Journal of Environmental Science and Engineering B 8 (2019) 129-133
doi:10.17265/2162-5263/2019.04.001

Evaluation of Partial Sand Replacement by Coffee Husks in Concrete Production

Alan Carlos de Almeida[1], Matheus Alves Lima da Silva[1], Queren Cabral de Abreu[1], Adriana Lau da Silva Martins[2], Sandro Pereira Ribeiro[1] and Cristiane de Souza Siqueira Pereira[1]

1. Chemical Engineering, Vassouras University, Av. Expedicionário Osvaldo de Almeida Ramos, 280, Centro, Vassouras, Rio de Janeiro 27700-000, Brazil

2. Departament of Engineering, University Center Geraldo Di Biase, Barra do Piraí, Rio de Janeiro 27600-000, Brazil

Abstract: Waste production in the industrial sector generates environmental impacts. Thus, it is necessary to search for means to reduce and reuse these residues. Brazil is the largest coffee producer and exporter worldwide, with this being one of the main products in the consumer market, at a production of 30 million sacks per year. Coffee production generates large amounts of by-products, such as husks. Therefore, the reuse of this residue is a good alternative for its disposal. In view of this fact, partial sand substitution by coffee husks in concrete production was evaluated, in order to reduce sand use in concrete manufacturing. For specimen production, traits were formulated by replacing sand by coffee husks at 5%. A 0.5:0.5:1:0.5 (gravel:sand:cement:water) ratio was considered for specimen preparation. To evaluate mechanical compressive strength, assays were performed after 7, 14, 21 and 28 days, using a hydraulic press with 80 MPa capacity. Partial sand substitution by the coffee residue was considered satisfactory, obtaining a compressive strength of ± 20 MPa, higher than the resistance obtained for the concrete produced without sand replacement. Coffee husk use did not compromise material resistance.

Key words: Coffee, concrete, waste.

1. Introduction

With industrialization advancements, waste has become a serious urban problem. One way to solve this is waste recycling. In this scenario, construction displays a significant potential in this regard, as it consumes up to 75% of natural resources [1].

The study of waste reuse by the construction industry has been increasingly consolidated as an important practice aiming at sustainability, as this activity presents the advantage of being able to incorporate solid waste generated in various production segments to construction materials. The search for new materials, construction techniques and waste and renewable material insertion is, thus, of paramount importance [2].

Concrete is one of the most commonly used building materials and is defined as a composite material consisting of cement, water, fine aggregate (sand), coarse aggregate (stone or gravel) and air. It may also contain additions (pozzolans, active silica, etc.) and chemical additives for the purpose of improving or modifying its basic properties [3].

Coffee processing generates large amounts of solid waste (peel or pulp, depending on the process). According to Silva [2], one ton of beans and one ton of waste are generated from the processing of two tons of coffee.

Coffee husks are traditionally used as fertilizer, animal feed and as fuel used in the coffee drying process [2].

Coffee husk ash had been tested in some countries for its pozzolanic possessions, which has been found to develop some of the properties of the paste, mortar and concrete-like compressive strength and water tightness in confident substitution percentages and

Corresponding author: Cristiane de Souza Siqueira Pereira, Ph. D., research field: environmental science.

fineness [4]. Coffee husk ash acts as a pozzolanic material when added to cement because of its silica (SiO_2 ± 14.65% coffee husk ash by weight) and aluminate content, which reacts with free lime released during the hydration of the cement and forms additional calcium silicate hydrate as a new hydration product [5]. To be mixed with cement, the shell is first heat treated at temperatures between 500 and 600 °C for about 15 hours. The coffee husk then becomes a fine ash that can then react with other materials.

Demissew, et al. [6] evaluated partial replacement of cement by coffee husk ash for concrete production. According Demissew, et al. [6] this research has demonstrated that concrete produced from coffee husk ash has high potential as a source of environmental-friendly cementitious material that reduces pollution and provides a sound coffee waste management option. In the literature, studies are found with the addition of coffee husk ash in concrete production, but studies related to the use of coffee husk are scarce. Prusty, et al. [7] presented a review about concrete using agro-waste as fine aggregate for sustainable built environment. According to these authors, new research is important for the use of these agro-industrial wastes.

In this context, the present study aimed to add crushed coffee husks to a mixture of sand, concrete and gravel, in order to minimize sand consumption as a raw material and assess husk behavior through compression tests.

2. Experimental Setup

2.1 Material

The coffee residue (Fig. 1) was kindly provided by the Serra da Garcia Farm, located in the municipality of Liberdade, MG, Brazil. The state of Minas Gerais is responsible for much of the country's coffee production. The coffee husks and sand were sieved and the fractions retained in a 1.18 mm sieve were considered for concrete production, following the Associação Brasileira de Normas Técnicas [8] standard, which states that sand is a natural material displaying suitable properties with a maximum nominal size of less than 2.0 mm and a minimum nominal size of 0.075 mm or more. Portland blast furnace cement (CP III-40 RS) consisting of silicates and aluminates was used, which hydrates in the presence of water to form a high mechanical strength material. The gravel was sieved and the fractions retained in a 9.5 mm sieve were used. According to Associação Brasileira de Normas Técnicas [8], this type of gravel is termed type 1 gravel.

