Influence of Construction and Demolition Waste Incorporation in Concrete

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Abstract The construction industry is the human activity that consumes the most natural resources. This occurs from before the beginning of the work, with the extraction of minerals for the production of aggregates and cement. Considering the high consumption of materials in the construction and the durability of the buildings, the continuous generation of CDW (Construction and Demolition Waste) presents itself as a problem. The objective of this work is to verify the influence that the incorporation of CDW promotes in the concrete properties. The CDW was incorporated into 50 and 100% replacement of natural sand. Materials and concrete characterization tests were performed by slump test, water absorption by immersion, water absorption by capillarity and mechanical strength. The tests indicated that the presence of CDW improves the performance of the concrete, increasing its resistance and decreasing its water absorption.

Keywords Construction and demolition · Waste · Concrete

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Introduction

The Construction Industry deserves to be highlighted in the study of sustainability as one of the most important activities for economic and social development, but it is also a major generator of environmental impacts [1]. Construction activities consume a considerable amount of inert materials such as sand and stones. With the rapid growth of urban regions, the exploitation of natural resources and the generation of construction and demolition waste has reached worrying levels as a result of mismanagement in the works, which generates waste and pollution [2].

Four points are important with regard to sustainability in the sector: the supply chain is long and disjointed, causing ineffective gaps in introducing new technologies; culturally sustainable actions are viewed as costly by builders; disagreements regarding the economic benefits of contractors; and lack of theoretical and practical knowledge and skills on sustainable measures by the population and even by professionals [3].

CDW generation precedes any work. The manufacturing processes of materials used for construction consume natural resources, consume energy, and generate their own waste [4].

According to Bourscheid [5], in construction, there are many losses due to the use of obsolete techniques. SINDUNCON-CE reiterates that waste in a job is the main generator of CDW. These can be caused by overproduction, ineffective stock control, defective manufactured goods, transportation, and processing. The process of unbridled urbanization causes existing buildings to undergo renovation and the increase in population income and housing credit policies has catapulted the emergence of new works and renovations, which further increased waste generation [6].

The CDW was always treated as garbage, expendable, paid for removal from the worksite, without worrying about its destination. 45.1 million tons of CDW were collected in a legal and registered manner in 2015 [7] in addition to a large amount of waste disposed of illegally. Despite its economic potential, concern about the CDW and its reuse and recycling is relatively new, dating back to the 1980s [8, 9]. Figure 1 presents the data of destination of CDW by region of Brazil.

CDW recycling has been successful in several countries [10]. According to Sormunen [11], countries like the USA, Japan, the Netherlands, France, Denmark , and England already have a consolidated industry with hundreds of plants installed.

The CDW recycling chain must be properly managed as it depends on many variables such as technology used, type of waste used, and purpose of recycled material [12].

Many studies have shown the possibility of using recycled aggregates in both the large portion [13, 14] and the small portion [15] for the manufacture of concrete. Leite [6], Corinaldesi [16], and other researchers showed satisfactory performances in fractional substitution of natural aggregates for those recycled in mortars.

The objective of this work is to evaluate the influence that the incorporation of CDW promotes in the performance of concretes.

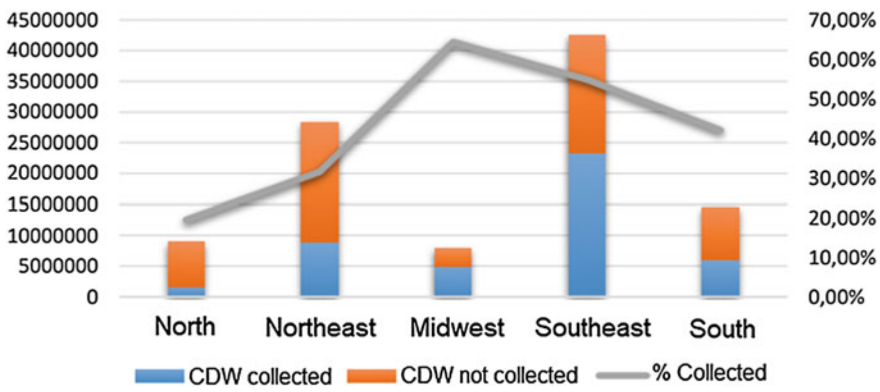

Fig. 1 CDW Collected and CDW not collected by region in Brazil in 2015 Source: ABRELPE, 2016

Materials and Methods

The CDW were manually ground (Fig. 2a) followed by equipment crushing (Fig. 1b) to be stored in suitable containers until use in the assays.

