NONLINEAR STRESS-DEFORMATION ANALYSES OF LAKE AGASSIZ CLAYS USING FINITE ELEMENT METHOD

by

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LIST OF SYMBOLS

Symbol	Meaning
a,b	Experimental constants
a,b	Soil constants determined by iteration
A,B	Semilogarithmic regression coefficients
$[A^{-1}]$	Displacement transformation matrix
b	Reciprocal of the asymptotic value of resultant deviatoric stress
b	Diameter of anchor shaft
B	Diameter of anchor base
$[B_{\alpha}]$	Strain displacement matrix
c	Cohesion (Mohr Coulomb strength parameter)
c'	Effective cohesion
[C]	Stress-strain matrix
C,D	Constants relating regression coefficient A and plasticity index
d	Slope of the transformed hyperbolic stress-strain relationship
D	Depth of anchor base
e	Element
e_i	Initial void ratio
e_{ic}	Void ratio after isotropic consolidation and expansion
E	Young's modulus
E	Number of elements in the global assemblage
E_i	Initial tangent modulus of elasticity
E_o	Initial tangent modulus of elasticity of soil when stress variant is zero

Symbol	Meaning
E_s	Initial tangent modulus of elasticity of soil under a given stress variant
E_z	Young's modulus as a function of depth
EL	Elastic type of soils
EP	Elasto-plastic type of soils
F	F-distribution value
G	Experimentally determined nonlinear parameter
G	Shear modulus
G_o	Initial tangent shear modulus
h	Height of an equivalent surcharge
h	Height of sample at any stage of test
h_c	Height of sample after isotropic consolidation and expansion
Δh	Change in height of sample
H	Vertical extent of failure surface
i	Stage of increment of loading
J_1, J_2	Stress invariants
K	Experimentally determined nonlinear parameter
K	Bulk modulus
$[K]$	Stiffness matrix for the whole continuum
K'	Modified bulk modulus
$[K_e]$	Expanded element stiffness matrix for an element
K_i	Initial bulk modulus
K_o	Coefficient of earth pressure at rest
K_u	Uplift coefficient
$[k_\alpha]$	Element stiffness

Symbol	Meaning
m	Modulus number
M	Tangent modulus
M	Number of increments
n	Experimentally determined nonlinear parameter
n	Shape parameter
n	Sample size
NC	Normally consolidated clays
NCQ	Normally consolidated quick clays
OC	Overconsolidated clays
OCQ	Overconsolidated quick clays
p	Atmospheric pressure
PI	Plasticity index
PL	Plastic type of soils
q	Uniform applied (base) pressure
$\{q\}$	Vector of nodal displacements&
Q_u	Critical uplift load
$\{Q_\alpha\}$	Element load vector
r	Radial coordinate
r	correlation coefficient
$\{R\}$	Load vector for the whole continuum
$\{R_e\}$	Expanded load vector for an element
R_f	Failure ratio
S	Shape factor
SS	Sandy soils
S_d	Resultant deviatoric stress

Symbol	Meaning
S_{df}	Resultant deviatoric stress at failure
S_{dult}	Asyptotic value of resultant deviatoric stress
S_i	Sum of squares between observed data and predicted values in an iteration
S_{ij}	Deviatoric stress component
T	Thickness of anchor base
$\{\bar{T}\}$	Vector known surface traction intensities for an element
u	Displacement in r-direction
UCK	Unconsolidated undrained triaxial test
v	Displacement in z-direction
V_c	Volume of sample after isotropic consolidation and expansion
ΔV	Change in volume of sample
$\{w\}$	Vector of displacement functions
W	Self weight of an anchor
W_E	External work
W_I	Internal work
$\{\bar{X}\}$	Vector of known body force intensities
$\Delta x^2, \Delta x^3$	Error terms
X,Q	Variables in three parameter relationship
X_y, Q_y	Characteristic values in three parameter realationship
y	Observed value
y'	Value predicted by regression
$\bar{y}$	Mean of observed value

Symbol	Meaning
z	Depth below surface
z,	Vertical coordinate
α	Positive constant indicating degree of deviation from linearity
α	Nonlinear coefficient of soil
α	Failure criterion parameter
$\{\alpha\}$	Vector of generalized displacements
β	Rate of increase of Young's modulus with depth
β	Nonlinear coefficient of soil
β	Failure criterion parameter
γ	Shear strain
γ	Unit weight of soil
γ_h	Hyperbolic strain
γ_{oct}	Octahedral shear strain
γ_r	Reference strain
δ	Uniform displacement
δ_{ij}	Kronecker delta
ε	Axial strain
ε_d	Resultant deviatoric strain
ε_{ij}	Strain components
ε_{kk}	Cubical dilation
ε_m	Isotropic strain
ε_m	Mean-normal strain
ε_{oct}	Octahedral normal strain
$\varepsilon_r, \varepsilon_z, \varepsilon_\theta, \varepsilon_{rz}$	Strains in cylindrical coordinates Strains in cylindrical coordinates

Symbol	Meaning
ε_v	Volumetric strain
ε_v	Isotropic strain
ε_{vc}	Characteristic isotropic strain
ε_{vd}	Normalized volumetric strain
ε_1	Axial strain
$\varepsilon_1, \varepsilon_2, \varepsilon_3$	Principal strains
θ	Angle
ν	Poisson's ratio
σ	Vertical stress
$\sigma_1, \sigma_2, \sigma_3$	Pricipal stresses
$\sigma_1-\sigma_3$	Principal stress difference
σ_c	Preconsolidation pressure
σ_{ij}	Stress component
σ_m	Isotropic stress (effective)
σ_m	Effective-mean-normal stress
σ_{mc}	Characteristic isotropic stress
$\frac{\sigma_m}{\sigma_c}$	Reduced consolidation ratio
$\left(\frac{\sigma_m}{\sigma_c}\right)_{cr}$	Critical reduced consolidation ratio
$\left\{\frac{\sigma_m}{\sigma_c \cdot e_{ic}}\right\}$	Combined variable
σ_{oct}	Octahedral normal stress

Symbol	Meaning
$\bar{\sigma}_{oct}$	Effective octahedral normal stress
σ_{ult}	A measure of shear strength
τ_{oct}	Octahedral shear stress
ϕ	Angle of internal friction (Mohr Coulomb strength parameter)
ϕ'	Effective angle of internal friction
$[\phi]$	Interpolation functions
Π	Potential energy of the global assemblage

ABSTRACT

For nonlinear stress-deformation analyses of soils, it is necessary to define the stress-strain behaviour of the soil in quantitative terms, and to develop techniques for incorporating this behaviour in the analyses. The stress-strain behaviour of Lake Agassiz clays was separated into mean normal and deviatoric components and the stresses and strains were interrelated through bulk and shear moduli.

Drained isotropic compression tests were used for the evaluation of bulk modulus. A three-parameter stress-strain relationship was used to represent the isotropic stress-strain data. Solutions were obtained for bulk modulus as a function of soil type, void ratio, and imposed stress system.

The shear modulus was investigated by drained constant-mean-normal-stress triaxial compression tests. The basic two parameter hyperbolic relationship in a modified form was used to represent the resultant deviatoric stress-strain data and an analytical expression was determined for the shear modulus. The solution for shear modulus was obtained as a function of soil type, previous stress history, failure criterion, void ratio, and imposed stress system.