Proceedings of the 10th World Congress on Civil, Structural, and Environmental Engineering (CSEE 2025)
Barcelona, Spain - April 13 - 15, 2025
Paper No. ICSECT 172
DOI: 10.11159/icsect25.172

Characterization of Hydraulic Concrete with Recycled Concrete Aggregates

César Isaac Álvarez González[1], Jean Carlos Paguada Castellón[1], Julio César López Zerón[1], Juan Carlos Reyes Zúniga and Karla Antonia Uclés Brevé[1]
[1]Universidad Tecnológica Centroamericana (UNITEC)
Kennedy Boulevard, V-782, in front of Residencial Honduras, Tegucigalpa, Honduras
cesaralvarez@unitec.edu; paguada_jeancarlos@unitec.edu; jclopezeron@unitec.edu; juancareyes@unitec.edu; karla_ucles@unitec.edu

Abstract **-** The rise of urban development has led to an increase in construction projects, resulting in the demolition of existing structures on sites designated for new construction. This demolition process generates construction waste, which becomes an environmental pollutant. In response to this issue, research has been undertaken to find solutions for waste management. One proposed alternative is the reuse of concrete waste as a replacement for natural aggregate materials such as sand and gravel in the production of hydraulic concrete. The treatment of construction waste involves a process that starts with the mechanical crushing of the material to produce smaller fragments. The recycled material is then subjected to laboratory tests to determine properties such as absorption, specific gravity, and bulk density. Test cylinders are prepared by substituting 33% of the natural aggregate with recycled aggregate, followed by tests with 66% recycled aggregate, and finally, 100% recycled aggregate. Additionally, research is conducted on the use of fine recycled aggregates in mortars, developing mortar cubes with the same principle of replacing natural aggregate with recycled aggregate in one-third increments. As an added value to the work, the same tests are performed for different mix combinations, with the inclusion of additives to evaluate their effect on the behavior of recycled concrete.

Keywords**:** Concrete stone aggregate, Recycled concrete aggregate, Density, Compressive strength.

1. Introduction

The study focuses on analyzing the mechanical and physical properties of hydraulic concrete waste to evaluate the use as recycled aggregate, which is crucial to promote sustainable construction practices, for which it is essential to understand the importance of recycled concrete properties to determine viability in the construction industry.

It will be shown that characteristics such as absorption and density of aggregates vary compared to conventional concrete, which directly affects compressive strength.

As part of the laboratory work, it will be shown that the compressive strength of recycled concrete tends to be lower, which could influence structural performance, therefore, the composition of recycled aggregates represents a challenge to meet quality standards and current regulations. However, the use of recycled construction materials not only reduces environmental impact by reducing waste accumulation and resource extraction but also offers economic advantages by reducing production costs.

1.1. Background of the Problem

The impact of construction on the environment is very diverse and occurs throughout all phases of construction, from the extraction and production of materials to the demolition of structures [1].

[2] Nowadays, with the expansion of urban projects, construction waste is increasing.

1.2. Problem Definition

Cylinders derived from compressive strength tests on hydraulic concrete not only consume space in construction waste landfills but also contain chemicals such as calcium hydroxide (hydrated lime), an essential component of Portland cement. This compound alters pH, which can be harmful to soil and water bodies if such waste is disposed of improperly [3].

Because aggregates comprise the largest percentage in a concrete mix, strength and durability are directly affected by their quality. The use of recycled aggregates produces new concrete that requires different stages, from demolition, removal to crushing to turn it into a new hydraulic concrete product with different characteristics [4].

1.3. Justification

At a global level, there has been a search to develop alternatives and innovations to use construction waste, with different innovative projects that have been of vital importance [5].

The incorporation of recycled aggregates in construction offers significant environmental advantages, by reducing the dependence on materials extracted from natural sources such as banks and quarries. In addition, it facilitates the management of demolition waste, contributing to a cleaner environment. From an economic perspective, the use of these aggregates can result in a notable decrease in construction costs. Recycling concrete for reuse as aggregate promotes more sustainable and eco-efficient concrete production [5].

Recycled aggregates obtained from construction and demolition have attracted more attention nowadays due to their promising potential for environmentally friendly concrete structures. In several countries, the shortage of natural aggregates causes higher transportation costs, the reduction of landfills and pollution has led to the use of recycled aggregates as a replacement in concrete production [1].

