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DEVELOPMENT OF LIGHTWEIGHT CONCRETE BLOCKS USING CONSTRUCTION AND DEMOLITION WASTE, AND THERMOELECTRIC ASH

DESARROLLO DE BLOQUES DE CONCRETO LIVIANOS UTILIZANDO RESIDUOS DE CONSTRUCCIÓN Y DEMOLICIÓN, Y CENIZAS DE TERMOELÉCTRICA

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Resumen: Los residuos de la construcción y demolición (RCD) representan un serio problema medioambiental global, debido a su elevado volumen e impacto en nuestro entorno. Este documento muestra la fabricación de bloques de concreto utilizando RCD, una opción tanto ecológica como económica que podría minimizar la cantidad de desechos que acaban en los vertederos y disminuir la explotación de nuevos materiales naturales. En Colombia, especialmente en el departamento del Norte de Santander, la gestión de RCD plantea importantes retos, aunque se están realizando esfuerzos para mejorar su manejo y fomentar una economía circular en el sector de la construcción. La meta de esta investigación fue incorporar RCD y ceniza de central termoeléctrica en la mezcla de agregados para la fabricación de bloques de concreto en el área metropolitana de Cúcuta, con el fin de fomentar la sostenibilidad en el sector constructor y minimizar el impacto medioambiental de los residuos procedentes de construcción y demolición. Se tiene la esperanza de que este estudio incentive el uso de RCD en la creación de bloques de concreto tanto en Colombia como en toda Latinoamérica.

Palabras clave: RCD, Concreto reciclado, Economía Circula, Concretos livianos

Abstract: Construction and demolition waste (RCD) represents a serious global environmental problem, due to its high volume and impact on our environment. This paper shows the manufacture of concrete blocks using RCD, both an ecological and economical option that could minimize the amount of waste that ends up in landfills and reduce the exploitation of new natural materials. In Colombia, especially in the department of Norte de Santander, RCD management poses significant challenges, although efforts are being made to improve its management and promote a circular economy in the construction sector. The goal of this research was to incorporate RCD and ash from thermoelectric plants into the aggregate mix for the manufacture of concrete blocks in the metropolitan area of

Cúcuta, in order to promote sustainability in the construction sector and minimize the environmental impact of construction and demolition waste. It is hoped that this study will encourage the use of RCD in the creation of concrete blocks both in Colombia and throughout Latin America.

Keywords: RCD, Recycled concrete, Circular economy, Light concrete

1. INTRODUCTION

Construction and demolition waste (RCD) have become a critical environmental concern worldwide, given its magnitude and its impact on the environment (Guarin et al., 2017). Poor management of RCD can lead to serious environmental problems, such as soil and water pollution, greenhouse gas emissions, exacerbating climate change, and reducing biodiversity by altering natural habitats.
Likewise, RCD can constitute a significant threat to the health and safety of the population if they are abandoned in inappropriate sites, such as vacant land, rural areas, or even along highways. (Sanchez Molina et al., 2022).

Research at a global level has employed RCD in a wide range of applications, such as recycled concrete production (Lotfi et al., 2015; Wagih et al., 2013), recycled mortars (Givi et al., 2010) and even in the reuse of its aggregates in other types of civil engineering projects (Contreras-Llanes et al., 2021). In addition, there are innovative alternatives for the sustainable and cost-effective reuse and recycling of RCD, such as the manufacture of concrete blocks from RCD, which could significantly reduce the volume of waste that ends up in landfills and the need to extract new materials from nature (Abraham et al., 2022).

The development of concrete blocks with RCD has been the subject of several scientific analyses. Based on previous research, the manufacture of concrete blocks with RCD can represent an economic and sustainable alternative for the construction industry in Latin America. RCD recycled aggregates are suitable for the production of concrete blocks (Leal et al., 2022; Silva et al., 2023).

