Influence of recycled aggregate on the compressive strength and absorption percentage of Lima 2020 pedestrian pavers.

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Abstract– A systematic review is carried out to determine the influence of recycled aggregate on the properties of concrete designed for pedestrian pavers, selecting highly relevant investigations, filtering them by years, focus and results. Which contribute to make a comparison of results in the properties of resistance to compression and percentage of absorption of pavers subjected to different percentages of replacement of recycled aggregate in its structure, in order to determine the influence, they have on said properties. Through the analysis and synthesis of results, the influence of the recycled aggregate is validated, affecting the decrease in its resistance to compression and the increase in the percentage of absorption. However, taking into account the information presented and based on the statistics, it is valid to conclude that by replacing up to 25% of the coarse aggregate with recycled aggregate, an adequate mixture can be achieved, complying with the parameters estimated by NTP. 399,611 according to their properties. Likewise, it is valid to mention that, at a higher percentage of replacement, the properties vary unfavorably

Keywords: pavers, concrete, recycled, strength, absorption.

I. INTRODUCTION

Caring for the environment, reducing the effects of global warming can achieve environmental sustainability in the world. However, the debris generated by construction activities is one of the main factors of global pollution, due to the large volume they occupy in landfills, this problem causes the use of other environments inappropriately, which saturate the landfills, causing significant environmental impacts, affecting biodiversity.

Construction and Demolition Waste (CDW) basically comes from construction activities, although in most cases the volume of CDW is produced as a result of the deterioration of buildings and infrastructures that have reached the end of their useful life. [1]

Waste is constantly discarded, making its reuse almost null, however, it has been noted that these can be used in different ways, transforming them from their raw state to products such as aggregates. This can be done specifically with respect to concrete, making it a renewable and continuous source of coarse or fine aggregates as needed, which increment the option of reducing the use of quarry material, thus avoiding its exploitation. [2]

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In Europe, the construction industry consumes about half of all extracted raw materials, in addition to being an important source of waste production [3]. The reuse of construction and demolition waste (CDW) is applied on a large scale in first world countries.

Such is the case of Finland, which has an important legislation and implementation which consists of the recycling of all reusable material that can be obtained from the demolition of structures. In the Netherlands, all rubble involving concrete is recycled, with the exception of some production waste. The Asian continent is not far behind and it is Japan that has a great management of the reuse of CDW, using it almost entirely in road sub-bases. In our continent, Brazil has legislation that promotes the management of CDW. These also derive in its road sub-base projects. [4]

One of the strategic lines of the European Union policies aims to ensure the “Circular Economy” through the efficient use of raw materials and residues and the generation of clean energy. For that, policies on waste management must be directed in respect of the hierarchy of 4Rs established by the normative: reduction, reuse, recycle, and recovery [5].

The regulations regarding CDW in Peru are recent, as well as the mechanisms for their management. However, according to CAPECO "Lima currently produces approximately 30,000 m3 of CDW daily, which more than 60% is disposed of in places that affect society" In Lima and Callao, waste has been abandoned in public areas without considering any environmental protection criteria. [6]

Concrete pavers are used in different parts of the capital city, they are designed according to their strength, depending on the purpose for which they are used, in brief, "their bearing capacity depends on their thickness". [7]

They are commonly used in the construction of pavements, in addition to acquiring an architectural value due to their aesthetics. It is basically used in light traffic routes such as pedestrian areas, therefore using CDW in the production of these can satisfy the need to use the waste.

Table 1. Technical specification of the pedestrian paver (Type 1).

Test	Requirement	Reference Standard	Test standard
DIMENSION	Length: 20 cm Width: 10 cm Height: 6 cm	NTP 399.611	NTP 339.604
DIMENSIONAL VARIATION	Length and width: ±1.6 mm Height: ±3.2 mm	NTP 399.611	NTP 339.604
ABSORPTION, Max. % (average 3 unt.)(unt. Individual)	≥ 6% of dry weight ≥ 7% of dry weight	NTP 399.611	NTP 339.604
Compressive strength min. MPa With respect to average gross area (Average of the 3 individual units)	31 MPa (310 kg/ cm^2) 28 MPa (280 kg/cm^2)	NTP 399.611	NTP 339.604
Uses Concrete pavers, for vehicular and pedestrian paving.		Color and texture According to approved sample	

Source: NTP 399 611, 2017.