Therefore, exploring new sources of material production to mitigate the excessive exploitation and destruction of natural resources has become a vital priority. And recycled aggregate technology made from construction waste is an effective way to solve this problem [6].

2. Methodology

The study methodology section details the strategies, techniques, and procedures that will be used for data collection and analysis. The choice of these methodologies is based on the nature of the research problem, the objectives of the study, and the resources available. This section ensures that the research process is systematic and appropriate for obtaining accurate and relevant results.

2.1. Material recovery from construction waste

For the investigation, concrete cylinders that were previously tested in a laboratory (generally a compressive strength test) were used as waste or concrete waste, representing the construction waste that is typically generated because of the demolition of building structures or other similar works. The main treatment that the waste from these concrete cylinders received was the execution of a mechanical manual crushing process using specific tools for this purpose, and in this way, it was possible to collect the raw recycling material.

2.2. Treatment of recovered material

After crushing the construction waste (waste from previously tested concrete cylinders), the material was processed using a mechanical sieve with its respective set of sieves to develop the classification according to its particle size, implementing the granulometric analysis of the crushed waste, and taking as a work base the table described in the ASTM C33 standard.

In addition to the particle size test described above, the crushed concrete waste was also studied through the following laboratory tests:

Volumetric Weight of Coarse Aggregate (ASTM C-29)

Specific Weight of Coarse Aggregate (ASTM C-127)

2.3. Hydraulic concrete mix design with recycled concrete aggregates

Based on the recommendations of the American Concrete Institute (ACI) in its section 211.1-91 for mix design, working with a design strength of 300 kg/cm2 at 28 days (arbitrarily established), the initial dosage and quantities

required to produce 4”x8” cylinders are calculated, both with recycled concrete aggregate (RCA) and with additives, and for mortars with ARC.

Once the dosages and quantities of materials are obtained, taking as a reference that the proportions of coarse material material replaced by ARC are 33%, 66% and 100% (also arbitrarily established), the hydraulic concrete cylinders and mortar mortar cubes, both types of samples, are manufactured with recycled concrete aggregate (RCA) to be subjected to compression tests and record their strength.

Below is a summary of the quantities of materials for concrete mixes that were generated as a result of the implementation of the tables and procedures recommended by ACI211 for mix design, through the use of data obtained in laboratory tests on the base materials, as well as technical recommendations from experts in the area of concrete additives for their correct application to concrete mixes according to their particular dosage.

Table 1: Unit quantities of materials for concrete manufacturing (4”x 8” cylinders).

Type of Concrete		**Portland cement (lb)**	**Sand (lb)**	**Normal gravel (lb)**	**Water (lb)**	**RCA gravel (lb)**
Simple Concrete		1.71	3.03	4.61	0.97	0.00
Recycled Concrete	RCA Gravel: 33%	1.71	3.03	3.09	1.08	1.52
	RCA Gravel: 66%	1.71	3.03	1.57	1.19	3.04
	RCA Gravel: 100%	1.71	3.03	0.00	1.29	4.61

Table 2: Unit quantities of materials for manufacturing concrete with additives (4”x 8” cylinders).

		Portland cement (lb)	**Sand (lb)**	**Normal Gravel (lb)**	**Water (lb)**	**RCA gravel (lb)**	**Integral Additive[1] (lb)**	**DX2 Additive[2] (ml)**	**Silica Fume Additive (lb)**
Recycled Concrete	RCA Gravel: 33%	2.35	2.03	3.09	1.43	1.52	6	5	1.00
	RCA Gravel: 66%	3.21	2.03	1.57	2.29	3.04	13	10	1.00
	RCA Gravel: 100%	2.35	2.03	0.00	2.06	4.61	16.25	12.5	1.00

[1] Additives used in the mixture to improve the waterproofing and workability properties of the mixture. It is also a water reducer and protects the structure from possible moisture damage.

[2] Additive that allows the workability of the mixture to be retained without the need to add more water.

In the case of the quantities of cement and water, in addition to the additive in the case of the mixtures manufactured with additives, empirical corrections were made to achieve a desired slump within an average of 2.00 to 3.00 cm.

