

(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





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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。

量 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。

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

优秀原点**达就出业工耕办**。作为土木工程专业本料生、研究生教材,也是一本极好的大学教师和 **达入育体等高**内参考书。

中国矿业大学(北京校区)

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則以序則出

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,对于人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 中国矿业大学(北京校区)

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

Preface by manual computations.

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 Stathamic test ing, load and resistance factor design (LRFD), and applications of the cone penetration test (CPT)

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 hoped been the result of comments and suggestions from those who used the first edition, my notify 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 behavior classroom testing allowed me to evaluate and refine the text, the example problems, the foliation homework problems, and the software.

Michael O'Neill (University of Housto: older include: older) Rey features of this book include: older to vitare vital (University of Housto: older)

- maili W. (6) Integration with Geotechnical Engineering: Principles and Practices (Coduto, 1998), including consistent notation, terminology, analysis methods, and coordinated by the consistent of topics. However, readers who were introduced to geotechnical engineering using another text can easily transition to this book by reviewing the topical laborate 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 foods in more detail. Foundation Design: Principles and Practices is principles and extension of the condition of the conditi
- as llew as vis. An instructor's manual is available to faculty. It may be obtained from your Prenning flood article Hall campus representative.

pleted at least one university-level course in soil mechanics, a ZTMANDAWONJA

Many friends, colleagues, and other professionals contributed to this work. Much of the monobook 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

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.

other parts cotuboo . A blanodo be conversant in both systems.

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.

		Typical I	Units	Defined
Symbol	Description	English English	SI	on Page
A III	Cross-sectional area	to grout table table	m^2	438
A mm	Base area of foundation	Effecti ² depth	m^2	155
A_0	Initial cross-sectional area	Bolt di ² in ² eler	mm ²	95
A_1 mm	Cross-sectional area of column	Vane c ² nineter	mm ²	337
A_2 mm	Base area of frustum	Reinfo s_{ni}ng bar diameter	mm ²	337
Unitles	Area of bottom of enlarged base			528
A_f^{coltinU}	Cross-sectional area at failure	Portiorsni steel in center section	mm ²	95
A_s $^{\text{GMM}}$	Steel area	Modul ² not elasticity		323
$a_{\theta}^{\text{solitiou}}$	Factor in N_q equation	Unitless Unitless		178
B	Width of foundation	Equival-11 modulus of elasticity		146
B' AGA	Effective foundation width	Undrain-th modulus of elasticity	m a	275
B_b	Diameter at base of foundation	Expansi ji n index	m III	548
B_s	Diameter of shaft	Eccentin ity	***	547
Unitlesd	Unit length	fter bioV		156
b_c, b_q, b_y	Base inclination factors	Bas sealtinu	Unitless	186
b_0 slimU	Length of critical shear surface			310
C_1	Depth factor	Ecc sellinU in the B direction		235
C_2	Secondary creep factor	nolposib A adv ii Unitless and	Unitless	235
C_3 all in U		Unitless M	Unitless	235
C_A^{collimU}		Unitless W	Unitless	122
C_B	SPT borehold diameter correcti	on Unitless	Unitless	119
C_C SAM	Compression index	Zzertz laiz Unitless	Unitless	66

and

	C_{OCR}	Overconsolidation correction fac	tor	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
10550	C_r	Recompression index		Unitless	Unitless	67
	C_s	SPT sampler correction	W.T.	Unitless	Unitless	119
1113	C_s	Side friction coefficient	NO.	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
	$c'_{ m adj}$	Adjusted effective cohesion		lb/ft ²	kPa	198
	c_T	Total cohesion		lb/ft ²	kPa	85
	Hower D. in	Depth of foundation		ft-in	mm or m	146
	D_{50}			Unitless	mm nou	122
	D_{min}	Minimun required embedment de	epth	ft	popular usai	593
	D_r	Relative density		percent	percent	51
	D_w	Depth from ground surface			Symbol	
		to groundwater table		ou ft - 2010	m A	188
	d	Effective depth		lo in see 8	mm A	306
	d mm	Bolt diameter		Initial (ni)55-8	mm A	344
	d com	Vane diameter		Cross-s ni tion	mm A	131
	d_b	Reinforcing bar diameter		Base arni of	mm	306
	d_c, d_q, d_γ	Depth factors		Unitless	Unitless	184
	$E_{\rm min}$	Portion of steel in center section			Unitless	333
	E $^{\circ}$ mm	Modulus of elasticity		lb/in ²	MPa	231
	E_{m}	SPT hammer efficiency		Unitless	Unitless	119
	E_{s} (RM)	Equivalent modulus of elasticity		lb/ft ²	kPa	231
	E_u	Undrained modulus of elasticity		lb/ft ²	kPa	226
	EI m	Expansion index		Unitless	Unitless	673
	e 111	Eccentricity		Diameith of	m a	159
	e 111	Void ratio		Unitless	Unitless	49
	Unitlesia			2.7183	2.7183	XXX
	e_0 mm	Initial void ratio		Unitless	Unitless	66
		Eccentricity in the B direction		Depth Hour		165
	e_L	Eccentricity in the L direction		no vittemoos	m	165
	e_{max}	Maximum void ratio		Unitless		51
	e_{min}	Minimum void ratio		Unitless	Unitless	51
	$F_{ m celtin}$ U	Factor of Safety		Unitless	Unitless	190
	F_{a}	Allowable axial stress		lb/in ²		439

