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Opinion

A Brief View on the Effect of Permeability and Shrinkage Parameters on the Design of Optimum Cement Suspensions for Soil Grouting

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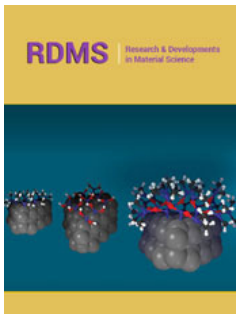

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Abstract

The use of very fine cement grouts for injection into fine-to-medium sands has been proposed to circumvent problems associated with the permanence and toxicity of chemical grouts and the inability of ordinary cement grouts to permeate soil formations finer than coarse sand. The rheological properties of a cement suspension grout significantly determine the success of an injection especially in those cases where geometric constraints do not arise from the size relationship between soil voids and suspension solids. For this reason, it is considered necessary to determine the rheological characteristics of the suspensions during the design phase of an injection program, so as to select the optimal suspensions on a case-by-case basis. In general, determining the rheological behavior of a cement suspension is not an easy task as there are many factors that intervene in it and have opposite effects. In this paper information is given regarding the effect of these factors on the rheological behavior of cement suspensions. In the present paper, reference is made to the properties of cement suspensions and how they change due to the combined use of these materials. At the same time, value ranges that these properties take are given - where possible - with data obtained from the literature review carried out.

Keywords: Permeation grouting; Cement suspensions; Permeability; Shrinkage

Introduction

The safe construction and operation of many technical projects often requires the improvement of the properties and mechanical behavior of the soil formations. The shear behavior of a soil material is of particular interest because it has a direct impact on practical bearing capacity problems [1,2], stability of slopes and embankments [3,4] as well as permanent seismic movements of slopes [5].

The selection of the optimal suspension for the needs of a technical project must be the subject of thorough investigation and documentation and is primarily determined by its properties always combined with the specialized requirements of each application. The criteria, which advocate or not in the selection of an optimal suspension, are related to penetration, setting times, strength, stability, rheological properties, permeability, permanence, shrinkage, etc. Determining and documenting the properties of the suspensions is the first approach to choosing the best solution. However, the final choice presupposes the investigation of further influencing parameters such as reasons of economy and particular requirements of each technical project.

The basic rheological characteristics of cement suspensions are consistency and plastic viscosity. Cohesion is considered to play an important role in grout injectability and penetrability, as the distance that a suspension can penetrate depends on it. This is because it sets the value of the injection pressure required to start the flow and determines the penetration length at which the injection pressure is balanced, at which point the flow stops. On the other hand, the viscosity controls the injection rate and the behavior of the suspension when in the flow state depends on this [6,7]. Consistency and viscosity values should be adjusted appropriately so that control is not lost and the injection process is optimized [6].

The process of optimizing the rheological properties of cement suspensions is not particularly difficult, as there are several methods by which they can be tested. These methods provide either the addition of certain components to the composition of the suspensions or the use of an appropriate type of cement or the change of the water-to-cement (W/C) ratio. Pure cement suspensions show a viscosity ranging from 5cP to 100cP [8] and increased consistency, indicating that, in general, improvement of their rheological characteristics is required. According to Gouvenot [9], suspensions with a viscosity of not more than 5cP should be used to achieve satisfactory results in injection injections, while Kutzner [8] states that the cohesion of suspensions should not exceed 50Pa in applications. field.

Permeability as a design parameter of cement suspensions

For injection applications a more critical factor is the permeability of the impregnated formation than the permeability of the grout. In light of this, the following information is provided for completeness and with a view to improving cement suspensions.

As with strength, the permeability of cement suspensions is significantly dependent on the water-to-cement ratio [10]. Suspensions that show high permeability are more susceptible to alteration especially when they are in a low pH environment. For this reason, when a combination of high strength with simultaneous recruitment of water is desired, it is recommended, instead of using cement suspensions, to use special shaped cement foams [11]. It has been found that the use of silica sand can significantly improve the permeability of cement suspensions, while the use of bentonite whose content must therefore be limited to 1% and in suspensions with water-to-cement ratios lower than 0.7:1 has opposite results [12].

Shrinkage as a design parameter of cement suspensions

The shrinkage of a cement slurry is primarily related to the amount of water expelled. A suspension that is left to mature in a slightly moist environment and is going to remain that way throughout its life will not shrink, but may swell slightly over time. On the other hand, a suspension that is allowed to mature in a dry environment or after being matured in a moist environment is allowed to dry out then it will show shrinkage [10]. Under normal conditions, shrinkage is not a significant problem in field applications, as the subsoil is usually wet or saturated. Of course, in cases where the shrinkage leads to the creation of small cracks then it is possible to affect the tightness of the suspension. For this reason, measures must be taken against shrinkage by using special chemical improvers that cause swelling of the suspension [10,13]. Suspensions with low water-to-cement ratios and those containing bentonite or silica-based materials have been found to exhibit better shrinkage behavior [14].

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