In Colombia, specifically in the department of Norte de Santander, there are significant challenges in the management of RCD, lack of adequate infrastructure for waste management and recycling and lack of effective policies and regulations to control waste. Despite these obstacles, efforts are being made to improve the management of RCD in Colombia and Norte de Santander, including initiatives and policies that encourage the reduction and re-use of construction and demolition waste in the production of sustainable building materials. These efforts seek to boost the circular economy in the construction industry, as well as minimize dependence on the extraction of new materials and the accumulation of waste in landfills (Ali, 2023).

The purpose of the following research was to take advantage of this waste as part of the aggregates used in concrete blocks in the metropolitan area of Cúcuta, in order to contribute to the sustainability of the construction sector and reduce the environmental impact of construction and demolition waste (Ma et al., 2023; Sharma et al., 2023).

2. MATERIALS AND METHODS

The methodology used in this study consisted of four main stages. In the first phase, construction waste originating in the metropolitan area of Cúcuta was collected. Subsequently, these wastes were subjected to a manual crushing process to obtain the recycled aggregates that would be incorporated in the manufacture of concrete blocks. In the third stage, a characterization of raw materials was carried out, which included both recycled and natural aggregates used in the production of concrete blocks.

A base formulation was then proposed to partially replace the thicker aggregate with RCD, as well as a portion of the fine aggregate with thermoelectric ash. Finally, cylinders were prepared to determine the appropriate percentages and then concrete blocks were produced using the established proportions. These blocks were tested for compressive strength and water absorption.

2.1. Collection of construction waste

To develop this study, concrete residues were collected produced by the materials resistance laboratory of the Francisco de Paula Santander University (UFPS), where simple compression tests of cylinders manufactured by students are carried out. The collection of this waste was carried out meticulously and respecting the safety regulations established for the handling of said materials.

Fig. 1. Collection of construction and demolition waste.
Source: own elaboration.

The collection of waste was carried out with appropriate tools and equipment to guarantee the physical integrity of the collectors and avoid damage to the collected waste. It is important to note that the collection of concrete waste from this specific source was carried out to ensure the homogeneity of the sample and the representativeness of the concrete waste generated at UFPS.

2.2. Manual crushing

Once the concrete waste was obtained, the manual crushing procedure was performed. This process involved the fragmentation of the waste through the use of hand hammers, emulating the primary crushing done with demolition pneumatic hammers.

Fig. 2. Crushing RCD Manual. Source: own production.

It is important to note that the waste was shredded to a size below 3/8" (9,5 mm), which allowed to obtain recycled aggregates of an appropriate size for the manufacture of concrete blocks.

2.3. Characterization of raw materials

Tests were performed on fine sand, coarse sand and RCD to evaluate particle size distribution and aggregate uniformity (NTC 77, 2018). Natural moisture tests were also performed to determine the water content in the aggregates, which allowed adjusting the amount of water required for the production of concrete blocks (NTC 1776, 1994).

In addition, loose and compacted unit weight tests were performed to assess aggregate density and compactness in the concrete mixture (NTC 237, 1995; NTC 176, 1995). These tests also made it possible to determine the appropriate quantity of aggregates required for the manufacture of concrete blocks.

2.4. Proposed dosages

To carry out this project, the following basic formulation was considered, which is the result of a mixing design by the ACI method:

Table 1: Basic dosage.

MATERIAL	QUANTITY (KG)
Cement	1
Coarse aggregate	1.24
Fine aggregate	2.15
Water	0.44

Cylinders were then manufactured with replacement percentages of the coarse aggregate of 25%, 50%, 75% and 100%, with the aim of identifying the proportion that provided the best resistance. Subsequently, new cylinders were produced with percentages of 2.5%, 5% and 7.5% of thermoelectric ash, replacing cement. Finally, blocks were developed for both base dosing and dosing with the optimal replacement of RCD and for mixing with optimal replacement of RCD and thermoelectric ash.