For the manufacture of the test cylinders with silica fume, its incorporation into the mixture has been developed as a partial substitute for the fine aggregate (sand) of the mixture; and in this case the silica fume was worked by replacing 33% of the fine aggregate (according to the recommendation of an expert technician from the Honduran company "Lazarus & Lazarus" that acts as supplier of the additive), and the remaining 67% of the fine aggregate is composed of normal sand.

Table 3: Unit quantities of materials for manufacturing concrete with additives (4"x 8" cylinders).

		Portland cement (gr)	Normal Sand (gr)	Water (gr)	RCA Sand (gr)
Simple mortar		60.00	240.00	116.54	0.00
Mortar Concrete	RCA Sand: 33%	60.00	160.80	117.54	79.20
	RCA Sand: 66%	60.00	81.60	168.54	158.40
	RCA Sand: 100%	60.00	0.00	174.56	240.00

3. Results

A 2.77% reduction in average density is produced in a concrete mixture with recycled concrete aggregate (RCA) replacing 33% of the total percentage of coarse aggregate with respect to a mixture of simple concrete (SC) with concrete rock aggregate (CRA). The result shows that with the use of 33% RCA the weight of concrete is slightly reduced, being an alternative if the use of lightweight concrete is desired. The mixture with a percentage of 66% RCA as a substitute in the coarse aggregate presents a 3.67% reduction in density with respect to SC manufactured with CRA. In addition, a 0.88% reduction with respect to the mixture manufactured with 33% ARC.

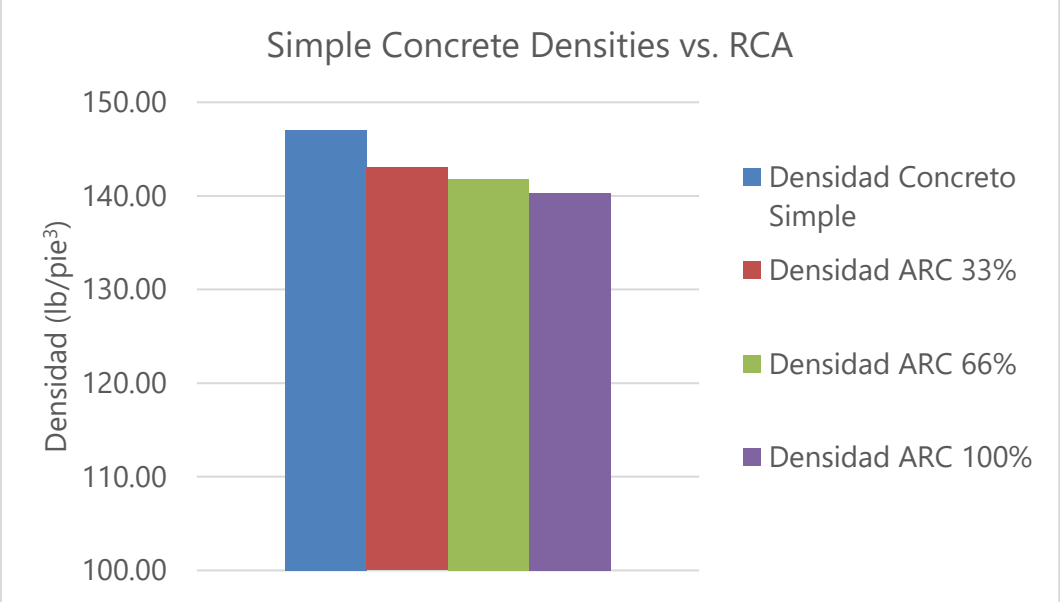

Fig. 1: Simple Concrete (CS) vs. Recycled Concrete Aggregate (RCA) density comparison chart.

The mixture made entirely with recycled concrete aggregate (RCA) as coarse aggregate (100% RCA) presents a 4.76% reduction in density compared to the simple mixture made with concrete rock aggregate (CRA). A 1.94% reduction compared to the mixture with 33% RCA, and 1.06% compared to the mixture with 66% RCA.

The concrete with 33% RCA and additives presents a reduction in density with respect to plain concrete and concrete manufactured only with RCA without additives. Compared to simple mortar (MS), there is a reduction of 11.68%, and compared to the mixture manufactured with 33% ARC without additives, there is a reduction of 8.67%.

