Introduction to SOIL MECHANICS




Béla Bodó & Colin Jones

WILEY Blackwell

free companion website

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About the companion website

This book's companion website is at www.wiley.com/go/bodo/soilmechanics and offers invaluable resources for students and lecturers:

- Supplementary problems
- Solutions to supplementary problems

www.wiley.com/go/bodo/soilmechanics

Preface

This book is intended to introduce the subject to students studying for BTEC Higher National Certificate/Diploma in Civil Engineering and Building Studies or for a Degree in Civil Engineering. It should also be practical reference to Architects, Geologists, Structural and Geotechnical Technicians.

The primary aim is to provide a clear understanding of the basic concepts of Soil Mechanics. We endeavoured to avoid the temptation of over-elaboration by providing excessively detailed text, unnecessary at this early stage of technical studies.

The purpose of this publication is threefold:

1. To introduce the student to the basics of soil mechanics.
2. To facilitate further advanced study.
3. To provide reference Information.

In order to satisfy the above requirements, the concepts of the subject are defined concisely, aided by diagrams, charts, graphs, tables and worked examples as necessary.

The text may appear to be excessively analytical at first sight, but all formulas are derived in terms of basic mathematics, except for a few requiring complicated theory, for those interested in working from first principles. They can be applied however, without reference to the derivation. The expressions are numbered and referred to throughout the text.

There are numerous worked examples on each topic as well as supplementary problems. All examples and problems are solved, many of them interrelated so that solutions can be compared and verified by means of several methods.

Some soil testing procedures are outlined only, as there are a number of excellent, detailed, specialized books and laboratory manuals available to cover this part of the subject.

There is some emphasis on the units employed and on the difference between mass and weight. This subject is discussed in Appendix A.

Béla Bodó and Colin Jones

Dedication

"I dedicate this book to my late wife Dorie."
Béla Bodó

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List of Symbols

Chapter 1

CBR	California bearing ratio
C_r	Relative compaction
D_r	Relative Density
e	Voids ratio
G_s	Specific gravity
k	CBR Load-ring factor
M	Total Mass of sample
m	Moisture (water) content
m_o	Optimum moisture content
M_s	Mass of solids
M_w	Mass of water
n	Porosity
P	CBR applied force
P_a	Percentage of air voids
Q	CBR Load gauge reading
S_r	Degree of saturation
V	Total volume of sample
V_a	Volume of air
V_c	Volume of calibrating cylinder
V_s	Volume of solids
V_v	Volume of voids
V_w	Volume of water
W	Total weight of sample
W_s	Weight of solids
W_w	Weight of water
δ	CBR Penetration distance (delta)
γ	Bulk weight density (Gamma)
γ'	Submerged weight density
γ_d	Dry Weight density
γ_d	Dry Unit weight to be achieved by compaction
γ_s	Weight density of solids
γ_{sat}	Saturated weight density
ρ	Bulk mass density
ρ_d	Dry mass density
ρ_{sat}	Saturated mass density
ρ'	Submerged mass density
ρ_s	Mass density of solids

Chapter 2

C_d Correction for dispersing agent
C_m Meniscus correction
D Equivalent particle diameter
D_{10} Effective size of a particle
f Specific Volume change
H Height from the top of the bulb to surface
h_b Length of bulb
H_R Height of centre of bulb to surface
LI Liquidity index
LL Liquid limit
M_p Mass passing the n^{th} sieve
M_r Mass retained on the n^{th} sieve
m_T Temperature correction
N Number of blows
PI Plasticity index
PL Plastic limit
P_n Percentage of soil passing the n^{th} sieve
R Mixing ratio
R'_h Recorded hydrometer reading
R_h Corrected hydrometer reading
RI Relative consistence index
SL Shrinkage limit
T Temperature
t Time
U Uniformity coefficient
u Velocity of sedimentation
V_b Volume of hydrometer bulb
V_o Volume of over-dried specimen
$\approx$ Volume at SL
x Magnitude of linear shrinkage or swelling
Z Saturation limit
η Dynamic viscosity <eta>

Chapter 3

A Cross-sectional area of specimen
a Cross-sectional area of standpipe
A_s Cross-sectional area of solids in specimen
A_v Cross-sectional area of voids in specimen
EPL Equipotential line
FL Flow Line
F_s Factor of safety
GL Ground level
GWL Groundwater level (Water Table)

h Head loss
H_T Total head at x
H_x Head loss to point x
h_x Pressure head at x
i Hydraulic gradient
i_{av} Average hydraulic gradient
i_c Critical hydraulic gradient
i_e Exit gradient
k Coefficient of permeability
L Length of flow path
N_e Number of squares (head drops)
N_f Number of flow channels
N_x Number of head drops to point x
P Hydrostatic force
Q Flowrate
q Quantity of flow in time (t)
R Radius of influence
r Radius to observation well
r_o Radius of central well
S Seepage force
u_x Seepage pore pressure at x
Δh Head Loss between equipotential line
υ Discharge velocity
υ_s Seepage velocity

