An Introduction to Soil Grouting

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An Introduction to Soil Grouting

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1. INTRODUCTION

This material is intended to provide a brief introduction to soil grouting materials and procedures for those engineers not familiar with the technology and its application. It is not a comprehensive treatment of the subject.

Grouting is a widely used method for strengthening and sealing rock, soil, and concrete. The possibilities for sealing structures are of great importance from both an economic and environmental point of view. The cost of grouting has, in certain projects, been as high as the cost of blasting and excavating the tunnel. To improve the technique for grouting with cement-based material, it is necessary to examine the properties of the grout mixture used.

In planning a grouting program for particular conditions, the engineer needs knowledge of the various types of grouts and their properties. The basic types of grouts now in use and their properties are discussed below. Types of admixtures and fillers used and their effects on the grout are also discussed. The most common types of grouts are Portland-cement, clay, chemical, and asphaltic grouts. No one grout is suitable for every situation. The properties of each specific grout make it desirable under certain circumstances. An important requirement for the selection of a grout is that its particles be substantially smaller than the voids to be filled. Figure 1 shows limiting grain sizes of materials that can be grouted by various types of grout. These data are based on experience and testing and should be used only as a guide. Another relationship can be determined by the groutability ratio, N, expressed by the equation

$$N = D_{15}/D_{85}$$

Where D_{15} is the 15 percent finer grain size of the medium to be grouted, and D_{85} is the 85 percent finer grain size of the grout. N generally should be greater than 25 but in some cases may be as low as 15, depending upon the physical properties of the grout materials.

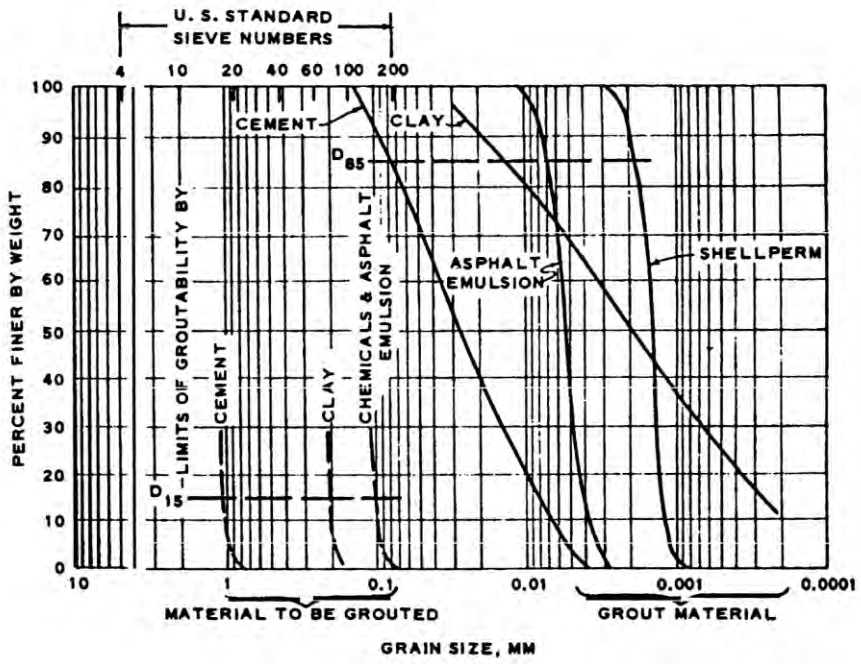

Figure 1

2. PORTLAND-CEMENT GROUT

Portland-cement grout is a mixture of Portland cement, water, and, frequently, chemical and mineral additives. The properties of materials generally used in Portland-cement grout are described below.

2.1 Portland-Cements. Five types of Portland-cement, produced to conform to the specifications of ASTM Designation C 150, are used in cement grouts.

2.1.1 *Type I* is a general-purpose cement suitable for most cement grout jobs. It is used where the special properties of the other four types are not needed to meet job requirements.

