时代教育·国外高校优秀教材精选

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（英文版·原书第2版）

基础设计：理论与实践

Foundation Design: Principles and Practices

（美）唐纳德 P. 科杜图(Donald P. Coduto）著

机械工业出版社
CHINA MACHINE PRESS

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出版说明

随着我国加入WTO,国际间的竞争越来越激烈,而国际间的竞争实际上也就是人才的竞争、教育的竞争。为了加快培养具有国际竞争力的高水平技术人才,加快我国教育改革的步伐,国家教育部近来出台了一系列倡导高校开展双语教学、引进原版教材的政策。以此为契机,机械工业出版社近期推出了一系列国外影印版教材,其内容涉及高等学校公共基础课,以及机、电、信息、建筑领域的专业基础课和专业课。

引进国外优秀原版教材,在有条件的学校推动开展英语授课或双语教学,自然也引进了先进的教学思想和教学方法,这对提高我国自编教材的水平,加强学生的英语实际应用能力,使我国的高等教育尽快与国际接轨,必将起到积极的推动作用。

为了做好教材的引进工作,机械工业出版社特别成立了由著名专家组成的国外优秀教材审定委员会。这些专家对实施双语教学做了深入细致的调查研究,对引进原版教材提出许多建设性意见,并慎重地对每一本将要引进的原版教材一审再审,精选再精选,确认教材本身的质量水平,以及权威性和先进性,以期所引进的原版教材能适应我国学生的外语水平和学习特点。在引进工作中,审定委员会还结合我国高校教学课程体系的设置和要求,对原版教材的教学思想和方法的先进性、科学性严格把关。同时尽量考虑原版教材的系统性和经济性。

这套教材出版后,我们将根据各高校的双语教学计划,举办原版教材的教师培训,及时地将其推荐给各高校选用。希望高校师生在使用教材后及时反馈意见和建议,使我们更好地为教学改革服务。

机械工业出版社

高等教育分社

序

一本好的教材,不管对于学生还是对于教师都是至关重要的。本人有幸较早地阅读了加州理工大学 Donald P. Coduto 教授所著的《FOUNDATION DESIGH PRINCIPLES AND PRACTICES》(Second Edition),感触颇深,爱不释手。

本书覆盖面广、内容丰富,几乎囊括了基础工程的方方面面,从一般性原理到浅基础和深基础,从特殊土地基到支挡结构,不但前后逻辑严密,而且每一个问题的概念都讲得非常清晰又很有深度。

难能可贵的是,书中既充分考虑了基础工程设计过程中岩土、结构和施工各专业学科的特点,又充分讲解了它们之间的相关性。无论在第二部分的浅基础中,还是在第三部分的深基础中,无不体现了岩土和结构有机的统一。

与国内相关教材不同的是,本教材应用了大量的例题,非常有助于学生对原理的理解,并且在每一章的末尾设计了大量的课后作业、思考题,很多思考题与工程实践密切相关。本书对深基础(桩基)的讲解很透彻,不少内容和分析方法在国内教材和专著中都是少见的。

书中还选择性地介绍了基础工程领域的几个最新进展,主要有可靠性设计、钢板桩墙以及 EXCEL 在基础工程设计计算中的应用。

此外,书中每一章前面的一小段格言,哲理深邃,相信能够引领大家去学习思考。

本书主要结合了美国流行的几个规范,对于入世后的中国师生和工程技术人员是有必要了解的,但也必须熟悉我国规范,老师在上课时可以进行适当的补充,也可以在课程设计或毕业设计中掌握。

总之,本教材具有良好的系统性、显著的先进性和较高的权威性,是一本典型的优秀原版教材,不但可以作为土木工程专业本科生、研究生教材,也是一本极好的大学教师和工程技术人员的参考书。

单仁亮

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Preface

Foundation Design: Principles and Practices is primarily intended for use as a textbook in undergraduate and graduate-level foundation engineering courses. It also serves well as a reference book for practicing engineers. As the title infers, this book covers both "principles" (the fundamentals of foundation engineering) and "practices" (the application of these principles to practical engineering problems). Readers should have already completed at least one university-level course in soil mechanics, and should have had at least an introduction to structural engineering.

