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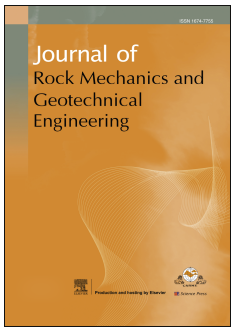

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Optimization of cement-based grouts using chemical additives

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Abstract: Grout injection is used for sealing or strengthening the ground in order to prevent water entrance or any failure after excavation. There are many methods of grouting. Permeation grouting is one of the most common types in which the grout material is injected to the pore spaces of the ground. In grouting operations, the grout quality is important to achieve the best results. There are four main characteristics for a grout mixture including bleeding, setting time, strength, and viscosity. In this paper, we try to build some efficient grouting mixtures with different water to cement ratios considering these characteristics. The ingredients of grout mixtures built in this study are cement, water, bentonite, and some chemical additives such as sodium silicate, sodium carbonate, and triethanolamine (TEA). The grout mixtures are prepared for both of the sealing and strengthening purposes for a structural project. Effect of each above-mentioned ingredient is profoundly investigated. Since each ingredient may have positive or negative aspect, an optimization of appropriate amount of each ingredient is determined. The optimization is based on 200 grout mixture samples with different percentages of ingredients. Finally, some of these grout mixtures are chosen for the introduced project. It should be mentioned that grouting operations depend on various factors such as pressure of injection, ground structure and grain size of soils. However, quality of a grout can be helpful to make an injection easier and reasonable. For example, during the injection, a wrong estimated setting time can destroy the injected grout by washing the grout or setting early which prevents grouting. This paper tries to show some tests in easy way to achieve a desirable sample of grout.
Key words: permeation grouting; bleeding; setting time; chemical additives; cement-based grout

1. Introduction

Grouting is one of the efficient ways to seal and strengthen the ground in geotechnical projects. It is used in both of the soil (e.g. Karol, 1990) and rock (e.g. Houlsby, 1990) environments with the same main purposes but different methods/technologies. There are many methods of grouting, and one of the most common methods is permeation grouting.

In permeation grouting, grout is injected to the pore spaces of the soil in order to fill them and create cohesion between the soil particles, thereby increasing the strength characteristics of the soil (Henn, 1996). Permeation grouting can be done using cement-based or chemical grouts. The decision about the type of grout depends on many factors, including the type of soil, purpose of grouting, or even financial matters.

In cementitious grouting, the main ingredients are cement, bentonite, and water (Gustin et al., 2007). Cement is the main ingredient of cement-based grouts and its type should be determined according to the grain size distribution in the site-specific project. This means that in coarse soils, Portland cement may be considered efficient, but as the soil grains become fine, other types of cement such as ultrafine, microfine, and superfine cements may be applicable. Portland cement is hydraulic cement mainly composed of hydraulic calcium silicate. This kind of cement is hardened by the chemical reaction known as hydration in touch with water (Warner, 2004). Bentonite is colloidal clay from montmorillonite group with high water absorption. Some bentonites absorb water up to five times their own volume. They are used to increase the viscosity and cohesion of the grout and cause the bleeding of the grout to be lessened (Brady and Clauser, 1986).

Chemical grouting can also be used when the target soil is cohesionless and its stability is the main aim of the grouting operation. The most conventional chemical grouts are sodium silicate-based grouts in which a chemical reaction occurs in between sodium silicate and acid. The result of this reaction is a jelly material. It is important to note that the setting time is highly dependent on the percentage of the ingredients in the grout mixture (Karol, 1990).

As the main scope of the paper is optimization of a cement-based grout, the most important characteristics of cementitious grouts are introduced. The main characteristics for cement-based grouts by which the efficacy of a grout is examined can be mentioned as follows:

(1) Bleeding. It is a phenomenon in which water is squeezed out from pores between cement particles into the ground. This process is similar to water drainage in soil consolidation. Bleeding has some consequences such as reducing the mobility and pumpability of the grout. Lambardi (1985) stated that a grout is considered stable when the final bleeding is less than 5% after 120 min. Tan et al. (2005) investigated the effects of bentonite, fly ash, and silica fume on the bleeding using Taguchi approach and found the silica fume as the most efficient additive among the above additives for bleeding reduction.

(2) Setting time. It defines the effective radius for the mobility of grout, and the ease of grouting operation. Depending on the individual conditions, either rapid or delayed setting may be desired. Rapid setting time is often desirable when injection is under water table (into moving or even not moving water), so that the grout will set before being excessively diluted or washed away. Conversely, where injection is to be made through a very long delivery system, extension of the setting time may be required. Likewise, where large linear void spaces require filling, delay of the initial set is usually desirable until filling is complete (Warner, 2004).

(3) Strength. It is a fundamental significance in the strengthening of rock or soil to enable it to withstand greater loads. It is highly crucial for strengthening of soils in slope stability and vertical trenches as well. In some grouting projects, however, especially those in connection with water control, strength is not of much importance.

(4) Viscosity. This characteristic refers to a fluid's resistance to flow, which is the result of internal molecular friction. The flow properties of a grout can be evaluated by the time in which a certain volume of grout is flowed out of a standard funnel. The pumpability of a grout mixture is primarily defined by its viscosity. Of course, based on the

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