# Mechanical and durability properties of alkali activated materials produced from brick waste and metallurgical slag

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Construction and Demolition Waste (CDW) represent one third of the total waste generated by economic activities. They derive from construction and demolition activities and mainly contain mineral waste (e.g concrete, masonry) and other materials in smaller quantities. It is estimated that approximately 54% of CDW comprise ceramic materials (i.e., bricks, tiles and other forms), and 12% is concrete (Salazar et al. 2017).

The EU Waste Framework Directive (2008/98/EC) renders CDW a priority waste stream, thus the need for their valorization is urgent. In recent years, there have been an increasing number of studies regarding recycling of CDW to produce eco-friendly concrete. A promising alternative appears to be alkali-activation for the production of secondary materials (often called inorganic polymers or geopolymers). These materials exhibit promising physical properties and may be used in the construction sector (Fort et al. 2018; Ghanbari et al. 2015).

Alkali activated materials (AAM) are synthesized by using alkali solutions based on sodium or potassium (hydroxide or silicate) and raw materials rich in silica and alumina. The alkaline solutions act as activators to trigger polymerization of Al and Si and form Si-O-Al-O bonds instead of calcium silicate hydrate (C-S-H) phases present in cement (Nergis et al. 2018). Ceramic wastes such as bricks and tiles contain high levels of $SiO_2$ and $Al_2O_3$. Metakaolin, fly ash and metallurgical slag are also rich in silica and alumina and can be used for the production of alkali activated materials (Wong et al., 2018).

This study aims to the production of alkali activated materials synthesized using brick waste from CDW collected from various demolished buildings (Crete, Greece), metallurgical slag derived from ‘‘LARCO S.A” ferronickel plant (Central Greece), sodium hydroxide and silicate solutions.

Raw materials characterization included: chemical composition using X-ray fluorescence analysis (XRF) (Table 1), particle size analysis (Table 2), Fourier transform infrared spectroscopy (FTIR) and mineralogical analysis (XRD). The typical mix proportions used for the AAM synthesis are shown in Table 3. Raw materials were mixed with activation solution for 15 minutes so that a homogeneous paste was obtained. The resulting paste was cast in cubic steel moulds 5x5x5$cm^3$. Moulds were vibrated for a few minutes to reduce the presence of air voids within the paste and then remained at room temperature until the paste hardened. Specimens were then demoulded, sealed in a plastic bag and heated at 60, 80 and 90 $^oC$ for 24 hours in a laboratory oven. After curing, strength and durability performance of specimens was investigated.

Table 1: Chemical analysis (%) of raw materials

| Material | $SiO_2$ | CaO | $Al_2O_3$ | MgO | $K_2O$ | $Fe_2O_3$ | $Cr_2O_3$ | $TiO_2$ | Total |
|---|---|---|---|---|---|---|---|---|---|
| Brick | 60 | 18 | 10 | 2 | 2 | 7 | - | 1 | 100 |
| Slag | 36 | 4 | 9 | 3 | - | 44 | 3 | - | 99 |

Table 2: Particle size of raw materials

| Material | $d_{90}$ (μm) | $d_{50}$(μm) |
|---|---|---|
| Brick | 94.3 | 16.7 |
| Slag | 45.6 | 8.9 |

Table 3: Typical mix proportions of raw materials and solutions (%wt)

| Specimen Code | Brick | Slag | NaOH | $H_2O$ | $Na_2SiO_3$ | Liquid to Solid (L/S) ratio |
|---|---|---|---|---|---|---|
| B | 71.4 | - | 3.2 | 9.5 | 15.9 | 0.40 |
| 75B-25S | 56.3 | 18.8 | 3.5 | 7.6 | 13.8 | 0.33 |
| 50B-50S | 38.2 | 38.2 | 3.3 | 7.2 | 13.1 | 0.31 |

Figure 1 illustrates the compressive strength of the specimens produced by mixing slag and brick waste (75B-25S, 50B-50S) compared to the compressive strength of control specimen (B). The highest compressive strength (41MPa) is obtained when 25 %wt of brick is replaced by slag. Specimens produced with 50 %wt brick replacement obtained a lower but still acceptable compressive strength value (29.4MPa). As indicated by the compressive strength, mixing brick waste with metallurgical slag improves the properties of the control mixture due to the finer particle size (Table 2) and higher reactivity of slag in alkaline solutions, due to the larger surface area. Brick waste and metallurgical slag can be co-utilized for the production of alkali activated materials with good mechanical performance.

