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Cement plate slab production with the incorporation of glass wool waste ground

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Abstract

One of the characteristics of Civil Construction is its ability to absorb a wide range of wastes to produce new products. Therefore, the objective of this study was to evaluate the behavior of cement plates produced with the addition of ground glass wool waste and *in natura*, in shredded form. The tensile strength tests in bending and permeability were performed, according to ABNT NBR 15498: 2007 as well as environmental ones according to ABNT NBR 10004: 2004. The plates produced in this study were characterized as being impermeable, with a satisfactory tensile strength in bending and being classified as plates for indoor and outdoor use, and as products that do not offer immediate risk to health and to the environment; however, it should be discarded in landfill.

Keywords: residue, glass-wool waste, mortar. cement plates.

1. Introduction

The ban on the use of manufactured products with asbestos fibers, due to several reports of asbestosis in workers, stimulated studies with other types of fibers in order to incorporate them into mortars and concretes (Studinkat, J.B, 1989; Ikai *et al*., 2010, EURIMA, 2013). Several fibers were and are still studied, yet few of them exhibit performance similar to those of asbestos fibers (Jamishidi and Ramezanianpour, 2011).

The incorporation of fibers in mortar and concrete is of great value since it acts as a reinforcement to the matrix, controlling cracking and redistributing efforts, thus improving their mechanical properties (Bentur and Mindess, 2007).

Then, we sought to combine the importance of fiber to a topic much discussed nowadays: large generation of industrial waste. Thus, we became interested in conducting the study of the incorporation of glass wool industrial waste into mortars to produce cement plates. Glass wool is a material composed of fine glass fibers having different lengths and is usually employed in industry as a thermal insulator; however, it tends to be exposed to high temperatures and consequently loses its insulating capacity being periodically changed and destined for sanitary landfill (Alves, 2008; Karamanos *et al.,* 2008; Achchag, 2009; Evangelista, 2011).

The survey conducted by Zucoloto *et al.* (2014), in Espírito Santo State shows that the study of this type of waste is of great value, because its generation in industries is continuous and if a way to use it and / or reuse it is found, a great amount of waste will no longer be disposed in the environment.

We found that glass wool waste in mortars are typically incorporated into the cement matrix as a partial cement replacement or added to the cement matrix. Marikunte *et al.* (1997) found that the incorporation of fibers significantly improves the behavior of the matrix tensile and flexural strength. Evangelista (2011) found that the incorporation of glass wool as a partial substitute for cement is not interesting because glass wool does not show pozzolanic features.

It was decided then to hold the incorporation of the ground residue to the mortar in the form of fillers, replacing the fine and shredded fraction aggregate, *in natura,* as an inner layer of the plate. And, the plates were produced according to ABNT NBR 15498: 2007 standard used for cementitious flat plates with the presence of fibers, which classifies them according to their use in: class A (plates that are used for external applications, or which are subject to the direct action of the sun, the rain, the heat and humidity) or Class B (the plates that are directed for indoor or outdoor use, as long as they are not subject to the direct action of the sun, rain, heat and humidity).

2. Materials and methods

The mortar used for the production of cement plates were produced by incorporating 20% of ground glass wool residues in the form of filler as a partial substitute for the fine fraction of the fine aggregate.

To incorporate the residue in the grout, we aimed to investigate the chemical composition, by making the x-ray fluorescence tests. The results showed that the residue is essentially composed of silicon oxide (SiO_2), aluminum oxide (Al_2O_3) and calcium (CaO), being oxide of the majority silicon, corresponding to 68.54% of its weight.

Glass wool waste, assigned by the company Vale SA, went through a process of grinding and screening to achieve the appropriate particle size. First, the residue was shredded manually and ground twice, consecutively, in a knife mill Willye Type (Model SP 31).

Then it was ground into 50g portions pestle in a mortar mill for 5 minutes. Finally, to obtain the filler, the material was sieved until 65% passed in a 0.075mm mesh sieve.

The constituents of the mortar materials for production of cement plates were: sand from Rio Doce, Portland Cement CP III 40 RS, water supplied by the local utility supply, glass wool waste and additive (the type hiperplasticizer of Glenium 61 type). The line used was 1: 3 (cement: sand) and water / cement ratio of 0.48, and the mix proportion of materials are shown in Table 1.

Mix proportion	Cement	Fine aggregate (g)				RLV (g)	Water (g)	Additive(g)
		Coarse fraction	Coarse Fraction Average	Fine Fraction Average	Fine Fraction			
20%*	3,679.1	2,759.33	2,759.33	2,759.33	2,207.46	551.86	1,768.8	18.39

*Viera *et.al.*, 2014.

