

Development of an Innovative Insulation Fire Resistant Material from the Construction and Demolition Waste

Salmabanu Luhar^{1*}, Ponsian Robert¹, Ioanna Giannopoulou¹, Demetris Nicolaides^{1,2}

¹Frederick Research Center, P.O. Box 24729, 1303 Nicosia, Cyprus

²Department of Civil Engineering, Frederick University, Nicosia 1036, Cyprus
e-mail address - *ersalmabanu.mnit@gmail.com

Abstract. This paper deals with a preliminary study for the valorization of construction and demolition waste (CDW) in the development of an innovative material to be used for the passive fire protection of constructions. The new material is based on the alkali activation of two CDW streams, according to the geopolymerization technology. Ground waste bricks and ground waste ceramic tiles were used as geopolymeric precursors, while the alkali activator was a mixture of KOH and Na₂SiO₃ aqueous solutions. The mechanical strength of developed materials after their exposure at elevated temperatures up to 1000° C was tested. According to the results, the material based on waste ceramic tiles showed higher compressive strength overall than the one based on waste bricks.

Keywords: Construction and Demolition Waste (CDW), Alkali Activation, Compressive Strength, Elevated Temperature.

1 Introduction

The non-hazardous waste from construction and demolition activity (CDW) stands for beyond 10% of the overall waste stream in Europe. CDW includes bulky amounts of materials of inorganic nature, such as concrete, bricks and tiles [1]. Reuse and recycling of CDW is enhanced in EU (Directive 2008/98/EC), as it significantly contributes to the reduction of CO₂ emissions, energy consumption and natural resources demand, as well as to the avoidance of using enormous land spaces for waste land-filling [1].

During the last years, intensive research on the utilization of CDW in alkali activated materials (AAM), as inert aggregates or partly reactive materials, takes place [2]. These materials have the potential to utilize several streams of industrial by-products and waste [3], comprising a promising option for the CDW valorization.

In this study, the effect of a fire incident event on the stability of two geopolymeric materials based on CDW streams was studied through the materials exposure at elevated temperatures for an adequate time. Residual compressive strength, weight loss and density were tested after the materials heating treatment, as the basic properties affecting their stability.

2 Materials and methods

2.1 Materials

Ground waste bricks and waste ceramic tiles, both provided by a CDW recycler in Cyprus, were used as precursors to prepare the geopolymeric materials elaborated in this paper. Actually, two geopolymeric materials were prepared for this study; one based on waste bricks (WB-G) and another based on waste ceramic tiles (WT-G). The composition of both geopolymeric materials is summarized in Table 1.

Table 1. Composition of geopolymeric materials.

Geopolymer code name	Precursor (g)	S/L	8M KOH (mL)	Na ₂ O·SiO ₂ ·H ₂ O (mL)
WB-G	5520	2.5	849	1359
WT-G	5000	3.6	566	904

2.2 Methods

For properties testing, specimens with dimensions 100x100x100 mm have been prepared and cured at 50° C for 7 days. These materials were considered as reference, in this study. The compressive strength was tested on a 2000 KN electro-hydraulic mechanical testing machine, while weight loss and density were determined through measurements of the specimens weigh and dimensions. A muffle furnace with the ability to reach temperatures up to 1200° C was used for materials heating, which took place at three different temperatures, 600° C, 800° C and 1000° C. The furnace has been operated under constant heating rate, 4.4 °C/min. Specimens were left at the desired temperature for 2 hours and then, were cooled down at room temperature, in open air conditions. The properties of geopolymeric materials were tested in 7 and 28 days, after their thermal treatment.

3 Results and Discussions

Table 2 summarizes the results taken form the materials testing. As seen in Table 2, density (D) of both WB-G and WT-G materials was remarkably decreased with the increase of temperature up to 800° C and 600° C, respectively and remained almost unchanged at the following temperatures, up to 1000° C. In general, WB-G geopolymer was less dense than the WT-G, at all temperatures examined. Moreover, hardening time seems to not affect the bulk density of both materials (Table 2).

Table 2. Properties of geopolymers after heating treatment at different temperatures.

Geopolymer code name	T (°C)	D (kg/m ³)		W L (%)		C S (MPa)	
		7 d	28 d	7 d	28 d	7 d	28 d
WB-G	50	1554	1556	-	-	19.3	23.0
	600	1476	1441	6.0	9.9	15.4	18.8

	800	1430	1434	8.0	13.7	19.4	23.7
	1000	1434	1443	8.0	14.2	21.1	25.7
WT-G	50	1736	1586	-	-	33.0	38.0
	600	1583	1579	9.6	13.1	16.8	27.7
	800	1569	1578	9.6	13.2	13.2	23.6
	1000	1577	1566	9.9	13.5	36.6	38.2

The changes of density can be attributed to the removal of water phases from the geopolymeric binder taken place in three different temperature ranges [4]. At around 100-115° C, the physically bound water molecules are evaporated. At higher temperatures, up to 600° C, hydroxyl groups of the adsorbed water (-OH) are removed and at above 600° C, the dihydroxylation of silanol groups (>Si-OH) is occurred [4].