This second edition contains many improvements and enhancements. These have been the result of comments and suggestions from those who used the first edition, my own experience using it at Cal Poly Pomona, and recent advances in the state-of-the-art. The chapters on deep foundations have been completely reorganized and rewritten, and new chapters on reliability-based design and sheet pile walls have been added. Extraneous material has been eliminated, and certain analysis methods have been clarified and simplified. The manuscript was extensively tested in the classroom before going to press. This classroom testing allowed me to evaluate and refine the text, the example problems, the homework problems, and the software.

Key features of this book include:

- Integration with *Geotechnical Engineering: Principles and Practices* (Coduto, 1999), including consistent notation, terminology, analysis methods, and coordinated development of topics. However, readers who were introduced to geotechnical engineering using another text can easily transition to this book by reviewing the material in Chapters 3 and 4.
- Consideration of the geotechnical, structural, and construction engineering aspects of the design process, including emphasis on the roles of each discipline and the interrelationships between them.
- Frequent discussions of the sources and approximate magnitudes of uncertainties, along with comparisons of predicted and actual behavior.
- Use of both English and SI units, because engineers in North America and many other parts of the world need to be conversant in both systems.

- Integration of newly-developed Excel spreadsheets for foundation analysis and design. These spreadsheet files may be downloaded from the Prentice Hall website (www.prenhall.com/coduto). They are introduced only after the reader learns how to perform the analyses by manual computations.
- Extensive use of example problems, many of which are new to this edition.
- Inclusion of carefully developed homework problems distributed throughout the chapters, with comprehensive problems at the end of each chapter. Many of these problems are new or revised.
- Discussions of recent advances in foundation engineering, including Statnamic testing, load and resistance factor design (LRFD), and applications of the cone penetration test (CPT).
- Inclusion of extensive bibliographic references for those wishing to study certain topics in more detail.
- An instructor's manual is available to faculty. It may be obtained from your Prentice Hall campus representative.

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Many friends, colleagues, and other professionals contributed to this work. Much of the book is the product of their stimulating discussions, constructive reviews, and support. Professor Joseph Caliendo of Utah State University was especially helpful. Stanley Vitton (Michigan Technological University), Samuel Clemence (Syracuse University), Richard Handy (Iowa State University), Raymond Moore (University of Nebraska), John Horvath (Manhattan College), José Pires (University of California, Irvine), Paul Chan (New Jersey Institute of Technology), William and Sandra Houston (Arizona State University), and others reviewed part or all of the manuscripts for the first or second editions and provided many useful suggestions and comments. Iraj Noorany (San Diego State University), Michael O'Neill (University of Houston), Major William Kitch (U.S. Air Force Academy), James Olson (University of Vermont), Samuel Paikowsky (University of Massachusetts, Lowell), Richard W. Stephenson (University of Missouri, Rolla), William Kovacs (University of Rhode Island), Dan Burgess, Rick Drake (Fluor Daniel), Bengt Fellenius (Urkkada Technology), Mohamad Hussein (Goble, Rausche, Likins), and others also provided useful suggestions and advice.

A special note of thanks goes to the foundation engineering students at Cal Poly University who used various draft manuscripts of this book as a makeshift text. Their constructive comments and suggestions have made this book much more useful, and their proofreading has helped eliminate mistakes.

I welcome any constructive comments and suggestions from those who use this book. Please mail them to me at the Civil Engineering Department, Cal Poly University, Pomona, CA 91768.

Donald P. Coduto

Notation and Units of Measurement

There is no universally accepted notation in foundation engineering. However, the notation used in this book, as described in the following table, is generally consistent with popular usage.

Symbol	Description	Typical Units English	Typical Units SI	Defined on Page
A	Cross-sectional area	ft^2	m^2	438
A	Base area of foundation	ft^2	m^2	155
A_0	Initial cross-sectional area	in^2	mm^2	95
A_1	Cross-sectional area of column	in^2	mm^2	337
A_2	Base area of frustum	in^2	mm^2	337
A_b	Area of bottom of enlarged base	ft^2	m^2	528
A_f	Cross-sectional area at failure	in^2	mm^2	95
A_s	Steel area	in^2	mm^2	323
a_θ	Factor in N_q equation	Unitless	Unitless	178
B	Width of foundation	ft-in	mm	146
B'	Effective foundation width	ft-in	m	275
B_b	Diameter at base of foundation	ft	m	548
B_s	Diameter of shaft	ft	m	547
b	Unit length	ft	m	156
b_c, b_q, b_y	Base inclination factors	Unitless	Unitless	186
b_0	Length of critical shear surface	in	mm	310
C_1	Depth factor	Unitless	Unitless	235
C_2	Secondary creep factor	Unitless	Unitless	235
C_3	Shape factor	Unitless	Unitless	235
C_A	Aging factor	Unitless	Unitless	122
C_B	SPT borehole diameter correction	Unitless	Unitless	119
C_C	Compression index	Unitless	Unitless	66

