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INCORPORATION OF BASALT FILLER WASTE IN THE MANUFACTURE OF CONCRETE BLOCKS FOR INTERLOCKED PAVING

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Abstract: Filler waste originates from the crushing or grinding of basalt rock of igneous or magmatic origin. This artificial process of making crushed stone generates an enormous amount of fine powder, mostly and to a lesser extent small flakes of basalt, thus forming the residue of basalt filler. The main objective of this work was to study the potential and feasibility of incorporating a certain waste in the area of civil construction. Basalt filler residue was incorporated, with 50% and 100% being added in place of sand. To verify the quality of the produced parts, water absorption, dimensional and compressive strength tests were carried out and they were carried out in the MECFOR test laboratory. The interlocking block obtained from the addition of 50% of basalt filler and 100% in replacement of fine aggregate presented mechanical resistance of compression lower than that required by the standard.
Keywords: Basalt filler, aggregate, residue, interlocking block.

INTRODUCTION

Brazil has an analyzed reserve of about 8.57 billion cubic meters of ornamental rocks for more than 500 varieties (GUERRA, 2005). Among the states of the Union with the highest production, Espirito Santo leads, followed by Minas Gerais, Bahia and Ceará. The extraction and industrialization generates around 800,000 tons of waste annually (CHIODI FILHO, 2005). The waste material can be used together with other types of aggregates, being able to have a correct destination and not pollute the environment.

Civil construction is one of the oldest branches of work of humanity, present in all civilizations and fundamental not only for the establishment of cities and other urban spaces, but also for the displacement and for the infrastructure of countries as a whole.

In the construction processes, they generate waste and use a series of natural resources, as a way to enable the realization of the various projects. Therefore, approaching ways to reuse these residues allows reducing the pressure for natural resources in projects. This basalt mineral filler can become an aggregate to be attached to mortar for use in interlocking block construction. It will also relieve the production value, in addition to giving a correct destination to the product that will no longer be a polluter (CLEMENTINO, 2013; RUBIN, 2015).

Filler residue is a material generated by rock crushing or grinding and when washed it generates a fine powder with small basalt particles originating from the Basalt Filler residue, currently not used or used as a large-scale incorporation of products causing enormous environmental impact by the amount of material generated daily (PIOVEZAM *et al,* 2006).

The interlocked block is produced in accordance with the Brazilian Technical Standard ABNT NBR 9781 of 02/07/2013. They are ideal for application in external environments such as sidewalks, squares, parking lots, etc.

They are resistant to petroleum derivatives, which is why they are often used at gas stations. They allow the immediate use of the pavement (interlocked concrete floor) right after its execution and easy repair because it is removable. The great advantage of using the interlocked floor block is the ease of repair without heavy machinery and low maintenance cost, quickly releasing the site for use (MESQUITA FILHO, 2019).

The feasibility of the research study on presenting the potential as an alternative in the use of basalt filler residue, generated in the industrial process as a raw material, replacing totally and or partially the fine sand aggregate in the making of the interlocking floor mortar.

Self- draining interlocking concrete blocks are used in the preparation of sidewalks and pavements with the function mainly of paving, but with the concern of being a product with sustainable characteristics. To produce the pieces, appropriate shapes, of different dimensions and formats, and a mixture of components, such as fine aggregates, coarse aggregates, cement and water, are needed. It is important to emphasize that it is necessary to use compaction or a vibration system to add resistance to the material (MACEDO, 2008).

The general objective was to study the viability of incorporating a certain residue in the civil construction area and to analyze the study of the use of its quality, resistance, economy of the use of residues from the extraction of gravel and specific area of floors in the paving.

MATERIALS AND METHODS

The described method was used in the study of raw material and development of the concrete block product for interlocking flooring, linked to the study process of incorporation of residues from the extraction of basalt obtained from ''Votorantim Agregados".

This work was carried out in a factory of blocks and interlocking floors located in the city of Campo Grande/MS. The samples and materials used in the work were the same as those used in the industrial manufacture of the pavers and are listed below for a better understanding of the project developed.

