IOSR Journal of Business and Management (IOSR-JBM)
e-ISSN:2278-487X, p-ISSN: 2319-7668. Volume 27, Issue 10. Ser. 4 (October. 2025), PP 58-68
www.iosrjournals.org

Bauxite Residue In The Production Of Synthetic Coarse Aggregates For Structural Concrete: Physical-Mechanical Analysis

Marcella Camilly Dias Ribeiro[1], João Carlos Lisboa De Lima[1], Sabino Alves De Aguiar Neto[2], Alessandro Resende Machado[6], Aedjota Matos De Jesus[3], Williams Jorge Da Cruz Macêdo[5], Lucineide Nazaré Barata Pinheiro[1], Danusa Mayara De Souza[1], Bianca Jefres Lima De Sousa[1], Celestina Lima De Rezende Farias[4], Marcelo Martins Farias[4], Vitor Hugo Lopes Branco[4], Elsimar Souza Santos[1], Robson Da Silva Fernandes[1], Cristiane Araújo Dos Santos Silva[1], Carlos Alberto Bendelack Nicolau Junior[1], Wladimir Rafael De Matos Lamarão[1], Lucas Miranda Pantoja[1], Marcelo De Souza Picanço[1]

(Institute Of Technology, Faculty Of Civil Engineering / Federal University Of Pará, Brazil)
(Civil Engineering / State University Of Pará, Brazil)
(Civil Engineering / Technology Center, Federal University Of Rondônia, Brazil)
(Civil Engineering / Federal Institute Of Education, Science, And Technology Of Pará, Brazil)
(Laboratory Of Molecular Modeling And Simulation System, Federal Rural University Of Amazônia)
(CEUMA University, Brazil)

Abstract:
Background*: Bauxite residue, commonly known as red mud, represents a major environmental challenge due to its high alkalinity and large volume of disposal. Its reuse in civil construction is a promising alternative for reducing environmental impact and the demand for natural aggregates. The study focuses on the development of synthetic aggregates capable of meeting the mechanical and durability requirements for structural applications.*
Materials and Methods*: The BR used originated from the Hydro Alunorte refinery (Barcarena, Brazil). Three synthetic aggregates were produced AGS 70, AGS 80, and AGS 90 containing 70–95% BR, combined with silica and clay, and sintered at 1200 °C for 3 h. These aggregates and their corresponding concretes were characterized through chemical, physical, and mechanical tests following Brazilian standards (ABNT NBR).*
Results*: The synthetic aggregates demonstrated adequate density, abrasion resistance, and mechanical strength. Among them, AGS 70 showed the best overall performance, with the lowest water absorption and highest compressive strength, similar to conventional concrete. All concretes achieved compressive strength above 20 MPa at 28 days, classifying them as structural. Capillary absorption followed the same trend as the aggregates, increasing with higher BR content.*
Conclusion: *Synthetic aggregates produced from bauxite residue can replace natural coarse aggregates in structural concrete. AGS 70, in particular, exhibited satisfactory mechanical and durability performance, meeting normative requirements. The reuse of BR in aggregate production represents a sustainable solution for waste management and natural resource conservation.*
Key Word: *Bauxite residue; Coarse synthetic aggregate; Concrete; Characterization.*

Date of Submission: 07-10-2025 Date of Acceptance: 17-10-2025

I. Introduction

Regarding the consumption of natural resources, the civil construction industry, which serves as a major economic and social driver, is also responsible for approximately 57.5% of global raw material use[1]. Among the materials employed in civil construction, coarse aggregates stand out due to their wide range of applications, such as in mortars, dams, pavements, concrete, and more.

Over the years, there has been a marked increase in the consumption of these aggregates. As an example, between 2011 and 2014, China consumed more than the United States did throughout the entire 20th century[2]. In Brazil, according to[2], the consumption of coarse aggregates tends to rise during economically favorable periods, which contributes to a slight scarcity of this resource due to high demand. Consequently, the limited supply highlights the need to obtain new types of aggregates, aiming also to mitigate the environmental degradation caused by the extraction of natural aggregates (e.g., gravel).

Mining is a sector of great importance for both the economy and social development, and it is closely linked to civil construction. Despite its benefits, it generates large quantities of waste, which entail high management costs, pose potential risks to humans, and often lack standardized applicability. Within this context, the alumina industry stands out due to its main waste product, bauxite residue (BR), commonly known as "red mud." BR is characterized as the residual fraction of the insoluble mineral components of the ore during the refining stage of the Bayer process for alumina production[3]. According to data from ABAL[4], it is estimated that approximately 14.5 million tons of this residue (drained disposal) are generated annually in Brazil. Worldwide, this figure reaches 120 million tons, with an estimated total of 2.7 billion tons currently stored[5,6].

Over the years, with the aim of reuse, many countries have considered BR a viable alternative raw material for applications in civil construction[6,7,8]. This global motivation is mainly linked to the increasing generation of BR an environmental liability[9] and the continuous depletion of non-renewable raw material reserves (e.g., aggregates).

In the scientific field of civil construction, and increasingly in practice, there are proposals for using BR in the production of coarse aggregates through calcination with other materials, also targeting its application in concrete. Several authors[10,18] have reported that synthetic aggregates often exhibit superior performance compared to natural aggregates, both in their intrinsic properties (e.g., abrasion resistance, impact loss, and water absorption) and in the properties they impart to the concrete (e.g., compressive/tensile strength, elastic modulus, and capillary water absorption). According to[12,19], the production of synthetic aggregates aims to reduce the high demand for natural aggregates, mainly consumed by the construction industry. The use of these new aggregates, given the compositional variability of BR, should be based on prior studies to assess their performance in the intended application. As stated in[20], one of the major challenges in this field is achieving satisfactory performance using the highest possible proportion of BR safely, due to the high alkalinity of this residue in its raw state.