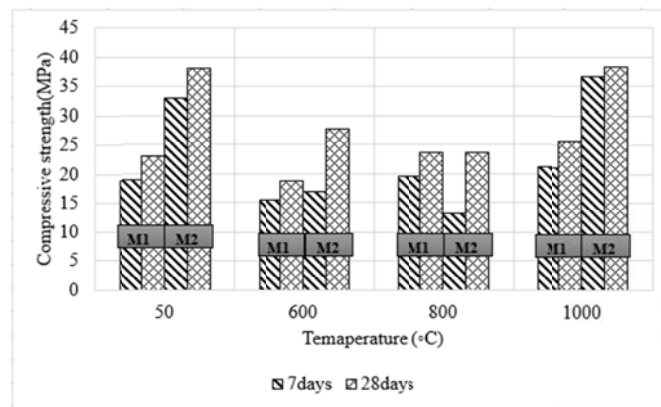


Fig. 1. Compressive strength of WB-G (M1) and of WT-G (M2) materials versus temperature.

The weight loss (WL) of both WB-G and WT-G geopolymers has been changed similarly to density and was increased up to 800° C and 600° C, respectively; from there on, it was remained constant until 1000° C (Table 2). In addition, the weight loss of WT-G material was higher than that of WB-G, at all the investigated temperatures, revealing extensive alkali activation in its geopolymeric matrix [3,5]. High degree of alkali activation involves extended densification in the geopolymeric matrix, which in turns favors the development of mechanical strength [5]. In Fig. 1, the residual compressive strength (CS) of WT-G material is higher overall than that of WB-G, at all tested temperatures, which is in accordance with the above conclusion given that WT-G material presented also higher weight loss and density than WB-G (Table 2).

According to Fig. 1, the initial compressive strength of WT-G material was substantially reduced up to 800°C. Then, it was increased and reached a slightly higher value than the initial one at the highest examined temperature (1000° C), regardless hardening time. The compressive strength developed by WB-G material followed a similar trend, but with a less sharply decrease limited up to 600° C (Fig. 1).

The improvement in the residual compressive strength at 1000° C, which was observed for both geopolymeric materials, is strongly related to the alkali melting

occurred at temperatures above 800° C. Alkali activation of the geopolymeric precursors involves surface attack of the solid particles and formation of an amorphous phase of alkali-aluminosilicate composition (geopolymeric binder) around them. At temperatures above 800° C, alkalis act as fluxes, causing partial sintering of the unreacted solid particles in the contact zone, between them and the geopolymeric binder, which results in more durable structures [3].

During the heating exposure up to 1000° C, there were no signs of spalling or deformation for both studied materials. An amount of small size cracks appeared on specimens' surface of both materials at 800° C, which became more intense and larger after their heating exposure at 1000° C.

4 Conclusions

Waste bricks and waste tiles from CDW are suitable precursors for the development of alkali activating materials, which remain stable after being exposed at temperatures up to 1000° C. The temperatures of 600° C and 800° C were considered as critical for materials properties. Density and weight loss were decreased at these temperatures and remain constant at the following. Compressive strength was also decreased at 600° C - 800° C and increased importantly at 1000° C. Improvement of materials mechanical strength at the 1000° C is attributed to the structural changes occurred in the geopolymeric matrix.

References

1. Behera, M., Bhattacharyya, S.K., Minocha, A.K., Deoliya, R., Maiti, S.: Recycled aggregate from C&D waste & its use in concrete – A breakthrough towards sustainability in construction sector: A review. *Constr. Build. Mater.* 68, 501–516 (2014).
2. Alhawati, M., Ashour, A., Yildirim, G., Sahmaran, M.: Properties of geopolymers sourced from construction and demolition waste: A review. *J. Build. Eng.* 50 (2022)
3. Bajare, D., Vitola, L., Dembovska, L., Bumanis, G.: Waste steam porous alkali activated materials for high temperature application. *Frontiers in Materials* 6 (92), 1–13 (2019).
4. Dimas, D., Giannopoulou, I., Papias, D.: Polymerization in sodium silicate solutions: a fundamental process in geopolymerization technology. *J. Mater Sci* 44, 3719–3730 (2009).
5. Van Deventer, J.S.J., Provis, J.L., Duxson, P., Lukey, G.C.: Reaction mechanisms in the geopolymeric conversion of inorganic waste to useful products. *J. Hazard. Mater.* 139(3), 506–513 (2007).

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