The raw materials used in this work are:

- Residue based on Basaltic Filler (resulting from the basalt extraction process) that was collected at the company ''Votorantim Agregados", placed in plastic bags for transport at room temperature and transported to the Civil Construction Laboratory of ''Faculdade Estácio de Sá" for analysis;

- CP-V-ARI-(ULTRA) type CP-V-ARI-(ULTRA) high-strength Portland cement purchased locally;

-Coarse aggregate, of the pebble or stone type 0, with a granulometry of 4.8mm to 8.5mm, which was purchased in local shops;

-As a fine aggregate, sand, with a granulometry of 0.05mm to 0.3mm, purchased from local shops.

The plastic forms for making the specimen were provided by the company, as shown in Figure 1. For the collection of waste, the criteria of the ABNT NBR 10007:2004 standard were used for sampling solid waste. The sampler chosen was the manual shovel and the Jones splitter. Sampling, in turn, was defined according to the container chosen for storing waste from the recycling industry, seeking to obtain a sample that was as representative as possible.

Figure 1. Plastic form used in making the specimen and/or interlocking blocks.

Source: Prepared by the author.

For the formulation of the blocks, the following steps were followed:

-Stage 1, from the mixture of 20 liters of sand, 20 liters of pebbles 10 liters of cement 2.5 liters of water;

-Stage 2, additions replacing the fine aggregate with 20 liters of basaltic filler residue. 20 liters of gravel and/or stone 0. 10 liters of cement and 2.5 liters of water;

-Stage 3, addition of 10 liters replacing fine aggregate with basaltic filler residue, 10 liters of fine aggregate sand. 20 liters of gravel and/ or stone 0, 10 liters of cement and 2.5 liters of water.

*All constructions for the interlocking floor in the form of 16 faces.

The plastic forms used in the production and manufacture of the test specimens, with 16 faces, provided by the company where the preparation was carried out and the mixture formulation was optimized from the standard mixture (company) 20 liters of sand, 20 liters of gravel and 10 liters of cement and 2.5 liters of water, with the addition of waste percentages, replacing the fine aggregate from the standard mix, according to the formulation below (see Table 1), and the preparation was carried out using a 400 liter concrete mixer.

Formu-lation	Sand (liters)	Waste (liters)	Gravel (liters)	Cement (liters)	Water (liters)
THE	BR	20	20	10	2.5
B	10	10	20	10	2.5

Table 1. Concrete formulations for block production.

Source: Prepared by the author.

For the preparation of the blocks, the residue based on basaltic filler resulting from the extraction process of the coarse aggregates already has an average granulometry of 0.2 mm, which was formulated together with the fine aggregate or in total replacement, gravel and added cement to a specific measure in analysis for testing. As preparation of the mold, it was greased with diesel oil, preventing the finished material from sticking to the mold. The dimensions of the form will be 10cm x 20cm x 6cm.

The material was manually prepared using a concrete mixer in the measurements above, placed in the molds on a vibrating table that reduces the number of voids and increases the resistance of the material to compression in a period of approximately 5 minutes, being removed from the machine in the direction of the made from the first to the last, thus respecting the same vibration time for the forms. After this period, they were placed in a parallel position for drying for two days before stripping.

For the water absorption test, the Technology and Civil Construction Test Laboratory of the company MECFOR was used, using water tanks for immersion of the bodies and a semi-analytical scale BEL 1101744 in accordance with the ABNT NBR 9781 standard.

The determination of the Breaking Load was carried out at MECFOR's Technology and Civil Construction Test Laboratory, using an EMIC 8627 hydraulic press, as shown in Figure 2, in accordance with ABNT NBR 9781:2013.

Figure 2. Hydraulic press used to break interlocked blocks.

Source: Prepared by the author.

For the calculation of rupture of the blocks, the cylindrical radius of the press in contact with the block was assumed as the adopted area. To determine the dimensional tests, a Mitutoyo caliper (300mm) was used, carried out in the Test Laboratory of Technology and Civil Construction of the company MECFOR, in accordance with the ABNT NBR 9781:2013 standard, as shown in Figure 3.

Figure 3. Dimensional test of the blocks obtained.

Source: Prepared by the author.

ANALYSIS AND DISCUSSION OF THE RESULTS

Figure 4 shows the preparation of forms with diesel oil to receive the concrete prepared with the addition of basalt filler residue carried out in the company mentioned above.

Figure 4. Lubrication stage of the molds for preparing the blocks.