Based on these findings, approaches that ensure high consumption rates of BR for the production and/or replacement of construction materials[21], such as coarse aggregates for concrete, become necessary in light of the issues presented. Thus, producing an aggregate that guarantees good physical and mechanical properties in structural concrete benefits both the civil construction industry and the alumina industry. The present study employed BR (dry-disposal type) from the Hydro Alunorte refinery (Barcarena, Pará, Brazil) to produce three types of synthetic coarse aggregates for structural concrete, which were evaluated regarding their respective physical and mechanical characteristics.

II. Material And Methods

Materials

Primary Materials

Table 1 presents the primary materials used in this study, along with the corresponding reference for their characterization.

Table 1 – Characterization tests of the primary materials used in the research.

Materials	Testing	Standard
Cement CP IV - 32 RS	Specific mass	ABNT NBR 16605 (2017)[22]
	Setting time	ABNT NBR 16607 (2018)[23]
	Fineness index	ABNT NBR 11579 (2012)[24]
Sand Silica	Specific mass	ABNT NBR 16916 (2021)[25]
	Bulk density	ABNT NBR 16972 (2021)[26]
	Particle size distribution (granulometry)	ABNT NBR NM 248 (2003)[27]
Bauxite Residue	Chemical composition (XRF)	ABNT NBR 14656 (2001)[28]
Pebble	Alkali–aggregate reaction (AAR)	ABNT NBR 15577 (2018)[29]
	Specific mass	ABNT NBR 16917 (2021)[30]
	Bulk density	ABNT NBR 16972 (2021)[26]
	Water absorption	ABNT NBR 16917 (2021)[30]
	Particle size distribution (granulometry)	ABNT NBR NM 248 (2003)[27]
	Shape index	ABNT NBR 7809 (2019)[31]
	Los Angeles abrasion	ABNT NBR 16974 (2021)[32]
	Impact loss	DNER-ME NR 399/99[33]

Synthetic Coarse Aggregate

In the present study, the synthetic coarse aggregates were produced using the primary materials shown in figure 1.

Figure 1 – Raw materials used in the composition of the synthetic coarse aggregates (adapted from[34]).

For proper use in the production of the synthetic aggregates, the constituent materials were subjected to the respective pre-treatments presented in Table 2.

Table 2 – Pre-treatment of raw materials (natural aggregates and clay).

Materials	Application	Pre-treatment		
		Drying	Grinding	Sieving
Clay	Synthetic coarse aggregate	Air-circulating oven at 105°C for 24 h (MARCONI MA 035 model).	Steel ball mill for 30 min to disaggregate the particles.	Only the material passing through the #150 µm sieve was used.
Silica				
BR				
Seixo	Structural concrete	Oven drying at 100°C for 24 h.	-	-
Sand				

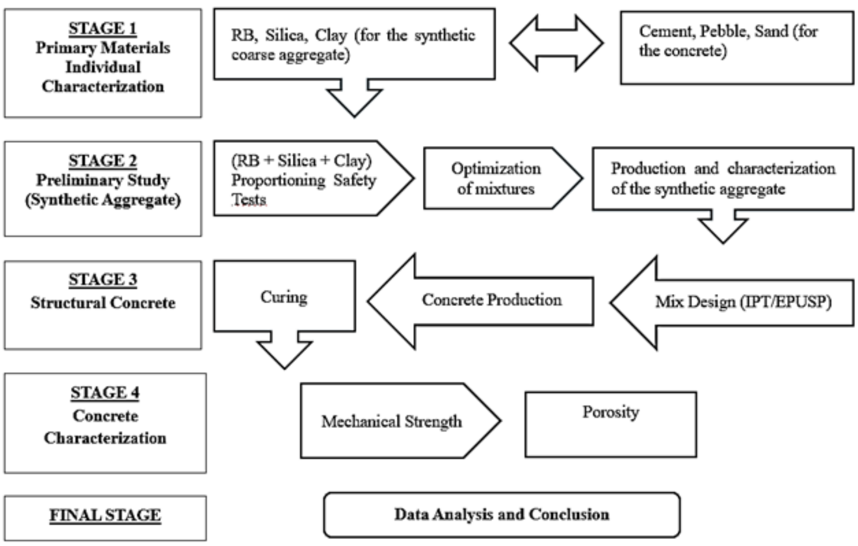
The pre-treatment described aimed to achieve a better particle size adjustment of the materials, resulting in greater efficiency in the sintering reactions of the aggregates, in addition to preventing the possible formation of cracks caused by the use of moist raw materials, which could affect both performance and final quality[35].

Experimental Program

Summary of the Experimental Program

The experimental program of this research followed the sequence shown in Figure 3, comprising five sequential stages.

Figure 2 – Simplified flowchart of the experimental program.



Preliminary Study for Coarse Aggregate Sintering

Before the proper use of the synthetic aggregates, a preliminary compositional study was carried out based on the works of [36,37,38]. This study involved 26 calcined pre-mixtures of BR (60–95%), silica (0–30%), and clay (0–30%) in different proportions, in order to determine the optimal compositions.

All samples were subjected to solubilization tests (ABNT NBR 10005:2004)[39] and leaching tests (ABNT NBR 10006:2004)[40] for solid wastes as an initial criterion, to ensure the removal of any residual Na(OH) present in the BR. From the proposed mixtures, five were selected that met the initial established criteria.

Based on the performance of these initial samples, three new optimized mixtures were formulated for aggregate production (via extrusion), designated as AGS 70, AGS 80, and AGS 90. Table 3 presents the parameters adopted in the production of these synthetic coarse aggregates.

