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REUSE OF SOLID BRICK WASTE MIX IN GEOPOLYMERIZATION – A PRELIMINARY INVESTIGATION

Ivana Jelić[128]; Aleksandar Savić[129]; Tatjana Miljojčić[130]; Marija Šljivić-Ivanović[131]; Slavko Dimović[132]; Marija Janković[133]; Vojislav Stanić[134]; Dimitrije Zakić[135]; Dragi Antonijević[136]

Abstract

The applicability of solid bricks waste in geopolymerization technique was considered. Waste samples were characterized in terms of mineralogical composition by XRD prior to mechanical testing. XRD analysis showed that both brick samples contained anorthite, wollastonite, and mullite as the main components. The compressive strength investigation was carried out by screening method with three geopolymer mixtures. Geopolymer mixtures were prepared with alkaline activators; the mixtures were poured into molds and air-dried for 28 days. The compressive strength of samples was measured according to the standard SRPS EN 12390-3:2010 for cubic samples. The compressive strength values ranged from 9.8 MPa for the newer solid brick, 10.2 MPa for the older solid brick, and 10.5 MPa for the solid brick mix waste geopolymer sample. The most likely underlying reason for the higher compressive strength results of the older solid brick and the mixed sample is their mineral composition, i.e. higher proportion of aluminosilicate. However, all samples showed satisfactory compressive strengths, and it represents an excellent basis for further research.

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Key words: *Reuse, recycle, compressive strength, construction.*

Introduction

Construction is one of the oldest and fastest growing industries in the world [1]. This industry consumes a huge amount of natural non-renewable materials generating a large amount of waste at each stage. Generally, rapid technological progress has led to an increase in the exploitation of non-renewable resources, energy consumption, and the generation of a large amount of waste in the environment [2-5]. Accordingly, the safe disposal of various types of waste materials and industrial by-products has become a key concern for the global community [5-6]. Nowadays, the problems arising from the amount of waste generated are gaining great social and environmental importance [2]. Summing up the consumption of raw materials and energy for the production of new concrete, the growing amount of concrete waste, and the area required for its disposal, the need for recycling construction waste becomes clear. The possibility of recycling and reusing such waste for the production of new economic value has been widely investigated [7-9].

Many state-of-the-art technologies have been proposed, and one of them represents geopolymerization. The production of geopolymers from waste not only ensures lower raw material consumption but also solves waste disposal problems. The term geopolymer and its description as a green cementitious material was first introduced in 1978 [5]. In recent years, geopolymerization technology has proven to be beneficial for reusing various types of waste to produce new materials for many purposes. This new class of materials, called inorganic polymers [5], has been proposed for the use of solid aluminosilicate wastes and the development of new materials with added value [10-11]. Geopolymers have a small environmental footprint and contribute to the conservation of natural resources [12-13]. However, their most important advantage is that, depending on the design, they obtain properties adapted to the needs of the end product [13]. Geopolymerization technology, which uses various types of industrial byproducts or wastes instead of raw materials, has been extensively studied.

The advantage of this technology is the possibility of using any waste material containing silicon and alumina that can be dissolved in an alkaline solution [14]. Such waste material could be used as a precursor for geopolymer synthesis. Fly ash, red mud, construction and demolition waste (C&DW), slag, or mining waste are the most commonly used waste types in combination with complementary waste materials, depending on their characteristics, e.g. silica and alumina content, quantities produced, and physicochemical properties.

The aim of this study was a preliminary investigation of the utilization of solid brick from the C&DW in geopolymerization processes.

Materials and Methods

The solid brick waste was collected from different demolition sites in the city of Belgrade, Republic of Serbia. The used bricks were two kinds of solid bricks, originating from the buildings from the 1930s and 1970s.

The mineralogical composition was identified by X-ray diffraction (XRD) analysis using the Ultima IV Rigaku diffractometer equipped with Cu $K\alpha_{1,2}$ radiation. The range of 4° - 65° 2θ was used in a continuous scan mode with a scanning step size of 0.02° and at a scan rate of $5°min^{-1}$. The recorded peaks were detected based on the comparison with the International Centre for Diffraction Data (ICDD) base [15].

The collected samples were crushed, ground, and sieved to a particle size of 0.3-0.6 mm, and dried at 100 °C (Figure 1).

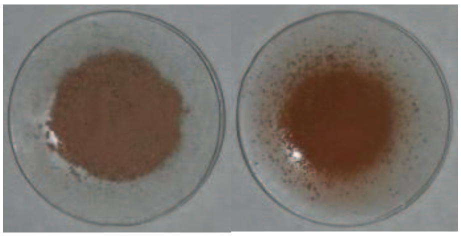

Figure 1. Homogenized solid brick samples

The experimental samples were produced by mixing solid brick powders with an alkali activator, a sufficient amount of water, and a superplasticizer (Cementol Hiperplast 463, TKK, Slovenia). The used alkali activator was a mixture of ~ 10 M NaOH solution (Merck, 99 wt%) and water glass, i.e. sodium silicate solution (Na_2O: 7.5 – 8.5 %; SiO_2: 25.5 – 28.5 %; Supelco).