The study of the use of construction and demolition waste is rising, due to the saturation of landfills. However, the only way to ensure its use is to demonstrate its role in the use of new concrete technologies.

The research question posed was: How does the use of recycled aggregates influence the manufacture of pavers to be used in pedestrian paving in Lima? In this way, the main interest of the research is to evaluate and know the influence of recycled aggregates in the design of concrete for a pedestrian paver, based on previous studies on the subject, emphasizing data and theoretical bases, generating a more concise knowledge for beneficial results.

The results obtained can serve as a support and guide for new large-scale research, both nationally and internationally. However, the main approach is in our country, because it does not have a culture of reuse and is reluctant to new technologies and innovations. The problem of construction and demolition waste can be tackled by using it in elements that are in great demand and easy to manufacture. Therefore, the objectives of our research were the following:

Determine the influence of the recycled aggregate on the compressive strength of the pedestrian paver (type 1)

Determine the influence of recycled aggregate on the moisture content of pedestrian pavers (type 1).

Determine the adequate percentage of recycled aggregate replacement by natural aggregate, which will allow us to comply with NTP. 399.611 for use in pedestrian pavers.

II. METHODOLOGY

This research is based on the analysis of scientific articles related to the use of recycled aggregates and their influence on the properties of concrete designed for pedestrian pavers, for which a "systematic review" was carried out. Then, sources of information and databases were compiled, from which the most relevant ones were chosen according to our approach and objectives. The results from synthesizing the data are presented in tables and statistical figures

Finally, conclusions are drawn by interpreting the tables and statistical analysis of the results obtained, and the implications of the research are also mentioned.

The research question formulated for the topic was:

How does the use of recycled aggregates influence the manufacture of pavers for the use in pedestrian paving pathways in Lima? The database was based on articles collected from reliable data, such as: Google Scholar, Ebsco, Scopus, etc.; the data was classified, analyzed and synthesized, comparing it with the information provided by its peers.

Systematic review (SR)

Certain aspects were taken into account for the inclusion criteria

- The type of research was analyzed, only scientific articles were studied.
- That the research is within the field of civil engineering.
- The study is related to the use of recycled aggregate in concrete mixes.
- The time of the research does not exceed the last 10 years
- The content of the information should be concise and present empirical results.

Certain aspects were taken into account for the exclusion criteria

- Thesis research, monographs and any other relevant information not found in our databases.
- Articles that present a totally different approach to our purpose.
- Articles that do not present empirical results
- Articles containing more than 14 pages
- Foreign items whose results are not slightly linked to our standard ranges

The following is the database and search engine that we will use for our research, presented in tables and based on the selection of 28 articles.

Table 2: Repository search statistics according to years

Source	**2006**	**2007**	**2010**	**2015**	**Total**
INGE CUC			1		1
Ebsco	1	2			3
Redalyc	1	1			2
Scielo	1			2	3

Source: Own elaboration, 2022.

Table 3: Influence of recycled aggregate applied in concrete by year of application

Source	**2016**	**2017**	**2018**	**2019**	**2021**	**2022**	**Total**
IBERO			1				1
Ebsco	1		1				2
Redalyc	1			1			2
Scopus		1			5	7	13
Scielo	1	1					2

Source: Own elaboration, 2022.

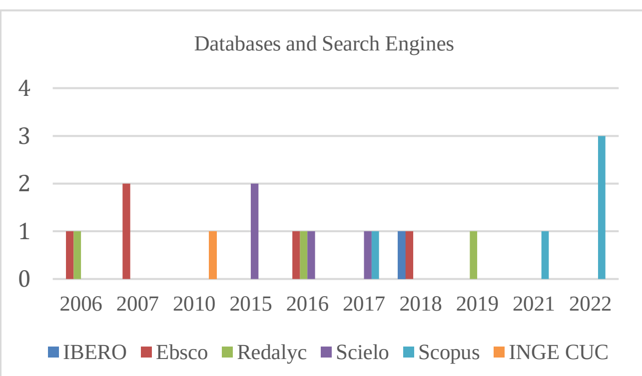

Fig. 1 Information search statistics by search engine. *Source: Own elaboration, 2022.*

III. RESULTS

The 22 main scientific articles on which the research is based, followed a pattern using the aforementioned inclusion and exclusion criteria in methodology, in order to analyze the objectives and to be able to answer our research question.