Table 3 – Composition, temperature, and sintering time of the optimized samples for the production of synthetic coarse aggregates.

Sample	BR (%)	Silica (%)	Clay (%)	Temperature (°C)	Time (h)
AGS 70	70 - 75	20 - 25	5	1200	3
AGS 80	80 - 85	10 - 15	5	1200	3
AGS 90	90 - 95	0 - 5	5	1200	3

The optimized coarse aggregates are, to date, still in the patenting process by UFPA. Therefore, as a protective measure, the information regarding the BR and silica contents (the most relevant components) is presented in the form of interval ranges. Similarly, the production process and other technical details are presented in summarized form in this study.

Production of Synthetic Coarse Aggregates

The synthetic coarse BR aggregates were produced according to the manufacturing process shown in Figure 4, and their final appearance is illustrated in Figure 5.

Figure 3 – Flowchart of the production process of synthetic coarse aggregates.

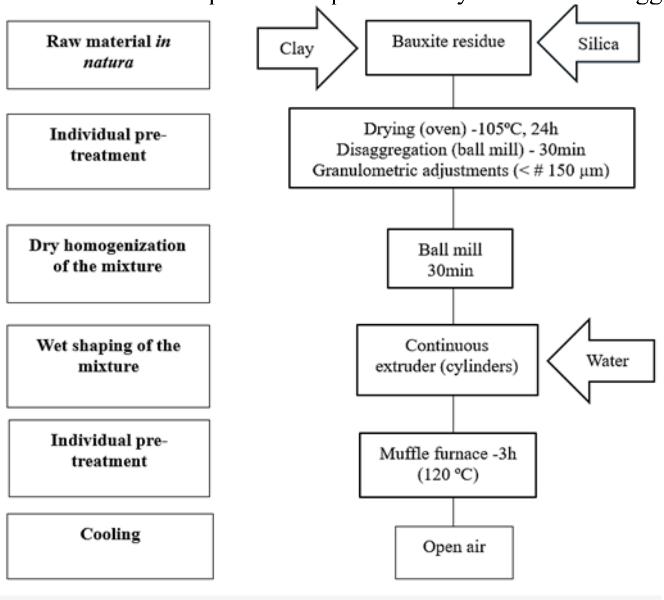


Figure 4 – Samples of optimized synthetic coarse aggregates.

The produced samples exhibited an elongated–lamellar shape with irregular grains. Their surface was moderately rough, with pronounced texture in parts of the grains, and a characteristic maximum particle size (DMC) of approximately 19 mm. The synthetic aggregates were subjected to the same physical mechanical characterization tests applied to the natural aggregate (pebble), as previously described in Table 1.

Mix Design and Concrete Production

For the mix design of the concretes used in this research, the method developed by the Instituto de Pesquisas Tecnológicas da Escola Politécnica de São Paulo – IPT/EPUSP[41] was adopted for structural concretes, following the parameters summarized in Table 4. The final mix design variables obtained are presented in Table 5.

Table 4 – Initial mix design parameters adopted.

Unit ratio – kg/kg (cement:aggregates)	[1] α (%)	[2] Ratio a/c	Slump (mm)	AGS content (%)
1 : 5,0	51 ≤	≤ 0,65	100 ± 20	100

[1] Mortar content of the concrete.

[2] For exposure class I, according to ABNT NBR 6118:2014[42]

Table 5 – Características finais de dosagem**.**

Concrete	Single Mix Design (cement : aggregates)		α (%)	Water a/c	Coarse Aggregate (%)		Slump (mm)
					[3] natural	sintético	
REF	1	: 5,0	51	0,55	100	0	≈ 90
AGS 70	1	: 5,0	55	0,65	0	100	
AGS 80	1	: 5,0	59	0,65	0	100	
AGS 90	1	: 5,0	61	0,65	0	100	

[3] Rolled pebbles.

Due to the differences in water absorption exhibited by the synthetic coarse aggregates, the concretes required different amounts of mortar to meet the initial parameters established in the mix design.

During the consistency tests, workability, segregation, and cohesion were also taken into account because of the intended application of the concrete (columns, beams, and slabs). Alongside the concretes with synthetic aggregates, conventional concrete using rolled pebbles (REF) as coarse aggregate was also produced for reference purposes.

Figure 6- illustrates the appearance of the concretes during the mixing procedure.

III. Result And Discussion

Material Characterization

Primary Materials

Tables 6, 7, and 8 show the results of the characterization of the primary materials.

Table 6 – Chemical composition of raw bauxite (RB) used in the production of synthetic aggregates Compound; Loss on ignition

Compound	Al_2O_3	SiO_2	Fe_2O_3	TiO_2	Na_2O	CaO	LOI [4]
%	21,27	17,72	34,31	6,89	9,25	1,22	8,11
[4] Loss on ignition							

Table 7 – Characterization of Portland cement

Type	Specific gravity (g/cm³)	Fineness index (%)	Setting time (hour: minute)	
			Start	End

CP IV - 32 RS	2,83	3,17	2:56	5:31

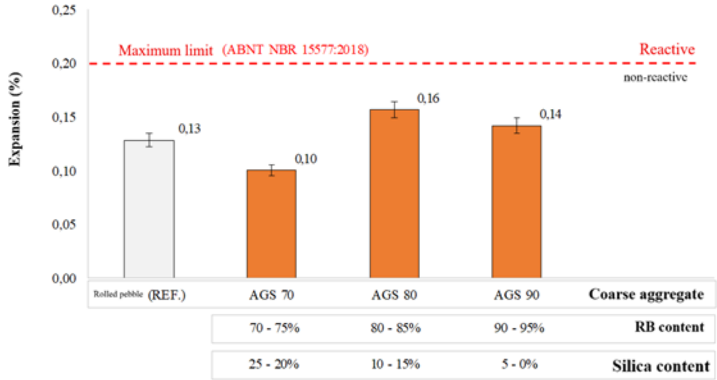
Table 8 – Characterization of natural fine aggregate (sand)

Sample	Specific gravity (g/cm³)	Bulk density (g/cm³)	Fineness modulus	Maximum characteristic diameter (mm)
Areia	2,33	1,68	1,86	1,18

Synthetic coarse aggregate

The characterization results of the coarse aggregates are shown in Figures 6, 7, and 8.

