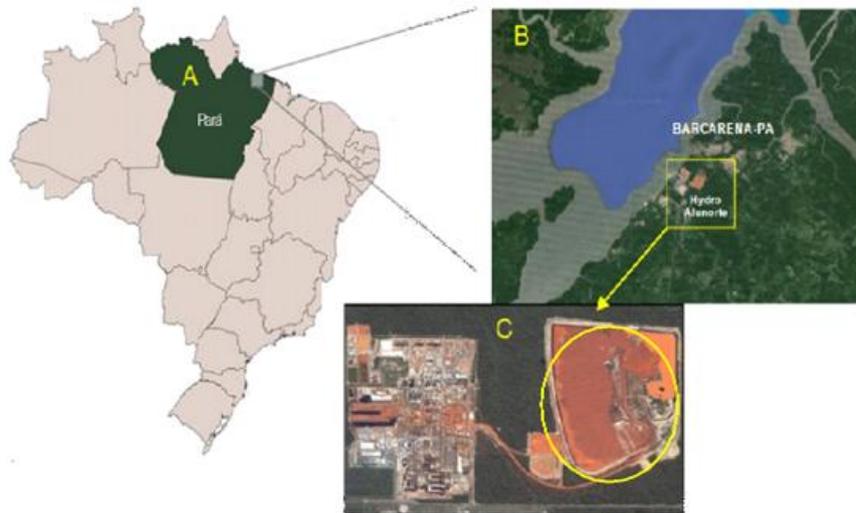
Therefore, this study also establishes a correlation of the influence of synthetic coarse aggregates on the mechanical strengths and modulus of elasticity of Portland cement concrete with the normal strength class. This research presents comparative results of concretes produced with these two types of SFA, analyzing their respective performances in the fresh state such as consistency, bulk density and cement consumption. In the hardened state, aspects of water absorption, porosity, specific mass and static modulus of elasticity are analyzed. In the fracture state of the concrete, the strength to axial compression, diametrical traction and flexion are measured. Finally, the matrix-aggregate interface is analyzed by scanning electron microscopy (SEM).

2 METHODOLOGY

The bauxite residue (RB) used in the research comes from solid waste deposits (DRS), with a storage capacity of 92.2 Mm³ (mega cubic meters) (Souza, *et al.*, 2019), from the HYDRO Alunorte refinery located in the State of Pará, as shown in Figure 1.

Figure 1

Location of the bauxite residue deposit. A and B) Factory Location (Google Maps, 2025) and C) Waste storage area by the company Hydro Alunorte, in Barcarena-PA



Source: Souza, et al., 2019. Adapted. Authors, 2025.

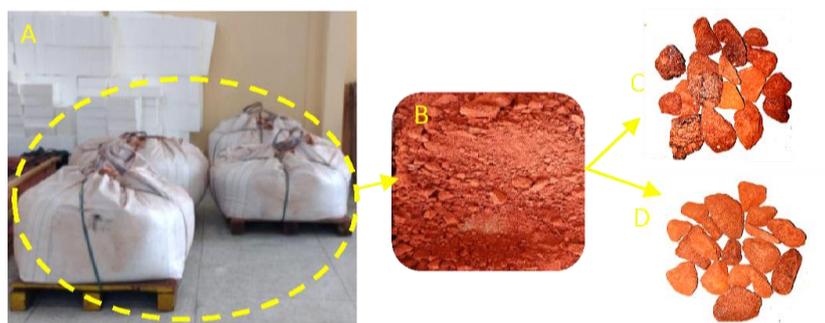
2.1 MATERIALS

2.1.1 Bauxite Residue

Fernandes *et al.* (2025) emphasize that the production of synthetic coarse aggregate took place through the use of raw materials: kaolinite clay, silica and bauxite residue (RB), supplied by the company Hydro Alunorte, located in Barcarena in the state of Pará and stored in the Civil Engineering Laboratory of the Federal University of Pará (UFPA), as shown in Figure 2.

Figure 2

Storage of bauxite residue in the Civil Engineering laboratory of UFPA. A) Arrangement of the way in which the material was transported and subsequently stored; B) Appearance of the Waste in natura; C) and D) Samples of AGS70 and AGS80 obtained in the second production cycle



Source: Adapted, Fernandes, et al. (2025).