Table 4: Research matrix

Search engines	Publication title	Author(s)	Year
Ebsco	Use of recycled rubber grain for the production of ecological pavers as an alternative to the construction industry	Luis Ángel Jaimes Leal, Karina Paola Torres Cervera	2019
Ebsco	Evaluation and comparison of the granulometric analysis obtained from natural and recycled aggregates	Oscar Palacio León, Álvaro Chávez porras, Yessica Liceth Velásquez Castiblanco	2016
Ebsco	Strength of Concrete with Clay Block Aggregate crushed as a replacement for coarse aggregate	Luis Ángel Moreno Anselmi, Miguel Ángel Ospina García, Kelly Andrea Rodríguez Polo	2018
Scielo	Concrete with recycled aggregates as a construction project urban sustainability	Carlos Bedoya, Luis Dzul	2015
Scopus	Utilization of RMC waste with chemical admixtures to manufacturing of sustainable building components	Krishnaraj, Suba Lakshmi, & Ravichandran	2017
Scopus	Recycled Concrete Aggregate as Alternative Pavement Materials: Experimental and Parametric Study	Alnedawi & Rahman	2021
Scopus	Effects of recycled fine aggregates on properties of concrete containing natural or recycled coarse aggregates: A comparative study	Singh, Nayak, Pandey, Kumar, & Kumar	2022
IBERO	Development of a cobblestone prototype for road use and/or Pedestrian that incorporates crushed rubble such as fine aggregate.	Miguel Ángel Morales Ackinson, Edgar Josué Carmona Pérez, Marcos González Martínez y Martín Martínez Fombona	2018
INGE CUC	Manufacture of pavers for use on roads Pedestrians, using African palm shell	Jorge Elías Buzón Ojeda	2010
Redalyc	Design of an articulated pavement with cobblestones composed of recycled of concrete as fine aggregate and ash from sugarcane bagasse of sugar as a partial replacement for Portland cement	Carlos Steven Caicedo Quinayás, Aníbal Cesar Maury Ramírez	2016

Scopus	Mechanical characterization of recycled concrete under various aggregate replacement scenarios	Sajan , Adhikari, Mandal , & Gautam	2022
Scopus	Properties and modification of sustainable foam concrete including eco-friendly recycled powder from concrete waste	Yang, Liu, Zhang, Yao, & Ma.	2022
Scopus	influence of the mix proportion and aggregate features on the performance of eco-efficient fine recycled concrete aggregate mixtures	De Souza, y otros	2022
Scopus	A review on the utilization of waste material in asphalt pavements	Victory, W.	2022
Scopus	Effect of Recycled Mixed Powder on the Mechanical Properties and Microstructure of Concrete	Liu, Liu, & Wu	2021
Scopus	Alkali-activated concrete paver blocks made with recycled asphalt pavement (RAP) aggregates	Nabil, y otros	2021
Scopus	The use of recycled aggregates in the construction sector: a scientific bibliometric analysis	Sánchez-Roldán , Zamorano, & Martín-Morales	2021
Scopus	Upcycling of waste concrete in eco-friendly strain-hardening cementitious composites: Mixture design, structural performance, and life-cycle assessment	LI , Lv, Zhou, Meng, & Bao	2022
Scopus	Recycled Aggregates from Construction and Demolition Waste in the Manufacture of Urban Pavements	Contreras-Llanes, Romero, Gázquez, & Bolívar	2021
Scopus	Utilization of recycled concrete Aggregates for sustainable porous Asphalt pavements	Nwakaire, Yap , Onn , Yuen, & Moosavi,	2022
Scielo	Comportamiento mecánico de concreto fabricado con agregados reciclados	Martínez–Soto & Mendoza–Escobedo	2006
Scielo	Recycled Concrete: A Review	W. Martínez-Molina, A. A. Torres-Acosta, E. M. Alonso-Guzmán, H. L. Chávez-García	2016

Source: Own elaboration, 2022.