Figure 6 – Reactive potential of the coarse aggregates, obtained from the AAR (Alkali-Aggregate Reaction) analysis



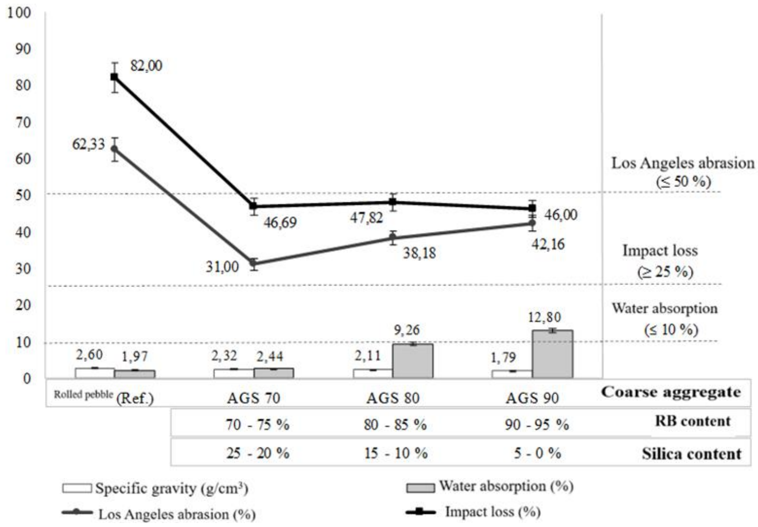
According to the results shown in Figure 6, regarding reactive potential, the synthetic coarse aggregates met the criteria established by ABNT NBR 15577:2018[29], not triggering the alkali-aggregate reaction (AAR). The samples remained below the regulatory maximum expansion limit, thus characterizing them as innocuous.

Analyzing the AAR results together with the composition of the synthetic aggregates, it can also be observed that, although innocuous, they showed a slight increasing trend with higher RB content and lower silica content.

According to studies by[43], some caution is necessary when exposing RB to cementitious matrices, as the residue has a high alkali content (e.g., Na – sodium), which may favor the alkali-silica reaction (ASR). The same author also points out that mitigation of the reaction is linked to a minimum level of pozzolanic addition in Portland cement, which may or may not be sufficient, depending on the reactivity level of the aggregate analyzed.

Authors[44, 45] state that for ASR to occur, a sufficient silica content is required to react, along with an adequate amount of reactive aggregates in the cementitious matrix. According to these authors, these factors are not directly proportional or linear with respect to the occurrence of the phenomenon.

Figure 7 – Physico-mechanical characterization of the coarse aggregates. Intrinsic variables

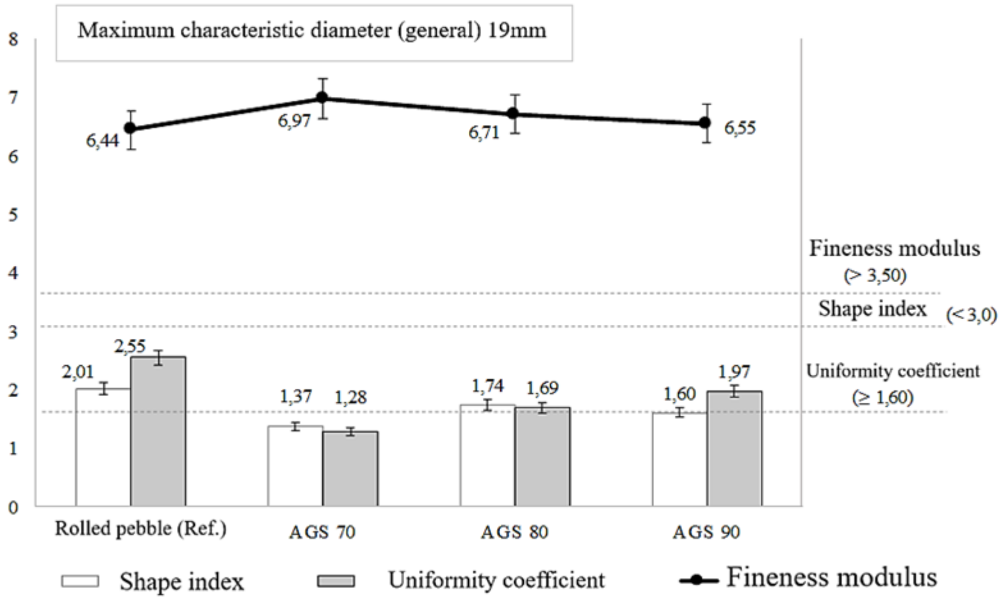


Based on the results of the coarse aggregate characterization (Figure 7), first considering abrasion resistance and mass loss under impact, it can be observed that all synthetic aggregates met the respective normative specifications. Notably, sample AGS 70 exhibited the highest abrasion resistance, losing the least mass during the test. According to[12], these two mechanical properties in the synthetic aggregates are directly related to the compositional silica content, as the properties of this mineral confer higher hardness and mechanical strength to the aggregate. Regarding the influence of the residue, studies by[3] indicate an improvement in the mechanical properties of calcined RB mixtures at 50–70% content in the production of ceramic materials for construction applications.

