

Recycled concrete blocks used as coarse aggregate in the floor of rural facilities

Reciclagem de blocos concreto para uso como agregado graúdo em pisos de instalações rurais

Matheus Viero da Costa¹; Sidiclei Formagini²; Rodrigo Couto Santos³;
Rafael Zucca⁴; Juliano Lovatto⁵

Abstract

Waste from construction industry has been improperly disposed in areas located between the outskirts of Brazilian cities and rural villages. Thus, such areas have become irregular deposits of construction waste that have damaged fountainheads. In order to enable sustainable development in rural areas, the subject “construction waste reuse” has been increasingly researched. In that regard, this study has verified the feasibility of using recycled concrete blocks as coarse aggregate in the floor of rural facilities. Firstly, the particle size distribution and specific mass of the material recycled were registered. Afterwards, lines of concrete were established, where R0 was the reference line, without crushed block, R25 (250 kg/m³ of crushed block), R50 (490 kg/m³ of crushed block), and R75 (721 kg/m³ of crushed block). Cement concentration was the same for all lines. Samples were observed fresh – through slump test – and hardened – through simple compression tests and trials to measure the absorption of water. In the end, R25 demonstrated to comply with the regulations and that can be used to build floors intended to livestock facilities, pedestrians, and ground floor dwelling with no structural purposes.

Keywords: Rural facilities. Construction waste. Sustainability.

Resumo

No Brasil o descarte inadequado de resíduos da construção civil em áreas de transição entre o urbano e rural tem resultado em danos aos mananciais, sendo comum entradas e saídas de cidades e povoados rurais serem utilizados como depósitos irregulares de entulhos. Pesquisas sobre o tema “reuso de resíduos da construção” estão evidenciadas nos dias atuais visando o desenvolvimento sustentável do meio rural. Posto isto, este estudo verificou a viabilidade do uso de resíduos de blocos de concreto como agregado graúdo em novos pisos de concreto de construções rurais. Inicialmente o material reciclado foi caracterizado por sua distribuição granulométrica e massa específica. Depois elaborou-se traços de concreto, sendo o de referência (R0) sem bloco triturado, R25 (250 kg/m³ de bloco triturado), R50 (490 kg/m³ de bloco triturado) e R75 (721 kg/m³ de bloco triturado), fixando-se o volume de cimento. As amostras foram caracterizadas no estado fresco pelo ensaio de abatimento do tronco de cone e estado endurecido pelos ensaios de compressão simples e absorção de água. Ao final verificou-se que o concreto R25 têm condição de ser utilizado em pisos de instalações para produção animal, pisos para pedestres e pisos de moradias térreas, sem fins estruturais.

Palavras-chave: Construções rurais. Resíduos da construção. Sustentabilidade.

¹ Me. em Engenharia Agrícola, UFGD, Dourados, MS, Brasil. E-mail: matheuscosta@ufgd.edu.br

² Prof. Me., Depto de Engenharia Civil, UFMS, Mato Grosso do Sul, MS, Brasil. E-mail: sidiclei.formagini@ufms.br

³ Prof. Dr., Faculdade de Ciências Agrárias, UFGD, Dourados, MS, Brasil. E-mail: rodrigocouto@ufgd.edu.br

⁴ Me. em Engenharia Agrícola, UFGD, Dourados, MS, Brasil. E-mail: rafael-zucca@hotmail.com

⁵ Me. em Engenharia Agrícola, UFGD, Dourados, MS, Brasil. E-mail: julianolovatto@ufgd.edu.br

Introduction

Problems caused by traditional construction in Brazil, which produces huge amounts of waste, severely impact on the environment of the country. Besides, there are many places where waste from construction industry is improperly disposed, causing the accumulation of environmental liability in areas which separates Brazilian cities and rural villages, and also damaging fountainheads. Frequently, unlawful deposits of rubbles can be observed in the outskirts of cities (SILVA; ASSUNÇÃO, 2015).

Construction industry is among the most important productive segments regarding economic development, since it provides several direct and indirect employments (LOCKREY *et al.*, 2018). Paschoalin Filho *et al.* (2013) affirm that although this segment affects environment severely, it is also one of those which invest the most in technology innovations and development of tools for managing waste production and other workflows. Society is interested in companies which use new technologies in their buildings, aiming do reduce environmental liability left to next generations. Thus, there is a competitive race in order to develop new materials and improve constructive techniques (BRESCANSIN *et al.*, 2015). In this scenario, construction industry wastes, used as aggregate, provide raw material that can deliver savings of up to 80% when compared to market inputs (SILVA; ASSUNÇÃO, 2015).

