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Marl-based geopolymers incorporated with limestone: A feasibility study

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ABSTRACT

The expanding raw materials base is one of the drivers for the further development of inorganic binders, including alkali-activated cements. This research focuses on studying marl with a high calcite/aluminosilicates ratio as a geopolymer precursor, and limestone as a mineral addition to this geopolymer. The calcination of marl at 800 °C resulting in the formation of reactive Si, Al, and Ca due to the dehydroxylation of clay minerals and decarbonation of calcite makes marl suitable for use as a geopolymer precursor. Calcined marl activated with sodium silicate and cured at ambient temperature had a 28-day compressive strength of 34 MPa. When incorporated with 50% limestone, the compressive strength became 39.2 MPa. XRD, TG/DSC, FTIR, optical and SEM have been used to investigate the reaction products, as well as the microstructure of the geopolymer hardened pastes.

1. Introduction

Geopolymerization, as a non-fire or low-temperature production method of binders based on various natural and technogenic aluminosilicate materials that are not inferior to the properties of Portland cement, increasingly appeals both in theory and practice [1,2]. Progress in this area is also driven by the constant expansion of the raw material base and the possibilities of using a wide range of both natural and waste aluminosilicate materials [3,4]. The use of different aluminosilicate precursors and ways to improve the performance of the geopolymers based on them through the introduction of chemical additives and mineral additions are also being researched and developed [5–8].

The increasing importance of thermally activated clays as supplementary cementitious materials for Portland cement [9–13] and as precursors for alkali-activated materials [1,2] should be noted. The most valuable clay for both Portland cement-based and alkali-activated cements is metakaolin, which is produced by heating kaolin clays. However, the scarcity of their reserves and the associated high costs have led to research in different countries involving feasibility studies on the use of the more common low-grade kaolin clays and other clays consisting of different minerals [14–18] including calcined marl [19]. Many studies stated the possibility of transforming a wide range of clays or natural and synthetic aluminosilicates like the smectite and the smectite/illite-types of clays [20,21], 16 aluminosilicate minerals with different structures and compositions (albite, illite, sillimanite, andalusite, and others) [22,23], halloysite [24], feldspars [17], etc. into alkali-activated cements. The mechanical performance of the alkaline cements obtained with common clay and feldspar is lower as a rule than that of the cements synthesized from fly ash or metakaolin (MK) [1].

The combination of calcined clays with calcium aluminosilicates (high-calcium fly ash, or slag) [25–30] and fillers is an effective way to reduce the dependence on aluminosilicate clay sources and manage the macro-, micro-, and nanostructures, as well as the technological and physical and technical characteristics of such blended activated systems.

One of the most used mineral additions, both for the blended Portland cements and non-clinker cements, is limestone [31–44]. In the case of alkali-activated cements, a combination of aluminosilicate precursors with physically or chemically active supplementary materials or with materials that are both physically and chemically active is effective because alkali activation allows not only the production of alkali-activated cements of superior technical efficiency in matrices, but also allows for an effective interaction between the alkali-activated cement paste and the fillers, as well as compatibility with mineral

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