GROUND CONTROL AND IMPROVEMENT

PETROS P. XANTHAKOS
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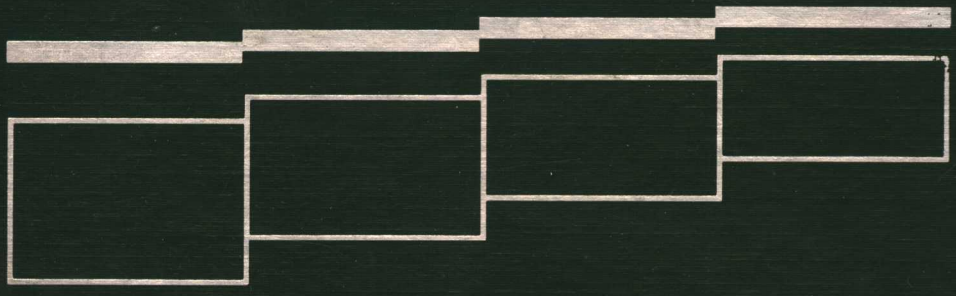

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PREFACE

A 1978 survey by the Committee on Placement and Improvement of Soils of the Geotechnical Division of the ASCE focused on possible future advances in this field. Participants were asked to identify long-range developments and to provide an assessment of their importance, feasibility, and probable time of occurrence. The consensus of opinion was that emphasis should continue on densification, admixture, reinforcement, moisture control, grouting, and regulation.

Motivated by similar considerations and an assessment of the current state of the art, the authors have selected 11 topics for discussion. Some of these topics are on traditional techniques, whereas others represent recent developments. Nonetheless, they all have demonstrated high capability, desirablity, and feasibility. Furthermore, the progress associated with them has been mainly technological rather than conceptual.

The book is a synthesis of the beliefs of its authors. The choice of material has been narrowed, however, to include techniques that have been tested in applications of ground support, control, and improvement schemes. Whereas this synthesis is the result of a logical assessment and merging of principles and concepts, the process does not stop here. Thus, impressive future advances in these and other areas may occur in a clear and consistent format, and progress will continue to evolve so that new developments will result from ideas and concepts that have not yet been foreseen.

The subject matter has been developed independently, but an effort has been made to produce a unified technology that can be used directly in new construction or in rehabilitation programs. The underlying principle is that demand in ground engineering has gone beyond the stage of a single application, and practice has moved into the realm of multiple uses and purposes that require a wide variety of

construction controls. In this context, the authors caution about problems related to the placement of foundations and supports on poor soils and deteriorated rocks. Often, these cases will signify the absence of ground control and may reflect uncertainties in design criteria. Thus, ground control and improvement should be considered as a formidable supplement that balances the support requirements or that may eliminate them completely.

The convergence between support and control or improvement options must, however, be based on the explicit understanding of ground response to an externally applied action. This response may be specific or random, rapid or slow, or temporary or permanent. Its forecast in engineering terms is the determining factor for the use of ground controls or for the exclusive reliance on ground supports. More often, this convergence will provide the optimum solution to most ground engineering problems, and, since this trend is expected to continue, planning to mitigate the risks of underground construction by combining artificial support with control and improvement techniques should become a common engineering approach.

What is unique about this book is the up-to-date information, data compilation, and synthesis of material that it provides. The book has two main purposes: (1) to enable practicing engineers to make the best decision, in technical and economic terms, regarding ground engineering problems or when alternative schemes are formulated and evaluated, and (2) to provide the necessary information and credible data for a complete design.

During the planning and development of the text, each author wrote his own content and discussion in light of his own background and design experience, so the scope of the book may vary. However, the authors made every effort to coordinate the end result and to ensure that unnecessary gaps and overlapping would be avoided. Cross-references between chapters and sections are provided where indicated, but readers are encouraged to consult the index in order to find all pertinent information. Because this is a textbook, not a handbook, each chapter describes the process, articulates the design philosophy, and presents the design methodology, and is supplemented by examples and case studies.

Chapter 1 discusses groundwater lowering and drainage techniques for projects that require construction or permanent dewatering. The text presents the details of dewatering methods and discusses the theoretical principles and the design of dewatering systems, while also articulating the effects on adjacent structures. Dewatering techniques are examined in conjuction with other controls, such as impermeable barriers, and criteria are developed for selecting a scheme in which dewatering is combined with other methods to produce a unified system.

Underpinning is the subject of Chapter 2. In the traditional context, underpinning involves the addition of structural foundation units to give extra support to structures at or below grade. In the technical context, underpinning is the insertion of a new foundation or support below an existing one for the transfer of load to a lower level, but, in a broader sense, it may also refer to the lateral protection of a foundation by a retention system, the strengthening of ground beneath, or both. The decision to underpin, protect laterally, or strengthen the ground depends on such various inter-

related factors as cost, technical expediency, and associated risks. These concepts are discussed in detail and are illustrated by examples and case histories.