F_b - M	Allowable flexural stress	Applini/dhoment to pile gro	MPa	439
$F_{ m V}$ 1-Mal	Allowable shear stress	Max ni/dl moment	MPa	439
f_{a} . All	Average normal stress due to axial l		MPa	438
f_b . We have	Normal stress in extreme fiber due			
	to flexural load	quore in a group	MPa	438
mnf_c' 08\2\wo	28-day compressive strength of con-		MPa	303
$f_{ m pc}$	Effective prestress on gross section	t heroenoo muoo lb/in² Tgz	MPa	448
mmf_s 08\200	Unit side friction resistance		kPa	513
$(f_s)_m$	Mobilized unit side-friction resistan	ce notosi vijosi lb/ft²	kPa	544
f_{sc}			MPa	
			or kg/cm ²	124
$f_{\rm volimU}$	Shear stress	lb/in ²	MPa	439
$f_{y_{\text{clinU}}}$	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
80, 89, 8y	CHOUNG INCHINATION PACTORS	Unitless WE HO RHIDGE SOUTH	Unitless	186
$H_{ V }$	Thickness of soil stratum	inder active conditions	m	60
H_{MM}	Wall height	Allowable load capacity of	m q	759
H_{c}	Critical height	bsol ft	m a	767
H_{fill}	Thickness of fill	Allowable upward load cap	m (SI)	64
I_1 , I_2	Influence factors	Unitless	Unitless	226
I_{ϵ}	Strain influence factor	Unitless	Unitless	234
Unitless	Plasticity index	Unitless	Unitless	56
I_r	Rigidity index	Unitless	Unitless	501
i_c , i_g , i_γ	Load inclination factors	Unitless	Unitless	185
I_{σ}	Stress influence factor	Unitless Unitless	Unitless	210
K	Coefficient of lateral earth pressure	Unitless Unitless	Unitless	61
K_a	Coefficient of active earth pressure	Unitless	Unitless	760
K_p	Coefficient of passive earth pressur		Unitless	762
k (a)	Factor in computing depth factors	Unitless	Unitless	184
k_s	Coefficient of subgrade reaction	lb/in ³	kN/m ³	356
L WH	Length of foundation	Side ni-thion resistance	mm q	146
$L'_{[0,1]}$	Effective foundation length	Toe-ni-th ne resistance	m q	275
LL	Liquid limit (see w_L)	Unitless Unitless	Unitless	54
I MA	Cantilever distance	Factored normal load	mm a	322
l_d		Ultimate downward load ca	mm a	318
l_{dh}	Development length for hook	ur very encentaions lie in	mm	337
M_{Mod}	Moment load	of for the sistance per un	kN-m	15
M_c bigU	Characteristic moment load	Comdl-thibility factor.	kN-m	601
M_D	Driving moment	Rear dl-th ressure	kN-m	796
Di 1./1	0.01			

