INDEPENDENT JOURNAL OF MANAGEMENT & PRODUCTION (IJM&P)
http://www.ijmp.jor.br v. 10, n. 4, Special Edition *IFLOG 2018*
ISSN: 2236-269X
DOI: 10.14807/ijmp.v10i4.972

RECYCLED CONCRETE ARTIFACTS: TOWARDS SUSTAINABILITY OF CIVIL CONSTRUCTION

Nilo Costa Serpa
Centro Universitário ICESP de Brasília, Brazil
E-mail: nilo.serpa@icesp.edu.br

Gisele Alves Fernandes
Centro Universitário ICESP de Brasília, Brazil
E-mail: gisele.af.bsb@gmail.com

Mariana Lucia Dayrell
Universidade Paulista, Brazil
E-mail: marianabsbadv@hotmail.com

Aline Santoro
Universidade de Brasília, Brazil
E-mail: alinemcsantoro@gmail.com

Submission: 01/18/2019
Accept: 02/10/2019

ABSTRACT

Present article discusses the production of concrete artifacts that use in their composition recycling aggregates of Solid Waste from Construction and Demolition (SWCD). The study was designed as experimental / comparative, with destructive tests of proof bodies made with recycled aggregates (test group) and with traditional aggregates (control group). Subsequent statistical analysis of the data collected from the comparison between these groups was conducted. The optimal dosage for artifacts produced with recycled aggregates was found, demonstrating that the choice of recycled materials could be an economical and environmentally sustainable solution in the context of the eco-innovations.

Keywords: recycling; solid waste; concrete artifacts

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1. INTRODUCTION

With the disorderly growth of large cities, coupled with technological and industrial advances, a significant percentage of natural resources have been consumed, causing damage to the environment and threatening considerably the future of younger generations. In this context, civil construction stands out as a major polluter and devastating agent of raw material sources. Since it is the activity that generates most of the solid urban waste, having in the cement industry and the cement applications in construction sites its most aggressive processes, civil construction accelerates the urban entropy from the point of view of the various irreversible processes that it accumulates.

Considering that the capacity of nature to absorb the enormous volume of waste produced annually by mankind has already been exceeded, it is wise to look at recent climate changes and the recent history of natural disasters, carefully assessing the extent to which anthropogenic environmental impacts will affect dramatically the world in few decades. Global public policies on the environment summarize realistic considerations about the high cost of those impacts if nothing is done, which will certainly lead to dim scenarios.

Regarding civil construction, concrete is identified as its greatest villain. It is a constructive essential consisting of the mixture of cement, water, coarse aggregate (crushed stone or gravel) and fine aggregate (sand). This is the most used material in construction sites, so that present study highlights the problems associated with the accumulation of its residues in the total amount of construction / demolition waste, showing the advantages of its reuse.

2. THE REAL SITUATION

Despite the rise of steel with its plastic advantages and as a promoter of cleaner production, concrete is still the most requested material in civil construction. However, its production causes the emission of pollutant gases, such as CO2, in addition to residues whose final destinations are often the open-air dumps — already banished in socially developed countries —, thus causing serious ecological harm. It is imperative to adopt solutions that seek to mitigate the effects generated by civil construction, which are globally detrimental in several aspects.

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The increasing use of nonrenewable resources, such as limestone in the production of cement, rocks and sand, is increasingly pressing the natural boundaries of exploration towards the complete depletion of reserves. The extraction of minerals causes damage to the environment, which compromises the ecological balance in favor of economic development. Under the prism of construction site management and the civil construction production chain, high generation of waste is neglected with regards to classification and safe and innocuous disposal processes (KARPINSK, 2009).

According to Malešev *et al* (2014), the recycling of construction waste began at the end of Second World War, in Russia and Germany, as a way to remove war-debris with its concomitant reuse in the construction of new buildings (MALEŠEV *et al*, 2014). Since then, mainly from 1992's World Summit Meeting at Rio de Janeiro, several authors have contributed to the understanding of recycled concrete as a constructive option driven by the best practices of cleaner production.

In recent years, Sharma and Singla (2014) produced a good study on recycled concrete aggregates and its various applications in the construction industry (SHARMA; SINGLA, 2014); also, Martínez-Molina *et al* (2015) done a competent review of the subject, pointing that concrete manufacturing from the recycling of concrete produces a new material with mechanical performance and durability in compliance with international standards (MARTÍNEZ-MOLINA *et al*, 2015); lastly, experimental results were well analyzed by Ganiron Jr. (2015) and by Malešev *et al* (2014).