Second Zucca *et al.* (2018), agricultural segment demands an infrastructure to be built in the next years, which provides means to use sustainable material in warehouses, rural dwellings, silos, flooring etc. The authors also state that combining recycled material to new ones is a recommended trend, mostly when using concrete to flooring. Such combination can be used in rural facilities floors, which enables a right and sustainable destination for a great amount of construction waste.

According to the Brazilian Association for Recycling Construction and Demolition Industry Waste - ABRECON (2015), construction industry waste is defined as amounts of fragments or debris of concrete, bricks, mortar, wood, steel, among other materials produced by the construction, restoration or demolition of dwellings, buildings, bridges, sheds etc. Hence, recycling construction material is technically feasible to reuse waste, providing damages reduction and sustainability to rural areas.

Recycling and reusing construction industry waste is a management alternative, which can be correlated to Triple Bottom Line concept: environmental – economical – social. Environmental bottom is intended to reduce waste amounts, usually addressed to unlawful landfills, and carbon emissions produced during waste transportation. Economical bottom is defined as savings built up when reducing costs related to raw material (transportation included). Finally, social bottom is related to the creation of employments and loan, provided by the linkage between the construction productive chain and the waste recycling process (PASCHOALIN FILHO *et al.*, 2016).

Since agricultural expansion demands construction raw material, and construction industry waste causes damages to environment, this study aims to assess if recycling waste - incorporated to non-structural concretes - is feasible as a technological alternative to be used in rural facilities floors.

Materials and methods

The trial was performed between December, 2016 and May, 2017. The experimental stage was carried out in the Testing Department of Anhanguera University Uniderp, in Campo Grande, state of Mato Grosso do Sul (MS), and the data registered were analyzed in the Federal University of Grande Dourados (UFGD), in Dourados/MS.

In January, 2017, a construction company from Campo Grande/MS, that uses to perform beneficiation of concrete blocks, ceded the waste used in the research. About 50 kg of blocks were collected. Afterwards, the material was described according to NBR 7211 (2009) parameters. Its granulometric range was equal to gravel and B0, that is, 4.75/12.5mm.

Cement CP-II-E-32, white average sand (small aggregate), B0/gravel (small aggregate), crushed waste of concrete blocks (coarse aggregate) and water were used in order to produce concretes. Three mixtures of concrete were produced replacing coarse aggregate (bulk) by contents of crushed concrete blocks in the proportions of: 25% (R25), 50% (R50) and 75% (R75).

Aggregates were described in compliance with NBR NM 248 (2003), in order to establish granulometric distribution, NBR NM 52 (2009), in order to establish the specific mass of small aggregate, and NBR NM 53 (2009), in order to establish the specific mass of coarse aggregate.

After describing the material, the dosage of traces was measured through the computer program MecFor® using the Compressible Packing Model of Formagini et al. (2005), based on the reference trace (R0) 1:4:6 without addition of waste. Also based on the reference trace (R0) with no crushed block and with the replacement percentages defined, MecFor® adjusted the other traces components: R25 (250 kg/m³ of crushed blocks), R50 (490 kg/m³ of crushed blocks) and R75 (721 kg/m³ of crushed blocks). Traces were adjusted in order to achieve a reduction from 8 cm ± 2 cm and the consumption of cement remaining similar for all mixtures, where Fck = 20 MPa with standard deviation level A = ± 4.0 MPa.

All the materials were mixed in a 120 liters tilting drum mixer. Twenty four specimens with 10cm diameter and 20cm height were produced to each trace. After 24 hours, the specimens were removed from molds and, afterwards, placed in a moist chamber for curing.

The preparation stage of the concrete was in compliance with NBR 12821 (2009). The description stage of the fresh concrete produced by the mixtures was in compliance with NBR NM 67 (1998), using slump test. The description stage of hardened concrete was in compliance with NBR 5739 (2018), in order to establish the resistance to simple compression.