2.1.2 Aggregates

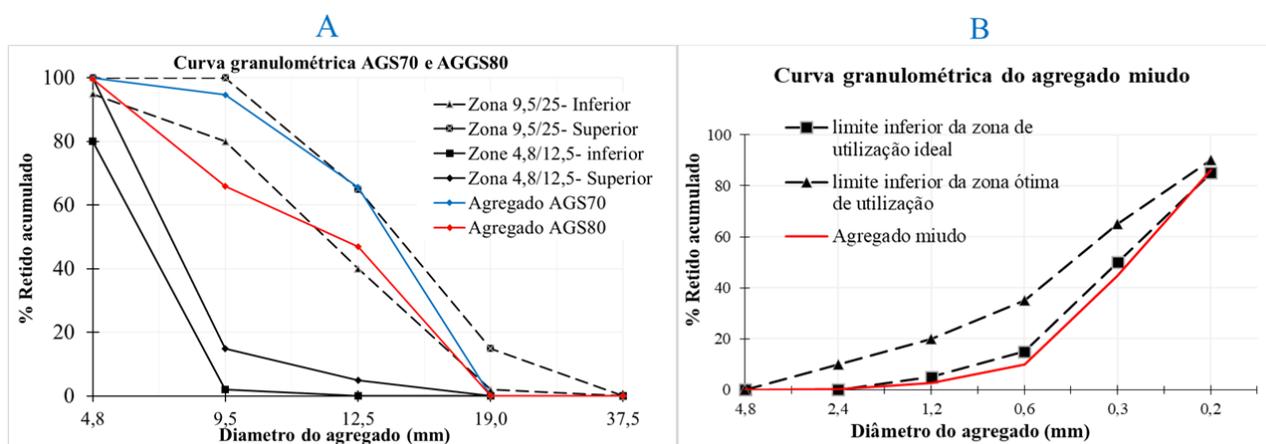
The fine aggregate used in the research is classified as a natural sand type, coming from the quartz riverbed of the Amazon region, more specifically in the vicinity of the municipality of Ourém, in the state of Pará. Physical characterization tests of the material were carried out, whose results indicate a specific mass of 2.62 g/cm³, unit mass of 1.61 g/cm³ and a water absorption of 1.5%. Through the granulometry test, the result of a fineness modulus of 2.4 and a maximum dimension of 1.18 mm was obtained, which indicates that the material is classified as medium sand.

The coarse aggregate is of the synthetic type, called AGS70 and AGS80 of the third production cycle, with percentages ranging between 70-75% and 80-85% of bauxite residue in its composition respectively, supplied by the company Hydro and produced in the chemical engineering laboratory of the Federal University of Pará, as described by Fernandes, *et al.* (2025). For these types of aggregates, physical characterizations were also carried out, presenting the results of maximum diameters of 19.0 mm, specific masses of 2.21 and 2.26 g/cm³, fineness modulus of 1.95 and 1.84, shape indices of 2.07 and 2.08. However, the values reported for water absorption are in the order of 5.24% and 6.50%, respectively Fernandes, *et al.* (2025). However, the authors informed in the research in an inverted way. The sintering temperatures were set at 1200 °C and the shapes of these coarse aggregates can be seen in Figure 2-C and 2-D.

Figures 3.A and 3.B show the particle size curves of the fine aggregate and the large aggregates AGS70 and AGS80.

Figure 3

Particle size range of AGS70 and AGS80 (A) and giblets (B) large aggregates



Source: Adapted, Fernandes, R.S. et al. (2025).

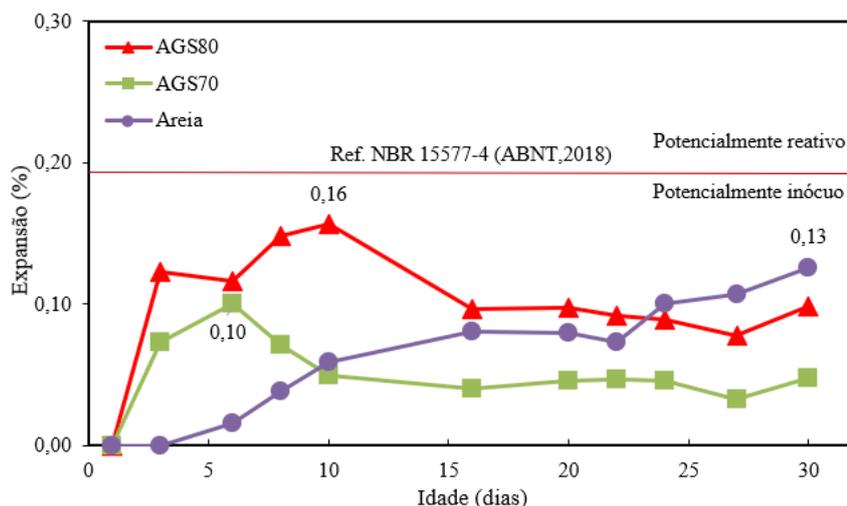
It can be easily observed that the particle size distribution of the sand is outside the frame between the ranges of the lower usable zone and the optimal lower usable zone. On the other hand, the particle size curves of the synthetic coarse aggregates show a partial framing between the upper and lower zones of the particle size range of the sieves #4.8-12.5mm. The equivalence of the curves of the coarse aggregates is an important aspect, as it was necessary to avoid the granulometric variability among the coarse aggregates to be used in the production of cementitious composites.

The coarse aggregates were submitted to mechanical abrasion tests in Los Angeles, whose results showed a mass loss of 41.06% for AGS70 and 43.94% for AGS80. This confirms that the synthetic aggregates in this study meet the minimum requirements of NBR 7211, of 2022, for use in structural concrete.