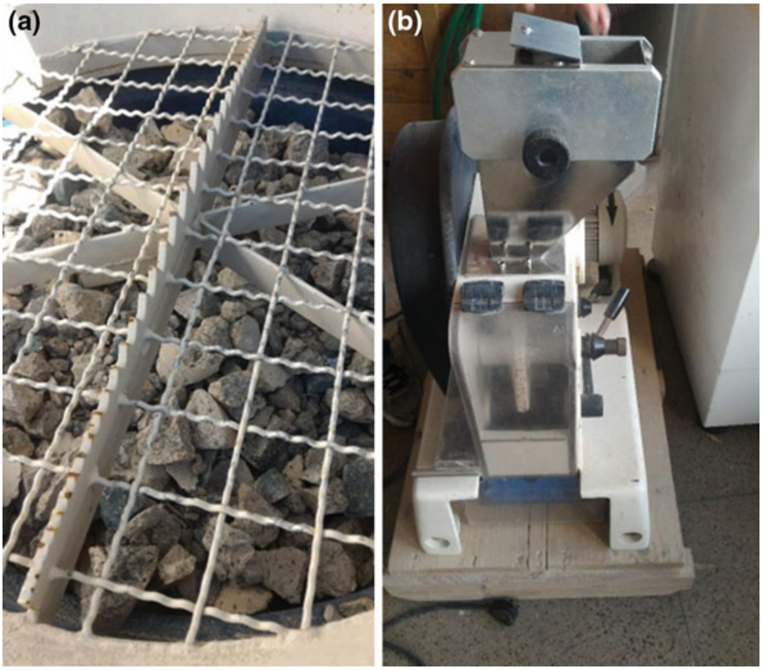

Fig. 2 CDW shredding: **a** Manual, **b** by jaw crusher

Table 1 Concrete traces

	w/c	Cement	Natural sand	Waste sand	Gravel
Ref. (100% NS)	0.46	1	1.32		2.65
100% WS	0.46	1		1.47	2.38
50% NA | 50% WS	0.46	1	0.66	0.74	2.51

The particle size of recycled CDW (WS) and natural sand (NS) sand was verified by sieving tests, according to NBR NM 26 [17] and NBR NM 27 [18].

Specific gravity, grain swelling, bulk density, and moisture absorption tests were also performed for characterization of materials.

The concrete was dosed according to the ABCP method to obtain the resistance of 40 MPa in 28 Days.

Three traces of concrete were prepared using 100% natural sand, 100% waste sand, and 50% natural sand/50% waste sand according to Table 1.

Concrete workability was evaluated by the slump test.

Compressive strength tests were performed at 7, 28, and 56 days according to NBR 5739. The times of 7 and 56 days will be important to follow the resistance growth due to the hydration of the waste sand.

Water absorption and voids index were evaluated according to NBR 9778 [19].

Capillary water absorption was evaluated according to NBR 9779 [20].

Results

Figure 3 shows the results of the particle size of the used sand.

The particle size analysis indicates a higher volume of fines in the waste sand. The largest volume of fines comes from the waste grinding process in which the dust is generated.

Table 2 presents the results of specific mass, unit mass, and moisture absorption.

Waste Sand has lower specific mass and unit mass due to the materials that compose the waste sand. The lower density combined with the higher water absorption of waste sand increases the amount of water needed to maintain concrete workability.

Figure 4 presents the results obtained in the swelling test.

In addition to having a much smaller maximum swelling, the Waste Sand did not have significant swelling up to 5% humidity, on the contrary and retracted in the first water additions behavior can be justified retraction in the first water additions as being caused by an internal cure, provided by water absorption from the aggregates.

Table 3 presents the results obtained in the slump test to verify the concrete workability.

