Synthesis of sodium waterglass from spent diatomaceous earth as an activator to produce copper slag alkali-activated cements.

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Portland cement is an essential building material. However, its manufacture involves the exploitation of quarries, high energy consumption and large amounts of emissions into the atmosphere (Deja et al., 2010). For this reason, the study and development of new alternatives to Portland cement is a priority line of research of great interest worldwide.

The cement industry has developed alternative cements such as alkaline activated cements (AACs) or geopolymer cements. Alkaline-activated cements are green materials that considerably reduce CO_2 emissions without high economic cost. In addition, they have significant technical advantages over conventional cements. These are non-Portland cements based solely on natural minerals, industrial waste or by-products and an alkaline activator (Duxon et al., 2007). Regarding the use of alkaline solutions, the most commonly used are alkaline hydroxides (NaOH, KOH) and commercial sodium silicate solutions (waterglass). However, most of the emissions and energy consumption of alkaline activated cements can be attributed to commercial activators. Sodium silicate is produced from silicon oxide and sodium carbonate, natural resources, at high temperatures (1300 ºC), so its production consumes a lot of energy and generates CO_2 in the atmosphere (Tempest et al., 2009). Thus, supplementary sources of silica are needed to reduce the economic and environmental impact of sodium silicate production, and in that way, rice husk ash, diatomaceous earth or glass can represent an attractive option due to their high silica content to produce silicate solutions by chemical reaction with NaOH or KOH (Mejía et al., 2016; Torres and Puertas, 2017). Therefore, it is necessary to look for alternative solutions to commercial alkaline silicates to achieve waste-based alkaline activated materials with near zero carbon footprint.

The purpose of this work was to investigate the possibility to synthesize sodium waterglass from spent diatomaceous earth and used it as an activator to produce copper slag (CS) based alkali-activated cements. Diatomaceous earth, or diatomite, is a sedimentary rock with a high amorphous silica content formed by fossilized diatom remains. In this research, the alkali-activated cements were obtained using copper slag as precursor and three different activation solutions prepared by mixing caustic soda with various amounts of spent diatomaceous earth. First, the precursors, cupper slag were entered in a Proeti planetary mixer. Then, the alternative or commercial activating solution was added and the mixture was homogenised for 90 seconds. The mixing was then stopped for 90 s to remove the paste adhering to the inner wall. Finally, the paste was mixed for 90 s at high speed (285 ± 10 rpm) to complete the mixing of the paste. The pastes were poured into stainless steel moulds to obtain prismatic samples ($1\times1\times 6\ cm^3$). Samples were covered with film and cured at room temperature. After 24 hours, they were demoulded and kept at room temperature in a laboratory environment until the day of testing, 7 and 28 days. Physical, mechanical y thermal properties of alkaline activated cements were determined.

The results indicate that it is possible to obtain alkaline activated cements with flexural strengths between 3.1-3.4 MPa depending on the amount of residue used and compression strengths between 16.0-19.0 MPa after 7 days of curing. Comparing the data of the activated cements with the commercial sodium silicate-sodium hydroxide activator, slightly higher flexural strengths of 6.9 MPa and slightly lower compressive strengths of 14.3 MPa are obtained.

The study confirms the possibility of using spent diatomaceous earth as an alternative source of silica in alkaline activation process. The results offer a new route for the reuse and recovery of diatomaceous earth residue, as well as, demonstrates that an economically and environmentally sustainable technology can be used to produce waterglass, reducing the environmental impact of alkaline activation materials. These promising results suggest that alkaline activated cements can be obtained using waste to structural and/or non-structural applications, which makes these cements very attractive from an environmental and economic point of view, moving towards a circular economy.

References

Deja J., Uliasz-Bochenczyk A., Mokrzycki E. CO_2 emissions from Polish cement industry. Int. J. Greenh. Gas Con. 4 (2010) 583-588. https://doi.org/10.1016/j.ijggc.2010.02.002.

Duxon P., Fernández-Jiménez A., Provis J.L., Luckey C.G., Palomo A., van Deventer J.S.J. Geopolymer technology: the current state of the art. J. Mater. Sci. 42 (2007) 2917-2933. https://doi.org/10.1007/s10853-006-0637-z.

Mejía J.M. , Mejía de Gutiérreza R., Montes C. Rice husk ash and spent diatomaceous earth as a source of silica to fabricate a geopolymeric binary binder. J. Clean. Prod. 118 (2016) 133-139. https://doi.org/10.1016/j.jclepro.2016 .01.057.

Tempest B., Sanusi O., Gergely J., Ogunro V., Weggel D. Compressive strength and embodied energy optimization of fly ash based geopolymer concrete. In: World of Coal Ash Conference 2009 in Lexington, KY, USA, pp. 1-17.

Torres-Carrasco M., Puertas F. Waste glass as a precursor in alkaline activation: Chemical process and hydration products. Constr. Build. Mater. 139 (2017) 342-354. https://doi.org/10.1016/j.conbuildmat.2017.02.071.

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