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Factors Affecting Rheological Characteristics Of Cement Suspension Grouts - A Mini Review

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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.

Keywords: Permeation grouting; Suspensions; Microfine cements; Rheological characteristics; Consistency

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 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.

Effect of superplasticizer and bentonite addition on cement suspension consistency

The most popular method of reducing the viscosity and consistency of cement suspensions is considered to be the use of superplasticizers [10-12]. In fact, the use of super fluidizers can lead to significant differences in the rheological model to which cement suspensions are subject, as it is possible for viscoplastic fluids with pseudoplastic flow behavior to be converted to Newtonian fluids [13]. The extent of the reductions achieved in viscosity and cohesion values depends on both the content and the type of super fluidizer [14-16]. Of course, the uncontrolled increase in the content of super fluidizer can lead to a change in the behavior of the suspensions and bring the opposite results from the desired. Incompatibilities have also been observed between cement types and certain superplasticizers and therefore any superplasticizer suspension compositions should be tested by preliminary laboratory tests [14].

Many times, and especially in cases where the penetration length is desired, the combined use of super fluidizers with flow regulators (eg: welan gum) is recommended, which cause an increase in consistency and viscosity [17]. In this way a balance of the action of the super fluidizers is achieved, the quality of the suspension is not altered, and cohesion and viscosity values can be obtained closer to the desired ones [18,19]. There are other chemical improvers used in cement suspension compositions, but for other reasons that indirectly affect the rheological properties of the suspensions. Typically, the use of coagulation accelerators (eg: calcium chloride, sodium silicate) is reported to cause an increase in viscosity [11,19], while the use of isopropyl alcohol (IPA) as a retardant causes a drastic reduction in viscosity [15].

The use of certain additives causes adverse effects on the rheological properties of cement suspensions. Cement-bentonite suspensions are known to behave as Bingham-type fluids [20]. The presence of bentonite has been found to cause more increase in consistency and less viscosity [21-23], while also exhibiting thixotropic behavior in cement suspensions [24]. For this reason, bentonite should be used as a rheological enhancer only in those cases where it is desired to limit the penetration of the suspensions [25]. In Italy, with the production of MISTRA suspensions, a significant reduction in the negative effects of bentonite use on the rheological behavior of suspensions has been achieved [26]. Cement suspensions containing fly ash, silica fume and natural pozzolan [27,28] exhibit similar behavior. In fact, the presence of silica fume in cement suspensions is reported to bring about thixotropic behavior characteristics in the suspensions [29].

This effect of the additives on the rheological characteristics of the cement suspensions is attributed to the fact that they are fine-grained materials with a grain size smaller than that of the cement grains. This results in an increase in the specific surface area of the solids within the suspensions leading to the capture of a larger amount of water reducing the one remaining available for the suspension to flow. This phenomenon takes on even greater proportions in those cases where a cement of finer fineness than ordinary cements is used as the basis of the suspension [28,30,31], which is due to the higher reactivity of the cements. in relation to pozzolans.

Effect of blaine specific surface area and cement type on cement suspension consistency

In general, it has been observed that increasing the specific surface area of cement leads to the preparation of suspensions with significantly higher cohesion values and viscosity [11,31]. For this reason, the use of superplasticizers in the manufacture of fine-grained cements is considered imperative, while the use of bentonite should be avoided [21]. In addition, the type of cement has been shown to play an important role in the rheological characteristics of the suspensions. In particular, suspensions based on fine-grained slag cements show significantly lower viscosity and consistency values than corresponding Portland cement suspensions of comparable fineness, which is a consequence of the low activity of slag [15]. In fact, the suspensions of fine-grained slag cements show lower viscosity and consistency than the suspensions of ordinary Portland cements. This difference in viscosity values is more significant at lower W/C ratios (≤1:1) and decreases considerably at higher W/C ratios [14].

Effect of W/C ratio on the cohesion of cement suspensions

The effect on the magnitude of the viscosity and consistency of the cement suspensions caused by the W/C ratio is significant. Increased W/C ratios provide larger amounts of water available for the flow of suspensions, which translates into suspensions as a reduced value of viscosity and cohesion, as documented by many research efforts [32-34]. These reductions are more pronounced at lower W/C ratios (≤2:1) and appear to be exponential. On the contrary, in high ratios (W/C ≥4: 1) the differences in viscosity due to change in the W/C ratio can be considered as negligible. This is due to the fact that at high W/C ratios the cement grains separate quite well so that the contacts between them - which could affect the viscosity - are few [14,33]. It has also been found that with increasing mixing time there is an increase in the viscosity of the suspensions [27,35]. The mixing time has a similar effect on the consistency of the suspensions, but only in cases where the W/C ratio is quite low [35].

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