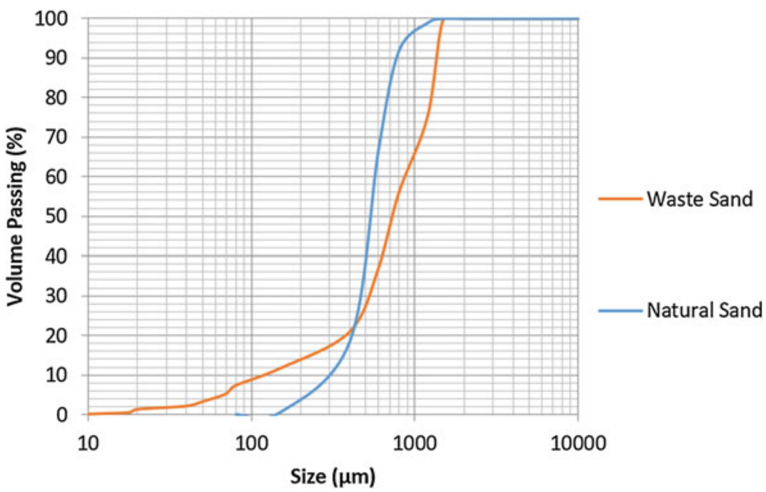

Fig. 3 Granulometry of the used sand

Table 2 Specific mass, bulk density, and moisture absorption results

Material	Specific mass (kg/m^3)	Bulk density (kg/m^3)	Moisture absorption (%)
Natural sand	2630	1370	0,58
Waste sand	2470	1290	13,72

The decrease in slump as the volume of waste sand increases is justified by the absorption of water from the grains. Part of the mixing water is absorbed by the cement grains present in the waste sand. The lower workability hampers the roll and molding, however, the reduction in workability is not so significant as to preclude their use.

Figure 5 presents the results of the concrete compressive strength test.

The incorporation of waste sand decreases the strength of concrete. The larger the incorporation the greater the reduction.

It is also noteworthy that at 7 days, the resistances of the three traces are similar. At 28 days, the difference between resistances increases considerably and decreases again at 56 days.

This behavior can be explained by the hydration of the waste sand cement that promotes increased resistance at older ages. Despite having lower resistance, the use of Waste sand presents similar results at the beginning and approaching tendency in advanced ages.

Figure 6 presents the results of the Water absorption and Void index.

The results indicate a clear increase in voids index and consequently greater water absorption as the incorporation of CDW was increased. The greater

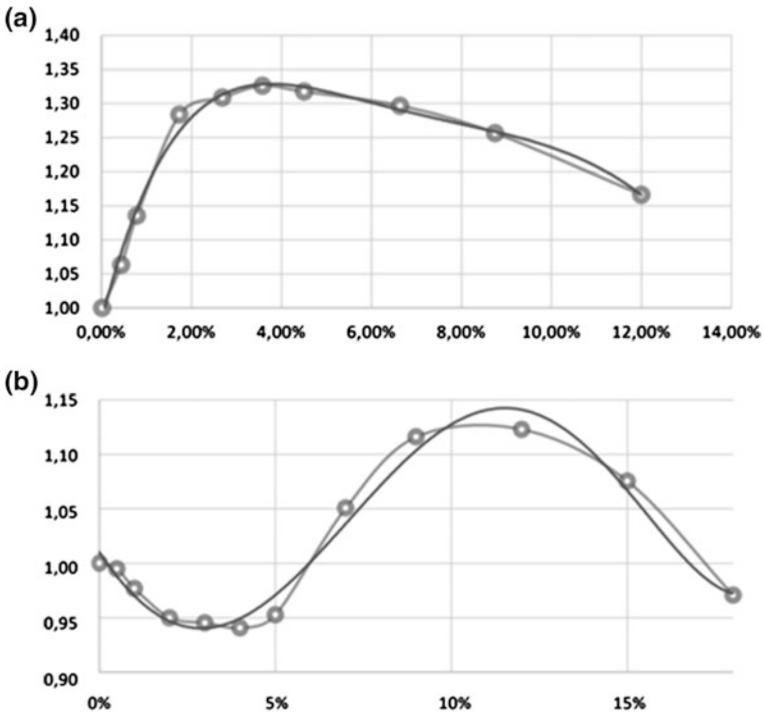

Fig. 4 Swelling test: **a** Natural sand, **b** Waste sand

Table 3 Slump test

Concrete trace	Slump (mm)
100% Natural sand	85
50% Natural sand 50% Waste sand	71
100% Waste sand	62

absorption of waste sand water by the cement promotes an increase in the voids content and greater absorption capacity of the concrete.

