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Hybrid Cements with ZnO Additions: Hydration, Compressive Strength and Microstructure

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Abstract: The effect of ZnO has already been studied for Portland cement, but the study of its impact on hybrid pastes is scarce. Thus, in this investigation, the influence of ZnO addition on hydration, compressive strength, microstructure, and structure of hybrid pastes is presented. The analyses were made by setting time tests, compressive strength tests, X-ray diffraction, Fourier-transform infrared spectroscopy, thermogravimetric analysis with differential scanning calorimetry, and scanning electron microscopy coupled with energy-dispersive X-ray spectroscopy. The results indicate that the setting time of the cements was delayed up to 39 min with additions of 3 wt% ZnO. Alternatively, the higher values of compressive strength were observed when 0.5 wt% ZnO was added to the cements for all curing days. In addition, no important differences in the microstructure of samples with different additions of ZnO were observed after 28 days of curing. It is expected that the use of ZnO contributes to the delay of the setting time and the increase of the compressive strength without negatively modifying the microstructure of hybrid pastes.

Keywords: ZnO; sodium silicate; hybrid cements; microstructure; compressive strength

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Citation: Soto-Felix, M.; Baldenebro-Lopez, F.J.; Carreño-Gallardo, C.; Herrera-Ramirez, J.M. Hybrid Cements with ZnO Additions: Hydration, Compressive Strength and Microstructure. *Molecules* **2022**, *27*, 1278. https://doi.org/10.3390/molecules27041278

Academic Editor: Krzysztof Pielichowski

Received: 25 January 2022
Accepted: 10 February 2022
Published: 14 February 2022

1. Introduction

Portland cement (PC) has been effectively replaced by supplementary cementitious materials (SCM), such as slag, fly ash, silica fume, and natural or artificial pozzolans such as metakaolin, leading to significant improvements of cement properties mainly in mechanical and durability properties [1–9]. In addition, this has contributed to sustainability [10,11] due to the replacement of cement, significantly reducing environmental problems related to cement production mainly associated with the calcination of raw materials and the burning of fuels to achieve high temperatures inside a kiln [12,13].

However, high replacement ratios in cement are known to be detrimental to mechanical properties development mainly at early ages [14,15]. The early reactivity of SCM can be improved in some ways, such as reducing particle size [16,17], mechanical activation [18,19], thermal activation of natural pozzolans [20,21], and with the addition of chemical activators such as NaOH, KOH, Na_2CO_3, or Na_2SiO_3, among others [22,23]. Nevertheless, the hydration of PC with highly alkaline solutions has been shown to alter its normal hydration process, with considerable delays in the formation of the main reaction products and the appearance of new products as sodium calcium carbonate and sodium sulfate [24,25].

The combination of traditional alkali activation precursors with PC is commonly referred to as hybrid alkali cements [26,27]. This type of cements combines some of the advantages of traditional PC, such as setting at ambient temperature with the development