C_{OCR}	Overconsolidation correction factor	Unitless	Unitless	122
C_P	Grain size correction factor	Unitless	Unitless	122
$C_{p\phi}$	Passive pressure factor	Unitless	Unitless	602
C_R	SPT rod length correction	Unitless	Unitless	119
C_r	Recompression index	Unitless	Unitless	67
C_s	SPT sampler correction	Unitless	Unitless	119
C_s	Side friction coefficient	Unitless	Unitless	535
C_t	Toe coefficient	Unitless	Unitless	534
C_w	Hydroconsolidation coefficient	Unitless	Unitless	709
c	Wave velocity in pile	ft/s	m/s	571
c	Column or wall width	in	mm	302
c'	Effective cohesion	lb/ft^2	kPa	84
c'_{adj}	Adjusted effective cohesion	lb/ft^2	kPa	198
c_T	Total cohesion	lb/ft^2	kPa	85
D	Depth of foundation	ft-in	mm or m	146
D_{50}	Grain size at which 50% is finer	Unitless	mm	122
D_{min}	Minimun required embedment depth	ft	m	593
D_r	Relative density	percent	percent	51
D_w	Depth from ground surface to groundwater table	ft	m	188
d	Effective depth	in	mm	306
d	Bolt diameter	in	mm	344
d	Vane diameter	in	mm	131
d_b	Reinforcing bar diameter	in	mm	306
d_c, d_q, d_γ	Depth factors	Unitless	Unitless	184
E	Portion of steel in center section	Unitless	Unitless	333
E	Modulus of elasticity	lb/in^2	MPa	231
E_m	SPT hammer efficiency	Unitless	Unitless	119
E_s	Equivalent modulus of elasticity	lb/ft^2	kPa	231
E_u	Undrained modulus of elasticity	lb/ft^2	kPa	226
EI	Expansion index	Unitless	Unitless	673
e	Eccentricity	ft	m	159
e	Void ratio	Unitless	Unitless	49
e	Base of natural logarithms	2.7183	2.7183	XXX
e_0	Initial void ratio	Unitless	Unitless	66
e_B	Eccentricity in the *B* direction	ft	m	165
e_L	Eccentricity in the *L* direction	ft	m	165
e_{max}	Maximum void ratio	Unitless	Unitless	51
e_{min}	Minimum void ratio	Unitless	Unitless	51
F	Factor of Safety	Unitless	Unitless	190
F_a	Allowable axial stress	lb/in^2	MPa	439

F_b	Allowable flexural stress	lb/in^2	MPa	439
F_v	Allowable shear stress	lb/in^2	MPa	439
f_a	Average normal stress due to axial load	lb/in^2	MPa	438
f_b	Normal stress in extreme fiber due to flexural load	lb/in^2	MPa	438
f_c'	28-day compressive strength of concrete	lb/in^2	MPa	303
f_{pc}	Effective prestress on gross section	lb/in^2	MPa	448
f_s	Unit side friction resistance	lb/ft^2	kPa	513
$(f_s)_m$	Mobilized unit side-friction resistance	lb/ft^2	kPa	544
f_{sc}	CPT cone side friction	T/ft^2	MPa or kg/cm^2	124
f_v	Shear stress	lb/in^2	MPa	439
f_y	Yield strength of steel	lb/in^2	MPa	303
G_h	Horizontal equivalent fluid density	lb/ft^3	kN/m^3	770
G_s	Specific gravity of solids	Unitless	Unitless	49
G_v	Vertical equivalent fluid density	lb/ft^3	kN/m^3	771
g_c, g_q, g_γ	Ground inclination factors	Unitless	Unitless	186
H	Thickness of soil stratum	ft	m	60
H	Wall height	ft	m	759
H_c	Critical height	ft	m	767
H_{fill}	Thickness of fill	ft	m	64
I_1, I_2	Influence factors	Unitless	Unitless	226
I_ϵ	Strain influence factor	Unitless	Unitless	234
I_p	Plasticity index	Unitless	Unitless	56
I_r	Rigidity index	Unitless	Unitless	501
i_c, i_q, i_γ	Load inclination factors	Unitless	Unitless	185
I_σ	Stress influence factor	Unitless	Unitless	210
K	Coefficient of lateral earth pressure	Unitless	Unitless	61
K_a	Coefficient of active earth pressure	Unitless	Unitless	760
K_p	Coefficient of passive earth pressure	Unitless	Unitless	762
k	Factor in computing depth factors	Unitless	Unitless	184
k_s	Coefficient of subgrade reaction	lb/in^3	kN/m^3	356
L	Length of foundation	ft-in	mm	146
L'	Effective foundation length	ft-in	m	275
LL	Liquid limit (see w_L)	Unitless	Unitless	54
l	Cantilever distance	in	mm	322
l_d	Development length	in	mm	318
l_{dh}	Development length for hook	in	mm	337
M	Moment load	ft-k	kN-m	15
M_c	Characteristic moment load	ft-lb	kN-m	601
M_D	Driving moment	ft-lb	kN-m	796