The density of concrete manufactured with 66% RCA with respect to plain concrete shows a reduction of 11.86%, compared to concrete manufactured with 66% without additives there is also a reduction, but in this case only 7.90%.

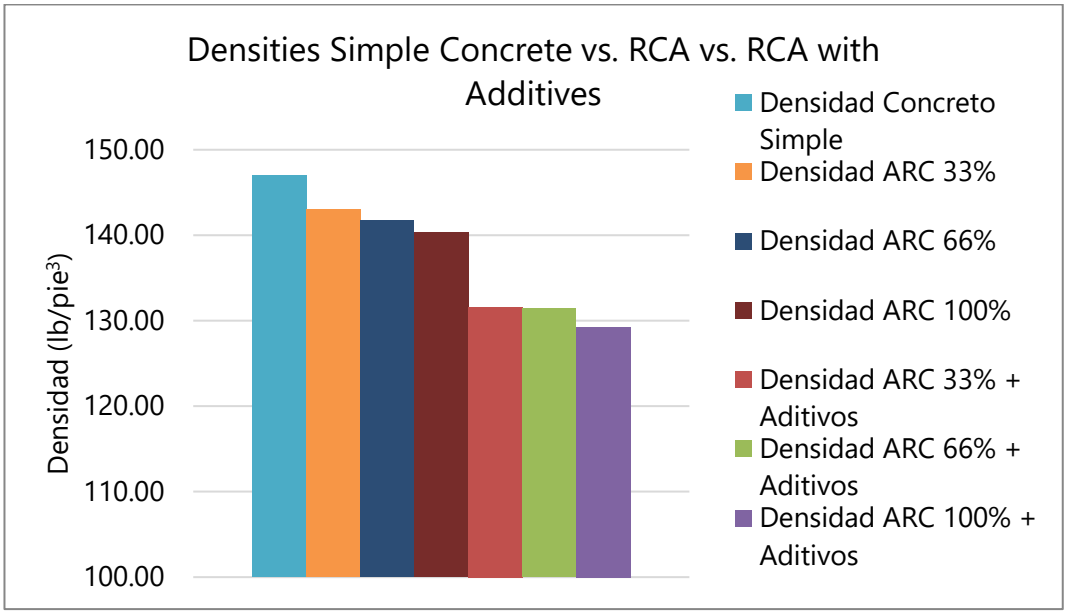

Fig. 2: Simple Concrete (CS) vs. Recycled Concrete Aggregate (RCA) vs. RCA with additive density comparison chart

In the case of the mixture made with 100% recycled concrete aggregate (RCA) and additives, the highest percentage of reduction is presented with respect to plain concrete, giving a reduction value of 13.72% with respect to the original value of a traditional mixture; in comparison with the mixture made with 100% RCA without additives, it presents a reduction of 8.55%, presenting a pattern of an equitable relationship; the greater the presence of RCA in the concrete, the lower its density will be, and it can be reduced even more with the presence of additives.

A mortar made with 33% RCA has a reduction of 4.64% of its density with respect to that of a simple mortar (SM). In the case of the mortar with 66% RCA, it presents a greater reduction, with a reduction of 6.78% compared to the density of the simple mortar. The mortar with 100% RCA presents an even greater reduction, being 10.16% with respect to the density of a simple mortar.

