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Microstructural characterization and reaction mechanism of home-brewed activator derived from eco-processed pozzolan for one-part geopolymer mortar

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ABSTRACT

Anhydrous sodium-based commercial activators for one-part geopolymer (OGP) may cause eye damage, skin burns due to their corrosive nature, highly hygroscopic nature, high carbon footprint during production, high energy consumption, and cost. This research developed a home-brewed activator (HBA) from industrial/agro-based ash such as Eco-processed pozzolan (EPP) using an alkali fusion method. In the alkali fusion method, a mixture of sodium hydroxide (NaOH) powder and EPP at various weight ratios of 1, and 2 was calcinated in a muffle furnace at 300 °C and 500 °C for 1.5 and 3 h. Ground Granulated Blast Furnace Slag and Fly ash were used as binders for casting the OGP and two-part geopolymer (TGP) mortar specimens. From the X-ray diffraction (XRD) results, the main activator compounds such as thermonatrite ($Na_2CO_3 \cdot H_2O$), natrite (Na_2CO_3), calcite ($CaCO_3$) and natrosilicate ($Na_2Si_2O_5$) in HBA that initiate the polymerization reaction. The OGP mortar specimen produced a 28-day compressive strength of 50 MPa under the ambient curing regime with a NaOH/EPP ratio of 1, calcination temperature of 300 °C, and duration of 1.5 h. Both the OGP and TGP mortar specimens showed the presence of calcium aluminosilicate hydrate and calcium sodium aluminosilicate hydrate (C-A-S-H/C-N-A-S-H) geopolymeric gel. The carbon efficiency of OGP mortar specimens was found 70 % lower than that of TGP mortar specimens.

Abbreviations: ~, approximately equal; °C, degree Celsius; %, percentage; μm, micrometre; A_c, Amorphous content; CC, Calcite; Cp, Specific heat capacity; C/S, Cross section; CS, Control specimens; D_c, Degree of crystallinity; g, gram; J, Joule; K_b, basicity coefficient; KN, kilo Newton; KV, kilo Volt; mA, milli Ampere; mg, milli gram; ml, milli litre; min, minutes; mPa.s, milli Pascal second; M, Molarity; M^+, Metal ion; N, Natrite; NH, Sodium hydroxide; NS, Natrosilicate; Q, Quartz; T, Thermonatrite; T, tonnes; W, Watts; w/b, water/binder; AAMs, Alkali activated materials; ASTM, American Standard for Testing and Materials; C-A-S-H, Calcium alumino silicate hydrate; COD, Crystallography open Database; C-N-A-S-H, Calcium sodium alumino silicate hydrate; DTG, Differential thermo gravimetry; EPP, Eco-processed pozzolan; FA, Fly ash; FESEM, Field Emission Scanning Electron Microscopy; EDS, Energy Dispersive Spectroscopy; EDX, Energy Dispersive X-ray; FM, Fineness Modulus; FTIR, Fourier Transform Infrared; GGBFS, Ground Granulated Blast Furnace Slag; GP, Geopolymers; GPC, Geopolymer concrete; HBA, Home-brewed activator; Hours, h; LOI, Loss on ignition; MPa, Mega Pascal; N-A-S-H, Sodium Aluminosilicate Hydrate; NBO, Non-bridging oxygen; N-C-A-S-H, Sodium calcium alumino silicate hydrate; OGP, One-part geopolymer; OPC, Ordinary Portland cement; POFA, Palm oil fuel ash; TGP, Two-part geopolymer; ppm, parts per million; RHA, Rice Husk Ash; SAF, $SiO_2 + Al_2O_3 + Fe_2O_3$; SBA, Sugarcane Bagasse Ash; SBE, Spent bleaching earth; SBEA, Spent bleaching earth ash; SE, Secondary electron; SEM, Scanning Electron Microscopy; SF, Silica Fume; SM, Silicate Modulus; SS, Sodium Silicate; SSA, Specific Surface Area; TGA, Thermo-gravimetric analysis; TPOFA, Treated palm oil fuel ash; WD, Wavelength -dispersive; XRD, X-ray Diffraction; XRF, X-ray Fluorescence; Al, Aluminium; Al_2O_3, Aluminium oxide; Ca, Calcium; CaO, Calcium oxide; $CaCO_3$, Calcium carbonate; $CaSO_4$, Calcium sulfate; CO_2, Carbon dioxide; Fe, Iron; Fe_2O_3, Ferric oxide; KOH, Potassium hydroxide; K_2O, Potassium oxide; MgO, Magnesium oxide; NaOH, Sodiumhydroxide; $NaAlO_2$, Sodium aluminium oxide; Na_2O, Sodium oxide; Na_2CO_3, Sodium carbonate; $Na_2CO_3.H_2O$, hydrated sodium carbonate; Na_2SiO_3, Sodium silicate; $Na_2SiO_3.H_2O$, Hydrated sodium metasilicate; $Na_2Si_2O_5$, Natro silicate; Na_2SO_4, Sodium sulfate; Si, Silica; SiO_2, Silicon oxide; SO_3, Sulfur trioxide.

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