The compressive strength investigation was carried out by screening method with three geopolymer mixtures. The recipes are shown in Table 1.

Table 1. Mix proportions of samples [g]

Materials	**SB1**	**SB2**	**SB3**
Brick powder 1930s	1200	0	600
Brick powder 1970s	0	1200	600
Sodium hydroxide, 10M	73	73	1200
Water glass	169	169	1200
Superplasticizer	15	15	1200
Water	35	35	1200

The samples were molded and cured for 1 day in the air at room temperature, covered with a wet cloth. Cubic shape molds of 100 mm diameter, complying with the standard SRPS EN 196-1:2018 [16] were used for the sample preparation (Figure 2).

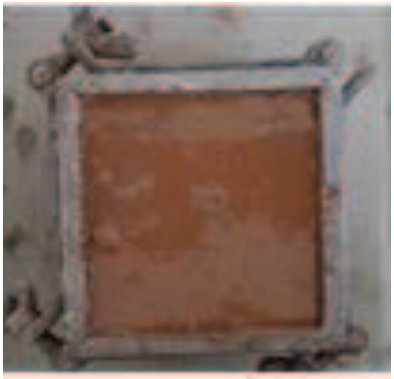

Figure 2. Molding of geopolymer sample

After demolding, the samples were cured in 20˚C water for 28 days and removed from water a little prior to testing (Figure 3).

Figure 3. Geopolymer cube sample

These samples were tested for compressive strength, as a dominant property in the assessment of mortar and concrete, by automated hydraulic press Amsler, Germany (Figure 4).

Figure 4. Compressive strength investigation

The compressive strength was measured according to the standard SRPS EN 12390-3:2010 [17] for cubic samples. The compressive strength was calculated as [18]:

$$fp = P_{p.gr}/S_0 \cdot [1000\ kPa]$$

where $P_{p.gr}$ was the load measured at the fracture point, [kN] and S_0 represents the initial cross-section area, [cm^2].
Tests were performed with two repetitions, and the results were calculated as the mean values.

Results and Discussion

XRD analyses of investigated waste samples showed that both brick samples contained anorthite (calcium feldspar group, $CaAl_2Si_2O_8$), wollastonite ($Ca_{0.957}Fe_{0.043}O_3Si$), and mullite ($Al_{2.4}O_{4.8}SiO_6$) [19]. Brick sample from the 1930s also contained calcium silicide (CaSi), while brick from the 1970s contained quartz and sanidine (a high-temperature form of potassium feldspar $KAlSi_3O_8$). It was presumed that different processing of solid bricks originated from different time periods, divergent baking temperatures and characteristics of their basic raw materials cause diverse chemical reactions and phase transformations giving new crystalline structures [20].
The results of compressive strength are shown in Table 2.

Table 2. Compressive strength of cube samples [MPa]

Sample	**Compressive strength**
SB30	9.8
SB70	10.2
SB3070	10.5

Based on the composition of this type of waste, i.e. satisfactory aluminosilicate content, it was expected to achieve satisfactory compressive strength results. The older brick samples SB70 and sample SB3070 with a combination of both waste types showed slightly better strength, which could be the starting point for further testing. These moderate values for all brick samples might represent the consequence of sensitivity to quality change of waste components and exploitation conditions. The most likely underlying reason for the higher compressive strength results of the older solid brick and the mixed sample is their mineral composition, i.e. higher proportion of aluminosilicate. However, all samples showed satisfactory compressive strengths, and it represents an excellent basis for further research.

Conclusion

The aim of this study was a preliminary investigation of the applicability of solid brick from the C&DW in geopolymerization processes.
The solid brick waste was collected from different demolition sites: buildings from the 1930s and 1970s. After brick waste homogenization, geopolymer pastes were produced by mixing solid brick powders with an alkali activator, a sufficient amount of water, and a superplasticizer. The samples were molded and cured for 1 day in the air at room temperature, covered with a wet cloth, after which the samples were cured

in 20˚C water for 28 days and removed from water a little prior to testing. Cubic shape molds of 100 mm diameter, complying with the standard SRPS EN 196-1:2018 were used for the sample preparation. The compressive strength was measured according to the standard SRPS EN 12390-3:2010 for cubic samples.

XRD analyses of investigated waste samples showed that both brick samples contained anorthite, wollastonite, and mullite. Brick sample from the 1930s also contained calcium silicide, while brick from the 1970s contained quartz and sanidine. The compressive strength values ranged from 9.8 MPa for the newer solid brick, 10.2 MPa for the older solid brick, and 10.5 MPa for the solid brick mix waste geopolymer sample. The most likely underlying reason for the higher compressive strength results of the older solid brick and the mixed sample is their mineral composition, i.e. higher proportion of aluminosilicate.

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