2.1.2 *Type II* cement has improved resistance to sulfate attack, and its heat of hydration is less and develops at a slower rate than that of Type I. It is often used interchangeably with type I cement in grouting and is suggested for use where precautions against a moderate concentration of sulfate in groundwater are important.

2.1.3 *Type III* cement is used where early strength gains are required in grout within a period of 10 days or less. It may also be used in lieu of type I or type II in injection work because of its finer grind, which improves its injectability.

2.1.4 *Type IV* cement generates less heat than type II cement and develops strength at a very slow rate. It is rarely used in grouting.

2.1.5 *Type V* cement has a high resistance to sulfates. It is not often used in grouts, but its use is desirable if either the soil to be grouted or the groundwater at the jobsite has a high sulfate content.

2.2 Mixing Water. Generally, water suitable for drinking may be regarded as suitable for use in grout. Ordinarily, the presence of harmful impurities (e. g., alkalis, organic and mineral acids, deleterious salts, or large quantities of silt) is known in local water sources. If there is reason to suspect a water source, it should be tested in accordance with CRD-C 400.

2.3 Fillers. Fillers in Portland-cement grout are used primarily for reasons of economy as a replacement material where substantial quantities of grout are required to fill large cavities in rock or in soil. Almost any solid substance that is pumpable is suitable as a filler in grout to be used in non-permanent work. For permanent work, cement replacements should be restricted to mineral fillers. Before accepting any filler, tests should be made in the laboratory or in the field to learn how the filler affects the setting time and strength of the grout and whether it will remain in suspension until placed. All aspects of the use of a filler should be carefully studied. The economy indicated initially by a lower materials cost may not continue throughout the grouting operation. Additional personnel and more elaborate batching facilities may be needed to handle the filler. Some fillers make the grout more pumpable and delay its setting time. Such new properties may add to the costs by increasing both the grout consumption and the grouting time.

2.3.1 *Sand*. Sand is the most widely used filler for Portland-cement grout. Preferably it should be well graded. A mix containing two parts sand to one part cement can be successfully pumped if all the sand passes the No. 16 sieve and 15 percent or more passes the No. 100 sieve. The use of coarser sand or increasing the amount of sand in the mix may cause segregation. Segregation can be avoided by adding more fine sand or using a mineral ad- mixture such as fly ash, pumicite, etc. Mixes containing up to 3/4-inch aggregate can be pumped if properly designed. Laboratory design of such mixes is recommended. Sanded mixes should never be used to grout rock containing small openings and, of course, should not be used in holes that do not readily accept thick mixes of neat cement grout (water and Portland cement only).

2.3.2 *Fly Ash.* Fly ash is a finely divided siliceous residue from the combustion of powdered coal and may be used both as a filler and as an admixture. Most grades of fly ash have about the same fineness as cement and react chemically with Portland-cement in producing cementitious properties. The maximum amount of fly ash to be used in grout mixtures is 30 percent by weight of the cement if it is desired to maintain strength levels comparable to those of Portland-cement

grouts containing no fly ash.

2.3.3 *Diatomite*. Diatomite is a mineral filler composed principally of silica. It is made up of fossils of minute aquatic plants. Processed diatomite is an extremely fine powder resembling flour in texture and appearance. The fineness of the diatomite may range from three times to as much as 15 times that of cement. Small amounts of diatomite may be used as admixtures to increase the pumpability of grout; however, large amounts as fillers will require high water-cement ratios for pumpability. As a filler, diatomite can be used where low strength grouts will fulfill the job requirements.

2.3.4 *Pumicite*. Pumicite, a finely pulverized volcanic ash, ashstone, pumice, or tuff, is also used as a filler in cement grout. Like fly ash and diatomite, it improves the pumpability of the mix and has pozzolanic (hydraulic cementing) action with the Portland- cement.

