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Influence of using slag cement on the microstructure and durability related properties of cement grouts for micropiles

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HIGHLIGHTS

- Microstructure and durability of OPC and slag cement grouts used for micropiles.
- Hardened slag cement grouts have a more refined microstructure than OPC ones.
- The use of slag cement grouts produces an improvement of micropiles durability.
- The w:c ratio of the cement grout does not influence on their long-term properties.
- The slag cement grouts for micropiles show good properties, better than OPC ones.

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ABSTRACT

Today, the use of micropiles for different applications has become very common. In Spain, the cement grouts for micropiles are prepared using ordinary Portland cement and w:c ratio 0.5, although the micropiles standards do not restrict the cement type to use, provided that it reaches a certain compressive strength. In this study, the influence of using slag cement on the microstructure and durability related properties of cement grouts for micropiles have been studied until 90 hardening days, compared to an ordinary Portland cement. Finally, slag cement grouts showed good service properties, better than ordinary Portland cement ones.

1. Introduction

Nowadays, the use of micropiles has grown significantly. They have been used mainly as elements for foundation support to resist static and seismic loading conditions, and as in situ reinforcements for slope and excavation stability [1]. A micropile is a small-diameter (typically less than 300 mm), drilled and grouted pile which is typically reinforced [1]. It is constructed by drilling a borehole, placing reinforcement and grouting the hole [1]. There are various types of reinforcement for micropiles, like steel bars or steel pipes. Fig. 1a depicts a schematic representation of a micropile reinforced with steel pipe, and Fig. 1b shows four different sections of a micropile, depending on the type of reinforcement employed [1–3].

In the case of Spain, the cement grouts for micropiles are usually prepared using an ordinary Portland cement. However, the Spanish Guide for Micropiles Project and Execution for Road Works [2] does not restrict the cement type to use, provided that it reaches a certain compressive strength, which depends on the requirements established in the project of the structure, although in general it should be higher than 25 MPa at 28 days hardening age. Besides, Spanish and European standard for micropiles UNE-EN 14199 [3] and the Implementation manual for Micropile Design and Construction Guidelines FHWA-SA-97-070 [1] of Federal Highway Administration (US Department of Transportation) do not restrict the cement type for micropiles too, as long as they achieve the compressive strength requirement previously mentioned. On the other hand, regarding the dosage of cement grouts for micropiles, they are usually prepared with w:c ratio 0.5, although the abovementioned standards and manuals [1–3] allow using different w:c ratios included in a particular range.

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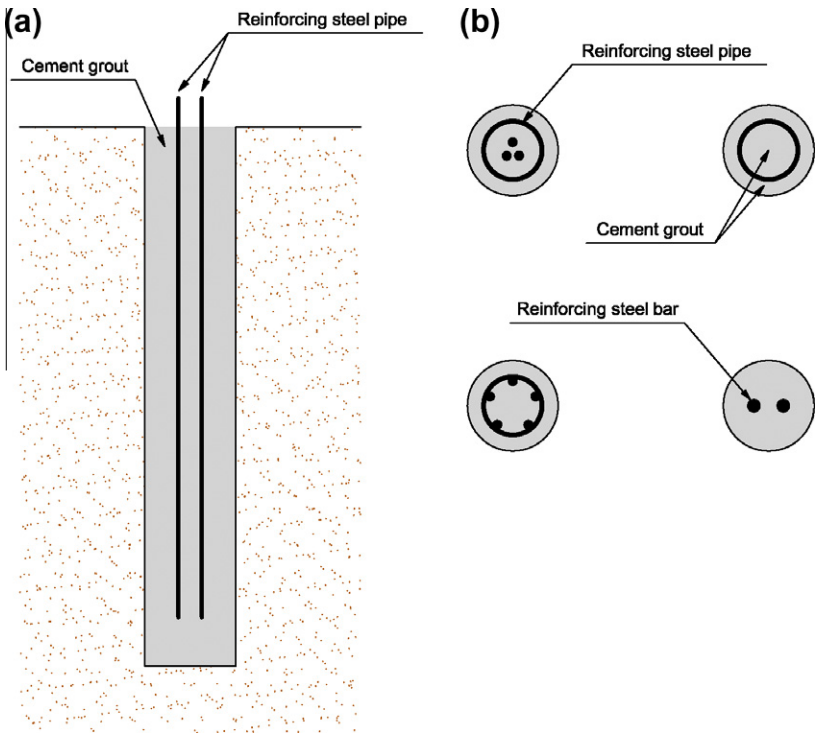

Fig. 1. (a) Schematic representation of a micropile reinforced with steel pipe. (b) Different sections of a micropile, depending on the type of reinforcement employed [1–3].

