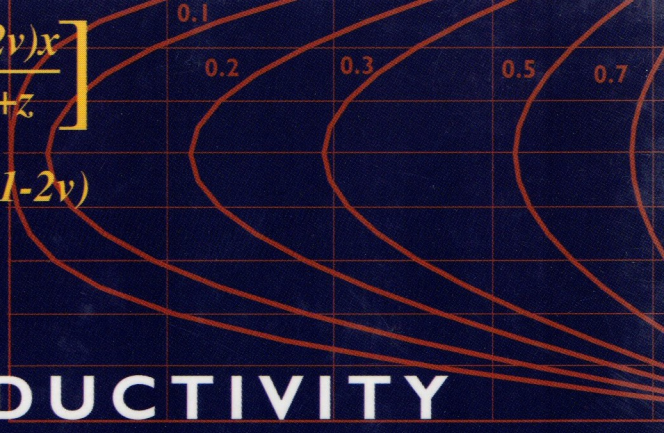
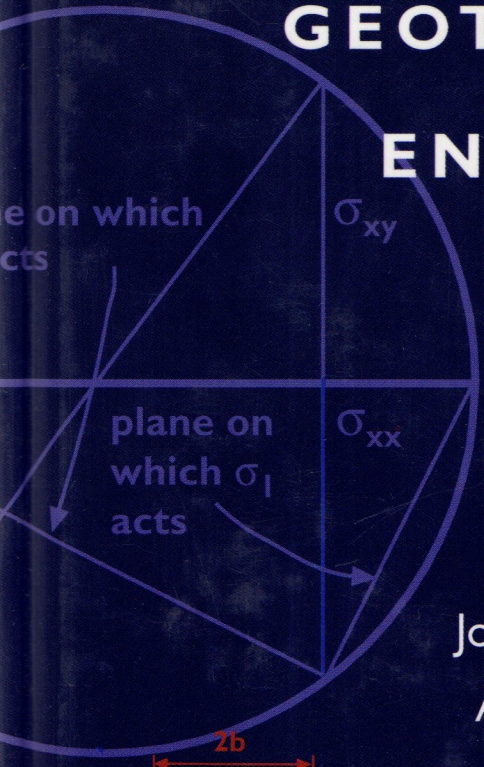
$$\frac{xz}{R^2} + \frac{(1-2v)x}{R+z}\Bigg]$$

$$\frac{x^2}{R^2} + (1-2v)$$



PRODUCTIVITY TOOLS FOR GEOTECHNICAL ENGINEERS

VOLUME I



$$\frac{Q(1+v)}{2\pi ER}\left[\frac{xz}{R^2} + \frac{(1-2v)x}{R+z}\right]$$

John T. Christian
Alfredo Urzua

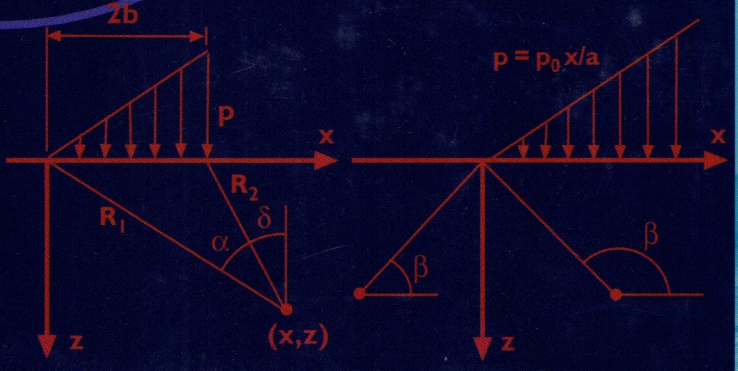


Table of Contents

1 Introduction 1

2 Stress Distribution in a Linearly Elastic Half-Space 7

2.1 Analysis of Stress 9
2.1.1 Definition of Stress 9
2.1.2 Geotechnical Sign Convention 12
2.1.3 The Importance of a Consistent Sign Convention 12
2.1.4 Coordinate Transformations in Two Dimensions 13
2.1.5 Three-Dimensional Stress 17
2.1.6 Equilibrium 20
2.1.7 Cylindrical Coordinates 21

2.2 Analysis of Strain 22
2.2.1 Definition of Infinitesimal Strain 22
2.2.2 Compatibility of Strains 25
2.2.3 Cylindrical Coordinates 26

2.3 Elastic Constants 27

2.4 Solutions of Problems in Linear Elasticity 30
2.4.1 The Boussinesq and Cerruti Solutions 31
2.4.2 Uniform Vertical Loading on an Infinite Strip 35
2.4.3 Linearly Varying Load on an Infinite Strip 35
2.4.4 Triangular Vertical Load on an Infinite Strip 36
2.4.5 Embankment Loads 37
2.4.6 Uniform Vertical Load on a Circular Area 39
2.4.7 Other Surface Loadings 39

2.5 The Computer Program STRESS 40
2.5.1 The Menu Structure in STRESS 40
2.5.2 The First or Main Menu 41
2.5.3 The Load Type Menu — Rectangular Loads 42
2.5.4 The Load Type Menu — Circular Loads 43
2.5.5 The Load Type Menu — Infinite Strip Loads 43
2.5.6 The Load Type Menu — Half the Infinite Surface 45