In the mentioned analysis, it is made known what is the adequate percentage of recycled aggregate to replace in order not to significantly affect the properties of the concrete designed to make pavers for pedestrian use, several tests were made in the article. “CONCRETE WITH RECYCLED AGGREGATES AS AN URBAN SUSTAINABILITY PROJECT”, mentioned that the purpose is to replace coarse aggregate with recycled aggregate from ground concrete and another percentage of brick masonry, the latter used to replace the fine aggregate. They performed the characterization of these aggregates using physical techniques: fineness modulus, absorption percentage and dry apparent absorption. They made cylindrical samples (test specimens) of 5 cm radius and 20 cm height, which were immersed in lime-saturated water for curing at temperatures of 23 +/- 3° C. These samples were tested at ages of 3, 7, 14, 28, 56 and 91 days. In addition to the compressive strength test, hardened samples were analyzed for absorption, density, porosity and carbonation.

Table 5. Selection of quantities according to percentage of substitution

code	**A.F (R)**	**A. G (R)**	**A. F**	**A. G**
A	-	-		100%
B	-	-	100%	
C		25%		75%
D	25%	-	75%	-
E		50%		50%
F	50%	-	50%	-
G	-	100%	-	-
H	100%	-	-	-

Source: [8]

It mentions that in the mixes that present a type of aggregate in its totality (A, B, G and H) they present the same fineness modulus because their weights were homologated in the sieving process. However, in mixtures with a combination of aggregates, there are changes, because the particle size tests were determined after the combination of these aggregates.

Table 6 Characteristics of the aggregates used in the mixes

variable	A	B	C	D	E	F	G	H
TMN (mm)	19.05	--	19.05	--	19.05	--	19.05	--
Dry bulk density (g/cm3)	2.87	2.74	2.82	2.69	2.63	2.66	2.53	2.52
Modulus of fineness	7.2	3.3	7.4	3.45	7.57	3.5	7.2	3.3
Absorption percentage (%)	1.28	3	1.34	3.06	2.7	3.1	4.2	3.2

Source: [8]

For our research we will focus on mixtures that evaluate coarse aggregate.

Table 7 Characteristics of coarse aggregates

Variable	A	C	E	G
Dry bulk density (g/cm3)	2.87 (100 %)	2.82 (98.26%)	2.63 (91.64%)	2.53 (88.15%)
Absorption percentage (%)	1.28 (100 %)	1.34 (104.69 %)	2.7 (210.94%)	4.2 (328.13%)

Source: [8]

The results obtained from the compression test are described below.

Table 8 Results for compressive stress resistance

Mix	Compressive stress resistance in MPa					
	3 días	7 días	14 días	28 días	56 días	91 días
0 – R	11.35	15.6	19.26	23.51	26.84	27.39
25 – R	11.15	15.33	18.9	22.91	26.35	26.83
55 – R	10.82	14.93	18.55	22.25	25.71	25.93
100 - R	10.10	13.89	17.33	20.33	21.92	23.02

Source: [8]

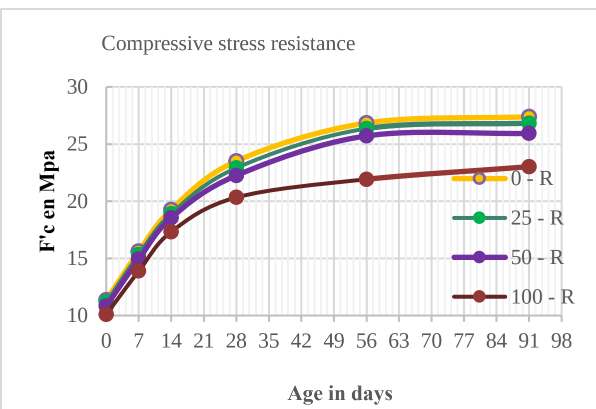

Fig. 2 Compressive stress resistance. *Source: [8]*

According to the data obtained, I conclude that recycled aggregates can be susceptible to be used as raw materials in a new material for construction, such as concrete, since not all mixtures are required for structural use. However, it is feasible to make concrete for structural use in the case of the mixture with 25% substitutions, it maintains a good performance in its properties. The 50-R mix showed a performance higher than 95% in terms of compressive strength, compared to the reference mix; the porosity and absorption of the 50-R mix also showed positive results.