The verification of whether these synthetic coarse aggregates produced in the laboratory have the potential for reactivity in relation to cement alkalis is essential to ensure the integrity and durability of the concretes. Therefore, the alkali-aggregate reaction assays were performed for synthetic coarse aggregates (AGS70 and AGS80) and also for fine aggregates (sand), as shown in Figure 4.

Figure 4

Results of the aggregate alkali reaction tests of the sand, AGS70 and AGS80 according to NBR 15577-4/2019.



Source: Authors.

2.1.3 Dosing and preparation of the dosing curve

The concrete mix was stipulated at 30 MPa at 28 days, based on the dosage diagram (Figure 5) by the IBRACON method and by the recommendations of NBR 12655:2022, adopting the aggressiveness class II, according to NBR 8953:2015. For the preparation of

the dosage curves of the traces, the same 57% mortar was maintained, considering a concrete for application in the superstructure of tall buildings by means of pumping. Nor were any additives used, in order to directly know the influence of the porosity of the coarse aggregates on the porosity of the concrete. Thus, the consistency class was fixed at S50 due to the reduction of the work through the slump test. Table 1 presents the results of compressive strength of the specimens (CP) at the age of 28 days for the poor, rich and normal traces for the elaboration of the dosage curves, according to the recommendations of the IBRACON Method (Figure 5).

Table 1

Compressive strengths of the dosage curve

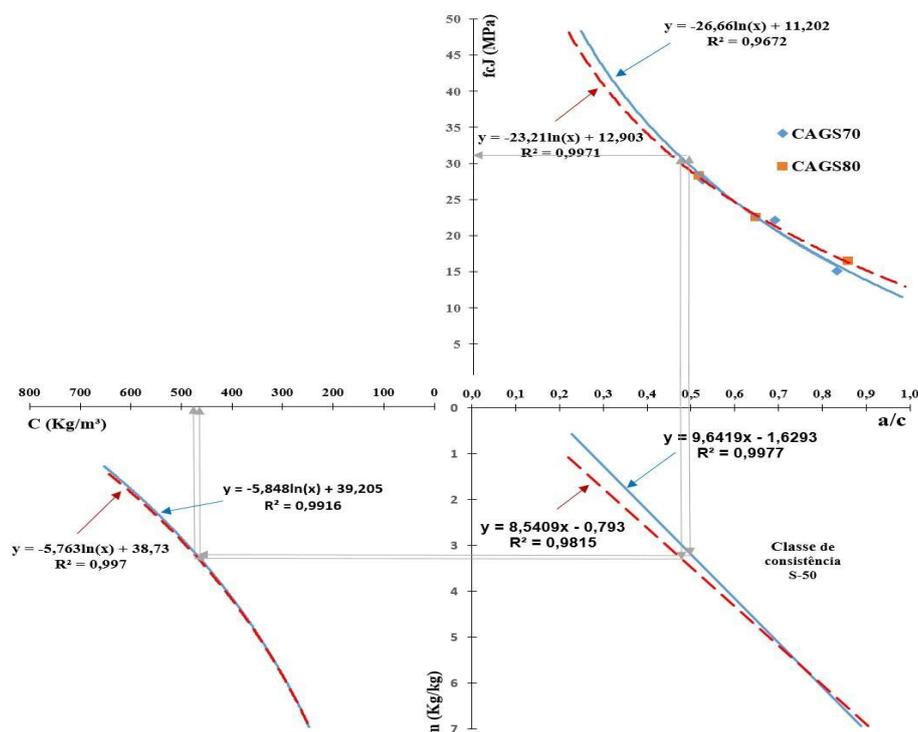
	CLASS	DASH	Attn:	α (%)	Consist. (mm) NBR 7112/2021	fckJ (MPa)	DP	CV
Normal	CAGS70N	1:5,0	0,70	57	S50: $50 \leq TO < 100$	22,17	1,03	0,05
	CAGS80N	1:5,0	0,65	57	S50: $50 \leq TO < 100$	22,50	1,66	0,07
Poor	CAGS70P	1:6,5	0,84	57	S50: $50 \leq TO < 100$	15,12	0,19	0,01
	CAGS80P	1:6,5	0,86	57	S50: $50 \leq TO < 100$	16,45	0,48	0,03
Rico	CAGS70R	1:3,5	0,53	57	S50: $50 \leq TO < 100$	27,70	1,27	0,05
	CAGS80R	1:3,5	0,52	57	S50: $50 \leq TO < 100$	28,30	2,33	0,08

SD - Standard deviation; CV - Coefficient of variation.

Source: Authors.

Figure 5

Dosing curve of the CAGS70 and CAGS80 composites. Adapted, IBRACON Method



Source: Authors.