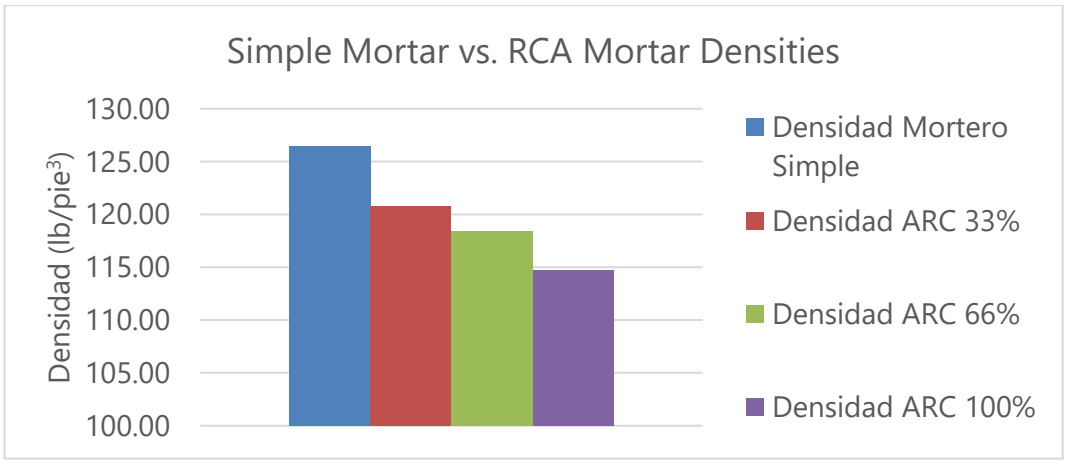

Fig. 3: Simple Mortar (SM) vs. Recycled Concrete Aggregate (RCA) density comparison chart.

The mixture that replaces 33% of the coarse aggregate with recycled concrete aggregate (RCA) has a lower strength compared to the mixture of simple concrete (SC) with concrete rock aggregate (CRA), more specifically, it presents a reduction of 12.82%, the concrete manufactured with 33% of ARC is of lower quality than that of a traditional mixture CRA.

There is an increase of 15.26% in the strength of a mixture manufactured by replacing 66% of the coarse material with ARC with respect to the strength of a SC, and an increase of 24.89% in strength compared to the mixture manufactured with 33% RCA.

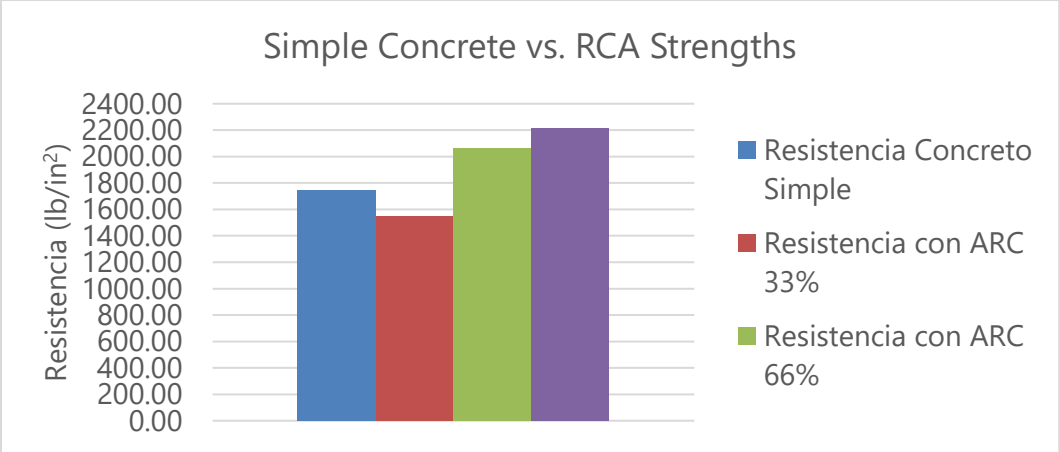

Fig. 4: Simple Concrete (SC) vs. Recycled Concrete Aggregate (RCA) Strength comparison chart.

The strength increases by 21.17% when manufactured by completely replacing the coarse material with recycled concrete aggregate (RCA), an increase of 30.13% compared to the mixture with 33% RCA, and 6.97% more than the mixture manufactured with 66% RCA.

The compressive strength is negatively affected by incorporating additives into the mixture, reducing the strength of plain concrete by 11.11%, but presents a slight improvement with respect to the mixture manufactured with 33% RCA without additives, increasing its compressive strength by 1.51%.

Concrete with 66% RCA and additives presents a slight increase in compressive strength compared to that of simple concrete, increasing by 0.11%; however, compared to concrete with 66% RCA without additives, compressive strength is reduced with the incorporation of additives, reducing its compressive strength by 15.17%.

