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A critical study on grouting technique and its usage

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Abstract
Grouting is effective in both sand and silt deposits. Grouts are liquid suspensions or solutions that are injected into the soil mass to improve its behaviour. Such liquids can permeate into the void space of the soil and bind the soil particles together. For medium sands or coarser materials the grout used most often is a slurry of water and cement. This slurry however, cannot enter into the void space of fine sand and silts for which chemical grouts are used.

Keywords: Grouting, Soil, Cement

Introduction

Grouts can be broadly classified as suspension grouts and solution grouts. Suspension grouts consist of small-size solid particles dispersed in a liquid medium. These include cement grouts, that is, slurry of cement in water; soil-cement grouts consisting of a slurry of soil and cement in water; and bentonite grouts comprising a slurry of bentonite in water. Cement grouts are the most widely used and usually have water and cement in the ratio ranging from 10:1 to 2:1.

Properties of a grout are described in terms of five parameters: groutability, stability, setting time, permanence and toxicity. Grouting methods for soils are classified as permeation grouting, compaction grouting, hydro-fracture grouting and jet grouting. Cement grout not only fills the voids and reduces permeability but also sets with time and binds the soil grains together.

As a consequence, the strength of soil mass increases and its compressibility decreases. Sometimes cement in a grout is replaced by clay to reduce the cost. When the objective of grouting is only to reduce permeability, bentonite grouts can be used (Lovely 2008) [1]. However, the permanence of such grouts under high hydraulic gradients is questionable and often cement is added to the bentonite to improve its permanence.

Even though grouting has found several applications in the practice of civil engineering, available studies on grouts and grouting have been very limited. Even today, the grouting operations are based on thumb rules and existing practices rather than rational design principles or well defined procedures substantiated by research data (Shroff and Shah, 2002) [2].

According to John (2002) [16] most of the U.S Army of Crop's foundation grouting is done with the grout composed of Portland cement, bentonite and water. The additions of small percentages of sodium bentonite produce beneficial results. Settlement is almost eliminated without significant reduction in strength or increase in setting time.

Grouts with3% super-plasticizer were easily injected into the soil samples and the strength of these samples increased as compared with those of cement- grouted samples (Akbulut and Saglamer 2002) [3].

The addition of latexes significantly improves the compressive strength, shear bond strength, stability, resistance to wet –dry cycles and resistance to Sulphate attack. The use of latexes in cement grouts has a considerable effect on their physical and mechanical properties of grouts (Anagnostopoulos, 2007) [4].

This behavior was reflected in the maximum pressure required to satisfactorily grout the sand; a 2:1 grout required about a 35% higher maximum injection pressure compared to a 3:1 grout, and 1:1 grout required more than a 300% higher pressure than a 2:1 grout. In addition, there is a strong relation between the grout viscosity and the amount of particle sedimentation and accumulate bleed water that occur in the grout filled voids, hence, increasing the water to cement ratio of the grout improves its injectability, but has an adverse effect on bleed capacity (Schwarz and Krizek, 2004) [5].

Sinroja *et al*. (2006) [17] Through their studies using microfine slag cement grouts found that gel time increases with increase in w:c ratio of the grout. Bleeding potential is lowest for microfine slag cement grout with sodium hydroxide. With respect to rheological properties, it can be concluded that apparent viscosity increases with increase in time and decrease in w: c ratio.

Deere (2002) [6] reported that in a very thin mix with a water-cement ratio 6:1 by volume there may be as much as 60 percent sedimentation of the cement grains in a 2 hour period. The thicker the mix, less is the sedimentation.

Lovely (2008) [1] while investigating on the properties grouts found that the cement grouts are least stable and stability increases with cement water ratio. This calls for continuous agitation of thin cement slurries.

The tendency of cement grout to bleed can be significantly brought down by addition of bentonite. The utility of bentonite as an excellent antibleeder of cement grout has been brought out.

Review of Related Literature

Grouting, which has several applications in the field of civil engineering, was once considered as a mysterious operation. The effectiveness of grouting requires a lot of understanding, skill, meticulous attention and an intuitive perception. Even though grouting was started 200 years ago, it was treated for a long time, as an art which eluded scientific investigation and improvement (Nonveiller, 2009) [7]. Its performance was for some time, more or less a privilege and a well-protected secret of a few specialist companies. The curious image of grouting is changing slowly, as research and development broaden our knowledge in this area.

Grouting is a procedure by means of which grout is injected into voids, fissures, crevices or cavities in soil or rock formation in order to improve their properties, specifically to reduce permeability, to improve strength or to reduce the deformability of formations. Grouting has a wide application in modern civil engineering. It reduce the permeability of formations under the water retaining structures, control the erosion of soil, increase the strength of materials below foundation of heavy structures and or reduce the deformability of the material in the foundation, fill the voids between rock and tunnel linings, form cut off walls, fill voids for rehabilitation etc.

Grout is injected under pressure into the material to be grouted until it fills the desired volume of material around the hole or until the maximum specified pressure is attained and a specific minimum grout flow is reached.

From injected watery suspensions, injected water is squeezed out in the pores and the compacted mass of the injected compound fills the fissures and voids.

Numerous instances arise of soils at a site being of inadequate strength to support a proposed structure and for which the needed improvement cannot be obtained using such method as vibration, rolling or preloading, either because of the inapplicability of these methods at such sites or because of economic considerations (Shroff and Shah, 2002) [2].

