Synthesis of geopolymer binders based on industrial waste

ABSTRACT

The aim of the study was to determine the possibility of using low-reactivity raw materials, i.e. chalcedonite, amphibolite, diatomite and fly ash from brown coal combustion, in the synthesis of geopolymer binders. The scope of the work included a broad review of the literature on the mechanism of geopolymerisation, the characteristics and influence of selected precursors on the final properties of geopolymers, as well as current research directions on the use of waste raw materials in the synthesis of geopolymer materials. In the experimental part, the base raw materials were characterised in detail by analyzing their chemical and phase composition, morphology, particle size distribution, specific surface area and porosity parameters. A series of one-, two- and four-component geopolymer mixtures were produced and their mechanical properties (compression, bending), chemical resistance (acids, alkalis, salt spray), resistance to physical factors (freezing/thawing, accelerated ageing) and structural analysis (optical microscopy, SEM, FTIR, mercury porosimetry, BET analysis). An important part of the research was the development of a model that allows the molar ratios of the main oxides (Na_2O, SiO_2, Al_2O_3) to be correlated with the compressive strength of the geopolymer binders obtained. This made it possible to determine the optimal ranges of molar ratios that can facilitate the design of geopolymer mixtures with specific properties. The results of the study confirmed that appropriately selected compositions of geopolymer mixtures, based on local raw materials considered as waste, can lead to the production of a binder with high strength and durability in various aggressive environments. The Ch+D+A+M and Ch+D+M+PB binders achieved high mechanical parameters and were characterized by increased resistance to moisture, aggressive chemical solutions and variable temperature cycles. These binders also showed a high ability to immobilize heavy metals and organic compounds. In addition, the optimal molar ratios for geopolymer binders were determined: Na_2O/Al_2O_3: ~0.7–0.9; SiO_2/Al_2O_3: ~4.1–5.9; Na_2O/SiO_2: ~0.15–0.17; H_2O/Na_2O: ~11.5–13.0; W/S: ~0.31–0.35), which are favorable for achieving compressive strength above 40 MPa. The results of the above studies confirm the possibility of using local, low-reactive waste raw materials for the production of durable and environmentally friendly geopolymer materials.