An electric hydraulic press – maximum capacity of 1000 KN – with strength measuring system class 1, and calibration certificate was used. For each period tested – 3, 7, 14 and 28 days -, the resistance of the four specimens was established. All samples tops were facing by grinding before pressing. Four specimens were used for each trace in the tests of absorption of water through immersion; void ratio; and specific mass, in compliance with NBR 9778 (2005).

Using descriptive statistics through software STATISTICA®, specimens were compared with different amounts of waste in the different periods established. In order to elaborate an interpretation and an eventual regression analysis, to those cases which present a functional relation between a dependent variable and an independent one - or more than one-, the variability of the attributes was assessed.

Results and discussion

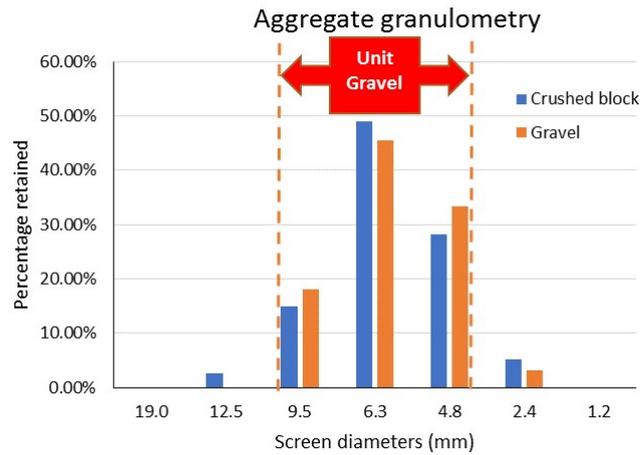
First, coarse aggregate obtained from waste was described in order to verify if the percentage of its granulometric distribution corresponded to the particles dimensions of the coarse aggregate used as reference, that is, gravel (B0). After screening, 92.1% of crushed material collected from the sample presented granulometry correspondent to B0. This result enables such material to be used in the specimens production, preserving the same characteristic of the coarse aggregate.

Figure 1 shows the percentage left after each time coarse aggregates were screened. The prevalent diameter of the crushed block waste presented the same gravel interstice: from 4.8mm to 9.5mm, which confirms the similar dimensions. According to Madrid et al. (2017), when using concrete of different ages, the effect of compression and absorption of by-products is directly related to the mechanical and physical properties of their aggregates, and is influenced by the concrete internal structure and existence of void spaces. Thus, it is important the aggregates produced by the recycling process of waste present similar dimension of the natural aggregate, since this characteristic affects the concrete ability of absorbing and resisting.

In compliance with NBR NM 67 (1998), a slump test was performed in order to describe fresh concrete, and the mixtures were preserved as stipulated by the dosage, in order to enable the reduction from 8cm ± 2 cm. These results were obtained by the addition of different amounts of water for each trace, due to the porosity of the aggregate used, which naturally presents a higher number of voids. According to Santos *et al.* (2016), slump test analysis is directly related to the addition of waste percentages. Therefore, since aggregate percentage increases, the concrete fluidity reduces and, consequently, a lower reduction occurs.

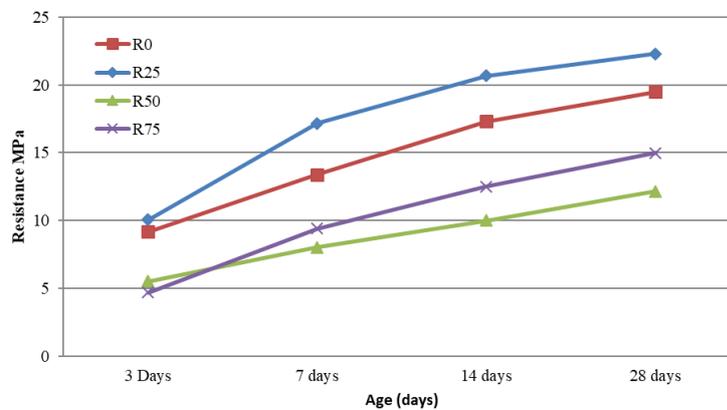
After the slump test, the resistance of the hardened concrete was described through a simple compression trail. The resistance results of the trials are presented in Figure 2. All traces presented similar upward curves. The lower resistance occurred on day 3 in the concrete R75, and the higher resistance, on day 28 in the concrete R25. Second Bressan *et al.* (2017), concrete resistance to compression increases based on their curing time, in consequence of a continuous hydration of cement particles, which reduces the number of pores in the hydrated cement mass.