Focusing on water absorption of the aggregates, sample AGS 70 showed the lowest results among the synthetics and was comparable to the natural aggregate (rolled pebble). On the other hand, AGS 80, and especially AGS 90, which exceeded the recommended limits (DIN 4226:2002[46]; WBTC No.12/2002[47]), exhibited higher water absorption compared to the others. It is evident that the absorption of the aggregates was influenced by variations in RB and silica content. According to[48,49], increasing the silica content in the composition thickens the vitreous layer in the aggregates, thereby reducing porosity and, consequently, water absorption.

Regarding the specific gravities of the aggregates, excluding AGS 90, all were above 2.0 g/cm³, placing them in the normal-density aggregate category. The silica present in the aggregate composition, as previously mentioned, contributes to pore closure and, consequently, also increases the density of the material.

Figure 8 – Physico-mechanical characterization of the coarse aggregates. Granulometric variables



According to the granulometric data presented in Figure 8, the shape index of the aggregates classified them as elongated-lamellar according to ABNT NBR 7809:2019[31]. Based on the uniformity coefficient of the aggregates, with the slight exception of AGS 70, they exhibited non-uniform granulometry (preferable for concrete according to[13].

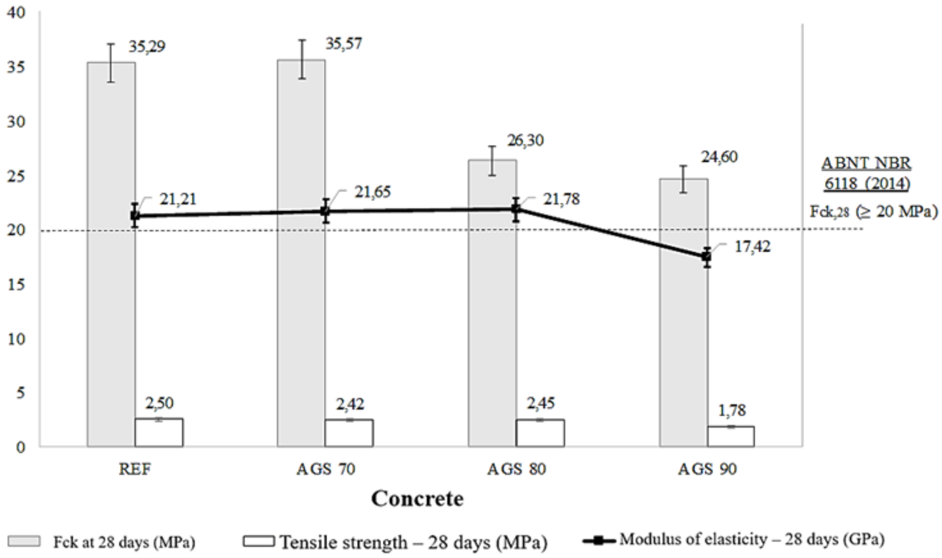
The fineness modulus of the aggregates showed very similar values, consistent with the referenced technical specifications. It is worth noting that due to the shaping process (extrusion) used in the production of the synthetic aggregates, all of them assumed a maximum characteristic diameter of 19 mm.

Physico-mechanical characterization of concrete

Mechanical Properties

The graphs in Figures 9 and 10 show the averages of the results obtained in the mechanical characterization tests of the concretes.

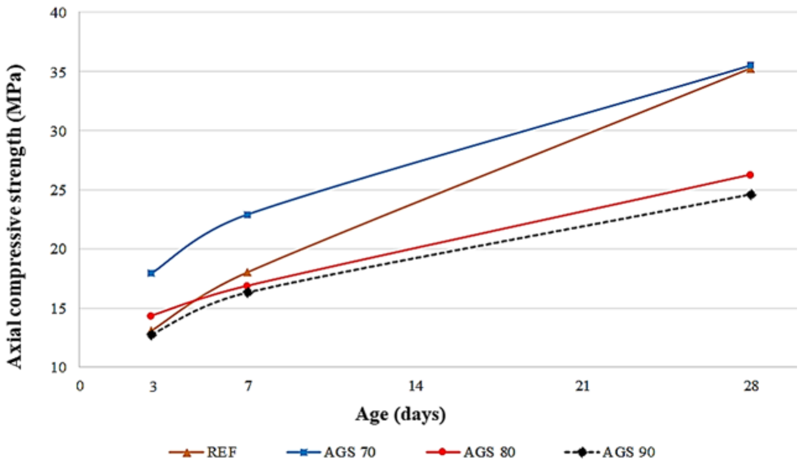
Figure 9 – Mechanical characterization of the concretes



According to the results presented in Figure 9, the axial compressive strength of the concretes at 28 days ($F_{ck,28}$) met the regulatory specification of ABNT NBR 6118:2014[42], remaining above 20 MPa. Based on this, the concretes were classified as structural according to the cited standard. Notably, the concrete with AGS 70 achieved the highest compressive strength, alongside the concrete with natural coarse aggregate (REF).

Regarding splitting tensile strength and static modulus of elasticity, the concretes except for AGS 90 showed very similar values with low variability, despite the different mortar contents.