M_g	Applied moment to pile group	ft-lb	kN-m	616
M_{max}	Maximum moment	ft-lb	kN-m	603
M_n	Nominal moment load capacity	ft-k	kN-m	21
M_R	Resisting moment	ft-lb	kN-m	796
N	Number of piles in a group	Unitless	Unitless	538
N	SPT blow count recorded in field	Blows/ft	Blows/300 mm	116
$(N_1)_{60}$	SPT blow count corrected for field procedures and overburden stress	Blows/ft	Blows/300 mm	120
N_σ	Bearing capacity factor	Unitless	Unitless	502
N_{60}	SPT blow count corrected for field procedures	Blows/ft	Blows/300 mm	119
N_c, N_q, N_γ	Bearing capacity factors	Unitless	Unitless	178
N_c^*, N_q^*, N_γ^*	Bearing capacity factors	Unitless	Unitless	501
N_u	Uplift bearing capacity factor	Unitless	Unitless	527
OCR	Overconsolidation ratio	Unitless	Unitless	69
P	Normal load	k	kN	15
P_a	Allowable downward load capacity	k	kN	467
P_a	Normal force acting on a wall under active conditions	lb	kN	759
P_{ag}	Allowable load capacity of pile group	k	kN	538
P_{upward}	Upward load	k	kN	470
$(P_a)_{upward}$	Allowable upward load capacity	k	kN	470
P_D	Driving force	lb	kN	791
P_f	Axial load at failure	lb	N	95
PI	Plasticity index (see I_P)	Unitless	Unitless	54
P_0	Normal force acting on a wall under at-rest conditions	lb	kN	751
PL	Plastic limit (see w_P)	Unitless	Unitless	54
P_n	Nominal normal load capacity	k	kN	21
P_{nb}	Nominal bearing capacity	k	kN	336
P_p	Normal force acting on a wall under passive conditions	lb	kN	759
P_R	Resisting force	lb	kN	791
P_s	Side-friction resistance	k	kN	466
P_t	Toe-bearing resistance	k	kN	466
P_t'	Net toe-bearing resistance	k	kN	407
P_u	Factored normal load	k	kN	21
P_{ult}	Ultimate downward load capacity	k	kN	481
p	Lateral soil resistance per unit length of foundation	lb	kN	587
Q_c	Compressibility factor	Unitless	Unitless	128
q	Bearing pressure	lb/ft^2	kPa	154