M_g	Applied moment to pile group	Alloydlife flexural stress	kN-m	616
M_{max}	Maximum moment	Alloydl-the shear stress	kN-m	603
M_n	Nominal moment load capacity		kN-m	21
M_R		Norrdl-thress in extreme	kN-m	796
Negm	Number of piles in a group	Unitless		538
NEGM	SPT blow count recorded in field			116
$(N_l)_{60}$	SPT blow count corrected for field		Joe Joe	110
(11/60	procedures and overburden stress	Blows/ft Blows	ows/300 mm	120
N_{σ}	Bearing capacity factor Some Parison no			502
N_{60}	SPT blow count corrected for field pro			119
N_c, N_q, N_{γ}	Bearing capacity factors	Unitless	Unitless	178
$N_c^*, N_q^*, N_{\gamma}^*$	Bearing capacity factors	Unitless	Unitless	501
AZ GYLVI	Uplift bearing capacity factor	Unitless	Unitless	527
OCR	Overconsolidation ratio	Unitless Unitless	Unitless	69
D	Normal load	Specific gravity of solids	kN	15
Pa Pa Pa Pa Pa	Allowable downward load capacity	Vertical equivalent fluid o	kN	467
Γ_{α}	Normal force acting on a wall			
TO.	under active conditions	Thickedes of soil stratum	kN H	759
P_{ag}	Allowable load capacity of pile group		kN	538
P_{upward}	Upward load	Criticalheight	kN	470
$(P_a)_{upward}$	Allowable upward load capacity	Thickenss of fill	kN	470
P_D	Driving force	Influence factors	kN	791
P_f	Axial load at failure	Strain diffuence factor	N	95
PI	Plasticity index (see I_P)	Unitless	Unitless	54
P_0	Normal force acting on a wall	Rigidity index		
	under at-rest conditions	Load idelination factors	kN	751
PL ^{oltinU}	Plastic limit (see W_P)	Unitless	Unitless	54
P_n^{obtinU}	Nominal normal load capacity	Cocinia cert of rateral earth	kN	21
P_n P_{nb}	Nominal bearing capacity	Coefficient of active earth	kN	336
P_p^{soltinU}	Normal force acting on a wall	Pactordn computing depit	, A	7.50
P_R^{max}	E a de la companya de	Coeffigient of subgrade re	kN A	759
	8	Lengthy of foundation	kN 1	791
P_s P_t	Side-friction resistance	Effectine foundation lengt	kN	466
P_t		Liquid $_{\mathbf{A}}^{\mathbf{k}}$ imit (see w_L)		466
P_u	Net toe-bearing resistance	Cantiley er distance	kN	407
P_{ult}	Factored normal load	Development length	kN kN	21
p mm	Ultimate downward load capacity Lateral soil resistance per unit length		KN o	481
p m-Vbl	of foundation	Monted load	kN M	587
Q_c		Charles noment los	Unitless	128
$q^{-1/2}$	Bearing pressure	Insmolb/ft²virQ	kPa	154
7	Pressure	10/16	ILL W	137

	q' mm	Net bearing pressure	Displ\$21dent of pile	kPa 🕠	158
	q squ	Quake	Pore waier pressure	mm 🕠	566
	q_a BY	Allowable bearing capacity of and	Pore 47/dl pressure behind of	kPa M	190
	qA BAN	Allowable bearing pressure	Pore 47/dl pressure at botton	kPa an	262
	q_c sqx	CPT cone resistance	Exces ² ff/Tre water pressure	MPa	
				or kg/cm ²	124
15	q_E M	Effective cone resistance	T/ft² ment	kg/cm ²	
	kN		Shear ounder active cond	V_{ω}	533
	q_{EG}	Factor in Eslami and Fellenius me	Nominal shear capacity of the	MPa	534
	q _{equiv}	Equivalent bearing pressure	Chara tic shear load	kPa	275
	q_{max}	Maximum bearing pressure	Allowing shear load	kPa	162
	q_{min}	Minimum bearing pressure	Nomina lear load capacity	kPa	162
	q_i'	Net unit toe-bearing resistance	Nominal shear capacity on cr	kPa	500
	$(q_t')_m$	Mobilized unit toe-bearing resistar	nce lb/ft²	kPa	544
	qu' M	Reduced net unit toe-bearing resis	tance lb/ft ²	kPa	506
12	q_u	Unconfined compressive strength	Factor load	kPa	511
	quit V	Ultimate bearing capacity	Factored shear force on critic	kPa	176
154	r_{MM}	Distance from centerline of cap	Weight foundation	mm _W	615
	r_{N2}	Rigidity factor	Unitless Unitless	Unitless	219
	$R_{f_{1} = 0.75}$	Friction ratio	Unitless	Unitless	124
	$R_{I = I \cap U}$	Moment of inertia ratio	Unitless	Unitless	601
	RQD	Rock quality designation	Unitless	Unitless	511
	$R_{u=U}$	Ultimate resistance	Shrinkae limit	kN	566
	s_{mm}	Slope of foundation	radians	radians	587
564	S	Elastic section modulus	Depth nelow ground surface	mm^3	438
	S	Number of stories	Department of soil resis	Unitless	109
210	S	Degree of saturation	not lo mottod of w percent	percent	49
	S	Column spacing	Depth to imaginary footing	m	33
	S_0	Degree of saturation before wetting	g percent percent	percent	678
	S_1,S_3	Allowable lateral soil pressure	Wetting coefficient	kPa	593
	Unitles	Shear strength	lb/ft ²	kPa	84
	deg z	Center-to-center spacing of piles	Slope ni footing bottom	mm	540
	deg z	Pile set	Inclination of wall from vertic	mm	560
	Sc, Sq. Sy	Shape factors	Sidestinu factor in B metho	Unitless	184
759	Su gob	Undrained shear strength	Slope of ground surface	kPa	89
	UnitlesT	Torsion load	Reliath Ny index	m-kN	15
	UnitlesT	Thickness of foundation	Correlation factors	mm	146
	T_f	Torque at failure	Ratio dimeter to	N-m	131
	TMI	Thornthwaite moisture index	drikess dameter	Unitless	666
49	t m/vbl	Time indi-	Unit w it ght	yr	235
	Unitlest	Age of soil (since time of depositi		yr _Y	122