Figure 10 – Development of axial compressive strength of the concretes over time



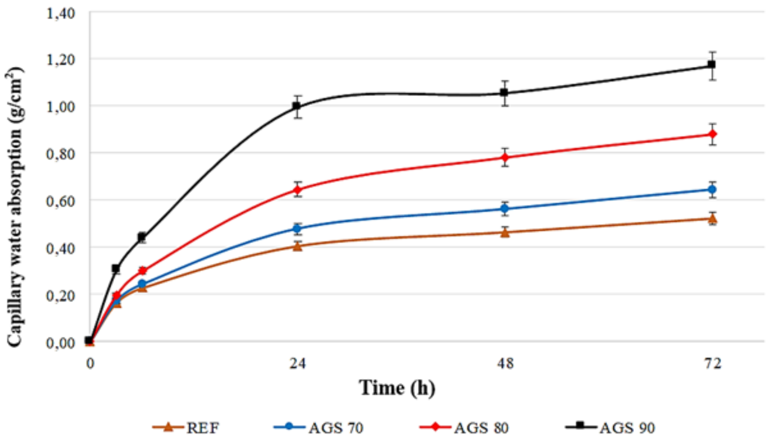
Analyzing the mechanical performance of the concretes over time (Figure 10), it can be observed that the initial development of compressive strength for REF, AGS 80, and AGS 90 (at 3 and 7 days) was similar, while AGS 70 was and remained superior from the beginning. At 28 days, AGS 70 and REF showed very similar results, whereas the concretes with AGS 80 and AGS 90 exhibited somewhat lower but close values at the same final age.

Studies by[12], focusing on the production of concretes with synthetic RB aggregates, indicate that the increase in axial compressive strength when using such aggregates (e.g., AGS 70) is attributed to their lower abrasion wear. The improvement in the mechanical properties of the concrete when using synthetic RB aggregates is also linked to the higher silica content in the composition of these aggregates[12].

Water absorption by capillarity

In the determination of water absorption by capillarity, the concretes showed the average results presented in the graphs of Figures 11 and 12.

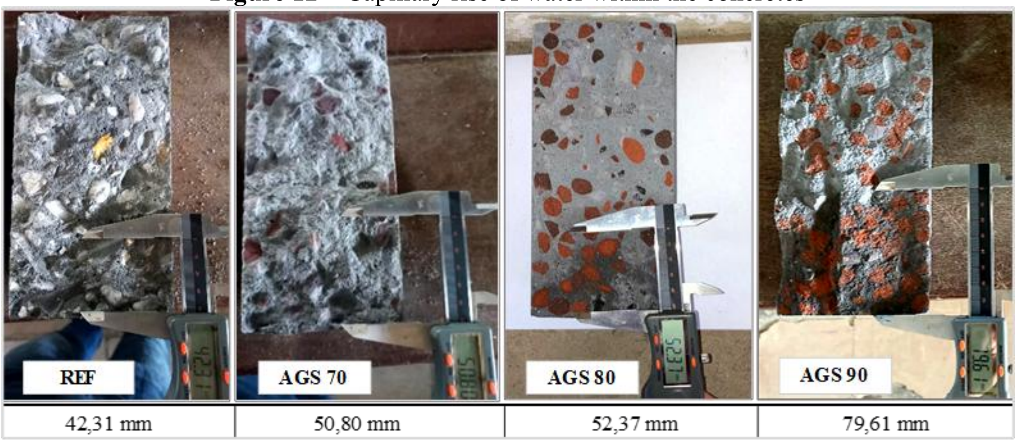
Figure 11 – Capillary water absorption of the concretes over time



As shown in Figure 11, the final capillary absorption of the concretes exhibited a distinct and increasing behavior, starting with REF, followed by AGS 70, AGS 80, and AGS 90 in sequence.

Within the first 24 hours of testing, differences in absorption were already noticeable. The concrete with AGS 70 showed the lowest absorption among the synthetics, approaching that of the concrete with natural aggregate, despite differences in mortar content. It is noteworthy that the capillary absorption of the concretes maintained a certain individual proportionality with the water absorption of the coarse aggregates.

Figure 12 – Capillary rise of water within the concretes



Regarding the capillary rise of water within the specimens (Figure 12), it exhibited the same behavior as capillary absorption, showing a linear increasing trend starting with REF, followed by AGS 70, 80, and 90, respectively. As expected, the concrete with AGS 70 showed the lowest capillary rise among those containing synthetic aggregates.

As previously evidenced in the characterization of the coarse aggregates, which had different water absorptions due to their compositional silica content, this factor may have significantly influenced the differences in capillary absorption of the concretes and their respective mortar contents. According to[50, 51], the lamelo-angular shape and minor variations in the shape index of the aggregates can also affect the rheology of the concretes, which in turn impacts their porosity differences.

IV. Conclusion

Based on the results obtained and their respective discussions, it can be concluded that the analyzed synthetic BR aggregates met the technical and normative specifications for use in structural concrete, contributing satisfactory physical and mechanical properties for this purpose. Other specific conclusions could be drawn from the results, such as:

• The synthetic aggregates were found to be non-reactive in the potential reactivity tests, thus not favoring the álcali aggregate reaction (AAR);

• The intrinsic characteristics of the synthetic aggregates (AGS 70 and AGS 80) showed satisfactory results, meeting the specifications for use in structural concrete, with only AGS 90 as an exception due to its higher water absorption;
• The rheology of the concretes exhibited distinct behavior due to the different absorption capacities of the coarse aggregates, requiring adjustments in the mortar content to achieve adequate consistency, workability, and cohesion according to their intended structural applications (e.g., columns, slabs, and beams);
• The axial compressive strength (at 28 days) met the requirements of ABNT NBR 6118 (2014) [41], exceeding 20 MPa, thereby classifying the concretes as structural for exposure class I environments. The concrete containing AGS 70 demonstrated the best mechanical performance among those produced with synthetic aggregates;
• The capillary water absorption of the concretes followed a similar linear increasing trend to that of the synthetic coarse aggregates. The concrete containing AGS 70 presented the best physical performance, showing the lowest capillary absorption.