In recent years, the use of mineral admixtures has become very common in cement manufacture, because they provide important benefits, like the reduction of CO_2 emissions and the lower energy consumption during the cement production. The particular case of ground granulated blast-furnace slag and its effect on the properties of the cementitious materials is a topic of study [4–6]. Many studies have demonstrated that mortars and concretes prepared using slag cements have good behaviour for numerous applications [5], especially for marine structures [7–9]. However, the performance of slag cements for micropiles cement grouts has never been studied, especially with regard to their microstructure and durability.

The study of the microstructure of cementitious materials is very important, because it is well known that the microstructure of these materials is directly related to their durability properties [10,11]. Besides, the microstructure characterization using non-destructive techniques is an important research field now. In this study, the non-destructive technique of impedance spectroscopy (IS) has been used for studying the evolution of the microstructure of hardened cement grouts (pastes). This technique is based on the possibility of correlating dielectric and mechanical properties of a solid material [12]. The interpretation of the parameters is made using an equivalent circuit, where each one of the electrical elements in the circuit (resistances and/or capacitances) represents one of the aspects of the microstructure of the material. This technique has been widely used for OPC pastes, mortars and concretes [13–15]. Nevertheless, regarding materials prepared with cements which contain active additions, this technique has been hardly used for fly ash cements [11,16] and it has been never used for characterizing the microstructure of cement pastes with slag.

On the other hand, in the case of cement grouts for micropiles, the study of their durability related properties has lots of interest, due to the importance of preventing the corrosion of reinforcing elements of micropiles. For micropiles those reinforcement elements are embedded in the hardened cement grouts (cement pastes), which constitutes a great difference with regard to the majority of civil engineering structures where the reinforcement steel bars are embedded in concrete. This difference increases the interest of analysing the durability properties of cement grouts, especially if a slag cement is used.

In order to characterize these durability properties, it is important to study the capillary suction of hardened cement grouts, because it is a fact well known that aggressives in concrete can arrive where water arrives [10]. Besides, the study of chloride diffusion is also important, because the chloride ingress is an important factor which can cause the pitting corrosion of reinforcing steel elements, especially for micropiles in contact with aggressive soils and waters.

Then, the objective of this research is to study the influence of using slag cement on the microstructure and durability related properties of cement grouts for micropiles, prepared using different w:c ratios, in comparison with an ordinary Portland cement. This influence has been studied since very early ages (2 days), because the hardening of the cement grout is produced in contact with the adjacent ground and soils, and as consequence, exposed to aggressive agents.

2. Experimental setup

2.1. Sample preparation

The tests were performed on cement pastes, which were prepared using an ordinary Portland cement (OPC), I 52.5 R/SR (CEM I from now on), and a ground granulated blast-furnace slag (GGBS) cement (with a content of GGBS between 66% and 80% of total binder), III/B 42.5 L/SR (CEM III from now on), according to the standard UNE-EN 197-1 [17]. Both cements have a resistant class equal or higher than 42.5, and both are sulphate-resistant, as requires the Spanish Guide for Micropiles Project and Execution for Road Works [2]. Besides, both cements would also achieve the design compressive strengths indicated by the Implementation manual for Micropile Design and Construction Guidelines FHWA-SA-97-070 [1], which suggest that the neat cement grouts should reach compressive strengths between 28 and 35 MPa. Finally, they would also reach the minimum compressive strengths required by Spanish and European standard for micropiles UNE EN 14199 [3], which is 25 MPa at 28 days.