Potential Use of Amazon River Sediments in Civil Construction: Environmental and Socioeconomic Perspectives

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Abstract: It is estimated that the Amazon River transports 1.2 billion tons of sediment annually from the Andes. Research indicates that Amazon sediments can be used in the production of mortars, concrete, and other construction materials, exhibiting favorable physical and mechanical properties. To contribute to this topic, this article explores the potential reuse of Amazon River sediments in civil construction, highlighting their capacity to promote sustainability and reduce environmental impact. Physical, chemical, and mineralogical analyses of the sediments were conducted, confirming their composition rich in quartz and clay minerals. The results of the analyses confirm other studies as an excellent raw material for production in the construction industry.
KEYWORDS: Amazon River Sediment; Civil Construction; Sustainability

1.Introduction

For a sustainable future, it is necessary to change current trends and rethink how to better manage available resources, as well as the development of new materials that do not degrade the environment. Industries, such as the construction industry, require large quantities of raw materials in their manufacturing processes, which negatively impacts the environment [1,2]. One way to minimize this impact is to use waste from other industries, or from within the industry's own supply chain, which, in the construction industry, would reduce the burden on natural resources and carbon emissions [3].

Another possibility is to seek different sources of raw materials, one option for civil construction being sediments from the Amazon River. For many years, the intense accumulation of sediments transported by the river has impacted Amazonian cities located along the Amazon River, which depend on river transportation to ensure the region's supply and economic sustainability [4]. Faced with this impasse, it is necessary to link the demands of industry with socioeconomic activities related to the navigability of the North region. It is noted that this opportunity aligns with the reduction in the extraction of natural resources that are being depleted and opens the possibility of other resources.

Studies indicate that the sediments of the Amazon River (Figure 1) originate from the Andes (the main source of Amazonian rivers) and are transported to the Atlantic Ocean. This phenomenon has been observed in the Amazon lowland region, as have the processes of storage (sedimentation) and resuspension. These phenomena result from changes in the hydraulic gradient over the course of the hydrological cycle [5,6].

Figure 01 - Sediments transported out of the Andes

Fonte: Aliança Águas Amazônicas (2023).

Lins [7] reports that the silting of the river and its tributaries significantly impacts navigability, interfering with transport capacity and speed, in addition to the formation of fluid mud [8], which affects the local economy. Therefore, the use of sediments from the Amazon River in civil construction, in addition to meeting industrial demand, would contribute to a local need.

1.1. Use of Amazon River sediments in Civil Construction

The geochemistry of the Amazon River is predominantly influenced by inputs from mountainous environments, especially the Andes Mountains in Peru and Bolivia. According to Oliveira [9], approximately 84% of the river's suspended solid sediments originate from these mountainous areas, while about 12% comes from other regions of the Amazon Basin. According to data from the Amazon Water Alliance [10], the Amazon River transports approximately 1.2 billion tons of sediment annually, passing through the Óbidos stretch, considered the narrowest of the river. Of these sediments, approximately 75% reaches the Atlantic, while the remaining 25% is deposited along approximately 800 km downstream.

Slumped land, a phenomenon resulting from climatic events and sediment displacement, is caused by global warming, which intensifies erosion processes on riverbanks. This erosion promotes the formation of ravines, according to Oliveira [9]. The sediments transported by these actions contribute to the formation of river islands, which can partially or completely disappear, giving rise to new sedimentary islands [11,7].

The dynamics of the Amazon River's flow directly influence the formation of these islands. The reduction in current speed favors sediment settling, which can compromise navigability in the region. This variation in flow results in reduced vessel carrying capacity, helping to minimize groundings, especially during the period known as the "Amazonian summer" (October to December), when water volume in the river's headwaters decreases [7].

To mitigate the impact of Amazon River sediments, research is seeking an alternative destination for this material. Studies have been conducted on the use of these sediments in construction, with the goal of reducing the extraction and intensive use of mineral resources through alternative utilization possibilities. For example, Pimental et al. [6] investigated the changes in coating mortar when natural aggregate was partially replaced with Amazon River sediment. The presence of clay minerals increased the mortar's tensile strength and led to the formation of stable crystalline products, suggesting greater stability for the coating.

Azevedo et al. [4] state that Amazon River sediment has immense potential for use as a supplementary cementitious material due to its chemical composition (SiO_2 + Al_2O_3 + Fe_2O_3 = 91.49%) and mineralogical characteristics, which allow it to be incorporated into cement without compromising its essential properties. The study demonstrated that Amazon River sediment improves the workability of the cement paste. Rozière et al. [12] verified the use of treated sediments in self-compacting concrete as a substitute for aggregates and limestone fillers (mineral additives). As a result, they obtained a dense cement paste with compressive strength equivalent to that of conventional materials.

Ennahal et al. [13] used marine and river sediments from northern France in their studies, which were recovered as mineral aggregates for the composition of polymeric mortars for floor coverings. The mortars showed low void content and good chemical resistance, indicating the potential for using these sediments in polymeric matrix materials as well.

