

# Soil Improvement

## HISTORY, CAPABILITIES, AND OUTLOOK

Report by the  
Committee on Placement and Improvement of Soils  
of the  
Geotechnical Engineering Division  
of the  
American Society of Civil Engineers

Robert D. Anderson  
Ara Arman  
John P. Bara  
J. Richard Bell  
Ralph E. Brown  
J. Richard Cheeks  
Klaus Engelhardt  
Carl W. Garbe  
Edward D. Graf  
Wesley G. Holtz  
Henry W. Janes  
Walter V. Jones  
Robert I. Kaufman

James E. Laier  
David P. McKittrick  
William R. Pully  
Gilbert L. Roderick  
Roger K. Seals  
David F. Sheaff  
Vernon A. Smoots  
Marshall R. Thompson  
Frank C. Townsend  
William G. Weber, Jr.  
Anwar E. Z. Wissa  
Donald L. York  
James K. Mitchell, Chairman

February 1978



Published by  
American Society of Civil Engineers  
345 East 47th Street  
New York, New York 10017  
\$8.00



TABLE OF CONTENTS

	<u>PAGE</u>
I. INTRODUCTION	1
II. SOIL MOISTURE IN ENGINEERING WORKS	4
Introduction	4
Ancient Times	4
Roman Times	5
Middle Ages	6
Colonial Period	7
1776 to 1876 (First American Century)	9
1876 to 1976 (Second American Century)	13
References	26
III. CURRENT PRACTICES IN THE TREATMENT OF SOFT FOUNDATIONS	30
Introduction	30
Removal of Soft Soils by Excavation	32
Removal of Soft Soils by Displacement	34
Increment of Stage Construction of Embankments	36
Stabilization of Embankments on Soft Foundations with Berms	37
Lightweight Fills	38
Structural Fills	39
Preloading	40
Deep Compaction	44
Grouting	44
Electro-Osmosis	46
Blasting	47
Summary	49
References	50
IV. ADMIXTURE STABILIZATION	52
Introduction	52
Stabilization Mechanisms	54
Concepts for Successful Admixture Stabilization	54
Geotechnical Applications of Admixture Stabilization	56
Summary	64
References	65
V. MASSIVE COMPACTION OF GRANULAR SOIL	67
Introduction	67
Basic Concept	68
Shallow Compaction Methods	68
Deep Compaction Methods	69
Control	75
Case Histories	79
Discussion	89
Conclusions	94
References	96
VI. REINFORCEMENT - COMPRESSION ELEMENTS	98
Introduction	98
Available Methods	98
References	117

	<u>PAGE</u>
VII. REINFORCEMENT - TENSION ELEMENTS	121
Introduction	121
Prehistoric and Early Qualitative Practice	121
Retaining Walls Using Reinforced Soil Backfill	123
Strength of the Soil-Tie Connection	125
Cohesive Soils	128
Mechanism of Reinforced Earth	129
Tie Force Distribution in Full Scale Walls	129
Additional Considerations - Reinforced Earth Walls	131
Other Applications for Reinforced Earth	134
Relative Advantages over Conventional Construction	135
Conclusions	136
References	137
VIII. COLLAPSIBLE SOILS AND THEIR STABILIZATION	141
Introduction	141
Qualitative Methods of Predicting Susceptibility to Collapse	143
Quantitative Methods for Predicting Soil Collapse	144
Limitations of Current Prediction Methods	148
Current Treatment Methods for Collapsing Soils	148
Conclusions	150
References	151
IX. SOIL PLACEMENT AND IMPROVEMENT (Results of a Delphi Survey)	153
Introduction	153
Survey Methodology	153
Questionnaires and Analysis	156
Results	157
Discussion of Results	164
Conclusions	169
Note	169
APPENDIX I LIST OF PARTICIPANTS IN DELPHI SURVEY	170
APPENDIX II BASIC MECHANISM OF REINFORCED EARTH	172
APPENDIX III STATIC ANALYSIS OF REINFORCED EARTH RETAINING WALLS	178

## I.

### INTRODUCTION

Soil, nature's most abundant construction material, has been used by man for his engineering works since prior to the beginnings of recorded history. Virtually all construction is done on, in, or with soil, but not always are the natural soil conditions adequate to accomplish the work at hand. When poor soil conditions are encountered, the engineer has, apart from abandoning the project, four alternatives: (1) bypass the poor soil, for example, by moving to a new site or through the use of a deep foundation, (2) remove the poor material and replace it with a good one, (3) redesign the structure for the poor conditions, or (4) treat the soil to improve its properties. Each of these alternatives has been utilized extensively in the past. As the scarcity of good sites and materials intensifies, it is likely that the importance of the fourth alternative will increase in the future.

As the United States paused during the Bicentennial Year of 1976 to take stock of its past, present, and future, the GT Division Committee on Placement and Improvement of Soils considered it appropriate also to review the history, assess the present capabilities, and project the future of some of the methods and technology for soil and site improvement. Accordingly a Committee-sponsored program, "New Directions in Placement and Improvement of Soils," was developed for presentation at the ASCE Annual Convention and Exposition, "CE 76" held in Philadelphia, September 27 - October 1, 1976. The series of papers prepared by members of the Committee for that program have been combined to form the Committee Report that follows.