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Experimental investigation on the pozzolanic activity of some calcinated clays from Togo

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The cement industry is facing major challenges due to dwindling clinker reserves, high CO₂ emissions, and high electrical energy consumption. Partially or completely replacing clinker in cement production represents a possible solution, and the use of clays is one of the most promising options to achieve this. In the field of research, the partial replacement of clinker with calcined kaolinitic clays has been the subject of numerous studies. In this regard, many research projects have been undertaken by the research community by partially replacing clinker with calcined kaolinite clays. Togo, a cement producer (over 2,000,000 tons) and a major energy consumer (over 4,2.109 kWh), is affected by these issues. A study therefore assessed the feasibility of a Togolese low-carbon cement, obtained by partially replacing clinker with three types of local clays. Activation of these raw clays, whose reactivity is negligible, is essential for their use in the production of this low-carbon cement. This work therefore investigated the pozzolanicity of Togolese clays for their use in the production of low-carbon cement. The objective is to partially replace clinker with these clays, thermally activated at 700°C for 2 hours in a Nabertherm kiln. The study focused on three clays: Afagnan (KA), Bandjeli (KB), and Asuto (AS). Before and after calcination, a microscopic analysis (TGA/DTG) was performed to determine the kaolinite content and the optimal activation temperature. The mineralogical composition was determined by X-ray fluorescence, and the transformation of kaolinite into metakaolin upon thermal activation was confirmed by XRD. Macroscopic tests on mortars and cement pastes included evaluation of the pozzolanic activity index, measurement of compressive strength, determination of chemically bound water, and isothermal calorimetry. In application, binary LC2 and ternary LC3 cements were formulated. Analyses revealed varying kaolinite contents depending on the clay: 60.17% (KA), 57.31% (KB), and 28.65% (AS). An activation temperature of 700°C for 2 hours was optimal for all three clays, confirmed by TGA/DTG and XRD. According to ASTM C618, these clays are suitable as pozzolans, their oxide content (%SiO₂ + %Al₂O₃ + %Fe₂O₃) exceeding 70% (KA: 90.49%, KB: 80.16%, AS: 90.1%). Compression tests confirm this: the strengths at 7 days are 41.1 MPa (KA), 43.45 MPa (KB) and 36.6 MPa (AS) compared to 43.15 MPa for the control, and at 28 days, 57 MPa (KA), 59.1 MPa (KB) and 55.25 MPa (AS) compared to 59.8 MPa for the control. The pozzolanic activity index exceeds 70% for all substitution rates, with a maximum for PC-90-KB-10 (100.7%). These results confirm the potential of these calcined clay-based composite cements for construction. The heat of hydration of the composite cements varies according to the substitution rate. At 10%, the trend remains similar to the control, with a slight increase. At 20%, the total heat released decreases for all samples, except KB, which maintains the same trend as the control.

Abstract Category

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