2.6	**Example Applications**	**45**
2.6.1	Vertical Load on an Irregular Area	46
2.6.2	Load on a Buried Water Pipe	49
2.6.3	Stresses under a Ring Foundation	52
2.6.4	Horizontal Stresses on a Wall	56
2.7	**References**	**59**
3	**One-Dimensional Settlement Analysis**	**61**
3.1	**One-Dimensional Settlement Analysis**	**63**
3.1.1	Westergaard's Solution	64
3.1.2	Compressibility Relationships	65
3.1.3	Computing the Estimated Settlement	68
3.2	**The Computer Program SAF-1**	**68**
3.2.1	The Main Menu	68
3.2.2	Options for the Soil Profile and Parameters	69
	3.2.2.1 Description in Terms of Compression, Recompression, and Swelling Indices	70
	3.2.2.2 Description in Terms of Compression, Recompression, and Swelling Ratios	72
3.2.3	Options for Vertical Stress Computations	72
3.2.4	Computing the Settlement	74
3.3	**Examples**	**74**
3.3.1	Settlement under a 5 ft. High Fill	75
3.3.2	Settlement of a Raft Foundation	78
3.3.3	Settlement of a Highway Embankment	82
3.3.4	Effect of Pumping under a Compressible Clay Layer	84
3.3.5	Settlement of a Foundation Supporting Nine Columns	87
3.4	**References**	**92**
4	**One-Dimensional Primary Consolidation Analysis**	**93**
4.1	**Assumptions in the Basic Theory**	**94**
4.2	**Derivation of the Basic Consolidation Equation**	**95**

4.3	**Conventional Solution of the Basic Problem**	**98**
4.3.1	Boundary and Initial Conditions	98
4.3.2	Solution for Uniform Initial Excess Pore Pressure	99
4.3.3	Simplified Solution for $T \geq 0.15$	101
4.4	**Solution of Basic Problem by Laplace Transform**	**101**
4.4.1	The Alternate Solution	101
4.4.2	Comparison of Approximate Solutions	104
4.5	**The Computer Program SAF-TR**	**105**
4.5.1	The Main Menu	105
4.5.2	The Pore Pressure Distribution Menu	106
	4.5.2.1 Input for the Rectangular Option	107
	4.5.2.2 Input for the Linear Option	108
	4.5.2.3 Input for the Sinusoidal Option	108
	4.5.2.4 Input for the Triangular Option	109
4.6	**Examples**	**109**
4.6.1	Time-Dependent Settlement of an Embankment	112
4.6.2	Pumping beneath a Compressible Layer	114
4.6.3	Settlement over Time in Taylor's Problem	115
4.6.4	Ramp Loading to Steady State	118
4.7	**References**	**119**

5	**Bearing Capacity of Shallow Foundations**	**121**
5.1	**Some Results from Plasticity Theory**	**123**
5.1.1	Material Behavior and Definitions	123
5.1.2	Limit Theorems	126
	5.1.2.1 The Lower Bound Theorem	126
	5.1.2.2 The Upper Bound Theorem	128
	5.1.2.3 Use of the Limit Theorems	129
5.1.3	Normality	129
5.1.4	Soil and Associated Flow Rules	131
5.2	**Bearing Capacity of Infinite Strips on the Surface**	**132**
5.2.1	Strip Load on Cohesive Material	132

5.2.2	Strip Load on Material with Cohesion, Friction, and Self-Weight	136
5.3	**Extensions of the Bearing Capacity Formulas**	**142**
5.3.1	Soil Properties	142
5.3.2	Correction Factors	143
	5.3.2.1 Meyerhof's Correction Factors	144
	5.3.2.2 Vesic's Correction Factors	145
5.4	**Two Layer Systems**	**148**
5.4.1	Vesic's Solution for Two Clay Layers	148
5.4.2	Stiff Frictional Soil over a Soft Layer	149
5.4.3	Soft Frictional Soil over a Strong Layer	151
5.5	**The Computer Program BCAF**	**151**
5.5.1	The Main Menu	151
5.5.2	The One Layer Soil System	152
	5.5.2.1 Input for the Footing Description Option	153
	5.5.2.2 Input for the Soil Description Option	153
	5.5.2.3 Input for the Bearing Capacity Factors Option	153
	5.5.2.4 Input for the Method of Analysis Option	154
	5.5.2.5 Input for the Options Choice	154
5.5.3	The Two Layer Soil System	155
5.6	**Examples**	**156**
5.6.1	A Simple Footing with Varying Depth of Water Table	156
5.6.2	An Embedded Footing with Two Surcharge Layers	162
5.6.3	Effects of Ground Slope and Tilted Foundation	165
5.6.4	A Two Layer Soil System	169
5.7	**References**	**174**
6	**Concluding Remarks**	**175**
6.1	**Analytical Abstraction and Approximation**	**176**
6.2	**Use of Computerized Tools in Practice**	**179**
6.3	**Errors, Bugs, and Undocumented Features**	**180**
6.4	**Future Developments**	**181**