Figure 1 – Flow diagram of the 3D Printer Mounting Stage



Source: The authors.

Figure 2 – Specimens resistance trial



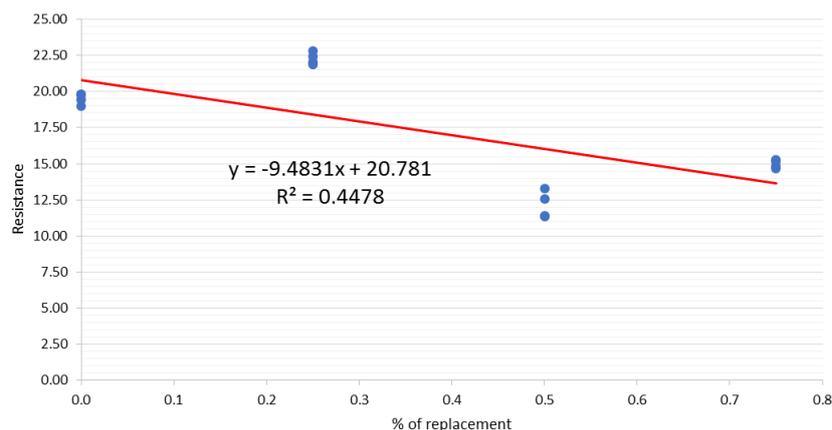
Source: The authors.

Concrete R25 presented the highest resistance to simple compression when compared to the others, even to standard R0, Figure 2. This suggests that, according to the mechanical characteristics tested in the simple compression trial, concrete R25 can be used for the same purposes that concrete standard R0, composed by coarse aggregates B0 (gravel). According to Madrid *et al.* (2017), considering the different ages, compression effect over concrete takes into account its by-products, linking the mechanical properties of each element, which are influenced by the internal structure and the existence of void spaces. The studies of Da Silva *et al.* (2017) state that the usage of construction industry waste together with concrete traces can produce a resistance statistically equal to standard concrete, emphasizing the usage feasibility of these materials.

Since the descriptive statistics test (test F) presented a non-significant result regarding the comparison among treatments of different ages, a linear regression was performed aiming to produce an equation to adjust treatment and replacement aggregate percentage, as shown in Figure 3, which enables the study of the correlation between the waste concentration and the specimens resistance.

According to Mello and Peternelli (2013), the coefficient of determination R^2 provides a result which assists the regression variance analysis, observing if the proposed model is appropriate or not, regarding the range from 0 to 1, been perfect negative when $R^2 = -1$ until perfect positive when $R^2 = 1$. Therefore, the straight line demonstrates that, in average, the higher is the concentration of construction industry waste incorporated, the lower is the standard concrete resistance.

NBR 8953 states that to structural purposes, just concretes from class C20 (20Mpa) can be used. Concretes from class C15 (15 MPa) can be used just in temporary constructions or in concretes without structural purposes. Based on the minimum values established by NBR 8953 and the medium resistance of the traces analyzed on the 28th day (21.30 e 15.14 MPa) to R25 and R50, respectively, mixtures R25 and R50 can be used to flooring rural facilities; and trace R25 is emphasized, since it also presents minimum resistance to objects with structural purposes, although it is not recommended. Similar results were obtained by Andrade; Teixeira and Oliveira (2016), who indicated the replacement level increase and the com-

Figure 3 – Specimens resistance trial

Source: The authors.

ponents' mechanical heterogeneity as the main causes of the variation of the resistance to the compression applied by the concrete produced from construction industry waste.

Table 1 presents the relation between cement consumption through MPa and resistance achieved on day 28. Among the four mixtures, concrete R25 presented the lowest consumption of cement through MPa, although it has achieved the highest mechanical resistance to simple compression. Concrete R75, in turn, consumed more cement and achieved the lowest resistance, showing that the higher is natural aggregate replacement, the lower is the resistance. As stated by Wang *et al.* (2018), when concretes are subjected to a higher deformation level, concrete crashes along the aggregate, presenting a variable resistance to compression, directly related to the kind and amount of aggregate comprised by the concrete.

Table 1 – Cement consumption through MPa and resistance to simple compression after 28 days

	R0	R25	R50	R75
Cement consumption (kg/MPa)	12.057	10.358	14.616	18.827
Resistance after 28 days (MPa)	20.50	21.30	14.14	13.60

Source: The authors.