2.3.5 *Other fillers.* Silts and lean clays not contaminated with organic materials are sometimes used as fillers. Loess, a windblown silt containing 10 to 25 percent clay, is a suitable filler. Rock flour, a waste product from some rock-crushing operations, is also used as a filler. Rock flour produced during the manufacture of concrete sand is very fine but not always well graded. Grouts containing poorly graded rock flour are frequently highly susceptible to leaching. Most finely divided fillers increase the time required for the grout to set. It may be expedient to add an accelerator, described subsequently, to compensate for this.

2.4 Admixtures. Admixtures, as described herein, are substances that, when added to Portland-cement grout, impart to it a desired characteristic other than bulking.

2.4.1 *Accelerators*. Accelerators cause a decrease in the setting time of grout. These additives are used to reduce the spread of injected grout, to reduce the erosion of new grout by moving groundwater and increasing the rate of early strength gain. The most commonly used accelerator is calcium chloride. It can be added to the mixing water in amounts up to 2 percent of the weight of the cement. Greater percentages of calcium chloride increase the very real danger of having the mix set up in the grout plant. High alumina cement and plasters having a calcined gypsum base may be proportioned with Portland cement to make a grout having various setting times. Other accelerators include certain soluble carbonates, silicates, and triethanolamine. Small amounts of some accelerators are capable of producing instantaneous or near-instantaneous setting of the grout. Triethanolamine added to some cements in the amount of 0.2 percent can produce such sets. When using accelerators, competent technical advice should be sought, and preliminary tests conducted to determine the behavior of accelerators in the grout mix.

2.4.2 *Lubricants*. Fly ash and rock flour added to the grout mix increase its pumpability.

Fluidifiers and water-reducing admixtures improve the pumpability or make possible a reduction in the water-cement ratio while maintaining the same degree of pumpability. Most of these substances are also retarders. Laboratory or field trial mixes should be batched, and all pertinent effects observed and tested before adopting an unknown admixture for any project.

2.4.3 *Other effects.* Numerous other substances can be added to Portland-cement grout to obtain special effects. Bentonite or other colloids, or finely powdered metal, are added to grout to make it more viscous and stable powdered metals unite with hydration products of the cement and release tiny bubbles of hydrogen, which, in addition to increasing the viscosity, cause a slight expansion of the grout. Aluminum is the metal most often used. It is added at the rate of about 1 teaspoonful of aluminum powder per sack of cement. Very small amounts of carbohydrate derivatives and calcium lignosulfonate may be used as retarders. Sodium chloride is used to brine mixing water when grouting is performed in salt formations. This prevents erosion of in situ rock salt and provides a degree of bonding of grout to salt. Approximately 3 lb. of dry salt for each gallon of water will provide a saturated mixture and will result in some retardation of the grout set.

2.5 Effect of Groundwater. Alkalis, acids, or salts contained in groundwater may cause more damage to Portland-cement grouts placed in sandy soils than to these placed in clays. This increase in damage is a result of the sandy soils permitting rapid leaching as opposed to clays which tend to retard groundwater movement. In most clays, sulfate salts are found in very small quantities. Rich type V Portland-cement grouts will not [illegible] y low or moderate concentrations of calcium sulfate [illegible] uts should not be used in formations containin [illegible] esium and sodium sulfates. Where such [illegible] uts should be considered. Harmful chemicals in [illegible], e.g., manufacturing plant wastes, water fr [illegible] te areas, and leaching of sodium or magnesium [illegible] estern United States are very harmful to Portlar [illegible].

2.6. Effect of Seawater. [illegible] d grouts because of shrinkage, temperature [illegible] f seawater, which causes chemical decomp [illegible] ilicates decompose into lower silicates and c [illegible] dissolve slowly in water, resulting in subsec [illegible] tion of new quantities of calcium hyd [illegible] free lime in the grout also reacts with ma [illegible] te, causing swelling in the interstices. Portlanc [illegible] e of seawater should contain air-entraining Portland cemen [illegible] aterproofing agents and have low water-cement