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American Society of Civil Engineers

Compaction Grouting Consensus Guide

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The following standards have been issued:

ANSI/ASCE 1-82 N-725 Guideline for Design and Analysis of Nuclear Safety Related Earth Structures
ASCE/EWRI 2-06 Measurement of Oxygen Transfer in Clean Water
ANSI/ASCE 3-91 Standard for the Structural Design of Composite Slabs
ASCE 4-98 Seismic Analysis of Safety-Related Nuclear Structures
Building Code Requirements for Masonry Structures (ACI 530-02/ASCE 5-02/TMS 402-02) and Specifications for Masonry Structures (ACI 530.1-02/ASCE 6-02/TMS 602-02)
ASCE/SEI 7-05 Minimum Design Loads for Buildings and Other Structures
SEI/ASCE 8-02 Standard Specification for the Design of Cold-Formed Stainless Steel Structural Members
ANSI/ASCE 9-91 Standard Practice for the Construction and Inspection of Composite Slabs
ASCE 10-97 Design of Latticed Steel Transmission Structures
SEI/ASCE 11-99 Guideline for Structural Condition Assessment of Existing Buildings
ASCE/EWRI 12-05 Guideline for the Design of Urban Subsurface Drainage
ASCE/EWRI 13-05 Standard Guidelines for Installation of Urban Subsurface Drainage
ASCE/EWRI 14-05 Standard Guidelines for Operation and Maintenance of Urban Subsurface Drainage
ASCE 15-98 Standard Practice for Direct Design of Buried Precast Concrete Pipe Using Standard Installations (SIDD)
ASCE 16-95 Standard for Load Resistance Factor Design (LRFD) of Engineered Wood Construction
ASCE 17-96 Air-Supported Structures
ASCE 18-96 Standard Guidelines for In-Process Oxygen Transfer Testing
ASCE 19-96 Structural Applications of Steel Cables for Buildings
ASCE 20-96 Standard Guidelines for the Design and Installation of Pile Foundations
ANSI/ASCE/T&DI 21-05 Automated People Mover Standards—Part 1
ANSI/ASCE/T&DI 21.2-08 Automated People Mover Standards—Part 2
ANSI/ASCE/T&DI 21.3-08 Automated People Mover Standards—Part 3
ANSI/ASCE/T&DI 21.4-08 Automated People Mover Standards—Part 4
SEI/ASCE 23-97 Specification for Structural Steel Beams with Web Openings
ASCE/SEI 24-05 Flood Resistant Design and Construction
ASCE/SEI 25-06 Earthquake-Actuated Automatic Gas Shutoff Devices
ASCE 26-97 Standard Practice for Design of Buried Precast Concrete Box Sections
ASCE 27-00 Standard Practice for Direct Design of Precast Concrete Pipe for Jacking in Trenchless Construction
ASCE 28-00 Standard Practice for Direct Design of Precast Concrete Box Sections for Jacking in Trenchless Construction
ASCE/SEI/SFPE 29-05 Standard Calculation Methods for Structural Fire Protection
SEI/ASCE 30-00 Guideline for Condition Assessment of the Building Envelope
SEI/ASCE 31-03 Seismic Evaluation of Existing Buildings
SEI/ASCE 32-01 Design and Construction of Frost-Protected Shallow Foundations
EWRI/ASCE 33-01 Comprehensive Transboundary International Water Quality Management Agreement