Table 9 Density, absorption and voids of hardened concrete

Mixture	Absorption after immersion and boiling (%)	Bulk dry density (g/cm3)	Volume of permeable pores (Voids) (%)
0 – R (1)	7.8	2.24	17.4
0 – R (2)	7.8	2.24	17.5
Average 0 – R	**7.8**	**2.24**	**17.5**
25 – R (1)	7.9	2.20	18.4
25 – R (2)	8.0	2.19	18.6
Average 25 -R	**8.0**	**2.20**	**18.5**
50 – R (1)	9.2	2.15	19.8
50 – R (2)	10.1	2.12	21.3
Average 50 – R	**9.7**	**2.14**	**20.6**
100 – R (1)	12.5	2.01	25.1
100 – R (2)	12.7	2.00	25.3
Average 100 – R	12.6	2.01	25.2

Source: [8]

On the other hand, in the article "RESISTANCE OF CONCRETE WITH CRUSHED CLAY BLOCK AGGREGATE AS A REPLACEMENT OF COARSE AGGREGATE" in their results concerning the compressive strength using recycled aggregate from clay block. For this purpose, they evaluated and analyzed different investigations, in which, according to their research, they concluded that the amount of recycled aggregate should be limited to avoid a considerable loss in the strength of recycled concrete, recommending the use of CCB recycled aggregates as a replacement of 25% and 50% of the natural coarse aggregate for concrete mixes with 350 and 250 kg of cement, respectively. Some results are mentioned:

- For a mix containing 350 kg/m3 of cement at 25% replacement of coarse aggregate, 34 MPa with an A/C ratio of 0.5.
- For a mix containing 350 kg/m3 of cement at 50% coarse aggregate replacement, 22.5 MPa at an A/C ratio of 0.5.
- For a mix containing 431 kg/m3 of cement at 100% coarse aggregate replacement, 30 MPa with an A/F ratio of 0.38.
- For a mix containing 314 kg/m3 of cement at 100% coarse aggregate replacement, 17.7 MPa with an A/F ratio of 0.5

Referencing the data to our objectives, we can analyze the data extracted from these authors, in order to synthesize and respond to them. As can be observed according to the percentage of replacement of recycled aggregate by natural aggregate, the compressive strength tends to decrease and on the other hand the percentage of absorption tends to increase, this can be seen reflected in the following figures:

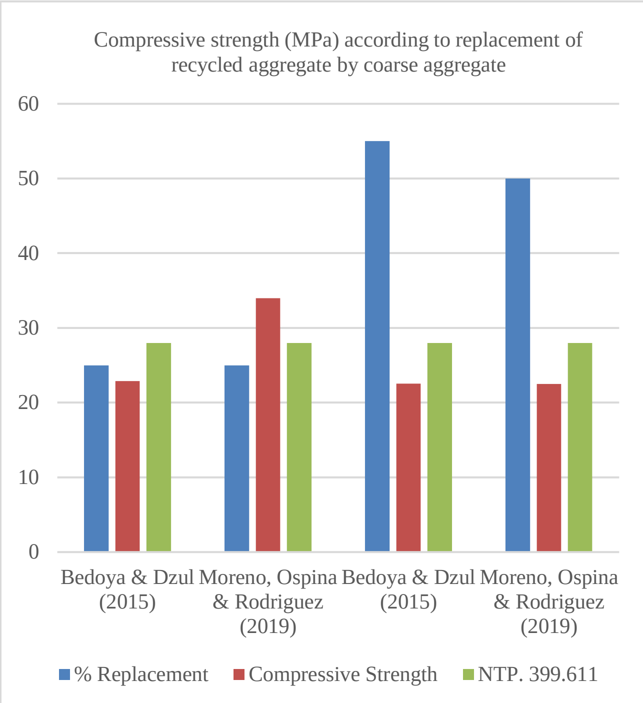

Fig. 3 Compressive strength (MPa) according to replacement of recycled aggregate by coarse aggregate. *Source: Own elaboration.*