2.1.4 Unit traits extracted from the curve

The CAGS70 and CAGS80 concretes were evaluated in the hardened state by means of simple axial compression mechanical tests at the ages of 7 and 28 days in cylindrical specimens of 100x200 mm (Figure 7-B and F); diametrical compression traction and flexion traction at the age of 28 days, in cylindrical specimens of 100x200 mm (Figures 7-C and D) and in prismatic specimens of 150x150x500 mm, respectively (Figures 7-D and H). The static modulus of elasticity is measured in cylindrical specimens, whose characteristics are presented in Table 1. In addition, water absorption and void index tests were carried out to correlate with the mechanical strengths of the concretes.

Considering the need to keep the experimental parameters within the same consistency range established by the dosing curves, the mixing water used was adjusted for the concretes, differing from the amount predicted in the initial trace. It is important to emphasize that such changes directly influenced the relationship of the final binding water of the composites and their respective mechanical properties. As shown in Table 2, the properties of cementitious composites are presented

Table 2

Design of the mixtures of the composites studied

Composite/Aggregate Type	Mortar content (%)	Unit Trace	Binding water (initial)	Binding water (final)	Consistency S50 (mm)	Lampshade (mm)	Cement Consumption (Kg/m ³)	Concrete Mass (Kg/m ³)
CAGS70	57	1:1,39:1,81	0,51	0,61	50-100	66	466	2243,16
CAGS80	57	1:1,37:1,78	0,48	0,55	50-100	57	477	2247,27

Source: Authors.

The concrete slump was established in a range ranging from 50 mm to 100 mm, depending on the S-50 strength class. The axial compressive strength, defined in this study as 30 MPa (C30), corresponds to the concrete usually used in vertical works. The concrete dosage was carried out at the Civil Engineering Laboratory of the Federal University of Pará. Figure 6 details the sequencing of the concrete dosing process with the synthetic coarse aggregate. Figure 7, in turn, demonstrates the immersion cure of the samples, as well as the mechanical tests and the static modulus of elasticity.

Figure 6

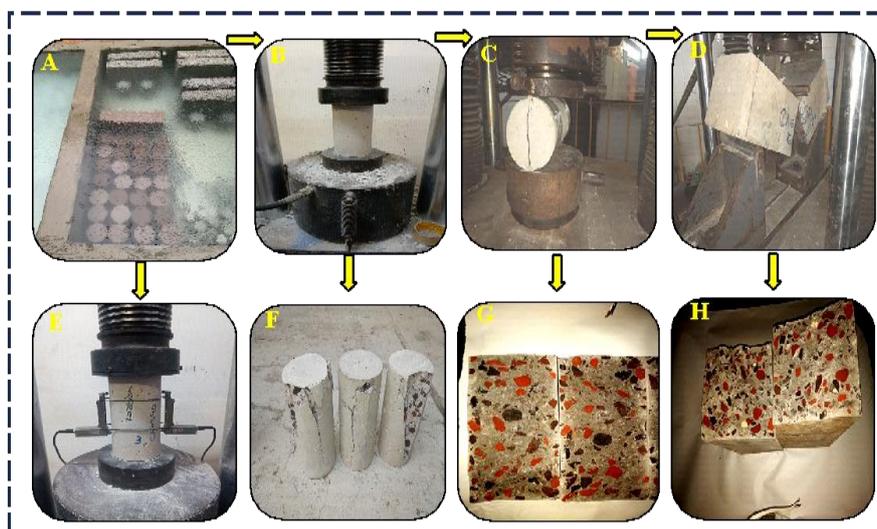
Dosage sequencing and molding. A) Dosing materials; B and C) Mixtures of aggregates in the concrete mixer; D) concrete consistency test; E) and F) Molding of cylindrical and prismatic specimens; G) detail of the concrete for analysis of the apparent specific mass



Source: Fernandes, et al. (2025).

Figure 7

Sequencing of the mechanical strength tests of the CAGS. A) Immersed cure; B) Axial compression test; C) Tensile test by diametrical compression; D) Flexural tensile test; E) Static modulus of elasticity test; F/ G/ H) Detail of the rupture of the PC's to axial compression, diametrical compression and traction in flexion, respectively



Source: Adapted, Fernandes, et al. (2025).

3 RESULTS AND DISCUSSION

3.1 INFLUENCE OF THE VARIATION OF THE RESIDUE CONTENT IN THE SYNTHETIC AGGREGATES AGS70 AND AGS80 IN RELATION TO THEIR PHYSICAL, CHEMICAL AND MECHANICAL PROPERTIES

The results found for AGS70 and AGS80 coarse aggregates of the third cycle produced in a muffled furnace at a controlled temperature at 1200 °C, were considered excellent for presenting normal specific mass, above 2.0 g/cm³. In addition, it is noteworthy that in most of the studies used as a basis for this research, the generation of samples occurred at burning temperatures above 1200 °C, using muffled ovens for the production of synthetic coarse aggregates.

