Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NHI–00–045		

4. Title and Subtitle	5. Report Date
SOILS AND FOUNDATIONS WORKSHOP REFERENCE MANUAL	July 2000 6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
Authors of Original Manual: Richard Cheney[+], Ronald G. Chassie* Revisions to the Original Manual: Richard Cheney[+]	

9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
[+]Parsons Brinckerhoff Quade & Douglas, Inc. One Penn Plaza, New York, NY 10119 *Federal Highway Adminstration	11. Contract or Grant No. DTFH-61-97-D-00025

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
National Highway Institute U.S. Department of transportation Federal Highway Administration Washington, D.C. 20590	14. Sponsoring Agency Code

15. Supplementary Notes

FHWA Contracting Officer – Richard Murray/Dennis Luquette

FHWA COTR – L. Jones

FHWA Technical Review – J.A. DiMaggio, A. Muñoz, P. Osborn

16. Abstract

The Soils and Foundations Workshop manual is directed to bridge and foundation engineers, particularly those involved in design and construction aspects of a highway project. The manual is geared to the practicing engineer who routinely deals with soils and foundations problems but has little theoretical background in soil mechanics or foundation engineering. The manual content follows a project-oriented approach where foundation work is traced from preparation of the boring request through design computation of settlement, allowable footing pressure, etc., to the construction of approach embankments, pile driving operations, etc. Recommendations are presented on how to layout borings efficiently, how to minimize approach embankment settlement and eliminate the bump at the end of-the bridge, how to design the most cost-effective pile foundation, and how to transmit design information properly to construction through plans, specifications, or contact with the project engineer.

The objective of this workshop manual is to present a recommended method for safe, cost-effective design and construction of foundations. Coordination between engineers in all project phases is stressed. Readers are encouraged to develop an appreciation of foundation activities in all project phases which influence or are influenced by their work

17. Key Words	18. Distribution Statement
Foundation design, site investigation, soil testing, spread footings, piles, wave equation	No restrictions.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED	335	

Form DOT F 1700.7(8-72) Reproduction of completed page authorized

PREFACE

The Soils and Foundations Workshop is designed for bridge and foundation engineers involved in the preliminary layout, design, or construction aspects of a highway project. This manual is intended to serve both as the workbook for the course and later as a reference notebook on foundations. The material contained in this book is geared to the practicing engineer in the foundation field who routinely deals with soil and foundation problems but has little theoretical background in soil mechanics or foundation engineering.

The manual follows a project oriented approach whereby the soils input to a fictitious bridge project is traced from conception to completion in a serialized illustrative workshop design problem.

The concepts presented in each chapter are concise and specifically directed at a particular operation in the foundation design process. Basic examples are included in several sections for hands-on knowledge. Continuity between chapters is achieved by sequencing the information in the normal progression of a foundation design study. In each phase of the fictitious project the soil concepts are developed into specific foundation designs or recommendations for that segment of the workshop design problem.

ACKNOWLEDGEMENTS

Permission by the FHWA to adapt the July 1993 Soils and Foundations Workshop Manual prepared by Richard Cheney and Ronald Chassie (FHWA) is gratefully acknowledged. Provision by the FHWA of the electronic files and hard copy of exhibits is also acknowledged. Furthermore the efforts of Jerry DiMaggio, Andy Muńoz, Ivan Marreo, Chris Dumas, and Peter Osborn of the FHWA are acknowledged for their thorough technical reviews and recommendations.

The author would also like to acknowledge the assistance of Jeremy Hung, Roger Gobin, and a number of professionals from Parsons Brinckerhoff Quade and Douglas, Inc., in the preparation of this revision of the manual. Many thanks to Theresa Kong for overall compiling, Roger Gobin for overseeing the preparation and production, and Theresa Kong, Moises Young, and Sandor Aguilar for graphic preparation and word processing.