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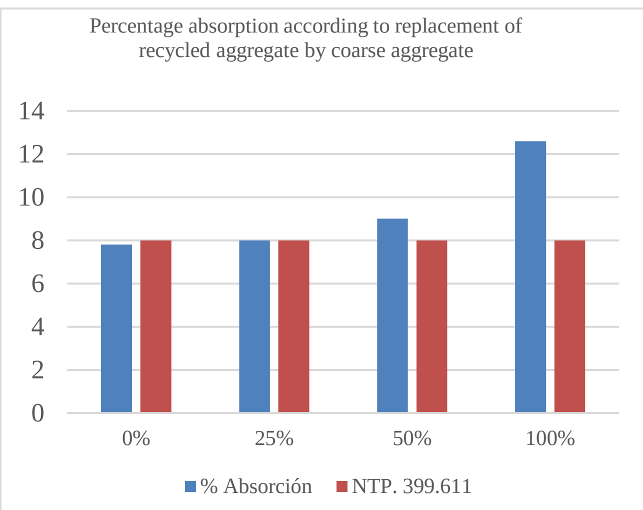

Fig. 4 Percentage absorption according to replacement of recycled aggregate by coarse aggregate. *Source: Own elaboration*

Considering these results, it is clear to note the influence of recycled aggregates. However, the mixture with 25% replacement achieves acceptable values according to the authors. Even [8] comment that up to 50 % of the compressive strength can obtain up to 95 % of resistance according to their standard sample.

If we contrast with the values that we need so that they can be applied in the elaboration of pedestrian pavers.

Table 10 Nominal Thickness and Compressive Strength

Type	Nominal thickness (mm)	Compressive strength. Min. MPa(kg/cm2)	
		Average of 3 units	Single unit
I (pedestrian) Type B, C AND D *All types	40 60	31 (320) 31(320)	28 (280) 28(290)
II (light vehicular)	60 80 100	41(420) 37(380) 35(360)	37(420) 33(380) 32(360)
III (heavy vehicular, industrial or container yards)	≥ 80	55 (561)	50 (510)

Source: NTP 399.611, 2017.

Table 11 Absorption of pavers

Type of paving stone	Average of 3 units	Single unit
I y II	6	7.5
III	5	7

Source: NTP 399.611, 2017.

V. **DISCUSSION AND CONCLUSIONS**

DISCUSSION

In this stage we evaluate the results obtained from the database, with those described in the results obtained. With the purpose of determining the adequate replacement percentage to elaborate a suitable mix that will allow us to comply with the values estimated by NTP. 399.611 for use in pedestrian pavers, evaluating its properties of compressive strength and absorption percentage.

- The use of recycled material in the production of concrete has become a common practice as studies have progressed. Although concrete with recycled aggregate degrades the mechanical properties, with the support of other materials or admixtures it meets the values stipulated by the respective standard.

• According to the systematic review, we can summarize that the use of recycled aggregates causes significant changes in the mechanical properties of concrete. In which a great variability of the properties can be appreciated, taking into account the state and/or type of the recycled material to be used.

• It is important to mention that in spite of the variability caused by the use of these aggregates in the mixes, with a correct dosage it is possible to create useful elements, thus facing the problem of contamination by CDW.

• [9] taken as background, showed us that the use of recycled concrete is useful in the elaboration of concrete pavers with a correct dosage, this is demonstrated in the article by [10] who made a systematic review of different authors that confirmed the above.

• This conclusion argues with [8] since it mentions that at a 50% replacement of recycled aggregate, the compressive strength reaches 95% with respect to natural aggregate. However, in both cases the use of recycled aggregate is valid. In addition, [11] mentions that the results of his background suggest that the recycled mixtures that contain 100% Residue can produce 35% more drying shrinkage along with 30% and 50% less compressive strength.