Tuan *et al.* (2013) says that the burning temperature plays a key role in controlling the water absorption capacity. This is because the sintering of the mixture promotes the densification of the particles, reducing the entry of water into the aggregate matrix. The high porosity index of the aggregate is directly related to its water absorption capacity and the higher the porosity of the material, the greater its water absorption capacity. The samples were tested and had absorption rates between 5.59% and 6.50%. Therefore, the aggregates meet the limits established by the NBR 7211 (2022) standard.

According to Borba and Santos (2021), the shape index of coarse aggregate grains indicates how much they resemble a cube. NBR 7211 (2022) states that the shape index of

a coarse aggregate, determined according to NBR 7809 (2016), should not be higher than 3, allowing lamellar aggregates. The results of the shape indices of the samples were below the regulatory limit, thus meeting the required standards.

It is important to note that highly porous aggregates are typically more brittle, making them unsuitable for the production of structural concrete. The average results of the Los Angeles abrasion index, carried out according to the NM 51 (2001) standard, in which the analyzed samples showed abrasion resistance for AGS70 of 41.06% and for AGS80 of 43.94%, show that these indices are considered satisfactory, since NBR 7211 (2022) stipulates that the percentage of mass loss must be less than 50%. It is worth mentioning that the greater the water absorption of the aggregates, the greater the mass loss by the abrasion test.

A durability test was carried out through the reaction test of alkaline aggregates established by NBR 15577-4 (2018) to qualitatively evaluate the condition of the aggregates. The results indicated that the synthetic aggregates do not have the potential to reactivity with the alkalis of the cement studied, that is, they are inert.

3.2 INFLUENCE OF THE PHYSICAL PROPERTIES OF CONCRETE ON THE AXIAL COMPRESSIVE STRENGTHS OF CAGS70 AND CAGS80 CONCRETES

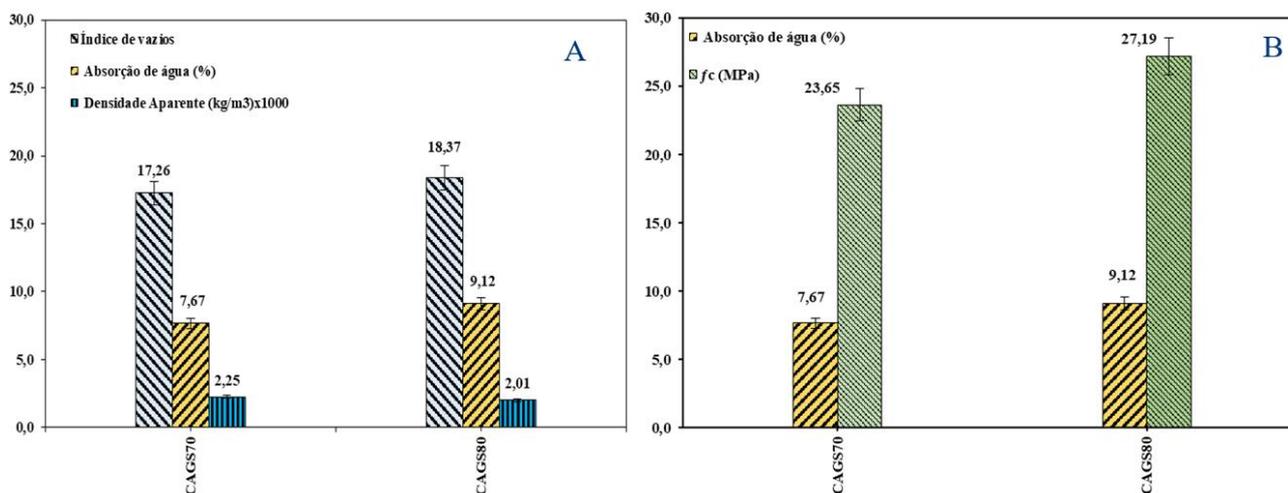
Figure 8-A shows the graph of the relationship between water absorption, void index and apparent specific mass of concrete with synthetic coarse aggregates. When analyzing the spectrum of the existing porosity of the concretes at the age of 28 days, it is observed that CAGS70 has lower porosity than CAGS80, according to the results of the void index and water absorption tests. In this condition, initially it could be said that the CAGS70 presents better physical durability performance than the CAGS80. However, through the information contained in Table 2, it is observed that the final binding water index in CAGS70 is higher than CAGS80 and that the subsidence was 66 mm and 57 mm, respectively. Thus, it can bring the understanding that both concretes are framed in the same porosity range, causing an equivalence between them.

As exposed by Rossignolo (2009, p. 25), a high rate of water absorption in the aggregate can cause damage to concrete in its hardened state. However, the high water absorption capacity of the aggregate can provide benefits, such as improving the properties of the transition zone between the aggregate and the cement slurry, resulting in the reduction of the "wall effect". Another situation to highlight is that the results showed that the apparent specific masses of the CAGS70 and CAGS80 composites are 2250 kg/m³ and 2001 kg/m³, respectively. This reaffirms that AGS80 is less dense than AGS70, as it is more porous due

to the higher bauxite content in its composition. This may demonstrate that CAGS80, being more porous, caused a greater amount of voids, thus less dense.