Many other analyzes could be given elsewhere, and in all of them there is enthusiasm about the use of recycled concrete. The recycling of hardened concrete into large aggregate for use again in structural concrete has proved to be an easily argued alternative to builders and engineers. However, it is necessary to seek greater practical foundation regarding the technical characteristics of the materials originated from recycling in order to safely establish fundamental qualities such as fluency and durability.

Due to lack of a parameter that serves as a quality index for recycled aggregates, studies have addressed different ways of using them. The first suggestion is to apply the recycled material only as a substitute part of the natural aggregate,

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affecting not so much the properties of the concrete. Another form has been speculated from the investigation of the effect of various compositions of the aggregate on the properties of concrete, as if we were looking for an ideal composition. However, it is assumed that the porosity of the material is a property with great potential to serve as a control parameter of the recycled aggregate and can be monitored by means of the specific mass of the aggregate and / or water absorption capacity.

3. THE STUDY

According to Brandes and Kurama (2018), the replacement ratio R of natural aggregate with recycled concrete aggregate (RCA) can be calculated using

$$R = 1 - \frac{V_{NA}^{RCA}}{V_{NA}^{NA}}, \qquad (1)$$

where

V_{NA}^{RCA} = volume of natural coarse aggregate in RCA concrete,

V_{NA}^{NA} = volume of natural coarse aggregate in natural aggregate concrete (BRANDES; KURAMA, 2018).

Following these authors, but expanding the number of measurements, the compressive strength of RCA concrete in comparison with the natural aggregate concrete was observed and registered by us at 3, 7, 14, 21 and 28 days (Figure 1).

3.1. Experimental context

The mixtures defined in the dosage study performed were analyzed from the properties observed in fresh and hardened states of the concrete. In order to replace conventional aggregates by recycled aggregates in the production of a sustainable concrete that could replace the conventional concrete, the RCA characterization tests were done, as well as the tests for the analysis of the characteristics of this new material with a standard trait.

The experimental blocks were molded in compliance with the Brazilian standard (NBR 5738), being cylindrical, with 15 cm in diameter and 30 cm in height, adopting a

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reference age of 28 days. The rupture tests were performed in accordance with NBR 5739.

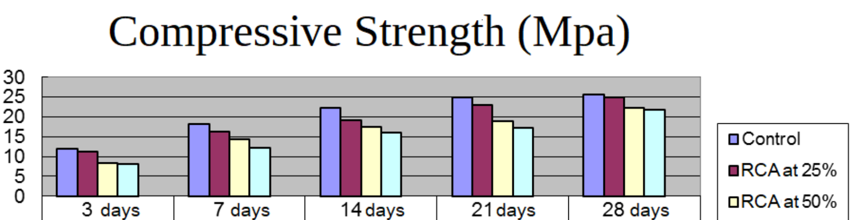
3.2. Results

For water absorption, the recycled aggregate tested showed a very similar result to that of the control group, with a difference of 2.3% less for the test group. Regarding the resistance, considering RCA at 25%, 24.96 Mpa were achieved as shown in Figure 1. During test procedures, the important observations of Modler and Pozzobon (2008) were taken into account, when they state that

> The most important analysis to be done in this case is related to the fact that the higher absorption rates of the concrete aggregates do not increase the absorption of the hardened concrete. In this way, the influence that the type of aggregate exerts on the absorption of the concrete is related to the granular arrangement between different aggregates (MODLER; POZZOBON, 2008).

Results corroborate the measurement of the amount of water required when dosing was done. It was clear that the presence of recycled aggregate made the workability adjustment a very delicate activity. The longer the mixing time, the greater the need for concrete handling.

The goal at this point of the research was then to adjust the slump of the mixture as fast as possible, otherwise the sample would be abandoned because it would present values of workability beyond that specified with minimum amounts of water added. From the mean results given by the compression of the experimental blocks, it was observed that the minimum value of 4.5 MPa established by the norm NBR 6136 was reached at the age of 3 (three) days.



	3 days	7 days	14 days	21 days	28 days
Control	11,95	18,12	22,34	25,03	25,55
RCA at 25%	11,14	16,18	19,13	22,98	24,96
RCA at 50%	8,32	14,36	17,59	19,01	22,17
RCA at 75%	8,03	12,29	16,02	17,22	21,85

Figure 1: Evolution of compressive strength registered by the authors.