2.5 Block building

The concrete blocks were manufactured with RCD using a mould. Recycled aggregates and other components necessary for the production of concrete blocks, such as cement and water, were homogeneously mixed and poured into the mould. The concrete was then compacted into the mold by vibration to ensure proper density and resistance. The concrete blocks were left to heal for a period of 21 days, during which time they acquired their resistance.

Account was taken of the Colombian standards in force with regard to the elaboration of concrete blocks for the elaboration of this practice (NTC 4026, 1997; NTC 4076, 1997; NTC 4024, 2001)

3. ANALYSIS OF RESULTS

3.1. Characterization of raw materials

The findings of the characterization of raw materials, such as fine sand, coarse sand, which were obtained from the quarries of the Pamplonita River, and the RCD, showed the following results.

3.1.1 Granulometry

Figure 1 shows the results of the fine sand particle size test.

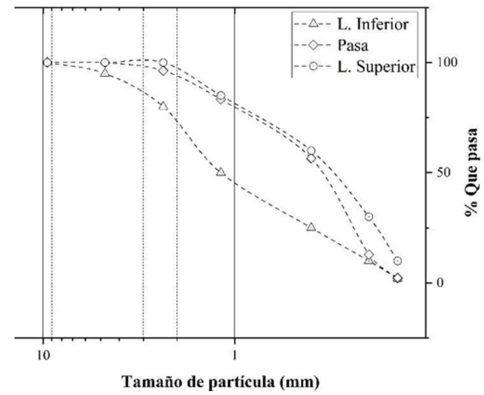

Fig. 3. Fine sand granulometry
Source: own elaboration.

Similarly, the granulometric results of coarse aggregate and RCD can be seen in figures 4 and 5. These were evaluated according to the ranges dictated by the regulations. (NTC 174: Concrete. Aggregates Specifications for Concrete., 2000).

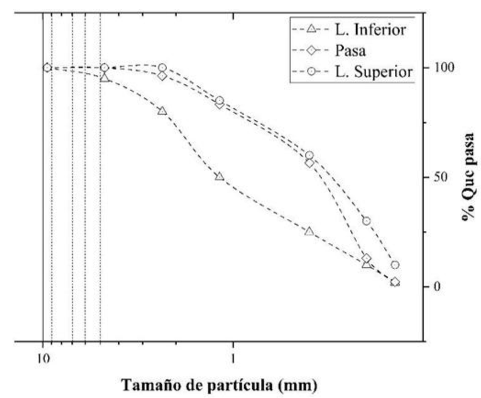

Fig. 4. Coarse sand granulometry
Source: own elaboration.

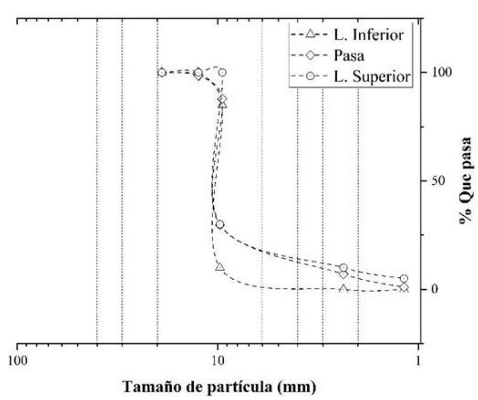

Fig. 5. RCD granulometry.
Source: own elaboration..

The particle size tests confirmed that the raw materials used complied with the particle distribution required by the regulations.

3.1.2 Natural water content

Table 2 shows the natural water content of each of these aggregates:

Table 2: Natural water content of aggregates.

AGGREGATE	NATURAL WATER CONTENT (%)
Fine sand	1.86%
Coarse sand	1.47%
RCD	2.23%

These contents allowed the necessary corrections to be made for the different dosages used. In addition, it was noted that the natural water content in RCD was slightly higher than in the other aggregates.