Source: Elaborated by the author

The figure shows the oil application process using a spraying system for plastic molds using a poison sprayer. Figures 5 and 6 show the preparation of the interlocking blocks with the addition of basalt filler residue carried out in the aforementioned company.

Figure 5. Preparation of interlocking blocks.

Source: Prepared by the author.

It is noteworthy that according to figures 5 and 6, the placement of concrete is done manually by the operator, using a rubber glove. The molds are grouped on a vibrating table, and the vibration lasts for about 01 minute, a process similar to that of the company.

Figure 6. Preparation of interlocking blocks.

Source: Prepared by the author.

Figure 7 below shows the shaped blocks that were placed in the company's yard for natural drying. Stripping was performed 24 hours after forming.

Figure 7. Formed interlocking blocks.

Source: Prepared by the author.

Regarding the dimensional tests, Table 2 shows the values of the measures obtained from the test for the blocks under analysis.

The values of the tested measures were obtained using a caliper and show similarity between the values. Comparing the individual values of length, width and height with the averages of these values, it was observed that the deviation is less than 3, the maximum value allowed by the standard (ABNT NBR 9781:2013).

The water absorption test was carried out in accordance with ABNT NBR 9781: 2013 and the values are shown in Table 3.

Comparing the water absorption values of the blocks obtained through the test carried out, we can verify that the measured data are greater than the value allowed according to the standard. This variable is related to the resistance of the analyzed material. Higher absorption, higher porosity, lower compressive strength.

With regard to the data obtained from the compressive strength test listed in Tables 4, 5 and 6, blocks from lots A, B and C do not meet the strength criterion according to ABNT NBR 9781:2013.

It is worth mentioning that the samples of lot A are the blocks produced by company A (Table 4). Blocks from batch B correspond to the replacement of fine aggregate with 100% basalt filler and blocks from batch C correspond to replacement of 50% basalt filler in place of fine aggregate.

The compressive strength values shown in Table 4 for batch A showed breaking load values, in KN, with a coefficient of variation of 2.3% and standard deviation of 0.2 Mpa.

It is important to point out that the resistance obtained for blocks from batch B, due to their higher values and making a comparison with the water absorption values shown in Table 3, blocks 2 and 6 presented the lowest absorption values. This is due to a smaller porosity, consequently greater is the resistance of the blocks.

The compressive strength values shown in Table 5 referring to lot B, presented breaking load values, in KN, with a coefficient of variation of 4.3% and standard deviation of 1.2 Mpa.

As the batches do not meet the standard according to the breaking strength criterion, it is important to point out that replacing the sand with basalt filler increased the mechanical strength (Tables 4 and 5), which indicates that replacing the granulometry of the aggregate coarse (gravel), would also increase the compressive strength.

Table 6, in turn, addresses data from the compressive strength test of the blocks. Another factor that must be taken into account is that the blocks by the process adopted were of the "sleep" type. With vibration. If the block compression system is used, the resistance would increase and possibly meet the standard.

The compressive strength values shown in Table 6 referring to batch C, presented breaking load values, in KN, with a coefficient of variation of 13% and standard deviation of 1.1 Mpa. Figure 8 shows the ruptured block after the axial compression resistance test according to the ABNT NBR 9781:2013 standard.

Block	Length (mm)	Width (mm)	Height (mm)
1	242.00	96.50	60.00
two	245.00	99.00	63.50
3	245.00	98.00	60.03
4	245.00	98.50	63.50
5	242.00	96.00	61.00
6	245.50	98.20	60.50
Average (X)	244.08	97.70	61.42

Table 2. Block dimensional test data.

Source: Prepared by the author.

Rehearsal	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6
Dry (g)	3,477	3,366	3,267	3,364	3,367	3,416
Saturated (g)	3,875	3,644	3,792	3,849	3,754	3,756
Water absorption (%)	11.44	8.25	16.06	14.41	11.49	9.95

Table 3. Data from the blocks water absorption test.