Chapter 3 reviews excavation support methods. The associated support systems are primarily intended for temporary use and may or may not become part of the permanent structure. The rationale of convergence of the support control process is emphasized and articulated by examples. The text discusses ground response in supported excavations and gives a comparative review of artificial supports. Special problems are commonly encountered for excavations in clays, particularly those in which the effects of anisotropy must be considered, and in collapsible soils. In addition to the conventional ground support systems, the discussion includes shotcrete, grouting applications, blasting, and special systems, such as the soil-cement structural walls.

In Chapter 4, it is demonstrated that, with the availability and popularity of soil compaction and consolidation techniques, there are no longer unacceptable construction sites. Three tested and promising techniques supplement the theory of soil compaction and consolidation: vibro techniques, dynamic compaction, and compaction grouting. Dynamic compaction improves weak soils by controlled high-energy tamping. In this case, a comprehensive understanding of soil behavior is vital to a successful application. Compaction grouting involves the injection of material under high pressure to compact and densify loose soil beneath distressed structures. The application offers economic advantages when a thin, loose, deep stratum, overlain by a very dense stratum, requires densification. Vibrocompaction densifies granular soil by rearranging loose grains into a denser array. The stone column technique, or vibroreplacement, enhances displacement and drainage to improve weak ground.

In situ ground reinforcement is the subject of Chapter 5. The main topic is soil nailing, a process whereby steel rods or nails are installed in a cut face of original ground and are connected by steel mesh or shotcrete facing to support the soil near the cut. The steel nails reinforce and strengthen the ground, and, as the latter deforms, the nails share the loads, gradually becoming more stressed in tension. Uses and applications of soil nailing are mentioned for excavation support, slope reinforcement, slope stabilization, and retaining wall repair. The text traces the history and development of soil nailing, reviews the theoretical principles, and presents the design considerations. Corrosion protection and construction methods are discussed in detail.

A different form of in situ earth reinforcement is discussed in Chapter 6. This technique involves small-diameter cast-in-place elements. The broad usage of this system is reflected in the wide variety and range of names such as minipiles, micropiles, root piles, pali radice, needle piles, pin piles, and so on, all of which are used to describe basically a special type of small-diameter bored pile. Pin piles may be used as load-bearing elements. Reticulated micropiles may be installed in various configurations to produce a stable block of reinforced soil that can act as a coherent retaining structure. Soil doweling is another application whereby dowels are used to reduce or stop downslope movement on well-defined shear surfaces. The text re-

views the theoretical background, origin and development, construction procedures, and uses and applications of soil doweling.

Chapters 7 and 8 summarize the most recent practice in permeation and jet grouting. In some respects, the techniques involved in permeation grouting are the oldest and best researched. In practical terms, the intent of permeation is to introduce grout into soil pores without any essential change in the original soil volume and structure. The method can be applied to both rocks and soils, but clearly the soil properties and pore geometry are the determining factors of the success of the application. On the other hand, jet or replacement grouting is the most recent category of ground treatment, and it is only since the early 1980s that the various derivatives of the method have reached its economic and operational potential. Jet grouting can be executed in soils with a wide range of characteristics, such as granulometrics and permeabilities, and, in fact, limitations to the applicability are usually imposed by strength parameters or by economic considerations. These chapters present the theoretical principles, design considerations, construction requirements, performance data, and applications.

Aging rock slopes show stability problems, and this is documented in mine quarries, water resource projects, and transportation facilities. A rehabilitation program requires a detailed assessment of site conditions, potential modes of failure, failure causes, slope condition rating methods, and monitoring and maintenance procedures. These principles are interfaced with rehabilitation methods and are discussed in Chapter 9, along with practical problems and appplications.

Vertical screens, which are discussed in Chapter 10, cover a broad area of protective or remedial systems that include continuous earth, semirigid and rigid cutoff walls, plastic barriers, permeable treatment beds, synthetic membranes with overlapping or interlocking sheet-pile sections, and clay-cement grouts injected under pressure into preformed narrow slots. The advantages of the technique are fully realized if the screens satisfy certain requirements, namely: (1) the insertion of the screen is not inhibited by site and ground conditions, even in very mobile formations; (2) the barrier is made continuous but is flexible enough to deform, if necessary; (3) the construction is rapid and has a low cost; and (4) the groundwater flow or level is not required to be altered. These principles are discussed in the chapter, along with the various types of screens.

Chapter 11 reviews the fundamentals of ground freezing. This technique is applied in the mining and construction industries in two basic modes: (1) as a supplementary or emergency procedure for stabilizing excavations and installations where the more traditional supports are used, and (2) as a primary independent construction method for stabilizing underground openings. Although freezing can be used practically in any type of soil that has pore water, it is more often used below the groundwater table. The principles of freezing are reviewed in this chapter, modeled, and quantified, and emphasis is placed on freezing design, applications, and examples. Among the various uses, shaft construction and temporary tunnel support by artificial ground freezing are given special consideration.

Inasmuch as the text focuses on the structural and geotechnical aspects of ground

engineering, it should apply equally to these two fields. The text should also be of interest to construction engineers, contractors, planners, and administrators. In general, the book is oriented toward the needs of practicing engineers, but the material may be rearranged to fit one or two courses at the graduate level.

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Great Falls, Virginia
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