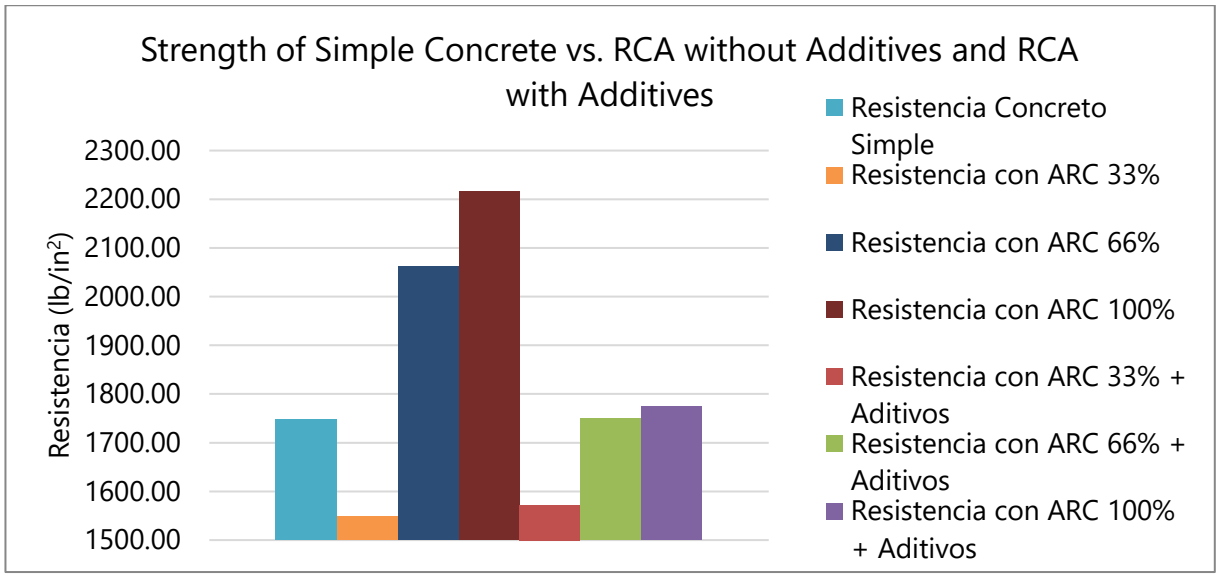

Fig. 5: Simple Concrete (CS) vs. Recycled Concrete Aggregate (RCA) vs. RCA with additive Strength comparison chart

Concrete with 100% recycled concrete aggregate (RCA) and additives presents a slight increase in its compressive strength compared to the strength of a simple concrete, the increase in its compressive strength is 1.56%; but when compared to the strength of concrete with 100% RCA without additives, the strength is reduced by 19.92%.

Mortar, with a percentage of 33% RCA, presents an increase of 25.58% in its compressive strength with respect to that of a traditional mortar.

Mortar, with 66% RCA, increases its compressive strength by 35.07% compared to the strength of a traditional mortar with concrete rock aggregate (CRA), and presents a greater strength than mortar made with 33% RCA.

The compressive strength of the mortar with 100% RCA increases by 16.61% compared to a traditional mortar, being a smaller increase compared to mortars with 33% RCA and 66% RCA.