Fig. 1 Coffee residue (crushed husks).

2.2 Trace Concrete Specimens

Traces without residue addition and traces with the addition of 5% coffee residue (husks) replacing sand at a 1:0.5:0.5:0.5 gravel:sand:cement:water, ratio were prepared. The residue was replaced at the same ratio as the amount of sand. These raw materials were mixed in a concrete mixer (120 L capacity) and water was gradually added until homogenization (Fig. 2).

Fig. 2 Concrete mixer (120 L capacity).

2.3 Specimens for Mechanical Compressive Strength Testing

The concrete specimen molding and curing procedure for the mechanical compressive strength test was carried out in accordance to the Associação Brasileira de Normas Técnicas [9] standard. The slump test was performed according to the Associação Brasileira de Normas Técnicas [10] standard. The test was performed by filling a trunked conical form in three equal thickening stages with 12 strokes, slowly removing the form and measuring the difference between the concrete and the mold. Twelve specimens were filled adopting the dimensions of 20 cm in height and 10 cm in diameter. The specimens were gradually filled with the aid of an iron bar to perform mixture thickening, avoiding pore concrete formation. After preparation, the specimens were placed on a horizontal surface and stored for 28 days. After the minimum concrete curing time (seven days), axial compression tests were performed using a hydraulic press (80 MPa capacity) according to the Associação Brasileira de Normas Técnicas [11] standard. All tests were performed in triplicate at 14, 21 and 28 days.

3. Results

The results of the compressive strength tests are described in Table 1, while Fig. 3 displays the compression test results after the 28-day concrete curing time. The results were generated using the Pavitest concrete software v. 1.3.0.24 according to the cylindrical body compression test [11] standard.

Concrete resistance (expressed as MPa) was obtained by the relationship between the applied force and the cross-sectional area of the specimen.

According to Batista, et al. [12], concrete contains micro cracks even before being subjected to external stresses. Therefore, strength is related to the stress required to cause the fracture and is synonymous with the degree of rupture at which the applied stress reaches its maximum value. The concrete produced (Fig. 4) with the addition of 5% coffee husks presented satisfactory results, displaying higher mechanical resistance (19.30 ± 1.00 MPa) than the concrete produced without the addition of this residue, of 12.2 ± 1.95 MPa.

According to what is exposed by Associação Brasileira de Normas Técnicas [8], concretes with structural function (reinforced concrete) need to achieve compressive strengths greater than 20 MPa depending on its purpose.

The compressive strength achieved herein represents 57% of the values for light vehicle loads, where the established criterion for the compressive fck

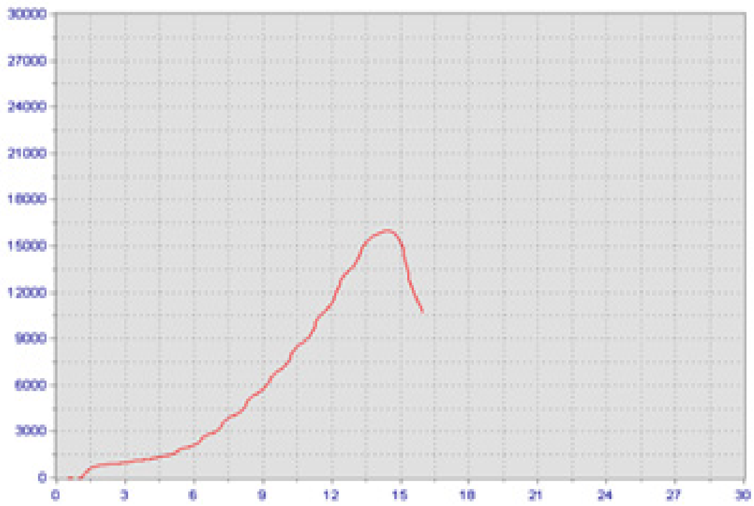

Fig. 3 Compressive strength test results after 28 days with the addition of 5% coffee residue.
(Pavistest Concrete Software v. 1.3.0.24)

Fig. 4 Concrete produced.

Table 1 Axial compression analysis data.

Curing time (days)	Compressive strength (MPa)
7	12.33 ± 0.69
14	17.07 ± 1.38
21	20.97 ± 1.44
28	19.30 ± 1.00

Table 2 Compressive strength test results after 28 days.

This work	Da Costa et al. [15]
19.3 MPa	15.3-16 MPa

(Feature Compression Know) strength applied for this purpose is 35 MPa. On the other hand, the obtained resistance exceeds the value for the application of artifacts (interlocks) for interlock pavements.

