Chapter 1
Introduction

1-1. Purpose

This manual provides information and guidance for the investigation and selection of materials, equipment, and methods to be used in chemical grouting in connection with construction projects. Elements discussed include types of chemical grout materials, grouting equipment and methods, planning of chemical grouting operations, and specifications. Emphasis is placed on the unique characteristics of chemical grouts that benefit hydraulic structures. Uses of conventional portland-cement-based grouts and microfine-cement grouts are not included here, but are discussed in Engineer Manual (EM) 1110-2-3506, Grouting Technology.

1-2. Applicability

This manual is applicable to all HQUSACE/OCE elements, major subordinate commands, districts, laboratories, and field operating activities having military programs and/or civil works responsibilities.

1-3. References

References are listed in Appendix A. The most current versions of all references listed in Appendix A should be maintained in all districts and divisions having civil works responsibilities. The references should be maintained in a location readily accessible to those persons assigned the responsibility for chemical-grouting investigations and chemical grouting in construction.

1-4. Definitions

Terms used this document are defined in Appendix B.

1-5. Chemical Grout and Grouting

a. Chemical grouts. Chemical grouts are injected into voids as solutions, in contrast to cementitious grouts, which are suspensions of particles in a fluid medium. Chemical grouts react after a predetermined time to form a solid, semisolid, or gel. The distinction between chemical and cementitious grouts is arbitrary in that some particulate grouts are made up of suspension of microfine cement with particles generally less than 10 µm in diameter. The distinction is further complicated by the development of chemical grouts that have particles that are 10 to 15 nm in diameter. Grouts have been formulated that are mixtures of particulate materials in chemical grouts with the particulate materials themselves being capable of solidifying reactions. Grouts discussed in this manual are those in which the liquid and solid phases typically will not separate in normal handling and in which processes other than the introduction of solid particles and mixing are used to generate the grout. Mixtures of chemical and particulate grouts have the limitations of particulate grouts in terms of mixing, handling, and injection and so are best treated as particulate grouts (EM 1110-2-3506 and para 2-3*h*(2)).

b. Chemical grouting. Chemical grouting is the process of injecting a chemically reactive solution that behaves as a fluid but reacts after a predetermined time to form a solid, semisolid, or gel. Chemical grouting requires specially designed grouting equipment in that the reactive solution is often formed by proportioning the reacting liquids in an on-line continuous mixer. Typically, no allowance is made in chemical-grouting plants for particulate materials suspended in a liquid. Further, the materials used in the pumps and mixers are specifically selected to be nonreactive with the chemicals being mixed and pumped.

c. Background. Chemical grouts were developed in response to a need to develop strength and control water flow in geologic units where the pore sizes in the rock or soil units were too small to allow the introduction of conventional portland-cement suspensions. The first grouts used were two-stage grouts that depended on the reaction between solutions of metal salts and sodium silicate. The goal in this work was to bond the particles of soil or rock and to fill in the pore spaces to reduce fluid flow. The technology has expanded with the addition of organic polymer solutions and additives that can control the strength and setting characteristics of the injected liquid. Chemical grouting has become a major activity in remediation and repair work under and around damaged or deteriorated structures. Much of the technology for large-scale grouting of rock or soil can and has been adapted into equipment for repairing concrete structures such as pond liners, drains, or sewers.

1-6. Special Requirements for Chemical Grouts

a. General. In the selection of a grout for a particular application, certain chemical and mechanical properties should be evaluated. These include viscosity, durability, and strength. The following paragraphs serve to point out some of the more significant properties of grouts and grouted materials; however, these are not definitive guidelines for engineering design. In many cases, it may be advisable to construct a small field-test section to determine the handling and behavioral characteristics of the grout.

b. Viscosity. Viscosity is the property of a fluid to resist flow or internally resist internal shear forces. A common unit of measure of viscosity is the centipoise (cP).* Viscosity is important in that it determines the ability of a grout to flow into and through the pore spaces in a soil. Thus, the flowability of the grout is also related to the hydraulic conductivity (permeability) of the soil. As a rule of thumb, for a soil having a hydraulic conductivity of 10^{-4} cm/sec, the grout viscosity should be less than 2 cP. Grouts having viscosities of 5 cP are applicable for soils with hydraulic conductivity greater than 10^{-3} cm/sec, and for a viscosity of 10 cP, the hydraulic conductivity should be above 10^{-2} cm/sec.