Source: Elaborated by the author

Block	Part Dimensions			Index in Form	Assay Plate		Breaking Load (KN)	Individual Part Strength, fpi	
	L (cm)	Ç (cm)	AND (cm)		Diameter (mm)	Area (cm^2)		(KN/cm^2)	mpa
1	10.0 x 20.00 x 6.0			3.3	85.1	56.88	60.00	1.00	10.00
2	10.0 x 20.00 x 6.0			3.3	85.1	56.88	62.30	1.04	10.4
3	10.0 x 20.00 x 6.0			3.3	85.1	56.88	58.20	0.97	9.7
4	10.0 x 20.00 x 6.0			3.3	85.1	56.88	61.00	1.02	10.2
5	10.0 x 20.00 x 6.0			3.3	85.1	56.88	60.20	0.99	9.9
6	10.0 x 20.00 x 6.0			3.3	85.1	56.88	93.20	1.01	10.1

Table 4. Data from the compressive strength test of Batch A blocks.

Source: Prepared by the author.

Block	Part Dimensions			Index in Form	Assay Plate		Breaking Load (KN)	Individual Part Strength, fpi	
	L (cm)	Ç (cm)	AND (cm)		D (mm)	Area (cm^2)		(KN/cm^2)	mpa
1	10.0 x 20.00 x 6.0			3.3	85.1	56.88	105.1	1.76	17.6
2	10.0 x 20.00 x 6.0			3.3	85.1	56.88	77.70	1.30	13.0
3	10.0 x 20.00 x 6.0			3.3	85.1	56.88	79.20	1.32	13.2
4	10.0 x 20.00 x 6.0			3.3	85.1	56.88	94.10	1.57	15.7
5	10.0 x 20.00 x 6.0			3.3	85.1	56.88	93.70	1.56	15.6
6	10.0 x 20.00 x 6.0			3.3	85.1	56.88	93.20	1.56	15.6

Table 5. Data from the compressive strength test of Batch B blocks.

Source: Prepared by the author.

Block	Part Dimensions			Index in Form	Assay Plate		Breaking Load (KN)	Individual Part Strength, fpi	
	L (cm)	Ç (cm)	AND (cm)		D (mm)	Area (cm^2)		(KN/cm^2)	mpa
1	10.0 x 20.00 x 6.0			3.3	85.1	56.88	58.70	0.98	9.80
2	10.0 x 20.00 x 6.0			3.3	85.1	56.88	46.20	0.77	7.70
3	10.0 x 20.00 x 6.0			3.3	85.1	56.88	46.00	0.77	7.70
4	10.0 x 20.00 x 6.0			3.3	85.1	56.88	60.00	1.00	10.00
5	10.0 x 20.00 x 6.0			3.3	85.1	56.88	52.10	0.87	8.7
6	10.0 x 20.00 x 6.0			3.3	85.1	56.88	45.20	0.75	7.5

Table 6. Data from the compressive strength test of the blocks. Batch C.

Source: Prepared by the author.

Figure 8. Block ruptured after the compression test.

Source: Prepared by the author.

Figure 9. Block obtained after stripping.

Source: Prepared by the author.

As a final product obtained with the use of basalt filler residues, we have the block shown in Figure 9, which shows the water absorption test applied to the obtained product.

FINAL CONSIDERATIONS

According to the tests carried out, based on the proposed methodology and comparing the results obtained, we can conclude that the compressive strength test of the blocks of different types of batches presented values lower than those required by the standard.

The compressive strength of the blocks obtained using 100% basalt filler instead of the fine aggregate, showed a greater compressive strength than that of company A, which uses sand as the fine aggregate. This is due to the mineralogical constitution of the residue, originating from the extraction of basalt, since the mechanical resistance to compression of the blocks is related to the cement and the coarse aggregate (gravel). As the fine aggregate (sand) was replaced by gravel, the compressive strength increased significantly.

The water absorption test of the blocks obtained using 100% basalt filler instead of fine aggregate showed a lower % water absorption than that of company A, which uses sand as fine aggregate. An analysis in an accredited laboratory was necessary for the execution of works with the interlocked floor product, as it has lower resistance required by the standard in several companies in the segment.

It is worth mentioning that the granulometry of the basalt filler residue has similar results to that of sand, which is why the replacement occurs in place of sand. As the residue comes from the extraction of basalt, it has a mineralogical constitution similar to that of basalt (gravel), used in the formulation of concrete. Therefore, the values of % water absorption showed lower results, greater compaction and greater resistance.

From this premise, in the manufacture of blocks with greater resistance, it is interesting to replace the sand with the waste of basalt filler and also to use a gravel with a higher classification, that is, a higher average particle size. As a consequence, it would increase the resistance of the interlocking blocks without compromising the aesthetic finish of the product.