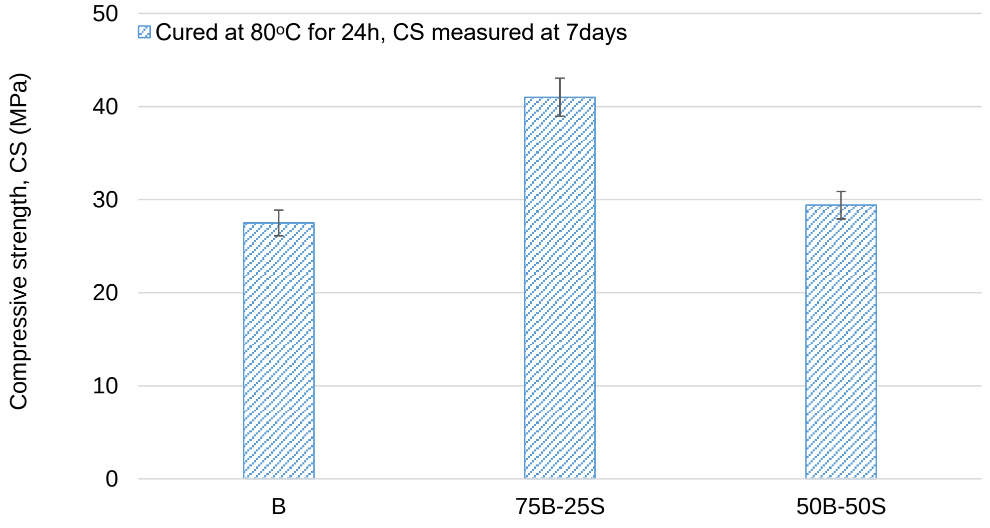


Figure 1: Compressive strength of the specimens produced by mixing slag and brick waste (75B-25S, 50B-50S) compared to the compressive strength of the control specimen (B)

**References**

C.L. Wong, K.H. Mo, S.P. Yap, U. J. Alengaram, L. Tung-Chai, Potential use of brick waste as alternate concrete-making materials: A review, Journal of Cleaner Production (2018), doi: 10.1016/j.jclepro.2018.05.193

R.A. Robayo-Salazar, J. Rivera, R. Mejía de Gutiérrez, Alkali-activated building materials made with recycled construction and demolition wastes, Construction and Building Materials 149 (2017) 130-138, doi: 10.1016/j.conbuildmat.2017.05.122

D.D. Burduhos Nergis, M.M.A.B. Abdullah, P. Vizureanu and M.F.M. Tahir, Geopolymers and Their Uses: Review, IOP Conf. Ser.: Materials Science and Engineering 374 (2018), 12-19, doi:10.1088/1757-899X/374/1/012019

J. Fořt, E. Vejmelková, D. Koňáková, N. Alblová, M. Čáchová, M. Keppert, P. Rovnaníková R.t Černý, Application of waste brick powder in alkali activated aluminosilicates: functional and environmental aspects, Journal of Cleaner Production (2018), doi: 10.1016/j.jclepro.2018.05.181

M. Ghanbari, A.M. Hadian A.A. Nourbakhsh, Effect of Processing Parameters on Compressive Strength of Metakaolinite Based Geopolymers: Using DOE Approach, 5th International Biennial Conference on Ultrafine Grained and Nanostructured Materials, UFGNSM15 Procedia Materials Science 11 (2015), 711-716, doi: 10.1016/j.mspro.2015.11.047