3.1.3 Loose and compact unit weights

Table 3 shows the loose and compact unit weights for each of these aggregates:

Table 3: Loose and compact unit weights of aggregates.

Aggregate	Unit weight (Kg/M^3)	Compact unit weight (Kg/M^3)
Fine sand	1628.07	1752.18
Coarse sand	1432.45	1555.58
RCD	1166.67	1284.81

Loose and compact unit weights were essential for the development of a more precise dosing proposal.

3.1.4 Specific weights and absorption

Table 4 shows the results related to the specific weight and absorption of each aggregate.

Table 4. Loose and compact unit weights of aggregates

Aggregate	Dry density (Kg/M^3)	Absorption (%)
Coarse sand	2592.02	1.051
Fine sand	2613.70	12.007
RCD	2393.51	5.940

These findings allowed to establish a better balance of aggregates in the mixture, in order to determine a concrete with a density of approximately 2085Kg/M3.

3.2. Resistance to unconnected compression

Figure 6 shows the results of unconnected compression resistance of cylinders with 0% RCD up to 100% RCD as a substitute for coarse aggregate.

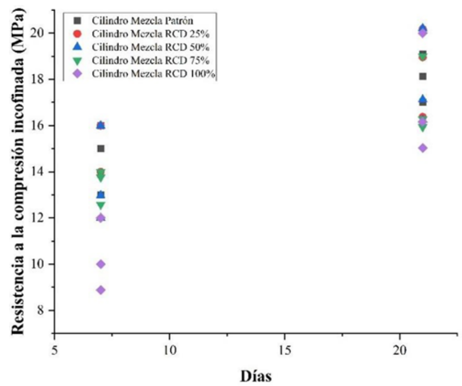

Fig. 6. Resistance to inconvenient compression of standard cylinders with RCD addition
Source: own elaboration.

Significant variability was observed in the resistance range in MPa, mainly during the first 7 days of curing. It is noticeable a decrease in resistance approximately in half, when comparing the cylinder containing 100% RCD with the reference.

However, at 21 days, the resistance of the cylinder with 100% RCD manages to match that of the cylinder with 0% RCD, although with a much higher standard deviation. Considering that the purpose of this research is the creation of an ecological block, the dosage was chosen with 100% RCD in order to maximize the use of this type of waste.

In Figure 7, the results of the cylinders with different % of thermal ash can be seen.

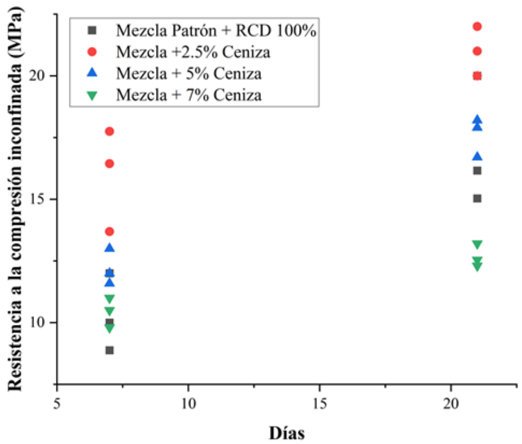

Fig. 7. Cylinders with 100% RCD + % microperlas.
Source: own elaboration.

The different dosages used for the development of these cylinders were:

Table 5: Dosages according to the percentage (%) of ash

Material	2.5% Microperlas Quantity (kg)	5% Microperlas Quantity (Kg)	7.5% Microperlas Quantity (Kg)
Cement	1.95	1.90	1.85
Fine sand	1.08	1.08	1.08
Coarse sand	1.08	1.08	1.08
RCD	1.25	1.25	1.25
Water	0.44	0.44	0.44
Ash	0.05	0.1	0.15

In this case, there is a degraded behavior in the resistance as more ash is added, also it is observed that the percentages of 2.5% and 5% exceed the values of the resistance of the mixture without adding ash, as the goal is to decrease the amount of raw materials, we choose to choose the mixture with 5% ash replacing cement.