4. DISCUSSION

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In Brazil, groups of environmentalists and scholars are warning of the need for a firm positioning of the governmental authorities about sustainability, a theme that gains space every day and involves professionals from different areas working together to find solutions to the challenges presented in the first decades of the 21st century. As Corrêa (2009) observes,

> The incorporation of sustainability practices in construction is a growing trend in the market. Its adoption is "a path with no return", as different agents — such as governments, consumers, investors and associations — alert, stimulate and pressure the construction sector to incorporate these practices in their activities (CORRÊA, 2009).

An important step in terms of legislation came when Brazilian Federal Government, through the Law Nº 12 305/2010, instituted the National Solid Waste Policy, by which it was created the necessary instruments to face the main environmental, economic, and social problems that arise when the management of solid waste is inadequately done (BRASIL, 2010). Porto and Silva (2008) explain that

> Waste can cause health and environmental hazards, especially in improper final disposal. Its inappropriate removal causes health problems (vector-borne diseases and chemical pollutants), environmental (soil and groundwater contamination), social (sewage), economic (devaluation of areas, drainage system damages, loss of materials and energy) (PORTO; SILVA, 2008).

In Brazil, the national industry has one of its main segments in the construction sector. It is sometimes considered, exaggeratedly, a thermometer indicative of economic and social growth. Because it is an industry that uses a significant amount of natural resources, civil construction collaborates to change landscape and, like any activities developed by society, generates waste.

In 2010, it was estimated that the sum of volume and weight quantities of the SWCD collected represented approximately 7,192,372.71 ton/year of public origin and 7,365,566.51 ton/year of private origin. It is reasonable to assume that these quantitatives do not represent the real situation, since according to data collected by IBGE, only 7.04% of the municipalities considered have some form of SWCD processing (IBGE, 2010). This amount should have remained relatively stable due to the socio-economic crisis that has been going on since 2015, affecting tremendously civil construction.

Anyway, the amounts of SWCD give an urgent tone to the question, since it is estimated that they will represent in the next years 50 to 70% of the mass of urban solid waste in the 5,564 Brazilian municipalities.

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4.1. Future trends

In recent years, advances in nanotechnology have encouraged nanoparticle aggregation research to concrete study (PACHECO-TORGAL; JALALI, 2011). Soon, if not already in progress, we shall face a real change of constructive paradigm, combining largely the experience of recycled concrete with the insertion of nanomaterials in its composition. Serpa (2017) has drawn attention to this in his lecture notes:

> Reinforced concrete can be said to be a relatively recent technology — since its consecration as a constructive material only took place long after the advent of Portland cement in 1824 —, continuously giving rise to a number of investigations, including the incorporation of nanotechnology (briefly, the use of nanoparticles, carbon nanotubes and nanofibers to increase the strength and durability of cementitious composites as well as to reduce pollution), highlighting the use of nanosilica particles to increase compression strength of cement pastes. The logical conclusion of all this shall be the combination of such technologies in a cleaner production of an efficient and environmentally less costly concrete (SERPA, 2017).

Unfortunately, due to Brazil's history of technological backwardness, this thinking will belatedly occupy the narrow mind of our business class and our rulers, for the misfortune of future generations of Brazilians.

5. CONCLUSION

Present study showed encouraging results regarding the use of concrete residues in the production of a recycled concrete. Despite the resistance that still exists respecting the reuse of RCA in Brazil, the tests performed showed that there is no reason for such resistance. The study also presented social and economic arguments that unequivocally clarify the need for eco-innovations in construction.

It is hoped that this article will motivate other researches into recycling processes, stimulating academics and entrepreneurs to search for processes that guarantee more quality of life for future generations. In this line of thought, the question of the durability of recycled concrete has been continuously addressed, especially in comparative research between carbonated and non-carbonated recycled concrete, in terms of deformation (drying retraction), water absorption and permeability. Preliminary experimental results seem to indicate that the carbonated version helps to reduce water absorption, in addition to reducing permeability. It is therefore an exciting topic open to the next generations of researchers.

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6. ACKNOWLEDGEMENTS

This work was carried out with financial support from the Centro Universitário ICESP de Brasília. The authors thank the institutional incentive for this research.

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