References

[1]. IEB – Instituto De Engenharia. Revista Engenharia [Online], Ano 76, Nº. 641, São Paulo - SP, Brasil. Imprensa Editorial LTDA, Julho/2019. Disponível Em: Https://Www.Institutodeengenharia.Org.Br/Site/2019/09/24/Edicao-641/ (Acesso: 15/12/2022).
[2]. OLIVEIRA, L. S.; ÂNGULO, S. "Entrevista - Agregados, Meio Ambiente E O Desafio Da Economia Circular (2020)". Escola Politécnica Da Universidade De São Paulo - EPUSP.
Disponível Em: Http://Cics.Prp.Usp.Br/Wp-Content/Uploads/2020/07/Entrevista-Agregado-E-Meio-Ambiente-Diagramado-.Pdf (Acesso: 20/12/2022).
[3]. HILDEBRANDO, E. A. "Aplicação Do Rejeito Do Processo Bayer (Lama Vermelha) Como Matéria-Prima Na Indústria De Cerâmica Estrutural". Dissertação De Mestrado. Programa De Pós- Graduação Em Engenharia Química - UFPA, 1998.
[4]. ABAL - ASSOCIAÇÃO BRASILEIRA DO ALUMÍNIO. "Alumínio Brasileiro: Soluções Para Uma Vida Sustentável". Publicação Própria. São Paulo - SP, 2017. 66p. Disponível Em: Http://Abal.Org.Br/Manifesto-Do-Aluminio/Downloads/ABAL-Aluminio-Sustentavel.Pdf (Acesso: 15/08/2022).
[5]. POWER, G., GRÄFE, M., KLAUBER, C., "Bauxite Residue Issues: I. Current Management, Disposal And Storage Practices". Hydrometallurgy 108, Pp. 33–45. 2011.
[6]. EVANS, K., NORDHEIM, E., TSESMELIS, K., "Bauxite Residue Management ", Light Metals 2012, Pp63-66, TMS, Wiley, Orlando, 2012.
[7]. ZHANG, J.Z., LIU, S.J., YAO, Z.Y., Et Al. "Environmental Aspects And Pavement Properties Of Red Mud Waste As The Replacement Of Mineral Filler In Asphalt Mixture", Constr. Build. Mater. 178, 288–300, 2018.
[8]. LI, N., HANB. R., LU. X., "Bibliometric Analysis Of Research Trends On Solid Waste Reuse And Recycling During". Pp. 1992–2016, Resources, Conservation & Recycling 130, Pp. 109–117, 2018.
[9]. CASTRO, R.J.S., SOARES, R.A.L., NASCIMENTO, R.M., "Produção De Revestimento Cerâmico Semi-Poroso Com Adição De Chamote De Telhas", Revista Matéria, V. 17, N. 4, Pp. 1166 –1175, 2012.
[10]. ROSSI, C. R. C. "Concretos Para Reparo Com Agregados De Lama Vermelha Sob Abrasão Hidráulica". 2009. Trabalho De Conclusão De Curso. (Especialização Em Engenharia Civil) - Faculdade De Engenharia Civil, Universidade Federal Do Pará, Belém, 2009.
[11]. ROSÁRIO, K. A. "Concreto Com Utilização De Agregado Graúdo Sintético Produzido A Partir Da Lama Vermelha: Estudos De Dosagem, Propriedades E Microestrutura". Programa De Pós-Graduação Em Engenharia Civil. Belém, PA; 2013.
[12]. SOUZA, J. "Estudo E Avaliação Do Uso De Resíduos Do Processo Bayer Como Matéria Prima Na Produção De Agregados Sintéticos Para A Construção Civil". (Tese De Doutorado). Universidade Federal Do Pará, Belém-PA, 2010.
[13]. AIRES, M. F. M. & PAIVA A. E. M. – "Utilização De Agregados Graúdos Sintéticos De Lama Vermelha E Argila Em Concretos". 58° Congresso Brasileiro De Cerâmica, Bento Gonsalves, RS, 2014.
[14]. MUDGAL. M.; CHOUHAN, R.; VERMA, S.; AMRITPHALE, S.; DAS. S.; SHRIVASTVA, A. Radiochimical Acta, 106 (2018) 59.
[15]. SOUZA, P. H. R., Arraes, L. A. X., Marques, M. S. P., & Santos, J. C. M. "Utilização Da Lama Vermelha Para A Produção De Agregado Sintético". Revista Científica Multidisciplinar Núcleo Do Conhecimento, 6(3), 30-43, 2019.
[16]. SUN, Y. Et Al. "Production Of Lightweight Aggregate Ceramsite From Red Mud And Municipal Solid Waste Incineration Bottom Ash: Mechanism And Optimization". Construction And Building Materials, Journal, 287 (2021) 122993.
[17]. TIAN, K.; WANG, Y.; HONG S.; ZHANG, J.; HOU, D.; DONG, B.; XING, F. Construction And Building Materials, Journal, 281 (2021) 122552.
[18]. SANTOS, D. H. "Utilização Do Rejeito Do Processo Bayer Como Matéria Prima Na Produção De Agregados Leves". (Dissertação De Mestrado). Universidade Federal Do Pará, Belém-PA, 2011.
[19]. ISAIAS, JR. L. F. Et Al. "Obtenção De Agregados Graúdos A Partir De Lama Vermelha Via Processo De Pelotização". Universidade Do Extremo Sul Catarinense, Departamento De Engenharia Química. Natal, RN; 2013.
[20]. GORDON, J.N.; PINNOCK, W.R.; MOORE, M.M. "A Preliminary Investigation Of Strength Development In Jamaican Red Mud Composites". Cement And Concrete Composites, V. 18, N. 6, P. 371-379, 1996.
[21]. ABNT NBR 16605 (2017): Cimento Portland E Outros Materiais Em Pó - Determinação Da Massa Específica.
[22]. ABNT NBR 16607 (2018): Cimento Portland - Determinação Dos Tempos De Pega.
[23]. ABNT NBR 11579 (2012): Cimento Portland - Determinação Do Índice De Finura Por Meio Da Peneira 75 μm (Nº 200).
[24]. ABNT NBR 16916 (2021): Agregado Miúdo - Determinação Da Densidade E Da Absorção De Água.
[25]. ABNT NBR 16972 (2021): Agregados - Determinação Da Massa Unitária E Do Índice De Vazios.
[26]. ABNT NBR NM 248 (2003): Agregados - Determinação Da Composição Granulométrica.
[27]. ABNT NBR 14656 (2001): Cimento Portland E Matérias-Primas - Análise Química Por Espectrometria De Raios X - Método De Ensaio.
[28]. ABNT NBR 15577 (2018): Agregados - Reatividade Álcali-Agregado - Guia Para Avaliação Da Reatividade Potencial E Medidas Preventivas Para Uso De Agregados Em Concreto.
[29]. ABNT NBR 16917 (2021): Agregado Graúdo - Determinação Da Densidade E Da Absorção De Água.