• [10] The author recommends using CCB recycled aggregates as a 25% and 50% replacement of natural coarse aggregate for concrete mixes with 350 and 250 kg of cement.

• [8] unlike [9] and [10] The above-mentioned models present an absorption percentage of 8% at a replacement of 25%. The difference is due to the fact that the former refers to a fine aggregate (mortars). [8] refer to coarse aggregate mix. However, both mention the increase of air voids and reduction of permeability as well as the article of [12].

CONCLUSIONS

According to the different results that have been reached in the aforementioned articles regarding the adequate percentage of replacement of recycled aggregate by natural aggregate. There is validity to affirm that replacing 25% of recycled coarse aggregate, coming from ground concrete presents certain influence in:
According to [13] it is valid to conclude that the granulometry of recycled aggregate compared to natural aggregate shows differences in its main characteristics, such as voids percentage, humidity and weight.

The compressive strength shows a slight decrease; however, it is demonstrated that at 28 days it achieves the strength for which it was designed. It is worth mentioning that the compressive strength is inversely proportional to the percentage of recycled aggregate replacement, according to [14], the compressive strength tends to increase as the curing time increases. The compressive strength of FC decreases slightly with the addition of RCP up to 15%.

It is also mentioned that by replacing 50%, the compressive strength reaches up to 95% of its design strength, achieving strengths of 24 MPa and 25 MPa. It should be noted that ACI mentions that the use of recycled aggregates can present reductions in strength of 15% to 40%, and the standard that regulates the use of construction and demolition waste mentions that a concrete can be used even if it does not reach its required strength, as long as it presents 95% of its required strength.

Therefore, it is valid to conclude that by replacing up to 25% of the coarse aggregate with recycled aggregate, we can obtain the values stipulated in NTP. 399.611 for use in pedestrian pavements (cobblestone type I), thus providing another alternative for the application of CDW (construction and demolition waste), reducing landfill saturation.

The percentage of absorption in mixtures with 25% replacement is up to 8% absorption. The higher the replacement percentage, the higher this property increases. Therefore, it can be stated that the percentage replaced is directly proportional to the percentage absorbed. It is important to point out, according to [15], that the water absorption of pavers is an important property, which indicates the pores in the structure of the hardened paste. Higher absorption values can influence the durability of pavers

Additionally, it is valid to conclude that although 50% is workable, the best option would be to replace 25% since the properties obtained with this percentage respect the parameters stipulated in the NTP. 399. 611

It has been concluded that the addition of construction and demolition waste (CDW) as coarse recycled aggregate to the concrete mix has a significant influence on the physical-mechanical properties of the concrete depending on its replacement percentage. With this in mind, many positive and negative aspects of the use of these wastes still need to be evaluated.

REFERENCES

[1] L. M. Velasquez Pacco, "PROPIEDADES FÍSICO MECÁNICAS DEL CONCRETO RECICLADO PARA LIMA METROPOLITANA," 20 agosto 2015.

[2] N. A. Vega Bazán , "Agregado de concreto reciclado, su influencia en las propiedades mecánicas de concretos 210, 280 y 350 Kg/cm², Lima – 2018," 13 octubre 2018.

[3] Z. Sánchez-Roldán , . M. Zamorano and . M. Martín-Morales, "The use of recycled aggregates in the construction sector: a scientific bibliometric analysis," *Scopus,* no. 72, 2021.

[4] "Cement Sustainability Initiative," [Online]. Available: http://ficem.org/publicaciones-CSI/DOCUMENTO-CSI-RECICLAJE-DEL-CONCRETO/RECICLAJE-D-CONCRETO_1.pdf.

[5] M. Contreras-Llanes, M. Romero, M. J. Gázquez and J. P. Bolívar, "Recycled Aggregates from Construction and Demolition Waste in the manufacture of urban pavements," *Scopus,* 2021.

[6] M. A. Silva Carbajal, "SITUACIÓN DE LA GESTIÓN Y MANEJO DE LOS RESIDUOS," 5 Junio 2018.