NOTICE

The information in this document has been funded wholly or in part by the U.S. Department of Transportation, Federal Highway Administration (FHWA), under Contract No. DTFH-61-97-D-00025. The document has been subjected to peer and administrative review by FHWA, and has been approved for publication as an FHWA document.

In this document, certain products have been identified by trade name and/or shown in exhibits. Other products, which are not identified in this document, may be equally viable to those identified. The mention of any trade name or use of an exhibit containing the product does not constitute an endorsement or recommendation for use by either the authors or FHWA.

SOILS AND FOUNDATIONS WORKSHOP

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Symbols

Chapter 2

ASTM	American Society for Testing and Materials
AASHTO	American Association of State Highway and Transportation Officials
ASCE	American Society of Civil Engineers
RQD	Rock Quality Designation
SPT	Standard Penetration Test
N	SPT blows per foot
C_u	Undrained shear strength
ϕ	Angle of friction

Chapter 4

W	Moisture content
γ	Unit weight
n	Porosity
e	Void ratio
G_S	Specific gravity
μ	Pore water pressure
P_T	Total overburden pressure
P_o	Effective overburden pressure
γ_b	Effective unit weight
γ_w	Unit weight of water
γ_T	Total unit weight
LL	Liquid Limit
PL	Plastic Limit
PI	Plastic Index
SL	Shrinkage Limit
SI	Shrinking Index
Ac	Activity
LI	Liquidity Index
C_c	Compression Index
P_c	Preconsolidation Pressure
C_r	Recompression Index
e_o	Initial Void Ratio
C_v	Coefficient of Consolidation
C_α	Coefficient of Secondary Compression
S	Shear Strength
C	Cohesion
N	Normal Force
ϕ	Angle of internal friction (total)
U	Unconfined Compression
UU	Unconsolidated Undrained Triaxial
CU	Consolidated Undrained Triaxial
CD	Consolidated Drained Triaxial
DS	Direct Shear

D_{10}	Gradation characteristics effective diameter (10% by weight of sample is finer than this

	diameter)
D_{30}, D_{60}, D_{85}	Percent grain size by weight of sample finer than 30, 60, 85%
C_F	Coefficient of uniformity
C_z	Gradation characteristics, Coefficient of curvature
a_v	Consolidation characteristics: coefficient of compressibility
m_v	Coefficient of volume compressibility
C_s	Swelling Index
ϕ'	Angle of internal friction (effective)
c'	Cohesion intercept (effective)
q_u	Unconfined compressive strength
S_t	Sensitivity
E_s	Modulus of elasticity
γ_{max}	Maximum dry unit weight
OMC	Optimum moisture content
D_d	Relative density
CBR	California bearing ratio

Chapter 5

C	Cohesion
γ_{Fill}	Fill soil unit weight
H_{Fill}	Fill height
S	Total shear strength
σ	The total normal stress against the failure surface slice base due to the weight of soil and water above the failure surface
μ	Water pressure on the slice base
ϕ	Angle of internal friction
F.S.	Factor of Safety
L_w	Level arm distance to the center of rotation
L_s	Radius of circle
R	Moment arm
N	Effective normal force against the slice base (force between granular soil grains)
W_t	Total slice weight
α	Angle between vertical and line drawn from circle center to midpoint of slice base
l	Arc length of slice base
P_a	Active Force (Driving)
P_p	Passive Force (Resisting)
γ	Soil unit weight
H	Height of soil layer in active wedge
K_a	Active earth pressure coefficient for level ground surface
K_p	Passive earth pressure coefficient for level ground surface
α_w	Slope of water table from horizontal
UU	Unconsolidated Undrained Triaxial
CU	Consolidated Undrained Triaxial
CD	Consolidated Drained Triaxial