Aiming to describe concrete permeability, trials intended to measure the absorption of water were carried out. Figure 4 shows that the absorption of water was proportional to void ration for all trials, that is, the higher is void ratio, the higher is the material capacity to absorb

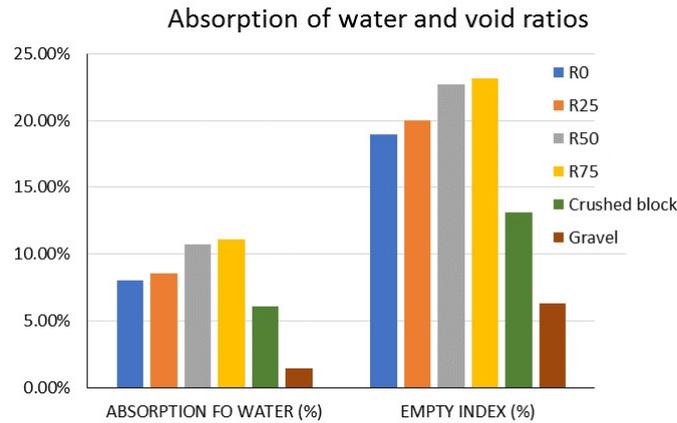
water. Besides, R25 was the concrete that most closely approximates the standard trace with the lowest void ratio, directly related to a lower absorption of water and, consequently, presenting a great improvement in the packing process of aggregates.

When comparing crushed blocks with natural gravels, a higher porosity of the block waste is observed, attesting its contribution to increase void ratio in the concretes presented in larger amounts, Figure 4. This behavior was reported by Lima and Leite (2012), who studied the porosity increase of recycled aggregates compared to natural aggregates. They have concluded that the absorption of water and the number of concrete voids increase, since crushed recycled aggregate, added to the mixture, also increases, which demonstrates that concretes produced with construction industry waste are indicated to pavements exposed to weather and where water uses to accumulate, like livestock facilities - constructed in rural areas -, usually more susceptible to humidity and with no sealing.

Figure 5 shows the specific mass of concretes. Trials, in compliance with NBR 9778 (2005), aimed to determine the weight per m³, since this is an important parameter to the structure of constructions.

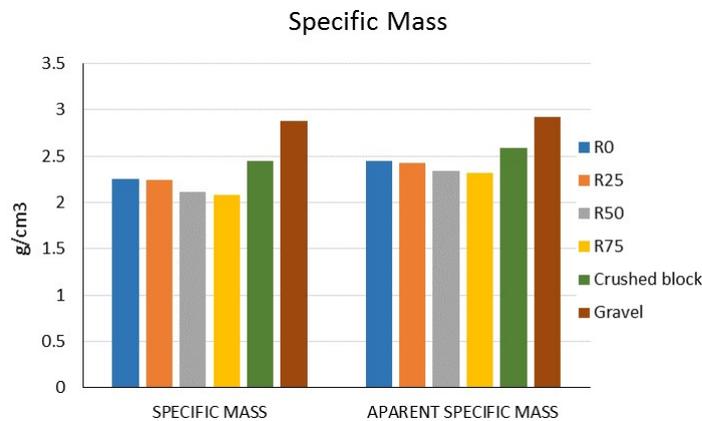
Specific mass and apparent specific mass of the mixtures were obtained. Based on Figure 5, it can be observed that when the crushed concrete block is added to the mixture, specific and apparent specific masses are reduced. Pimentel *et al.* (2014) has found similar results, in which the specific mass of recycled aggregates was lower than the natural aggregates, so that concrete becomes lighter. Such behavior is directly proportional to the amount of crushed block in the mixture, as it is an important characteristic of the concrete intended to be used in constructions with no structural purposes.

Figure 4 – Absorption of water and void ratios considering traces and coarse aggregate subjected to trials



Source: The authors.

Figure 5 – Specific mass of the different traces and coarse aggregates under trial



Source: The authors.

Conclusion

The specimens absorption of water was proportional to void ration, and the higher was the amount of construction industry waste, the higher was the porosity.

All traces analyzed were registered under the concentration recommended (25% to rural pavements).

Trials of resistance to block compression presented results which prove that concretes R25 and R50 are technically feasible to paving rural facilities floors and pavements.

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