[7] C. F. M. Ines, "Repositorio Digital," 12 octubre 2014.

[8] C. Bedoya and L. Dzul, "El concreto con agregados reciclados como proyecto de sostenibilidad urbana," *Scielo,* Agosto 2015.

[9] J. L. Montiel Miguel, "Uso de agregados reciclados para la fabricación de adoquines que se puedan utilizar en la pavimentacion de calles, avenidas y pasos peatonales," 14 Junio 2017.

[10] L. A. Moreno anselmi, M. A. Ospina Garcia and A. Rodriguez Polo, "Resistencia de concreto con agregado de bloque de arcilla triturado como reemplazo de agregado grueso," *Scielo,* Diciembre 2019.

[11] D. J. De Souza, M. T. de Grazia , H. F. Macedo, L. F. M. Sanchez, G. P. de Andrade , O. Naboka , G. Fathifazl and P.-C. Nkinamubanzi, "Influence of the Mix Proportion and Aggregate Features on the Performance of Eco-Efficient Fine Recycled Concrete Aggregate Mixtures," 2022.

[12] C. M. Nwakaire, S. P. Yap , C. C. Onn , C. W. Yuen and S. M. H. Moosavi, , "UTILISATION OF RECYCLED CONCRETE AGGREGATES FOR SUSTAINABLE POROUS ASPHALT PAVEMENTS," *Scopus,* 2022.

[13] O. Palacio León, A. Chavez Porras and Y. Velasquez Castiblanco, "Evaluación y comparación del análisis granulométrico obtenido de agregados naturales y reciclados," Septiembre 2017.

[14] D. Yang, M. Liu, Z. Zhang, P. Yao and Z. Ma, "Properties and modification of sustainable foam concrete including eco-friendly recycled powder from concrete waste," *Scopus,* 2022.

[15] H. Nabil, K. S. Hima , K. M. Mothi , H. R. Arjun, G. Santhosh and C. Jorisa, "Alkali-activated concrete paver blocks made with recycled asphalt pavement (RAP) aggregates," *Scopus,* 2020.

[16] L. Á. Jaimes Leal and K. P. Torres Cervera, "Aprovechamiento del grano de caucho reciclado para la elaboración de adoquines ecológicos como alternativa a la industria constructiva," *Redalyc,* 2019.

[17] L. Krishnaraj, R. Suba Lakshmi and P. Ravichandran, "Utilisation of rmc waste with chemical," *SCOPUS,* 2017.

[18] w. Victory, "A review on the utilization of waste material in asphalt pavements," *Scopus,* 2022.

[19] X. LI , X. Lv, X. Zhou, W. Meng and Y. Bao, "Upcycling of waste concrete in eco-friendly strain-hardening cementitious composites: Mixture design, structural performance, and life-cycle assessment," *Scopus,* 2022.

[20] R. Singh, D. Nayak, A. Pandey, R. Kumar and V. Kumar, "Effects of recycled fine aggregates on properties of concrete containing natural or recycled coarse aggregates: A comparative study," *Scopus,* 2022.

[21] A. Alnedawi and M. A. Rahman, "Recycled Concrete Aggregate as Alternative Pavement Materials: Experimental and Parametric Study," *Scopus.*

[22] J. Linares - Durand, D. Linares-Fonseca, L. Melgarejo-Madueño, N. Campos-Vásquez and R. Manturano-Chipana, "Influence of adding polypropylene fibers to concrete," *19th LACCEI International MultiConference for Engineering, Education Caribbean Conference for Engineering and Technology,* vol. 19, 2021.

[23] K. Sajan , R. Adhikari, B. Mandal and D. Gautam, "Mechanical characterization of recycled concrete under various aggregate replacement scenarios," *Scopus,* 2022.

[24] I. E. Martínez–Soto and C. J. Mendoza–Escobedo, "Comportamiento mecánico de concreto fabricado con agregados reciclados," *Scielo,* 2006.

[25] C. Liu, H. Liu and J. Wu, "Effect of Recycled Mixed Powder on the Mechanical Properties and Microstructure of Concrete," *Scopus,* 2021.