q'	Net bearing pressure	lb/ft^2	kPa	158
q	Quake	in.	mm	566
q_a	Allowable bearing capacity	lb/ft^2	kPa	190
q_A	Allowable bearing pressure	lb/ft^2	kPa	262
q_c	CPT cone resistance	T/ft^2	MPa or kg/cm^2	124
q_E	Effective cone resistance	T/ft^2 or MPa	kg/cm^2	533
q_{EG}	Factor in Eslami and Fellenius method	T/ft^2	MPa	534
q_{equiv}	Equivalent bearing pressure	lb/ft^2	kPa	275
q_{max}	Maximum bearing pressure	lb/ft^2	kPa	162
q_{min}	Minimum bearing pressure	lb/ft^2	kPa	162
q_t'	Net unit toe-bearing resistance	lb/ft^2	kPa	500
$(q_t')_m$	Mobilized unit toe-bearing resistance	lb/ft^2	kPa	544
q_{tr}'	Reduced net unit toe-bearing resistance	lb/ft^2	kPa	506
q_u	Unconfined compressive strength	lb/ft^2	kPa	511
q_{ult}	Ultimate bearing capacity	lb/ft^2	kPa	176
r	Distance from centerline of cap	in	mm	615
r	Rigidity factor	Unitless	Unitless	219
R_f	Friction ratio	Unitless	Unitless	124
R_I	Moment of inertia ratio	Unitless	Unitless	601
RQD	Rock quality designation	Unitless	Unitless	511
R_u	Ultimate resistance	k	kN	566
S	Slope of foundation	radians	radians	587
S	Elastic section modulus	in^3	mm^3	438
S	Number of stories	Unitless	Unitless	109
S	Degree of saturation	percent	percent	49
S	Column spacing	ft	m	33
S_0	Degree of saturation before wetting	percent	percent	678
S_1,S_3	Allowable lateral soil pressure	lb/ft^2	kPa	593
s	Shear strength	lb/ft^2	kPa	84
s	Center-to-center spacing of piles	in	mm	540
s	Pile set	in	mm	560
s_c,s_q,s_γ	Shape factors	Unitless	Unitless	184
s_u	Undrained shear strength	lb/ft^2	kPa	89
T	Torsion load	k-ft	m-kN	15
T	Thickness of foundation	ft-in	mm	146
T_f	Torque at failure	in-lb	N-m	131
TMI	Thornthwaite moisture index	Unitless	Unitless	666
t	Time	yr	yr	235
t	Age of soil (since time of deposition)	yr	yr	122

u	Displacement of pile	in	mm	564
u	Pore water pressure	lb/ft^2	kPa	59
u_2	Pore water pressure behind cone point	lb/ft^2	kPa	533
u_D	Pore water pressure at bottom of foundation	lb/ft^2	kPa	155
u_e	Excess pore water pressure	lb/ft^2	kPa	59
u_h	Hydrostatic pore water pressure	lb/ft^2	kPa	58
V	Shear load	k	kN	15
V_a	Shear force under active condition	k	kN	759
V_c	Nominal shear capacity of concrete	lb	kN	309
V_c	Characteristic shear load	lb	kN	601
V_{fa}	Allowable footing shear load capacity	k	kN	276
V_n	Nominal shear load capacity	k	kN	21
V_{nc}	Nominal shear capacity on critical surface	lb	kN	309
V_p	Shear force under passive condition	k	kN	159
V_s	Nominal shear capacity of reinforcing steel	lb	kN	309
V_u	Factored shear load	k	kN	21
V_{uc}	Factored shear force on critical surface	lb	kN	309
W_f	Weight of foundation	lb	kN	154
W_r	Hammer ram weight	lb	kN	560
w	Moisture content	percent	percent	49
w_L	Liquid limit	Unitless	Unitless	54
w_P	Plastic limit	Unitless	Unitless	54
w_s	Shrinkage limit	Unitless	Unitless	54
y	Lateral deflection	in	mm	598
z	Depth below ground surface	ft	m	564
z_c	Depth to centroid of soil resistance	ft	m	544
z_f	Depth below to bottom of foundation	ft	m	210
z_I	Depth to imaginary footing	ft	m	552
z_w	Depth below to groundwater table	ft	m	58
α	Wetting coefficient	Unitless	Unitless	678
α	Adhesion factor	Unitless	Unitless	522
α	Slope of footing bottom	deg	deg	183
α	Inclination of wall from vertical	deg	deg	764
β	Side friction factor in β method	Unitless	Unitless	516
β	Slope of ground surface	deg	deg	759
β	Reliability index	Unitless	Unitless	724
β_0, β_1	Correlation factors	Unitless	Unitless	233
γ	Ratio of steel cage diameter to drilled shaft diameter	Unitless	Unitless	455
γ	Unit weight	lb/ft^3	kN/m^3	49
γ	Load Factor	Unitless	Unitless	21

