Cimentitious material with kraft wastes and blast furnace slag

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ABSTRACT

The Portland cement (PC) production process is one of those responsible for emissions of greenhouse gases. Since PC is an essential product for civil construction, some authors seek possibilities to produce materials with cementitious properties to replace PC. This study aims to produce a cementitious material, exclusively from wastes, in this case the Biomass Boiler Ash (BBA) and Ground Granulated Blast Furnace Slag (GGBFS) and to verify the influence of the curing temperature on mortars produced with this cementitious material. For the analysis of the beginning and end of final setting time, according to NBR NM65, a reference paste was produced with 100% GGBFS and pastes with 5, 10, 15 and 20% BBA added to the GGBFS. According to the results, the BBA has the potential to accelerate the initial and final setting times of the GGBFS, confirming its ability to present faster setting when associated with alkaline wastes. In order to determine the compressive strength, mortars were produced according to NBR 7215 and the specimens were subjected to saturated, humid curing, 40ºC and 60ºC. The results confirm that the material formed with these wastes has cementitious properties, with saturated curing being the most efficient, and the material can be a sustainable alternative to replace the PC.

Keywords: *Cement without clinker; Ground granulated blast furnace slag; kraft wastes.*

1. INTRODUCTION

Portland cement (PC) is the cementitious material traditionally used in civil construction, and as its production process demands high energy consumption, and also because of its the high level of CO_2 emission, the scientific community looks for possibilities of producing cementitious materials to replace the PC. Since the amount of waste generated in industries increases gradually, the use of waste for the production of PC has proved to be a good alternative for reducing environmental impacts. (VASSALO, 2005; MODOLO, 2006; CASTRO et al., 2009; SADIQUE, 2012 et al.; GONÇALVES, 2014; TORRES et al., 2017).

On the one hand, ground granulated blast furnace slag (*GGBFS*), a by-product of the iron and steel industry, which is formed by the fusion of iron ore impurities, has a cementitious character and, in the presence of alkaline substances, the formed material can acquire high strengths and durability in relation to PC (RAJESH, 2013; QURESHI, 2014; TORRRES-CARRASCO, 2015). On the other hand, the

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cellulose industry uses several processes for the production of pulp. The most common use is by chemical means, called the Kraft process, during this process high amounts of alkaline waste are generated, and one of them is the Biomass Boiler Ash (BBA). In this scenario, this study proposes to produce a cementitious material, at room temperature, exclusively from wastes, in this case GGBFs and BBA. This new cementitious material, without clinker, provided that achieving suitable properties, can be used as substitute to the PC in the manufacture of construction materials.

Since the proposed material consists mainly of *GGBFS* and studies (BAKHAREV et al., 1999; MARQUES, 2013; GONÇALVES, 2014; BO QU et al., 2016) show that the strength of slag cements is influenced by heat treatment, mortars produced with the obtained material were submitted to different types of curing.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Ground Granulated Blast Furnace Slag (GGBFS)

The GGBFS was supplied by a cement company with appropriate grading of 0.05% of material retained in the #200 sieve.

2.1.2 Biomass Boiler Ash (BBA)

The BBA was processed by grinding to reach adequate granulometry. Its pH was 11.42, which confirms the alkalinity of the BBA and its potential for the activation of the GGBFS.

2.1.3 Sand

Sand standardized by NBR 7214 (2012) was used.

2.1.4 Water

It was supplied by the local supply system.

2.2 Methods

For the analysis of the initial and final setting times, according to NBR NM65, a reference paste was produced with 100% GGBFS and pastes with 5, 10, 15 and 20% BBA added to the GGBFS. (**Table 1**).

From the analysis of the setting times, the paste T10 was chosen and mortar specimens (CPs) were molded according to NBR 7215 (**Table 2**) and evaluated regarding compressive strength at 3, 7, 28 and 91 days. Due to the diversity of temperatures of cures found in the literature review: BAKHAREV et al. (1999) 70°C; MARQUES (2013) 40°C; GONÇALVES (2014) 40°C and 80°C, we decided to study the shortest curing times and temperatures. The temperatures and curing times adopted are shown in **Table 3.**

Table 1. Mix pastes.

Materials	T100	T5	T10	T15	T20
BBA (g)	0	25	50	75	100
GGBFS (g)	500	500	500	500	500
Water (g)	160	180	185	185	195

Source: Author, 2018.

Table 2. Mortar mix.

Materials (g)	GGBFS	BBA	Sand	Water
	567.27	56.73	1872.00	299.52

Source: Author, 2018.

Table 3. Types of curing.

<table>
<tr><td>Saturated</td><td colspan="2">24 hours after molding, the specimens were removed from the molds and immersed in a tank of saturated water of lime, where they remained until the compressive strength test.</td></tr>
<tr><td>Wet</td><td colspan="2">24 hours after molding, the specimens were removed from the molds and kept in a closed container on a water slide, without direct contact with the water for 7 days and subsequently kept in natural cure until compression strength test.</td></tr>
<tr><td>40°C 24h</td><td>After molding, the specimens were wrapped in PVC film and placed in the oven at 40°C for 24 hours.</td><td rowspan="4">After being removed from the oven, the specimens were kept in natural cure until compressive strength test.</td></tr>
<tr><td>40°C 72h</td><td>After molding, the specimens were wrapped in PVC film and placed in the oven at 40°C for 72 hours.</td></tr>
<tr><td>60°C 24h</td><td>After molding, the specimens were wrapped in PVC film and placed in the oven at 60°C for 24 hours.</td></tr>
<tr><td>60°C 72h</td><td>After molding, the specimens were wrapped in PVC film and placed in the oven at 60°C for 72 hours.</td></tr>
</table>

Source: Author, 2018.