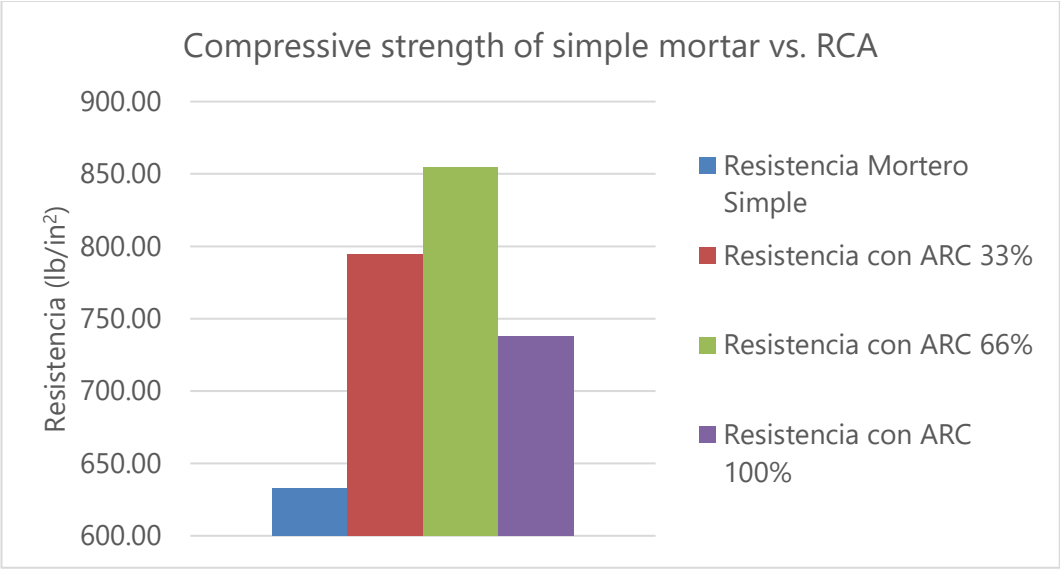

Fig. 6: Simple Mortar (SM) vs. Recycled Concrete Aggregate (RCA) Strength comparison chart.

4. Discussion

Concrete manufactured with recycled concrete aggregate (RCA) reduces its density the higher its RCA percentage and this factor can be reduced even further if additives are included in concrete; concrete manufactured with RCA, with or without additives, is an alternative when considering the use of lightweight concrete.

Mortars manufactured with RCA show the same tendency as in concrete; the greater the presence of RCA in the mix, the lower its density will be mixed with RCA for both concrete and mortar are an option when considering lightweight mixes.

The use of additives helps relatively little in the case of concrete with 33% RCA, but in the case of samples with 66% RCA and 100% RCA, lower strengths are presented with the incorporation of additives, so their incorporation is not recommended in this case.

The presence of additives in the design mix does not improve the compressive strength characteristics, significantly reducing the strength value compared to samples manufactured without the incorporation of additives.

Compressive strength increases with the addition of RCA instead of concrete rock aggregate (CRA), reaching its highest strength with a percentage of 66% RCA, but the higher the RCA content in the mortar mix, the lower its strength is compared to the value obtained with lower percentages, but without being lower than that of a traditional mortar; therefore, regardless of the RCA content, better strength can be obtained.

5. Conclusion

Recycled aggregates in hydraulic concrete are an ecological alternative to natural stone material, promoting the recycling of construction and demolition waste. There are various methods for treating these wastes, with the mechanical method being the most traditional and simple, which involves manual or machine demolition of concrete elements.

Mixtures with recycled concrete aggregate have lower densities than traditional mixtures, making them ideal for the manufacture of lightweight elements. A mixture with 66% recycled aggregate is the most effective option for concrete and mortars, as it significantly improves density and strength.

A high proportion of recycled aggregate in concrete or mortar increases its compressive strength. Hydraulic concrete with a higher recycled aggregate content shows a notable improvement in its strength.

Acknowledgements

Special thanks are given to Eng. Juan Carlos Reyes Zúniga (Technical Coordinator of the Civil Engineering Laboratory of UNITEC) for all his logistical support for the use of the facilities and equipment necessary to perform all the tests required in this research, and also, special thanks to the specialized company of the Honduran construction industry "Lazarus & Lazarus", who through Arch. Lindsey Higgins and Eng. Alejandro Licona, provided all the technical and logistical support in the configuration of concrete mixes, use and implementation of specialized construction materials, such as concrete additives.

References

[1] Lesovik, V., Lesovik, R., & Albo Ali, W., *Effect of recycled course aggregate from concrete debris on the strength of concrete*. 2021.

[2] Chen, G., Yu, Q.-Q., & Wan, B., *Materiales Reciclados en la Ingeniería Civil*. 2021.

[3] Moreno, L., Ospina, M., & Rodríguez, K, *Resistencia de concreto con agregado de bloque de arcilla triturado como reemplazo de agregado grueso*. 2019.

[4] Abdulrahman, M., Khazaal, A., Al-Attar, A., & Hamad, S., *Reinforced concrete slabs containing recycled concrete as coarse aggregate*. 2020.

[5] S. S. Hassan, *Effects of recycled concrete aggregate on some mechanical properties of high strength concrete*. 2018.

[6] Guo, Y., Li, Q., Yue, G., Zheng, S., & Wang, L., *Efectos en la Calidad e Índice de Reemplazo en Agregados de Concreto Doblemente Reciclados*. 2020.