Regarding the viability of incorporating basalt filler residue in the manufacture of interlocking blocks, the results of compressive strength and water absorption show the viability of the project, replacing all the fine aggregate by the residue from the extraction of basalt. As a result, the company

Votorantim Aggregates could market this "waste" as a raw material to be used and marketed in civil construction as a substitute for sand, contributing to the reduction of its extraction, giving a use to the waste generated and contributing to the environment.

It is important to point out that for future works it is worth testing different percentages of residues to be added to replace the fine aggregate in the formulation of interlocking blocks. The compression and absorption tests show that the basalt filler had characteristics more related to the coarse aggregate, since it is a residue from the extraction of these aggregates in day-to-day production.

It is worth mentioning that it is also necessary to analyze the aggregates separately, using granulometry and specific mass tests. In concrete apply Slump Test tests. In the residue granulometry and specific mass tests. In the final product, in addition to dimensional tests, resistance to compression, water absorption, it is necessary to test porosity and other tests to study the formulated product more accurately.

REFERENCES

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. NBR 9781: Peças de concreto para pavimentação: especificação e métodos de ensaio. Rio de Janeiro, 2013.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. NBR 10007: Amostragem de resíduos sólidos. Rio de Janeiro, 2004.

CHIODI FILHO, Carlos. Situação do setor de rochas ornamentais e de revestimento no Brasil – mercados interno e externo. IN: SIMPÓSIO DE ROCHAS ORNAMENTAIS DO NORDESTE, 5. **Anais...** Recife: Deminas, DAU, PPGEMinas, SBG, SINDIPEDRAS, 28p., 2005.

CLEMENTINO, Fabio Cruz; BARROS, Geraldo Rodrigues; SANTOS, Paulo Goulart Dourado. **Processo produtivo em uma indústria de artefatos de concreto.** Monografia apresentada ao Curso de Engenharia Civil da Universidade Federal de Goiás para obtenção do título de Engenheiro Civil. Goiânia, 2013.

GUERRA, Eraldo Ávila. Apoio do MCT ao setor de rochas ornamentais e revestimentos. In: SIMPÓSIO DE ROCHAS ORNAMENTAIS DO NORDESTE, 5. Recife: Deminas, DAU, PPGEMinas, SBG, SINDIPEDRAS. **Anais...** Recife, 12p., 2005.

MACEDO, Roberto Salvador; MENEZES, Geraldo Azevedo; FERREIRA, Humberto Carlos. Influência de aditivos na produção de blocos cerâmicos. **Cerâmica.** v.54, p.373-381, 2008.

MESQUITA FILHO, José. **Estudo e proposição de formas de pavies intertravados para** áreas **de passeios públicos.** Dissertação apresentada ao Programa de Pós Graduação em Design da Faculdade de Arquitetura, Artes e Comunicação da Universidade Estadual Paulista "Júlio de Mesquita Filho", campus de Bauru, como exigência para obtenção do título de Mestre em Design p 17. <https://repositorio.unesp.br/bitstream/handle/11449/89725/serafim_ma_me_bauru.pdf;jsessionid=74579B15746982DC7C6408F8C3F43086?sequence=1>. Acesso em: 12/06/2019.

NEVILLE, Américo Moisés. **Propriedades do Concreto.** 5. Ed. Editora Bookman. 2015.

OLIVEIRA, João Carlos de. **Indicadores de potencialidades e desempenho de agregados reciclados de resíduos sólidos da construção civil em pavimentos flexíveis.** Tese (Doutorado em Geotecnia)-Universidade de Brasília, Brasília, 2007. Disponível em: <http://repositorio.unb.br/handle/10482/5509>. Acesso em: 11 ago. 2018.

PIOVEZAM et al. Resistência à compressão do concreto autoadensável: influência da atividade pozolânica do calcário e do basalto. **Recife**. v. 15, p.95-100, 2006.

RUBIN, Ariane Prevedello. **Argamassas autonivelantes industrializadas para contrapiso:** análise do desempenho físico-mecânico frente **às** argamassas dosadas em obra. 2015. Dissertação do Programa de Pós-Graduação em Engenharia Civil da Universidade Federal do Rio Grande do Sul. Porto Alegre, 2015.