Figure 8

Physical and mechanical properties of the concretes studied. A) Void index x water absorption x bulk density. B) water absorption x axial compressive strength at 28 days



Source: Authors.

The porosity of the coarse aggregate is a factor that can affect the rheological and mechanical properties of structural concretes, as well as the modulus of elasticity of the concrete. Figure 8 shows the graph that relates the water absorption and the mechanical resistance to axial compression of CAGS70 and CAGS80 at the age of 28 days, where CAGS80 has higher porosity, in the order of 18% higher than CAGS70. However, when observing the compressive strength at 28 days, it is noted that, even though CAGS80 has greater porosity and greater water absorption than CAGS70, it still also has greater strength, in a proportion of 15% higher. Therefore, it is inferred that the constraints of porosity and water absorption, when analyzed individually, do not exert a direct influence on the axial compression of the composites object of this research.

3.3 ANALYSIS OF AXIAL COMPRESSIVE STRENGTHS AND MODULUS OF ELASTICITY OF CAGS70 AND CAGS80 CONCRETES

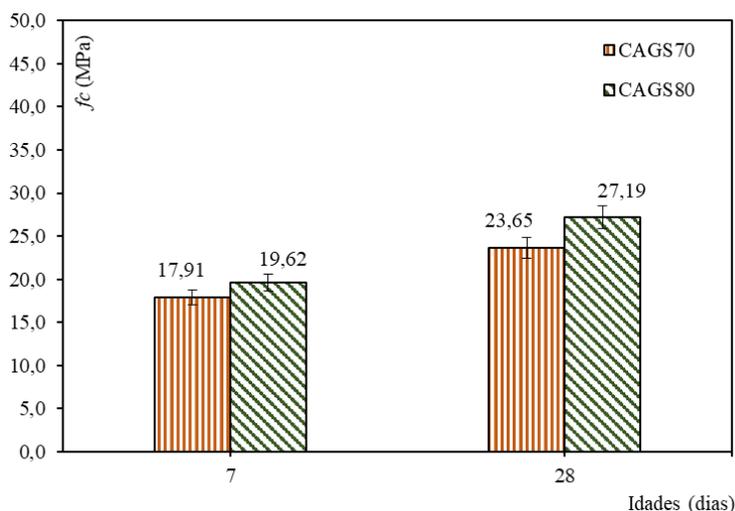
The compressive strength graph, illustrated in Figure 9, indicates that both composites showed a gradual increase in strengths over time at the ages of 7 and 28 days.

At the final age of the test (28 days), the results obtained indicated that CAGS80 presented axial compressive strength 15% higher than CAGS70. However, when relating the experimental trace extracted from the dosage curve to the age of 28 days, estimated at 30 MPa, it is clear that the batch of specimens produced initially would not meet the pre-

established resistance requirement at this age. However, even if the strengths of the concretes studied are lower than those stipulated in the traces of the dosing curves, it is important to emphasize that these concretes were framed within the class of aggressiveness established in NBR 12655:2022.

Figure 9

Graph of the mapping of the axial compressive strength of the CAGS70 and CAGS80 composites for ages 7 and 28 days

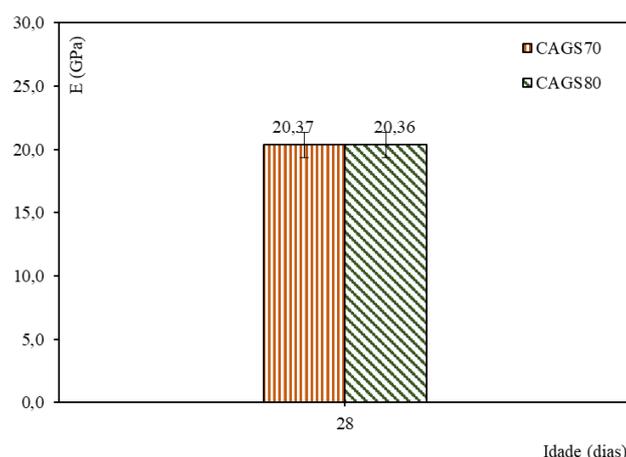


Source: Authors.

Some aspects in which the coarse aggregates may have contributed to the results obtained, lead to the reflection that AGS80 has greater loss to abrasion and greater water absorption than AGS70. However, CAGS80, even with higher porosity/water absorption and lower apparent specific mass than CAGS70, nevertheless obtained higher axial compressive strengths at the ages studied. This leads to the following conclusion: that, because they are concretes of normal strengths, the physical properties of porosity and surface hardness are not the main factors for compressive strength, but the water-binder ratio, if the other rheological parameters are equivalent, since for CAGS70 the ratio of 0.61 was used and for CAGS80 0.55.

Figure 10

Graph of the modulus of elasticity of the CAGS70 and CAGS80 composites



Source: Authors.