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EWRI/ASCE 34-01 Standard Guidelines for Artificial Recharge of Ground Water
EWRI/ASCE 35-01 Guidelines for Quality Assurance of Installed Fine-Pore Aeration Equipment
CI/ASCE 36-01 Standard Construction Guidelines for Microtunneling
SEI/ASCE 37-02 Design Loads on Structures during Construction
CI/ASCE 38-02 Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data
EWRI/ASCE 39-03 Standard Practice for the Design and Operation of Hail Suppression Projects
ASCE/EWRI 40-03 Regulated Riparian Model Water Code
ASCE/SEI 41-06 Seismic Rehabilitation of Existing Buildings
ASCE/EWRI 42-04 Standard Practice for the Design and Operation of Precipitation Enhancement Projects
ASCE/SEI 43-05 Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities
ASCE/EWRI 44-05 Standard Practice for the Design and Operation of Supercooled Fog Dispersal Projects
ASCE/EWRI 45-05 Standard Guidelines for the Design of Urban Stormwater Systems
ASCE/EWRI 46-05 Standard Guidelines for the Installation of Urban Stormwater Systems
ASCE/EWRI 47-05 Standard Guidelines for the Operation and Maintenance of Urban Stormwater Systems
ASCE/SEI 48-05 Design of Steel Transmission Pole Structures
ASCE/EWRI 50-08 Standard Guideline for Fitting Saturated Hydraulic Conductivity Using Probability Density Functions
ASCE/EWRI 51-08 Standard Guideline for Calculating the Effective Saturated Hydraulic Conductivity
ASCE/SEI 52-10 Design of Fiberglass-Reinforced Plastic (FRP) Stacks
ASCE/G-I 53-10 Compaction Grouting Consensus Guide

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FOREWORD

The Board of Direction approved revisions to the ASCE Rules for Standards Committees to govern the writing and maintenance of standards developed by ASCE. All such standards are developed by a consensus standards process managed by the ASCE Codes and Standards Committee. The consensus process includes balloting by a balanced standards committee and reviewing during a public comment period. All standards are updated or reaffirmed by the same process at intervals not exceeding five years.

The provisions of this document are written in permissive language and, as such, offer to the user a series of options or instructions but do not prescribe a specific course of action. Significant judgment is left to the user of this document.

This, the first edition of the *Compaction Grouting Consensus Guide,* has been written to promote good practice in compaction grouting. The authors of this guide believe that compaction grouting is a reliable methodology for improving the density and strength of the soil. Similar to other grouting technologies, compaction grouting is a technology based on sound engineering principles, not a "black magic" that can only be understood by a chosen few. And, like all other soil improvement techniques, compaction grouting needs to be applied competently.

This guide provides background for those interested in specifying, designing, and/or undertaking compaction grouting. This guide is not a manual and is not intended for use as a code of practice; hence it is not accidental that nonmandatory language is used throughout the text. But those involved in the development of this guide hope that it will become a useful reference for all those interested in compaction grouting.

This standard has been prepared in accordance with recognized engineering principles and should not be used without the user's competent knowledge for a given application. The publication of this standard by ASCE is not intended to warrant that the information contained herein is suitable for any general or specific use, and ASCE takes no position respecting the validity of patent rights. The user is advised that the determination of patent rights or risk of infringement is entirely their own responsibility.

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SCOPE OF THE CONSENSUS GUIDE

Compaction grouting is a ground improvement technique that improves the strength and/or stiffness of the ground by slow and controlled injection of a low-mobility grout. The soil is displaced and compacted as the grout mass expands. Provided the injection process progresses in a controlled fashion, the grout material remains as a growing mass within the ground and does not permeate or fracture the soil. This behavior enables consistent densification around the expanding grout mass, resulting in stiff inclusions of grout surrounded by soil of increased density.

This guide focuses specifically on applications of compaction grouting where the increased strength and/or stiffness of the soil due to compaction is a primary element of the ground improvement. Applications where a ground improvement design requires the injected grout to obtain a strength greater than that of the surrounding soil, although potentially a valid application of low-mobility grout, are not considered to be compaction grouting for the purposes of this guide and hence are beyond the scope of this document.

Both practical and theoretical aspects of compaction grouting are discussed.