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u 1931	Displacement of pile	Net be ni lng	mm b	564
u mm	Pore water pressure	lb/ft ² /hau	kPa	59
u2 592	Pore water pressure behind cone point pages gains	d lb/ft ² /oliA	kPa	533
u_D and	Pore water pressure at bottom of foundation	d lb/ft²/ol/A	kPa	155
u _e sqM	Excess pore water pressure	alb/ft² T90	kPa	59
uh	Hydrostatic pore water pressure	lb/ft ²	kPa	58
kg/cmy	Shear load annual season of the season of th	Effecti y e con	kN	15
V_a	Shear force under active condition	k	kN	759
V_c^{a}	Nominal shear capacity of concrete	Factor dl Est	kN	309
V	Characteristic shear load	o to Ipeninba	kN	601
V	Allowable footing shear load capacity	Maximizm b	kN	276
KPa V	Nominal shear load capacity	Minimam be	kN	21
V BAN	Nominal shear capacity on critical surface	Net unditoe-	kN	309
V	Shear force under passive condition	m bakilidoM	kN ()	159
V	Nominal shear capacity of reinforcing steel	Reduced net	kN	309
V SYDI	Factored shear load	Unconkned	kN	21
V_{uc}	Factored shear force on critical surface	Ultimadl bea	kN	309
W_{ϵ}	Weight of foundation		kN	154
W_{r}	Hammer ram weight	RigididIfact	kN	560
Unitless	Moisture content	percent	percent	49
$w_L^{collino}$	Liquid limit otter stren	Unitless	Unitless	54
WP	Plastic limit	Unitless	Unitless	54
w.	Shrinkage limit	Unitless	Unitless	54
gnaiber	Lateral deflection	Slope of four	mm 2	598
mur	Depth below ground surface	Elasticnectic	m 2	564
Unitless	Depth to centroid of soil resistance	Numbah of s	m 2	544
per cent	Depth below to bottom of foundation	Degreenfof sa	m 2	210
z_I		Columnt space	m 2	552
percentz	Depth below to groundwater table 91018d accusate	Degreent sa	m ²	58
a Edi	Wetting coefficient soil pressure	Unitless	Unitless	678
kPa a	Adhesion factor	Unitless	Unitless	522
α mm	Slope of footing bottom	oo-degolno)	deg	183
α mm	Inclination of wall from vertical	deg	deg	764
BeltinU	Side friction factor in β method	Unitless	Unitless	516
β ETX	Slope of ground surface	deg	deg	759
β ^{MM} -m		Unitless	Unitless	724
β_0, β_1	Correlation factors	Unitless	Unitless	233
y m-M	reacto of other eage diameter to			
Unitless	drilled shaft diameter xabni sanatom s		Unitless	455
Y TY	Unit weight	lb/ft3	kN/m ³	49
γ TY	Load Factor (noision)	Unitless	Unitless	21