According to NBR 6118, 2023, the elastic deformation of concrete depends on the composition of the concrete trace, especially the nature of the aggregates. According to Mehta and Monteiro (2014, p. 24), the modulus of elasticity and compressive strength of concrete are two properties that evolve in different ways over time. Considering the results obtained at the age of 28 days of the modulus of elasticity of CAGS70 and CAGS80 are practically the same, therefore, there is no intrinsic variation in the microstructure of this type of concrete, when the percentage of residue in the composition of the coarse aggregate is altered. Taking into account the notes of Rossignolo (2009), who states that, for concretes of normal specific mass, with axial compressive strength values ranging from 20 to 50 mega pascal (MPa), the value of the modulus of deformation can vary, in general, between 50% and 80% of the value obtained.

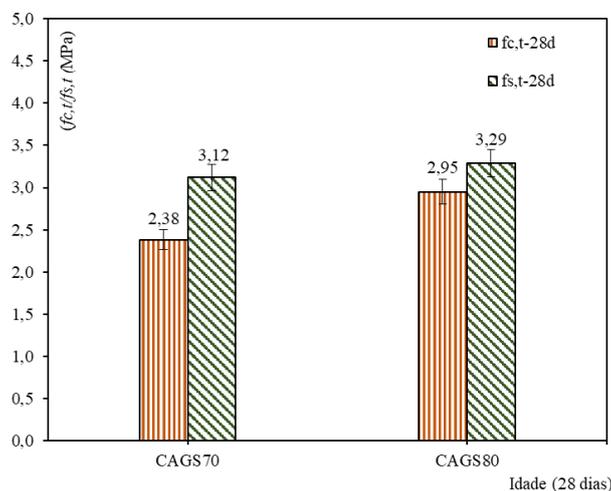
3.4 COMPARATIVE ANALYSIS OF THE RESULTS OF DIAMETRICAL COMPRESSION TRACTION AND FLEXURAL TENSILE

Figure 11 presents a comparison of the results obtained from the diametrical compression and flexural tensile strength tests, performed at 28 days, for the CAGS70 and CAGS80 composites. There were significant variations in the responses obtained between the above-mentioned assays for the CAGS70 and CAGS80 composites. However, when analyzing the results of axial compression and tensile diametrical compression for the CAGS70 and CAGS80 composites, it was understood that the tensile strength of both was equivalent to 10% of the axial compressive strength. In view of the above, it is inferred that the results are in accordance with the normative parameters established for standard strength concretes. This hypothesis is corroborated by the systematic review by Junior, Costa and

Macedo (2022), who cite the results of diametrical compression tensile strength from the works of Rosário (2013) and Souza (2010).

Figure 11

Graph of the relationship between indirect tensile strength and flexural tensile strength of CAGS70 and CAGS80 composites for 28-day age



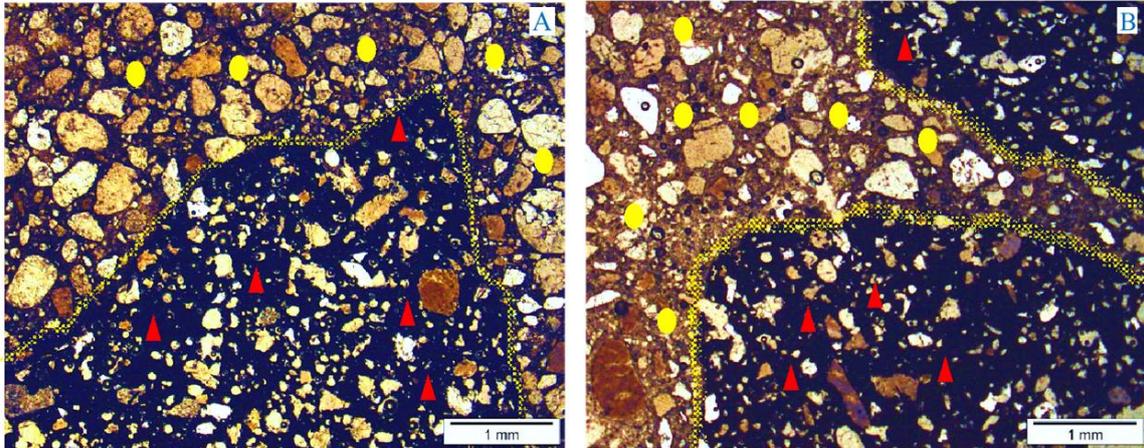
Source: Authors.

3.5 ANALYSIS OF THE MICROSTRUCTURE OF FRACTURED CONCRETE BY OPTICAL AND SCANNING ELECTRON MICROSCOPE (SEM)

In order to analyze the microstructure of the matrices and transition zones of the concretes with synthetic coarse aggregate, images were obtained using an optical microscope (Figure 12) and scanning electron microscope (SEM) (Figures 13) in samples of specimens of fractured concrete in the tensile test by diametrical compression at the age of 28 days. The preparation of the samples was carried out by fragmentation into appropriate sizes. Then, the samples were subjected to drying in an oven at a temperature of 100 °C for a period of 24 hours. Finally, the polishing was carried out on blades.