Chapter 6

b	Horizontal distance from embankment centerline to midpoint of slope
G_s	Specific gravity
h	Embankment height
γ_f	Unit weight of fill
ΔH	Settlement
H	Thickness of soil layer considered
C′	Bearing capacity index
P_o	Existing effective overburden pressure
ΔP	Distributed embankment pressure
P_F	Final pressure felt by foundation subsoil
N	Standard Penetration Test value
N’	Corrected SPT N value
P_c	Preconsolidation pressure
e_o	Initial void ratio at P_o
C_c	Compression indice
C_r	Recompression indice
ΔH_{sec}	Secondary settlement
C_α	Coefficient of secondary consolidation (determined from lab consolidation test)
t_{sec}	Time over which secondary settlement is being estimated
t_p	Time for primary consolidation
T	Theoretical time factor
H_v	Maximum length of vertical drainage path
C_v	Coefficient of consolidation
K	Pressure Coefficient
U_c	Percent consolidation combined radial and vertical
U_R	Percent consolidation radial
U_v	Percent consolidation vertical
$(_b$	Bouyant unit weight
TR	Radial time factor
d_C	Effective sand drain diameter
d_N	Sand drain diameter
S	Center to center spacing of sand drains
t_{90}	Time for 90%of primary consolidation

Chapter 7

N	SPT value
q_{ult}	Ultimate capacity
γ	Unit Weight
D	Footing embedment
B_w	Footing width
N_c, N_q, N_γ	Bearing capacity factor
X	Depth below footing
d_o	Depth of influence of footing
f	Lateral extent of influence of footing
N’	Corrected SPT value
ϕ	Angle of internal friction
C	Cohesion strength
q_{all}	Allowable bearing capacity

T	Theoretical time factor
H_v	Maximum length of vertical drainage path
t_{90}	Time for 90% of primary consolidation
L	Footing length
P, V	Applied footing pressure
ΔH	Settlement
H	Thickness of soil layer considered
C'	Bearing capacity index
P_o	Existing effective overburden pressure
ΔP	Distributed footing pressure
P_F	$P_o + \Delta P$
P_c	Preconsolidation pressure
e_o	Initial void ratio
C_c	Compression indices
C_r	Recompression indices

Chapter 8

γ	Soil unit weight
Q_{drive}	Driving resistance
Q_{ult}	Ultimate bearing capacity
Q_s	Total skin resistance
Q_p	Total point resistance
D	Pile length below ground
C_d	Pile perimeter
N'	SPT value corrected for overburden pressure
K_δ	Dimensionless factor relating normal stress and effective overburden pressure
P_d	Effective overburden pressure at the center of depth increment d
ω	Angle of pile taper measured from the vertical
δ	Friction angle on the surface of sliding
d	Depth increment below ground surface
C_F	Correction factor for K_δ when $\delta \neq \phi$ (soil friction angle)
Q_p	Total end bearing
A_p	Pile end area
α	Dimensionless factor dependent on depth-width relationship
N'_q	Bearing capacity factor
C_a	Pile adhesion
C_u	Undrained shear strength
P_{ult}	Group capacity
n	Number of group piles
E	Group efficiency
C_h	Horizontal coefficient of consolidation.
T	Time factor
H_v	Maximum vertical drainage path in the clay layer(s) below the pile tips
C_V	Coefficient of consolidation.
Q_T	Total axial capacity of the drill shaft
Q_B	Drill shaft base capacity
Q_S	Drill shaft side capacity
q_s	Capacity of pile segment (skin friction)
ϕ	Angle of internal friction

V	Volume per foot for pile segment
UU	Unconsolidated Undrained Triaxial

Chapter 9

W	Weight of the ram
H	Distance of ram fall
R	Total soil resistance (driving capacity) against the pile
S	Pile penetration (set) per blow
P	Safe pile load in kips
k	Constant which varies from 0.1 to 1 based on hammer type
E	Manufacturer rated energy (foot-pounds) at the stroke observed in the field
Log (10N)	Logarithm to the base 10 of the quantity 10 multiplied by N, the number of hammer blows per inch at final penetration (blows per inch)
Fy	Yield strength of steel
F′c	28 day concrete cylinder strength
F′a	Allowable compressive stress of timber including allowance for treatment effects
X	Estimated pile footage