3. RESULTS AND DISCUSSION

The **Table 4** shows the results of the initial and final setting times of the reference paste with 100% of GGBFS and the pastes with addition of BBA.

Table 4. Initial and final setting time.

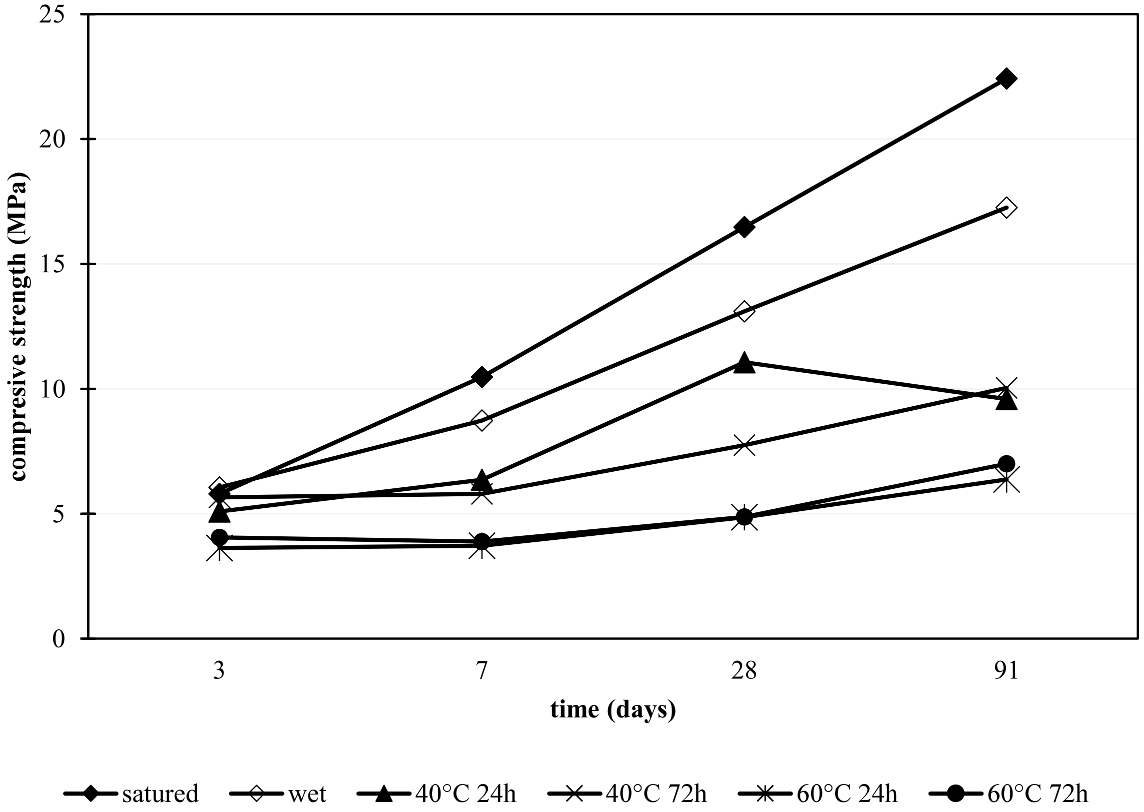
Pastes	T100	T5	T10	T15	T20	NBR 16697
Initial setting time	8h 50’	3h	3h 40’	3h	5h 40’	>1h
Final setting time	>12h	5h 10’	5h	5h 10’	6h 15’	<12h

Source: Author, 2018.

It is observed in **Table 4** that the addition of the BBA to the GGBFS decreased the initial and final setting time of the GGBFS. All the pastes with BBA addition meet the NBR 16697 initial and final setting time parameters. In this way, the T10 formulation was chosen to investigate the mortar performance because it presents the shortest final setting time, which is more feasible for civil construction.

The **Figure 1** presents the results of compressive strength for the different types of curing.

Figure 1. Compressive Strength.



Source: Author, 2018.

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The **Table 5** presents the results of compressive strength of saturated curing compared to the specifications of NBR 16697.

Table 5. Compressive Strength (MPa)

days	3	7	28	91
T10 saturated curing	6	10	16	23
CPIII 25 (NBR 16697)	8	15	25	32

Source: Author, 2018.

Figure 1 shows that the best compressive strength results were obtained with the saturated and wet cure, and that regardless of the type of curing the strength grows with time, which characterizes a behavior similar to PC. Therefore, the increase in curing temperature did not contribute to the improvement of mechanic strength performance, similar to BO QU et al. (2016) who observed that the curing temperature contributes only to the initial strengths, with a decline over time.

We observed in **Table 5** that the strength at 28 days of the cementitious material obtained is about 64% of CPIII 25 strength, and at 91 days it reaches the 91% rate, which proves that the material obtained exclusively from of waste has enough cementitious property to be applied as an option of cementitious material without clinker to replace PC.

4. CONCLUSION

The results confirm the potential of BBA to decrease the initial and final setting times of GGBFS, confirming its ability to present a faster setting time when associated with alkaline wastes. The best compressive strength results were achieved with the saturated and wet curing. Therefore, the thermal curing methods chosen for the cementitious material under study did not contribute to improved compressive strength. Since the strength at 28 days of the cementitious material obtained is around 64% of the resistance of CPIII-25, and at 91 days it reaches the rate of 91%, It can be concluded that the material has potential for application in the production of non-structural cementitious materials, and further studies are necessary with regard to material durability.

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