This guide follows the guidelines of the ASCE and uses the International System of Units (SI) as the primary system of units; imperial units are also provided in parentheses. Compaction grouting in North America typically uses imperial units in the field; hence many of the SI units have been calculated from the original imperial equivalents. In these cases an effort has been made to keep the "rule of thumb" values in their original form, and some loss of accuracy in the conversion between units may occur.

This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address the safety problems associated with its application. It is the responsibility of whoever uses this standard to establish appropriate safety and health practices and to determine the applicability of regulatory and nonregulatory limitations.

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INTRODUCTION TO THE COMPACTION GROUTING GUIDE

1.1 WHAT IS COMPACTION GROUTING?

Compaction grouting is a ground improvement technique that improves the strength and/or stiffness of the ground by slow and controlled injection of a low-mobility grout. The soil is displaced and compacted as the grout mass expands. Provided that the injection process progresses in a controlled fashion, the grout material remains as a growing mass within the ground and does not permeate or fracture the soil. This behavior enables consistent densification around the expanding grout mass, resulting in stiff inclusions of grout surrounded by soil of increased density. The process can be applied equally well above or below the water table. It is usually applied to loose fills and loose native soils that have sufficient drainage to prevent buildup of excess pore pressures.

1.2 SHORT HISTORY OF COMPACTION GROUTING

Although grouting as an engineered process is not new, with many records of grouting projects dating back before the 1800s, compaction grouting is a more recent grouting method, dating back only to the middle of the 20th century. Compaction grouting is also noteworthy as the only major grouting technology to originate in the United States. Today this technology is widely used worldwide. The development of compaction grouting is particularly interesting in that it appears to have come about serendipitously and seems to have progressed through the efforts and innovations of many small, independent contractors.

The first use of low-mobility grout (i.e., grouts that have a consistency similar to very stiff mortar) for ground improvement was in the latter part of 1952, when a small contractor in Los Angeles, California, named James Warner needed to fill some small voids under a structure (Warner 2003). Filling the void with a cement mortar seemed like the most expeditious repair, and "unable to find either established technology or equipment to pump the mortar, he constructed a 'pump,' which consisted of a length of six-inch-diameter steel casing about five feet long and positioned vertically in a wooden frame. It had a two-inch hose attached to the bottom and a 'piston' consisting of a wood disk fitted with a few layers of old carpet cut to the casing diameter to form a seal. The piston was attached to a push rod of 2″ × 4″ lumber."

Fortunately for the progress of compaction grouting, Warner was unaware of the then-well-established rule of thumb in grouting: "If you can't pour it, you can't pump it." So he directed his efforts to pumping plastic-consistency grouts. He was fortunate to meet others with the similar goal of pumping another low-mobility mortar, Portland cement plaster, to elevated scaffolds. Success came two years later, in 1954, when mainly because of the efforts of Marvin Bennett, a working pump was constructed. Marvin Bennett, along with his brother Richard, also went on to develop the first plaster pump in 1954, followed by the first concrete pump in 1961. Warner, however, continued his efforts to develop appropriate equipment and technology for grouting.

During the late 1950s, the use of low-mobility grouts for void filling had become common. The use of these plastic-consistency grouts was further extended to jacking of structures, using the important feature of such grouts: that they move as a globular mass whose movement can be controlled. However, compaction grouting for increasing the soil's strength was not yet a primary focus of the technology. The earliest mention of the use of stiff, mortarlike grout, termed *compaction grout*, was by Graf (1969), who described the use of the Koehring Mudjack, a machine dating from 1934, to pump a clayey loam mixture under pavement for highway maintenance. He reported that some of the mudjack operators had found it useful to pump "zero slump" grout through pipes driven into the ground for raising structures and that larger than calculated quantities were sometimes used, concluding that the surrounding soil was being compacted. He referred to this as *compaction grouting* and stated that "hundreds of jobs have now been successfully completed together with some failures," although no examples were provided. The term *compaction grouting* was further used by Mitchell (1970) as a method of foundation soil treatment.