Notation	and Units o	f Measurement			xxiii
	Y6 592	Buoyant unit weight	22911 lb/ft ³ 5 lb I	kN/m³	49
	Yd AD	Dry unit weight virosque especial to	notinive lb/ft3 not2	kN/m ³	49
67	Yfill 951	Unit weight of fill	Preci 6th/ft dation st	kN/m ³	64
	Yw STM	AND TO SEE SEE SEE SEE SEE SEE SEE SEE SEE SE	lb/ft3 noH	kN/m ³	49
	y' Mi	Effective unit weight bool to	noisivelb/ft3 mail	kN/m ³	188
	$\Delta \sigma_z$	Change in vertical stress	m noish lb/ft²	kPa	64
	kPa 8	Total settlement	Repres ni native pas	mm 🗇	29
	δ_a 91	Allowable total settlement	Thresh ni d collapse	mm T	29
	8c RAN	Consolidation settlement	Horizo <mark>ni</mark> al total str	mm 👨	72
	δ_D	Differential settlement	Horizonial effective	mm	31
	δ_{Da}	Allowable differential settlement	Vertical stress	mm T	31
	δ_d 901	Distortion settlement	Verticalisticative si	mm	224
	Se again	Settlement due to elastic compression	Initial ni rical effec	mm	544
	δ_u	Settlement required to mobilize roled a fliggel			
	kPa	ultimate resistance	the ground surface	*****	544
	δ_w	Heave or settlement due to wetting		mm	680
	€50	Axial strain at which 50 percent of the soil strength is mobilized and apply the soul strength is mobilized.	Unitless	Unitless	603
	ϵ_f BTM	Strain at failure	Unitless Unitless	Unitless	95
	€ _w Egol	Strain due to wetting los mort liew no be	Unitless	Unitless	676
	Unitles	Factor in Shields' chart	Unitless	Unitless	286
	η gab		Unitless	Unitless	538
861	deg θ		Unitless DA	Unitless	539
	θ_a gob		radians	radians	33
	λ gab	Lightweight concrete factor		Unitless	319
225	Unitlesk	Factor in Shields' chart		Unitless	286
	V^{mitles}	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

49	$\sigma'_{\rm m}/{\rm M}$	Effective stress	Buoy ² th/dlnit weight	kPa	60
	σ_{C}	Standard deviation of ultimate capa	ncity migrow kan vill	kN	724
64	$\sigma_{c}^{\prime\prime}$	Preconsolidation stress	If to relb/ft2 tinu	kPa	67
	σ_{hs}	Horizontal swelling pressure	Unit \$17/dlat of water	kPa	691
188	σ_L	Standard deviation of load	Effecti & unit weight	kN	727
	σ_m	Preconsolidation margin	Chan the vertical spress	kPa 🗠	69
	σ_{p} mm	Representative passive pressure	Inamalb/ft ² isto	kPa 8	602
	σ_{t} mm	Threshold collapse stress	Allow 11/dl total settlement	kPa 8	708
	σ_{x} mm	Horizontal total stress	Conschilding settlement	kPa	61
	σ_{x}' mm	Horizontal effective stress	inemelias lib/ft2	kPa 8	61
	$\sigma_{z {\rm IRM}}$ -	Vertical total stress	Allow latterential settler	kPa	60
224	σ_{z}'	Vertical effective stress	Distoithidl settlement	kPa 8	60
544	σ_{z0}'	Initial vertical effective stress	Settle the to elastic con	kPa 8	64
	$\sigma_{z\mathrm{D}}{'}$	Effective stress at depth D below			
		the ground surface	ulumath/dlesistance	kPa	178
	σ_{zD}	Total stress at depth D below the g	round surface lb/ft2	kPa 8	175
	σ_{zf}'	Final effective stress gos and lo made		kPa	64
	σ_{zp}' binU	Initial vertical effective stress at de			
95		peak strain influence factor	Strain 1 dailure	kPa	234
676	UnitlesT	Shear stress imparted on wall from		kPa	760
	Unitles	Resistance factor	Fac splant Unitless chart	Unitless	21
	Unitles 9	Effective friction angle	Group geniciency factor	deg	82
	φ' _{adj}	Adjusted effective friction angle	Factor geb Converse-Labarre	deg (198
	$\phi_{T_{18},087}$	Total friction angle	nobrotzib rafugna degwollA	deg	85
	Unitlew	Wall-soil interface friction angle	Light gabent concrete factor	deg	763
286	Unitless	Three dimensional adjustment fact	or Unitless	Unitless	225
	$\Psi_{ m nitless}$	Factor in Shields' chart	Unitless Valential Correction factor	Unitless	286
			Factor in Evans and Duncan'		
		fluid density lb/ft ³			
	Unitless	tion Unitless	Allowable coefficient of frict		
	KN				
502					
564			Mass density		
			Ratio of volume of spiral rein		
459		Unitless	to total volume of core		
		lb/ft².			
		wall from soil lb/ft	Normal pressure imparted on		

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