Table 1
Mix Proportion.

RLV: glass wool residues.

The choice of this type of cement was due to the fact that it had a high concentration of slag in its composition (35% to 70%) and, consequently, produced a smaller amount of $Ca(OH)_2$ (Calcium hydroxide). It was more suitable for producing a matrix reinforced with glass fibers and glass wool (Peruzi, 2002; Evangelista, 2011).

2.1 Production of cementitious plates

Rectangular plates with dimensions of (800x656x12)mm were produced. The molding process of the plates had the following steps: filling the mold with a layer of approximately 0.5 cm; 45 g layer of glass wool residue in the form of a blanket; a last layer of mortar of the same thickness as the first layer; leveling of layers with metallic ruler; and a vibration of 20 s. After molding, the plates remained in the air curing for 24 hours and were then sent to the humidity chamber. After 72 hours, they were unmolded and immersed in water saturated with lime for 25 days. After 28 days of curing, the tests were started.

2.2 Tests

2.2.1 Traction in flexion

A tensile test was performed in flexion according to ABNT NBR 15498: 2007. The 10 Specimens of (256x100x12) mm were kept at steady state (with a temperature between 23 ± 5 ° C and relative humidity of 50 ± 10%, for a period of 7 days), while 10 other specimens were kept in a saturated state (immersed in water for 24 hours) to be subsequently tested.

2.2.2 Permeability

For the permeability test, 3 plates of (800x656x12) mm were used. The top surface was in contact with water for 24 hours and after this period, the observation of the bottom face was performed to check if water flow occurred. The test was performed according to ABNT NBR 15.498: 2007.

2.2.3 An environmental test

To verify the classification of the final product, leaching and solubilization tests were performed in accordance ABNT NBR 10004: 2004 [12] specifications. Two test specimens of ground of (256x100x12) mm were sent for laboratory analysis. The environmental test was carried out by the Bioagri analysis laboratory.

3. Results and discussion

3.1 Tensile strength in bending

The rupture of the plates in the central region along the loading axis and new cracks were observed. The cement plates with low flexural strength materials, during the tests exhibited some deflection before total collapse.

The rupture of plates occurred between 10 and 30 seconds, as per NBR 15498: 2007. In Figure 1, we can observe the deflection of the plates before the breaking.

Figure 1
Deflection of the cement plate.

The mean values obtained for the plates in the saturated state and balance are shown in Tables 2 and 3.

Table 2
Tensile strength in bending - Saturated State.

Tensile strength in bending - Saturated State	
Average resistance	8.29 MPa
Average strength – longitudinal	8.22 MPa
Average strength - transverse direction	8.36 MPa
Ratio between the means of longitudinal and transverse direction	0.98

Table 3
Tensile strength in bending - State balance.

Tensile strength in bending - State Balance	
Average resistance	7.65 MPa
Average strength – longitudinal	8.04 MPa
Average strength - transverse direction	7.25 MPa
Ratio between the means of longitudinal and transverse direction	1.11

Based on the results shown in Tables 2 and 3, the signs can be classified as follows: Class A plates (Category 3 - A3) and Class B plates (Class 2 - B2). One can even say that the plates produced meet the requirements of NBR 15498: 2007, as:

- To the right of resistance in the longitudinal / transverse exceed 0.50;
- The average value of the saturated state is greater than 50% of the average strength of the samples in equilibrium.

3.2. Permeability

In the permeation test, there was not observed the presence of spots or leaks in the bottom of the plates, so the produced plates can be considered waterproof. Figure 2 shows the permeability test, and Figure 3 shows the underside of the test samples after the test.