γ_b	Buoyant unit weight	lb/ft^3	kN/m^3	49
γ_d	Dry unit weight	lb/ft^3	kN/m^3	49
γ_{fill}	Unit weight of fill	lb/ft^3	kN/m^3	64
γ_w	Unit weight of water	lb/ft^3	kN/m^3	49
γ'	Effective unit weight	lb/ft^3	kN/m^3	188
$\Delta\sigma_z$	Change in vertical stress	lb/ft^2	kPa	64
δ	Total settlement	in	mm	29
δ_a	Allowable total settlement	in	mm	29
δ_c	Consolidation settlement	in	mm	72
δ_D	Differential settlement	in	mm	31
δ_{Da}	Allowable differential settlement	in	mm	31
δ_d	Distortion settlement	in	mm	224
δ_e	Settlement due to elastic compression	in	mm	544
δ_u	Settlement required to mobilize ultimate resistance	in	mm	544
δ_w	Heave or settlement due to wetting	in	mm	680
ϵ_{50}	Axial strain at which 50 percent of the soil strength is mobilized	Unitless	Unitless	603
ϵ_f	Strain at failure	Unitless	Unitless	95
ϵ_w	Strain due to wetting	Unitless	Unitless	676
η	Factor in Shields' chart	Unitless	Unitless	286
η	Group efficiency factor	Unitless	Unitless	538
θ	Factor in Converse-Labarre formula	Unitless	Unitless	539
θ_a	Allowable angular distortion	radians	radians	33
λ	Lightweight concrete factor	Unitless	Unitless	319
λ	Factor in Shields' chart	Unitless	Unitless	286
λ	Vane shear correction factor	Unitless	Unitless	131
λ	Equivalent passive fluid density	lb/ft^3	kN/m^3	276
λ	Factor in Evans and Duncan's charts	Unitless	Unitless	602
λ_a	Allowable equivalent passive fluid density	lb/ft^3	kN/m^3	276
μ	Coefficient of friction	Unitless	Unitless	276
μ_a	Allowable coefficient of friction	Unitless	Unitless	276
μ_C	Mean ultimate capacity	k	kN	723
μ_L	Mean load	k	kN	723
υ	Poisson's ratio	Unitless	Unitless	502
ρ	Mass density	lb_m/ft^3	kg/m^3	564
ρ	Steel ratio	Unitless	Unitless	317
ρ_s	Ratio of volume of spiral reinforcement to total volume of core	Unitless	Unitless	459
σ	Total stress	lb/ft^2	kPa	60
σ	Normal pressure imparted on wall from soil	lb/ft^2	kPa	760

σ'	Effective stress	lb/ft^2	kPa	60
σ_C	Standard deviation of ultimate capacity	k	kN	724
σ_c'	Preconsolidation stress	lb/ft^2	kPa	67
σ_{hs}	Horizontal swelling pressure	lb/ft^2	kPa	691
σ_L	Standard deviation of load	k	kN	727
σ_m'	Preconsolidation margin	lb/ft^2	kPa	69
σ_p	Representative passive pressure	lb/ft^2	kPa	602
σ_t	Threshold collapse stress	lb/ft^2	kPa	708
σ_x	Horizontal total stress	lb/ft^2	kPa	61
σ_x'	Horizontal effective stress	lb/ft^2	kPa	61
σ_z	Vertical total stress	lb/ft^2	kPa	60
σ_z'	Vertical effective stress	lb/ft^2	kPa	60
σ_{z0}'	Initial vertical effective stress	lb/ft^2	kPa	64
σ_{zD}'	Effective stress at depth *D* below the ground surface	lb/ft^2	kPa	178
σ_{zD}	Total stress at depth *D* below the ground surface	lb/ft^2	kPa	175
σ_{zf}'	Final effective stress	lb/ft^2	kPa	64
σ_{zp}'	Initial vertical effective stress at depth of peak strain influence factor	lb/ft^2	kPa	234
τ	Shear stress imparted on wall from soil	lb/ft^2	kPa	760
ϕ	Resistance factor	Unitless	Unitless	21
ϕ'	Effective friction angle	deg	deg	82
ϕ'_{adj}	Adjusted effective friction angle	deg	deg	198
ϕ_T	Total friction angle	deg	deg	85
ϕ_w	Wall-soil interface friction angle	deg	deg	763
Ψ	Three dimensional adjustment factor	Unitless	Unitless	225
Ψ	Factor in Shields' chart	Unitless	Unitless	286

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