Figure 8 shows the result of the unconnected compressive strength of the different blocks developed, these being the block with the master mixture, the block with the master mixture and 100% of the coarse aggregate replaced by RCD, block with 100% RCD + 5% of Thermoelectric ash and the conventional block that is normally on sale in the metropolitan area of the city of San José de Cúcuta.

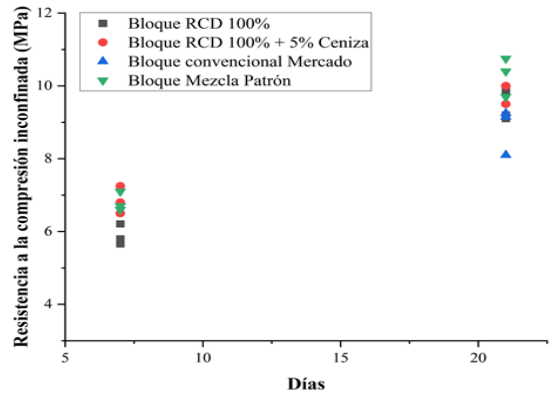

Fig. 8. Results compression concrete blocks in their different presentations.
Source: own elaboration.

The above figure shows a very similar behavior between the standard mixture, the conventional block and the block with RCD and ash, likewise, it is observed that in the short term the block with the lowest resistance is the one with 100% of RCD replaced by coarse aggregate, in addition to the blocks with less resistance were those found for sale to the general public.

Likewise, it is commented that each of the ecological blocks comply with the minimum resistance standards (5MPa) established by the NTC 4026.

Figure 8 shows the different densities of the blocks, as well as their absorption %

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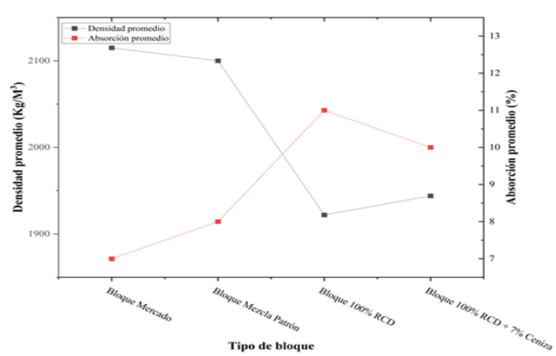

Fig. 9. Results of densities and percentages (%) of absorption of concrete blocks.
Source: own production

It is seen that the density of blocks decreased significantly as they went incorporating new materials into the mixture, the standard mixture reached the projected density, then the addition of RCD also contributed substantially to the weight decrease, however, the addition of ash slightly increased its density.

Likewise, it is seen that the percentage of absorption is inversely proportional to the density, since this was increasing as the density of the block decreased.

4. CONCLUSIONS

The creation of concrete blocks from RCD not only provides a solution to construction waste, but also benefits both the environment and the economy. The process leverages existing building materials, minimizing waste generation and promoting environmental sustainability.

Reusing these materials instead of generating new ones not only conserves natural resources, but also decreases the carbon footprint. Since the manufacture of new building materials is an important source of greenhouse gas emissions and air pollutants, this recycling approach can also contribute to improving air quality.

The production of cylinders with varying proportions of RCD and RCD combined with thermoelectric ash helped establish a precise methodology for the production of blocks, resulting in significant savings in time and materials. The addition of thermoelectric ash could have additional benefits beyond weight reduction, such as the potential to improve compression resistance, an area that could be explored further in future studies.

Comparison with conventional blocks provided a clear perspective on the advantages of these new green blocks, especially in terms of light concrete blocks for non-structural use.

This research paves the way for a range of exploration opportunities in the future. The application of RCD could be extended to a variety of engineering projects, which is especially relevant when considering the implications in terms of sustainable development.

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