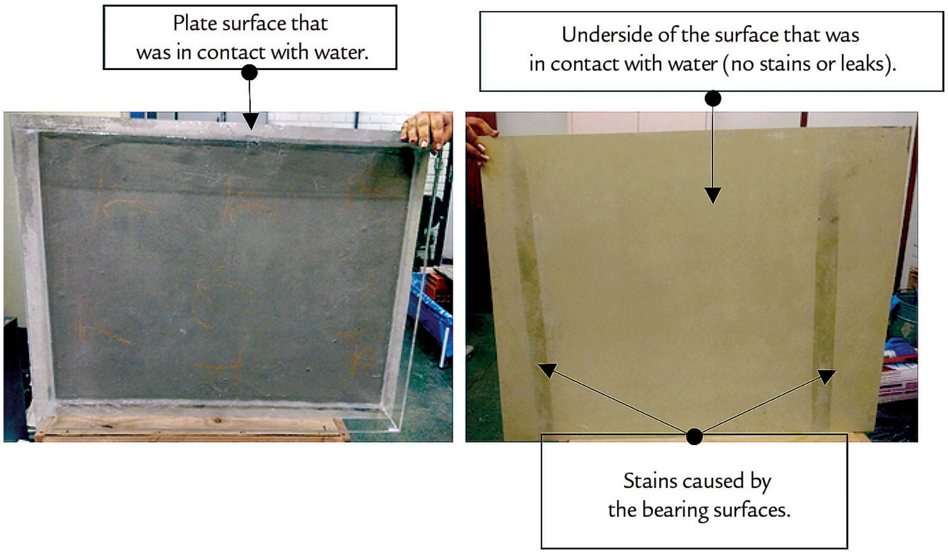

Figure2
The face of the cement plate.

When carrying out the calculations required by the standards for both study situations, there was dimensional variation of 0.243% or 2.43 mm/m. Therefore, we can affirm the plate has dimensional variations after immersion and drying similar to plates found in the market, as per the technical data sheet analyzed.

3.3 Apparent density

Table 4 shows the apparent density results for the four test specimens.

Test Specimen	Apparent Density (g/cm³)
CP 1	2.268
CP 2	2.280
CP 3	2.263
CP 4	2.273
Average	2.271
Standard deviation	0.007257

CP: Test Specimen (Portuguese acronym for Corpo de Prova).

Table 4
Apparent density.

According to the table analysis, we can see that cementitious plates produced at laboratorial scale showed apparent density higher than those found in the market and values close to those of 8mm Bricka Heavy plate, highlighted in the chart (Fig.3). Based on these results, the plates produced showed characteristics similar to those found in the market.

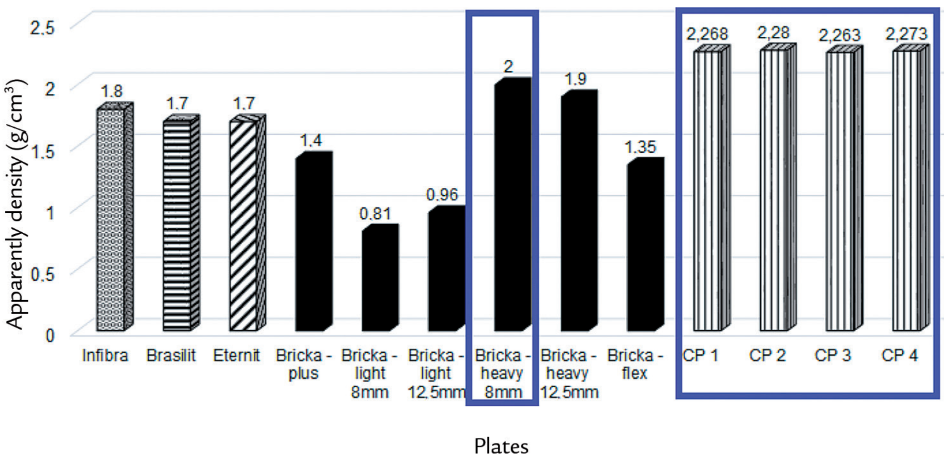

Figure 3
Plates produced
for the study vs commercial plates.

3.4 Water absorption

The values obtained for the four test specimens were very close in range, with average water absorption of 7.756% and standard deviation of 0.1383. These results show that the low standard deviation values indicate that values are very similar and results are coherent.

3.5 Environmental analysis

A concentration of aluminum over the limits established by Annexes F and G of ABNT NBR 10004: 2004 was observed. Therefore, the plates are classified as a Class II A waste, non-inert.

Table 5 shows the aluminum value allowed by the standard and the quantity found in the analysis.

Table 5
Environmental analysis.

Value allowed by NBR 10.004:2004	Analysis
0.2 mg/L	1.92 mg/L

4. Conclusions

The main conclusions derived from this study are:

1) The performance of the produced plates incorporating glass wool waste meet standard requirements and are classified as A and B with regard to resistance to bending, Category 3 and 2 (respectively), and can be used both internally and externally.

2) The produced plates are waterproof;

3) The plate showed density with values close to those of plates found in the market;

4) The plate showed low water absorption variation, with average water absorption around 7.756%;

5) The plates produced could be used provided that the final arrangement of plates be in Class II landfills.

6) The plates have commercialization potential.

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