As the Associação Brasileira de Normas Técnicas [13] standard indicates a value of 15 MPa to this end, this concrete strength overcoming can be attributed to coffee husk straw, which contains agents with pozzolan properties [14]. Da Costa, et al. [15] evaluated partial substitutions of sand (CPIII-30% sand) for coffee husk ash. The results are described in Table 2.

4. Conclusions

The preliminary results obtained herein indicate that the partial replacement of sand by coffee residue in concrete production is considered technically feasible, presenting a compressive strength of ± 20 MPa. The proposed concrete contributes to minimizing the use of sand, a non-renewable raw material, aiming to reduce environmental impact and, thus, increasing the proposals for more sustainable concrete production.

Replacing an aggregate mineral, sand and gravel, with agro industrial waste causes damage to a material with much lower mechanical performance than conventional. However, it is necessary to note when using these composite materials we do not look for a substitute for conventional concrete, but rather the proportion or use of an alternative concrete using the new applications. Further studies should be performed in this regard.

References

[1] Ângulo, S. C., Zordan, S. E., and John, V. M. 2001. "Desenvolvimento sustentável e a reciclagem de resíduos na construção civil." PCC, São Paulo, 13 f. Departamento Engenharia de Construção Civil da Escola Politécnica. Disponível em: http://www.reciclagem.pcc.usp.br. (in Portuguese)

[2] Silva, J. P. D. 2012. "Caracterização da casca de café (coffee arábica, l) in natura, e de seus produtos obtidos pelo processo de pirólise em reator mecanicamente agitado." M.Sc. thesis, Universidade Estadual de Campinas. (in Portuguese)

[3] Silva J. A., Leite, J. M. C., Faria, A. P. C., Santos, M. L., Pacheco, J.S., Pereira, C. S. S. 2018. "Avaliação da produção de concreto utilizando resíduo do processamento industrial da azeitona." *Impactos das tecnologias nas engenharias, Atena Editora*, Ponta Grossa (PR). doi: 10.22533/at.ed.578171412 (in Portuguese)

[4] Lin, T. K., and Hsu, Y. 2016. "The Application and Evaluation Research of Coffee Residue Ash into Mortar." *Mater Cycles Waste Manag* 18: 541-51. doi: 10.1007/s10163-015-0351-5.

[5] Gonzalez, E. 2010. "Novel Crystalline SiO_2 Nanoparticles via Annelids Bioprocessing of Agro-Industrial Wastes." *Nanoscale Research Letters* 5 (9): 1408-17.

[6] Demissew, A., Fufa, F., and Assefa, S. 2019. "Partial Replacement of Cement by Coffee Husk Ash for C-25 Concrete Production." *Journal of Civil Engineering, Science and Technology* 10 (1): 12-21.

[7] Prusty, J. K., Patro, S. K., and Basarkar, S. S. 2016. "Concrete Using Agro-Waste as Fine Aggregate for Sustainable Built Environment—A Review." *International Journal of Sustainable Built Environment* 5 (2): 312-33.

[8] Associação Brasileira de Normas Técnicas (ABNT). 1993. *NBR 7225 Concreto—Materiais de pedra e agregados naturais.* Rio de Janeiro, RJ. (in Portuguese)

[9] Associação Brasileira de Normas Técnicas (ABNT). 2015. *NBR 5738 Concreto—Procedimento para moldagem e cura de corpos de prova*. Rio de Janeiro, RJ. (in Portuguese)

[10] Associação Brasileira de Normas Técnicas (ABNT). 2007. *NBR NM 67 Concreto—Determinação da consistência pelo abatimento do tronco cone*. Rio de Janeiro, RJ. (in Portuguese)

[11] Associação Brasileira de Normas Técnicas (ABNT). 2007. *NBR 5739 Concreto—Ensaio de compressão de corpos-de-prova cilíndricos*. Rio de Janeiro, RJ. (in Portuguese)

[12] Batista, A. B., dos Santos, L. R. J., Ribeiro, M. S., & da Costa Gomes, G. J. 2018. "Estudo da utilização do PVC como constituinte de concreto reciclado." *Revista Eletrônica TECCEN* 11 (1): 39-46. (in Portuguese)

[13] Associação Brasileira de Normas Técnicas (ABNT). 2013. *NBR 9781 Peças de concreto para pavimentação—Especificação e métodos de ensaio*. Rio de Janeiro, RJ. (in Portuguese)

[14] Oliveira, D. C., and Souza, R. E. 2017. "Produção de bloquetes em concreto verde com adição de palha de café." *Revista Pensar Acadêmico* 15 (1): 109-19. (in Portuguese)

[15] Da Costa O. D., de Castro Inácio, J., Diniz, M. D. F. G., and Bifano, R. P. 2019. "Compósitos em concreto verde com adição de cinzas de casca de café." https://www.ibeas.org.br/conresol/conresol2019/VII-031.pdf. (in Portuguese)