Soil compaction can offer effective solutions for many foundation problems, and is especially useful for reducing total settlements in sands. However, efficient use of soil compaction methods requires that the geotechnical engineer understands all factors that influence in compaction process carefully. The poor quality soils, especially their low bearing capacity, make it necessary to improve their properties by stabilization.

Soil compaction requires geotechnical competence and careful planning on the part of the design engineer. The selection of the most suitable method depends on a variety of factors, such as: soil conditions, required degree of the compaction, type of structure to be supported, maximum depth of compaction, as well as site-specific considerations such as sensitivity of adjacent structures or installations, available time for completion of the project, competence of the contractor, access to equipment and materials etc. (Massarsch and Fellenius, 2002) [2].

Bement and Selby (2007) [18] investigated the compaction settlement of granular soils when exposed to vibrations typical of those generated in the ground by vibro-driving piles that the compaction of soil is strongly dependent upon vertical effective stress, the type and grading of the soils. Broadly, a well-graded soil compact more than a uniform soil, the moisture content is also a significant parameter and saturated soils compact the most, with much smaller settlements from dry soils.

For cohesionless soils with dominant particle-size increase, the angle of shearing resistance increases with increase of particle- size, at both constant density and constant relative density. However, the increase for constant density is insignificant compared to that in the case of constant relative density. For increase in relative density for any particle size of cohesionless soils, there is a definite increase in angle of shearing resistance. But the rate of increase of angle of shearing resistance with respect to relative density is much higher at bigger size particles, compared to that of lower sizes (Chattopadhya and Saha, 2001) [19].

Research

The selection of the appropriate grout compound to be injected depends on the effect to be achieved and on the properties of the injected materials to be permeated. Two classes of grouting materials are generally recognized; suspension type grouts and solution type grouts. The suspension type grout include soil, cement, lime, asphalt, emulsion, etc. while the solution type grouts include a wide variety of chemicals such as sodium silicates acrylamide, lignosulphonates, aminoplast, phenoplast, etc. (Shroff 2009) [15].

Cement based grout mixtures can be investigated in soil laboratories in order to study their flow characteristics, bleeding, consistency, gelation, time of set, density, compressive strength and pH. Simple testing procedures such as flow cone, bleeding and compressive strength tests are usually sufficient for the development of thin grout mixtures which are not injected under flowing water conditions and, therefore, gelling is not a fundamental requirement.

In order to take into account the effect of cement grout in the pores of the granular material, adhesive forces were added at each contact point to the mechanical forces determined from the external stresses applied on the granular assembly. The magnitude of those adhesive forces depends on the nature of the grout and on the concentration of the grout in cement particles. The expression of this adhesive force as a function of cement content is based on extensive experimental work performed by Dano (2004) [14] on grouted sand.

The groutability of sand with acrylamide grout was influenced by the fines content. The grout pressure fines content relationship was nonlinear. Unconfined compressive strength of grouted sand was influenced by the particle size and gradation, density, and fines content of sands (Ozgurel and Vipulanandan, 2005) [13].

Soil-grout mix called soilcrete was used for ground improvement to prevent liquefaction in Jackson Lake Dam and Wickiup Dam in United States.

While soilcrete was produced by deep soil mixing in Jackson Lake Dam, it was created by jet grouting in Wickiup Dam. Field tests showed that jet grouting was very successful and the strength attained were sufficient to make an appropriate design alternative as far as time and cost were concerned (Yilmaz *et al*. 2008) [12].

Suspended particles with an equivalent diameter less than about one-third the hydraulic radius of porous medium will pass through the medium and be present in the effluent (Arenzana *et al*.2009) [11].

Improving ground strength, considerations should include the ease with which the cement may be introduced and the robustness of the strength.

Portland cement gives a more ductile and strain hardening response compared with the other cements studied (Ismail *et al*. 2002) [10].

Some recommendation can be advanced regarding the development of a standard method for laboratory preparation and testing of grouted specimens.

Sand specimens should be grouted by injection to more closely simulate the field process. Longitudinally split moulds should be used to avoid jacking to minimize sample disturbance. Adequate curing time should be provided to assure full development of the mechanical properties of the grouted mass.

Cement and clay mixtures have found widespread use on Tennessee Valley Authority foundations composed largely of extremely porous limestone and dolomite. Cement- clay grout is more economical and is satisfactory from the porosity point of view for filling solution channels and caverns in rock subjected to erosion or leaching from hydrostatic pressures (Elston, 2008) [9]

There are two basic factors which govern the penetrability of grout, the first one is the viscosity of the grout and the second is granulometry of the grout material vis-a vis the permeability and dimensions of pore space in the alluvium. The viscosity of the grout into the inter-granular spaces of the formation to be grouted depends much on the viscosity of the grout. The viscosity of an ideal grout mix should be sufficiently low so that it can be pumped easily and can penetrate through the fine interspaces, but not as low as to travel long distance without appreciable pressure drop.

Conclusion

Among the various properties of grout suspensions, fluidity and stability are of prime importance (Nonveiller, 2009) [7]. Fluidity is an inverse function of initial viscosity, bearing an approximately linear relationship with viscosity. In the case of coarse grout, fluidity is affected principally by dynamic inter-particle forces of attraction and repulsion and/or by dilatancy of the moving suspended particles. A coarse grout can only be pumped easily when it contains sufficient fluid to prevent dilation of the particle matrix during shear while injecting. A reasonable percentage of fines is also desirable to increase the specific surface area of the grout particles and thereby prevent the separation of liquid and solid phase. The rheological properties significantly influenced the case of injecting microfine cement grouts.

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