High porosity values, as shown by waste sand concretes, can potentially present durability problems in the structure due to weathering.

Figure 7 presents the results of the Capillarity water absorption test.

Capillary absorption results indicate greater water absorption as the incorporation of the residue is increased, similar to that obtained in the previous assay. This behavior is justified by the type of absorption performed in the capillarity test.

Capillary absorption is highly influenced by active pores with diameters between 0.1 and 10 μm.

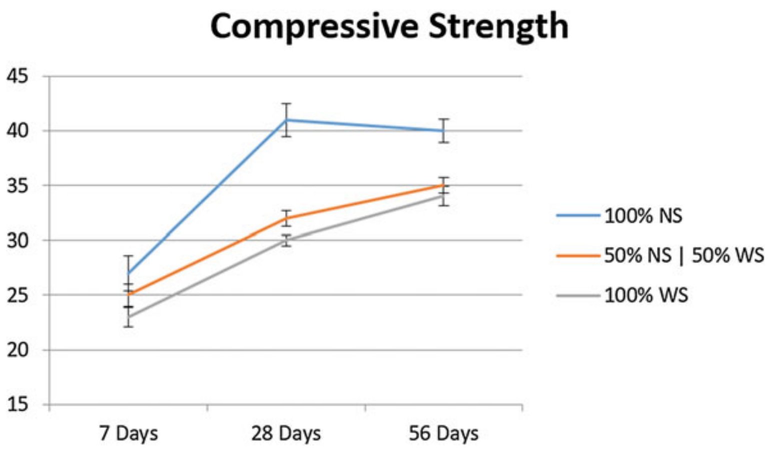

Fig. 5 Compressive strength results

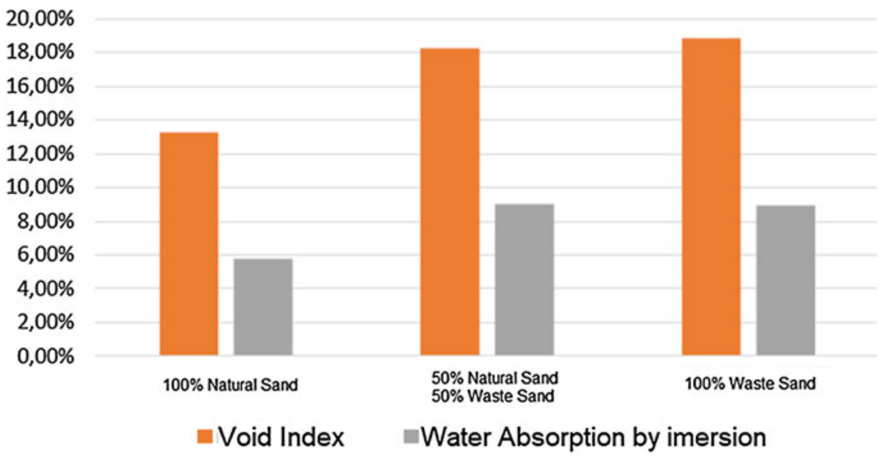

Fig. 6 Water absorption and Void index of concrete

Therefore, besides presenting a large volume of pores of high diameters as verified by the high void index, it also presents a considerable volume of active pores with smaller diameter.