Given the relevance of the studies presented and the limited amount of available data, a gap remains to be explored: the use of Amazon River sediments in civil construction as a partial replacement for traditional inputs. This approach can add value by fostering more sustainable performance for the industry and the local population. In this context, this article aims to present the characteristics of Amazon River sediments with a focus on their potential use in the production of materials in civil construction.

2. Methodology

To utilize Amazon River sediment in civil construction, its characteristics must be understood. Therefore, physical, chemical, and mineralogical characterizations were performed using analytical techniques and instruments. For this study, 200 kg of sediment was collected from the riverbed in a silted area on the dryland banks, at a distance of 200 m, called the sediment strip. This strip forms a "beach" where, starting 100 m away, the sediment is collected using wooden boxes measuring 170 cm x 30 cm x 30 cm, allowing for storage during tides. The sediments were then removed from the river, bagged, and transported to an open area, where moisture was removed and sieved. The collection criterion considers not interfering with the local ecosystem surrounding the riverbanks (organic matter - humus); therefore, this distance is important. For a new collection, try to maintain a distance from the initial collection site, covering an area of 1 hectare. The material's particle size distribution curve was obtained by diffraction with previously measured particle size standards. A PSA 1190L (Anton Paar) laser particle sizer with a reading range of 40 nm to 2.5 mm was used. The mineralogical composition was determined by X-ray diffraction (XRD) using a Bruker D2 Phaser model, with a 30 kV, 10 mA copper target tube, wavelength (λ) of 0.15406 nm, and no secondary monochromator filtering system. The diffraction spectra were in the 2θ range from 5° to 90°, continuous mode at 0.04°/s. The micromorphology of the sample was analyzed by scanning electron microscopy (SEM) with DENTON VACUUM (model JEOL-JSM-6510LV) and Thermo Scientific equipment. The XRF Axios Max equipment from Panalytical was used to study the chemical composition of the sediment.

3. Results and discussions

3.1. Granulometry

The particle size range of the Amazon River sediment was 1 and 100 µm, and the equivalent diameters (D10, D50, and D90) were 2.24 µm, 12.24 µm, and 46.35 µm, respectively. Most of the grains were between 0.002 mm and 0.05 mm, classifying the material as silty. This classification suggests a potential use in civil construction, as fine particles, such as silt, act to fill the voids between larger aggregates, promoting better packing for the mixture Santos, [14]. For example, in the study by Hussain et al. [3], sediments dredged from the Usumacinta River, France, were reused for adobe bricks. The laser granulometric test yielded percentages of clay (5.9%), silt (41.3%), and sand (52.80%) with an average D50 diameter of 51.85 µm. In the adobe bricks, the percentages of silt (41.3%) and clay (5.9%) promoted cohesion and minimized shrinkage.

In both cases, the sediments extracted from rivers presented fine grain sizes, which can contribute to good workability and adhesion. However, it is essential to perform appropriate analyses regarding the amount of water and additives to ensure good product performance.

3.2. Chemical Characterization

Chemical analyses were performed by X-ray fluorescence for the following oxides, yielding the following results, table 1.

Table 1 – Chemical composition obtained for the mineral fillers evaluated

Material	Óxidos (%)									
	SiO_2	Al_2O_3	Fe_2O_3	K_2O	MgO	Na_2O	CaO	TiO_2	Outros	P.F.*
A- Sediment	78,55	9,87	3,36	1,77	0,84	1,09	0,99	0,68	0,37	2,48
B- Sediment	78,87	9,48	3,14	1,57	0,67	1,44	0,89	0,71	0,12	3,04
C- Sediment	78,87	9,48	3,14	1,57	0,35	1,44	0,89	0,71	0,12	3,04

A- Sediment Source: Authors (2025); B [6];C[4]

The sediment exhibits a high SiO_2 content, possibly in the form of quartz, in addition to clay minerals. Regarding loss on ignition, the sediment presented a percentage of 2.48%, indicating high purity and thermal stability under high temperature conditions. The results obtained are similar to those of Azevedo et al [4];Pimentel and Paes [6], who also observed a high SiO2 value (78.87%) in the form of quartz, an inert material when in a cementitious matrix.

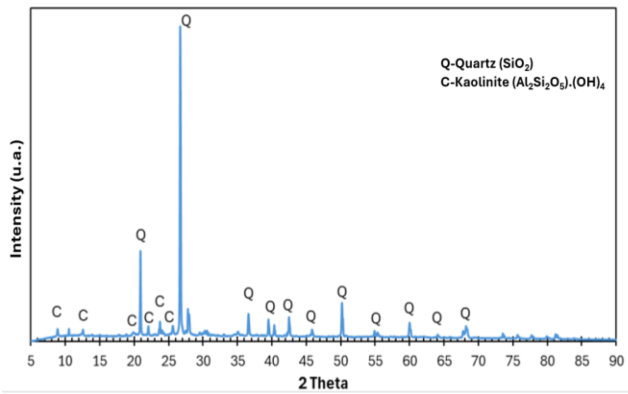
Unlike the applications discussed in previous studies, Laoufi et al. [15] used sediment to partially replace cement through the calcination process. For this purpose, the sum of the oxides ($SiO_2 + Al_2O_3 + Fe_2O_3$) presented values close to the 70% limit, as established by the ASTM C618-3 [16] standard, which corroborates the feasibility of its application. Therefore, the relevance of using river sediments both in the production of aggregates and in the partial replacement of cement as a pozzolanic material is highlighted, especially due to the presence of hydrated clay minerals, such as kaolinite, contributing to the reduction of costs and CO_2 emissions.