[30]. ABNT NBR 7809 (2019): Agregado Graúdo - Determinação Do Índice De Forma Pelo Método Do Paquímetro - Método De Ensaio.
[31]. ABNT NBR 16974 (2021): Agregado Graúdo - Ensaio De Abrasão Los Angeles.
[32]. DNER-ME 399. MT - Departamento Nacional De Estradas De Rodagem. Diretoria De Desenvolvimento Tecnológico – IPR. Agregados - Determinação Da Perda Ao Choque No Aparelho Treton (1999).
[33]. REIS, André W. C. Caracterização Mineralógica Do Agregado Obtido A Partir Da Lama Vermelha Do Processo Bayer. Programa De Pós-Graduação Em Engenharia Química. Belém-PA, 2014.
[34]. SOUZA, J. A. Da S.; MACÊDO, A. N.; MONTINI, M. "Agregado Sintético De Resíduo De Bauxita Para A Construção Civil: Produção E Caracterização". Relatório Interno 02 - Materiais De Partida: Análises E Caracterização. Programa De Pós-Graduação Em Engenharia De Processos. Universidade Federal Do Pará. Belém-PA, 2021.
[35]. RASHAD, A.M. "Lightweight Expanded Clay Aggregate As A Building Material – An Overview". Construction And Building Materials, 170, P. 757–775, March, 2018.
[36]. GAO, H.; XIA, S.; CHEN, F.; STUEDLEIN A., W.; LI, X.; WANG, Z.; SHEN, Z.; CHEN, X. "Dynamic Shear Modulus And Damping Of Cemented And Uncemented Lightweight Expanded Clay Aggregate (LECA) At Low Strains". Soil Dynamics And Earthquake Engineering, 142, P.1-11, January, 2021.
[37]. ROCES-ALONSO, E.A.; GONZÁLEZ-GALINDO, J. "Experimental Study On Grain Failure Of Lightweight Expanded Clay Aggregate Under Uniaxial And Biaxial Load Conditions", Powder Technology, 383, P. 542–553, January, 2021.
[38]. ABNT NBR 10005 (2004): Procedimento Para Obtenção De Extrato Lixiviado De Resíduos Sólido.
[39]. ABNT NBR 10006 (2004): Procedimento Para Obtenção De Extrato Solubilizado De Resíduos Sólidos.
[40]. HELENE, P.; TERZIAN, P. "Manual De Dosagem E Controle Do Concreto". São Paulo: Pini; Brasília - DF: SENAI, 1993.
[41]. ABNT NBR 6118 (2014): Projeto De Estruturas De Concreto — Procedimento.
[42]. RIBEIRO D. V. Et Al. "Análise Da Difusão De Cloretos No Concreto Contendo Lama Vermelha". Revista IBRACON De Estruturas E Materiais, Volume 5, Abril De 2012.
[43]. BICZÓK, I. "Corrosión Y Protección Del Hormigón". 6. Ed. Bilbao: Urmo, 1972.
[44]. HOBBS, D.W. "Alkali-Silica Reaction In Concrete". London: Thomas Telford, 1988.
[45]. DIN - DEUTSCHES INSTITUT FÜR NORMUNG. DIN 4226-100: Aggregates For Concrete And Mortar, Part 100: Recycled Aggregates. Germany, 2002.
[46]. WORKS BUREAU TECHNICAL CIRCULAR. WBTC No.12: Specifications Facilitating The Use Of Recycled Aggregates, Hong-Kong, 2002.
[47]. SANTOS, D. H. "Utilização Do Rejeito Do Processo Bayer Como Matéria Prima Na Produção De Agregados Leves". (Dissertação De Mestrado). Universidade Federal Do Pará, Belém-PA, 2011.
[48]. JÚNIOR, Adiel J. P. Da Cunha; COSTA, Dênis Carlos Lima; MACÊDO, Alcebíades Negrão. "Análise Sistemática Da Literatura Sobre O Uso Do Rejeito De Lama Vermelha Para A Produção De Agregados Sintéticos Leves". Research, Society And Development, V. 11, N.5, 2022.
[49]. TROIAN, Aline. "Avaliação Da Durabilidade De Concretos Produzidos Com Agregado Reciclado De Concreto Frente À Penetração De Íons Cloreto". Dissertação De Mestrado. Universidade Do Vale Do Rio Dos Sinos. São Leopoldo-RS, 2010.
[50]. SILVA, Danillo De A. E; GEYER, André Luiz Bortolacci; PANTOJA, João Da Costa. "Porosidade Do Concreto Versus Forma Do Agregado Graúdo". Brazilian Journal Of Development, V. 6, N. 8. Curitiba-PR, 2020.