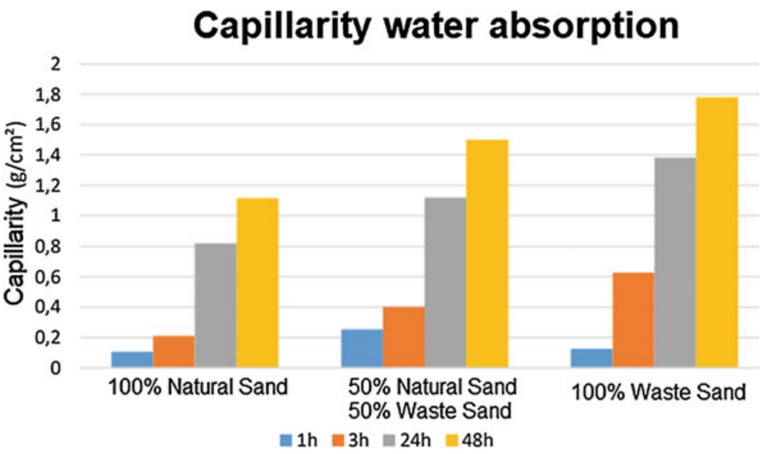

Fig. 7 Capillarity water absorption of concrete

Conclusion

After the results, it can be concluded that

- The characterization of the sands identified a large volume of fines and lower specific mass in Waste sand compared to Natural sand.
- Waste sand incorporation decreases the mechanical strength of concrete. The difference is minimum up to 7 days and increases considerably at 28 days. Even after 28 days, waste sand concrete continues to show strength growth and a tendency to approach the final strength of concrete with natural sand.
- Waste sand concretes showed higher water absorption, both by immersion and capillarity. The void content of concrete increases as the incorporation of waste sand increases.

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References

1. dos Santos FF et al (2012) Adequacy of the municipalities of Rio Grande do Sul state to the construction waste management legislation. Iberoam J Ind Eng 4(8):1–18 (In Portuguese)
2. Halmeman MCR, de Souza PC, Casarin AN (2010) Characterization of construction and demolition waste at the solid waste reception unit in campo Mourão-PR. Revista Tecnológica 203–209 (In Portuguese)
3. UNEP (2009) Buildings and climate change–summary for decision-makers

4. de Azevedo ARG, Alexandre J, Pessanha LSP, da S.T. Manhães R, de Brito J, Marvila MT (2019) Characterizing the paper industry sludge for environmentally-safe disposal. Waste Manag 95:43–52
5. Bourscheid AB, Souza RL (2010) Construction and demolition wastes as an alternative material. 1ª edição. Florianópolis, Publicações do IF-SC, 2010. (In Portuguese)
6. Leite MB (2001) Mechanical properties evaluation of concretes produced with recycled aggregates of construction and demolition waste. Tese de D. Sc, UFRGS, Rio Grande do Sul, Brasil (In Portuguese)
7. Associação Brasileira de Empresas De Limpeza Pública E Resíduos Especiais (ABRELPE) (2006) Overview of Solid Waste in Brazil
8. Hasaba S, Kawamura M, Torli K, Takemoto K (1981) Drying shrinkage and durability of concrete made from recycled concrete aggregates. Jpn Concr Inst 3:55–60
9. Pinto TP (1986) Use of construction waste. Study of the use in mortars. Dissertação de M. Sc., Departamento de Arquitetura e Planejamento da Universidade de São Carlos/USP, São Carlos, SP, Brasil. (In Portuguese)
10. Coimbra MA, Libardi W, Morelli MR (2004) Waste preparing of zinc battery for use in mortar and concrete materials of portland cement. Cerâmica 50(316):300–307
11. Sormunen P, Kärki T (2019) Recycled construction and demolition waste as a possible source of materials for composite manufacturing. J Build Eng 24
12. Islam R, Nazifa TH, Yuniarto A, Uddin AS, Salmiati S, Shahid S (2019) An empirical study of construction and demolition waste generation and implication of recycling. Waste Manage 95
13. Oikonomou ND (2005) Recycled concrete aggregates. Cement Concr Compos 27:315–318
14. Etxeberria M, Vázquez E, Mari A, Barra M (2007) Influence of amount of recycled coarse aggregates and production process on properties of recycled aggregate concrete. Cement Concr Res 37:735–742
15. Evangelista L, Brito J (2007) Mechanical behaviour of concrete made with fine recycled concrete aggregates. Cement Concr Compos 29:397–401
16. Corinaldesi V, Moriconi G (2009) Behaviour of cementitious mortars containing different kinds of recycled aggregate. Constr Build Mater 23:289–294
17. Associação Brasileira de Normas Técnicas. NBR NM 26: Fine aggregate: Sampling. Rio de Janeiro, 2009
18. Associação Brasileira de Normas Técnicas. NBR NM 27: Aggregate: field sample reduction for laboratory testing. Rio de Janeiro, 2001
19. Associação Brasileira de Normas Técnicas. NBR 9778: Hardened mortar and concrete-Determination of water absorption by immersion - Voids index and specific mass. Rio de Janeiro, 2009
20. Associação Brasileira de Normas Técnicas. NBR 9779: Hardened Mortar and Concrete-Determination of Capillary Water Absorption. Rio de Janeiro, 2012