Figure 12

Image obtained by optical microscope in polarized light of the microstructure of the transition zone of the composite. A) CAGS70; B) CAGS80



Legenda: ■ delimitação da zona de transição; ▲ Agregado graúdo (fase dispersa); ● Argamassa (matriz cimentícia).

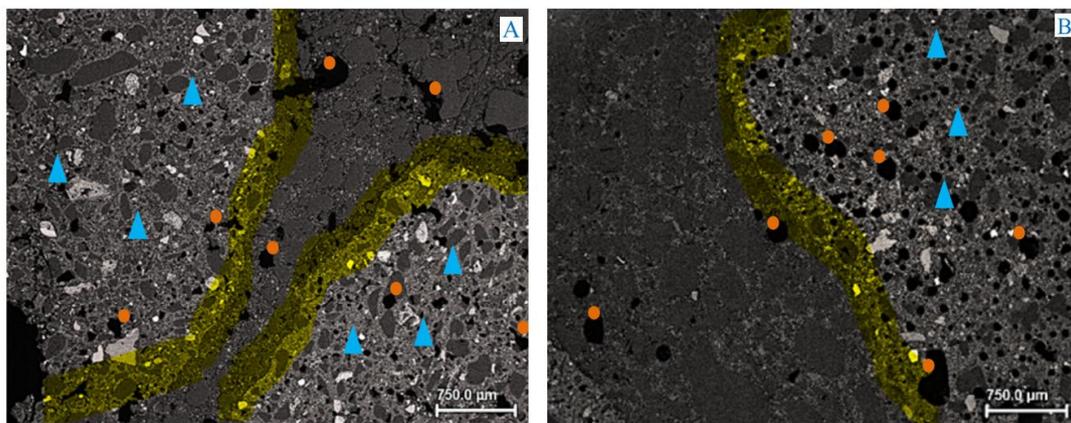
Source: Authors.

According to Isaia *et al.* (2007), the contact zone corresponds to the relationship between the grains of the coarse and small aggregates that fuse with the cement paste, surrounding and separating the aggregates. This process results in the formation of water films around the grains, generating a weaker layer at the interface. According to Neville (1997, p. 6), this transition zone has greater porosity and, consequently, less resistance.

Scanning electron microscopy (SEM) analyses were performed on the Zeiss model LS15 EVO microscope, equipped with the Lamin-Be system. The slides were metallized with a gold film to obtain backscattered electron (BSE) images.

Figure 13

Images obtained by (SEM). A) CAGS70; B) CAGS80



Legenda: ■ Delimitação da zona de transição; ■ Fissuras; ▲ Agregado graúdo (agregado graúdo sintético); ● Poros no agregado graúdo e argamassa cimentícia).

Source: Authors.

Figure 12 highlights the separation through the transition zone of the cementitious matrix of the composites with dispersed phase and the coarse aggregates. In addition, it is possible to observe the detail of the synthetic coarse aggregate in relation to the distribution of silica grains, symbolized by the white dots on the bauxite residue, represented by the entire dark area.

Scanning electron microscopy (SEM) analysis was crucial to verify the delimitation of the matrix and dispersed phases through the zones of the CAGS70 and CAGS80 composites, as well as the existing cracks and pores, as shown in Figure 13.

The occurrence of macro fractures in the cementitious matrix were not observed in the images obtained by the SEM, both in the CAGS70 and CAGS80 samples. However, the specialized literature says that for normal strength concrete, fractures tend to occur in the mortar and in the transition zone.

As observed in Figure 13, the greater amount of pores in the AGS80 was a factor that contributed significantly to the absorption of kneading water and, consequently, this factor caused an increase in the ratio of binding water.

4 CONCLUSION

The results of this research allow us to conclude that the variation in the percentage of bauxite residue in the production of synthetic coarse aggregates (AGS70 and AGS80) influenced the physical and mechanical properties of the aggregates and concretes produced by them. Both aggregates met the normative requirements of NBR 7211 (2022), presenting indices of shape less than 3 and abrasion resistance within the established limit of 50%. In addition, they did not present alkali-aggregate reaction potential.

Regarding the porosity of the aggregates, it was observed that the AGS80 presented a higher index of voids and water absorption (6.50%) compared to the AGS70 (5.24%). This behavior would normally indicate a composite that is less dense and therefore has lower mechanical performance. However, the results showed that the higher porosity of AGS80 did not significantly compromise the structural behavior of the concrete, demonstrating that other factors had a more determining influence on the strength.

Thus, it is concluded that both AGS70, with about 70 to 75% in its bauxite tailings composition, and AGS80, with about 80 to 85% in its bauxite tailings composition, are viable alternatives for the production of C30 class structural concrete, and AGS80, even more porous, demonstrated better overall mechanical performance, configuring itself as the most promising option for future commercial applications, since for its production the consumption of bauxite is higher than AGS70.

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