c. Gel time. Gel time or gelation time is the interval between initial mixing of the grout components and formation of the gel. Control of gel time is thus important with respect to pumpability. Gel time is a function of the components of the grout, namely, activator, inhibitor, and catalyst; varying the proportion of the components can change gel time. For some grouts, viscosity may be constant throughout the entire gel time or may change during this period. Thus, it is important to know variation with gel time because of problems related to pumping high-viscosity liquids. After gelation, a chemical grout continues to gain strength. The time interval until the desired properties are attained is called the cure time.

d. Sensitivity. Some grouts are sensitive to changes in temperature, dilution by groundwater, chemistry of groundwater including pH, and contact with undissolved solids that may be in the pumps or piping. Sensitivity to these factors may influence gel time.

e. Toxicity. Although most of the toxic grouts have been withdrawn from the market, personnel involved in grouting must maintain an awareness of the potential for certain materials to be or to become toxic or hazardous if not properly used. The basic approach should be to always follow the manufacturer's instructions in handling and disposing of such materials and to always follow safe practices in the field. Where large quantities of chemical grout are to be injected into the subsurface, it is prudent to consult the appropriate environmental regulatory agencies during planning.

f. Durability. Durability is the ability of the grout after pumping to withstand exposure to hostile conditions. These include repeated cycles of wetting and drying or freezing and thawing that may occur as a result of changes in climatic or environmental conditions. Certain chemicals in the soil or groundwater may also attack the grout and cause deterioration.

g. Strength. Among other applications, grouts are injected into soils, primarily granular materials, to add strength to the soil matrix. The unconfined compression test on grout-treated samples offers an index of the strength of the material and may suffice as a screening test for the effectiveness of the grout. In many situations, the grout may be placed and remain under the water table, in which case the strength of the saturated material may be lower than that of a dry specimen. In all cases, the strength of the grouted soil in situ must be sufficient to perform its intended function.

1-7. Advantages and Limitations of Chemical Grouts

a. The viscosities of chemical grouts can be very low, and except for fillers that may sometimes be used, chemical grouts contain no solid particles. For these reasons, chemical grouts can be injected into foundation materials containing voids that are too small to be penetrated by cementitious or other grouts containing suspended solid particles. Chemical grouts can therefore be used to control water movement in and to increase the strength of materials that could not otherwise be treated by grouting. Chemical grouts have been used principally in filling voids in fine granular materials; they have also been used effectively in sealing fine fissures in fractured rock or concrete. Chemical grouts have been frequently used for stabilizing or for increasing the load-bearing capacity of fine-grained materials in foundations and for the control of water in mine shafts, tunnels, trenches, and other excavations. Chemical grouts have also been used in conjunction with other void-filling materials for curtain grouting under dams constructed over permeable alluvium and for other treatments such as area grouting or joint grouting.

b. Chemical grouts suffer from the disadvantage that they are often more expensive than particulate grouts. Large voids are typically grouted with cementitious grout, and chemical grouting is done as needed. Chemical grouts are also restricted in some circumstances due to potentially toxic effects that have been observed with some of the unreacted grout components. Potential

* The SI unit of dynamic viscosity is the pascal.second; centipoise × 1.000 000*E-03 = pascal seconds (Pa.s)

groundwater pollution is a major consideration in the selection of the type of grouts to be used in many cases.

1-8. Proponent

The U.S. Army Corps of Engineers proponent for this manual is the Geotechnical and Materials Branch, Engineering Division, Directorate of Civil Works (CECW-EG). Any comments or questions regarding the content of this manual should be directed to the proponent at the following address:

Headquarters, U.S. Army Corps of Engineers
ATTN: CECW-EG
20 Massachusetts Ave., NW
Washington, DC 20314-1000