3.3. Mineralogical Characterization

The result of the diffractogram of the Amazon River sediment (Figure 2) indicates the presence of two crystalline phases: quartz (SiO_2) and kaolinite [$Al_2Si_2O_5(OH)_4$]. This result corroborates that obtained through XRF, since the identified oxides compose the minerals.

The presence of quartz and kaolinite in the Amazon River sediment is closely linked to the natural erosion process that occurs along its banks. Kaolinite is formed by the weathering of feldspar and other aluminosilicates under acidic conditions [17]. Quartz, on the other hand, is found in sedimentary deposits. These minerals have been widely used in processes related to sustainability and materials innovation due to their physicochemical properties [18,19, 20, 21, 22, 6].

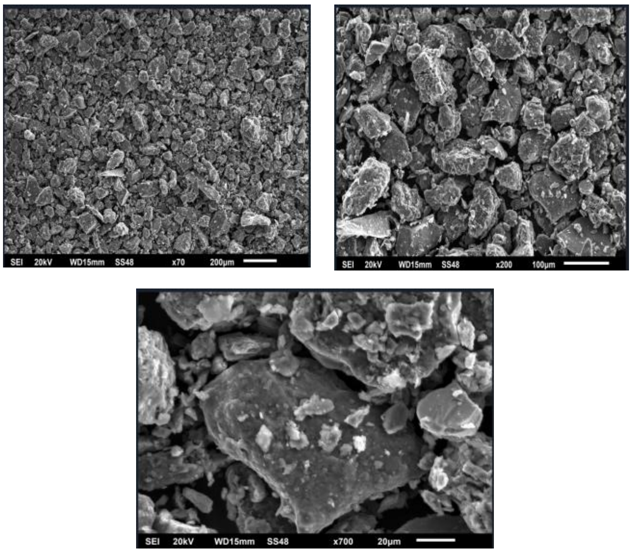
Figure 2 - Diffractogram of the Amazon River sediment.



3.4. Micromorphology

Figure 3 shows the image obtained from the scanning electron microscopy (SEM) test performed on the Amazon River sediment. The images show that the particles are smaller than 100 µm, corroborating the data obtained from the laser particle size analysis. The particle size distribution is somewhat heterogeneous, with diameters ranging from less than 1 micrometer to 90 micrometers. Furthermore, the presence of smoother particles with low roughness, typical characteristics of the mineral quartz, is observed [6, 23]. In Figure 3, it is also possible to note that the smaller particles, below 1 micrometer, exhibit characteristics of the mineral kaolinite, presenting tabular, pseudo-hexagonal, euhedral and subhedral crystals, the latter resulting from particles with irregular shapes, which reflect different orientations and crystalline arrangements of the mineral [24]. In general, fluvial sediments exhibit irregular contours and sharp edges, resulting from mechanical fragmentation and turbulent transport [25].

Figure 3 - SEM micrographs obtained for the Amazon River sediment sample**.**



As in the study by Rozière [13], developed for self-compacting concrete, the presence of randomly distributed mineral crystalline phases in the sediment particles was identified, including large crystals (> 50 µm) of quartz, hematite, albite, and orthoclase, which corroborates the results obtained in this study regarding chemical characterization. The presence of these minerals contributes to increased mechanical strength in mortars and concretes due to their highly hard structure. Rozière [12] reported that the mix for self-compacting concrete requires a significant amount of sediment. Although the initial average particle size was relatively large, microstructural analyses demonstrated that the largest particles were fragmented during concrete mixing, favoring particle packing and, consequently, improving the material's workability.

The characterization performed in this study on Amazon River sediment presented results that are consistent with those already demonstrated in the literature, reinforcing the viability of its use for industrial purposes. Therefore, it contributes to sustainable processes and, mainly, to reducing the consumption of conventional mineral resources in civil construction.

4. Conclusion

This study demonstrated river sediment as a viable alternative for the construction industry, potentially used as an aggregate or as a partial replacement for cement through the calcination process. Furthermore, its potential for producing adobe bricks, coating mortars, and self-compacting concrete stands out. The use of Amazon River sediments offers potential for reducing the consumption of conventional raw materials, which are becoming depleted, and opens opportunities for new resources. Furthermore, this practice can play a strategic role in improving navigability and mitigating the impacts of climate phenomena affecting the North region. To this end, it is essential to strengthen research and formulate public policies that promote the responsible reuse of these sediments, ensuring lasting benefits for the region's sustainable socioeconomic development.

5. References

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