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Assessment of waste sludge from chemical industry as sulphate-based additive in cements

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Cement production worldwide was approximately 4 billion metric tons in 2022 [1]. During this process, natural gypsum ($CaSO_4 \cdot 2H_2O$) is used as a crucial component to regulate the setting properties of Portland cement [2]. However, due to the great environmental concerns and the substantial stock reductions of this feedstock [3], it is essential to evaluate alternative sources that allow a sustainable development of the cement industry. In this sense, waste sludge (WS) from the production process of organic acids is seen as a highly promising raw material in the context of circular economy. Therefore, this study focuses on the valorization of WS as a setting retarder to replace mineral gypsum in the cement production.

Firstly, a complete characterization of WS was performed to determine its chemical composition, crystalline phases, and the presence of impurities that may later affect the cement formulation. Thus, it was found that WS is made up of 85% calcium sulphate hemihydrate when dried at 105 ºC, while it was mainly composed of calcium sulphate dihydrate (89%) at 60 ºC. Additionally, the main impurities were iron, sodium, silicon and organic compounds, which were present in low quantities. On viewing the favorable physicochemical properties of WS, the application of this residue as a key additive for cement production was evaluated. To that end, WS was thermally pretreated at both 60 ºC and 105 ºC. Subsequently, CEM I type cement samples were prepared using a mixture of clinker with WS, as shown in Table 1. After the mechanical analysis, it was found that the CEM I-60-2.5, CEM I-105-2.5 and CEM I-105-5 cement samples presented compressive strength values after 28 days between 32.5 MPa and 52.5 MPa (Table 1), as required by the regulations applicable to this class of mortars [4]. In this sense, the prepared samples must be expressed as CEM I 32.5N. Therefore, WS can be considered a suitable and highly viable additive for cement production.

Table 1. Composition of the prepared cement samples and compressive strength for 28 days.

CEM I	% Clinker	% WS	Compressive strength for 28 days (MPa)
CEM I-60-2.5	97.5	2.5	32.9
CEM I-60-5	95.0	5.0	27.8
CEM I-105-2.5	97.5	2.5	35.6
CEM I-105-5	95.0	5.0	38.8

References:

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[3] Tzouvalas et al. (2004), *Cem Concr Res* 34, 2119–2125.

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