Chapter 4

I Influence factor
n Number of elements on the Newmark chart
Q Concentrated point load
q Uniformly distributed load (UDL)
r Radius
z Depth
σ Horizontal pressure
σ_v Vertical pressure
τ Shear stress

Chapter 5

dh Total deformation of specimen of thickness h
h_A Artesian pressure head
h_c Capillary head
h_s Seepage pressure head
i_c Critical hydraulic gradient
m_E Equilibrium moisture content
m_o Optimum moisture content
pF Soil suction index
PI Plasticity index
S_r Degree of saturation

S_s	Soil suction
T	Surface tension
u	Pore pressure
u_{cs}	Pore pressure in the capillary fringe
u_h	Static pore pressure at depth h
u_s	Seepage pore pressure
z_c	Critical depth for piping
Δu	Small change in u
$\Delta\gamma$	Change in unit weight
$\Delta\sigma$	Small change in σ
$\Delta\sigma'$	Small change in σ'
δ	Deformation of specimen at time t
σ	Total pressure
σ'	Effective pressure
σ_A	Artesian pressure

Chapter 6

A	Pore pressure coefficient
$\bar{A}$	Pore pressure coefficient
B	Pore pressure coefficient
c	Cohesion
c_u	Undrained shear strength
CD	Consolidated-drained test
CU	Consolidated-undrained test
ESP	Effective stress path
NCC	Normally consolidated clay
n	Proving ring constant
OCC	Over consolidated clay
$p\&q$	Stress path coordinates
$p_f\&q_f$	Stress path coordinates at failure
QU	Quick-undrained test
r_x	Force dial reading at x
TSP	Total stress path
UU	Unconsolidated-undrained test
x	Strain gauge reading
Δu_d	Change in pore pressure due to $\Delta\sigma_d$
Δu_c	Change in pore pressure due to $\Delta\sigma_c$
$\Delta\sigma_c$	Change in cell pressure
$\Delta\sigma_d$	Change in the deviator stress
ε	Strain at x
ϕ	Angle of friction
σ_n	Normal pressure
σ_x	Deviator stress at x
σ_u	Unconfined compression strength
τ	Shear stress
τ_f	Shear stress at failure
τ_p	Shear stress on a plain
τ_m	Maximum shear stress

Chapter 7

A_c Area indicating completed consolidation
A_t Area under an isochrone
a_v Coefficient of compressibility
C_α Coefficient of Secondary settlement () to consolidation
C_c Compression index
C_v Coefficient of consolidation
D_x Dial reading at stage *x*
dH_i Initial settlement
E Modulus of elasticity
e_0 Initial voids ratio
e_f Final voids ratio
e_s Voids ratio after swelling
e_x Voids ratio at stage *x*
H Layer thickness
H_0 Flow path
h_x Height of specimen at stage *x*
I_p Influence factor
k Coefficient of permeability
m_v Coefficient of volume change
OCR Overconsolidation ratio
q Bearing pressure
T_v Time factor
t Time
U Average degree of consolidation
U_z Degree of consolidation
u Pore pressure at time t
u_0 Initial pore pressure
ΔH Long-term consolidation settlement
$\Delta\sigma'$ Effective consolidating pressure
δ Depth factor (Delta)
$\propto$ Poisson's ratio (My)
σ'_x Effective pressure at stage x

Chapter 8

c_u Unconfined compression strength
c_w Adhesion between soil and wall
e Eccentricity
F_ϕ Factor of safety in terms of friction angle
f_{max} Maximum compressive stress
f_{min} Minimum compressive stress
F_s Factor of safety
H Height of wall
H_0 Height of unsupported clay
K Coefficient of lateral pressure

K_0 Coefficient of earth pressure at rest
K_a Coefficient of active earth pressure
K_f Coefficient of earth pressure at failure
K_p Coefficient of passive earth pressure
L Length of slip surface
M_{max} Maximum bending moment
M_O Overturning moment
M_R Resisting moment
P_a Active force
P_p Passive force
P_W Force of water in tension crack
R Force on wedge
T Tension force in tie rod
z_c Pile penetration
z_0 Depth of tension crack
δ Angle of wall friction
ϕ'_m Mobilised friction
μ Coefficient of friction
σ_a Active earth pressure
σ_c Cell pressure in triaxial test
σ_d Deviator stress in triaxial test
σ_p Passive earth pressure
σ'_a Effective active earth pressure
σ'_p Effective passive earth pressure
$\bar{\sigma}$ Average pressure
τ_f Shear stress at failure

Chapter 9

$\bar{c}_u$ Average undrained shear strength
A_e End bearing area
A_s Surface area of pile
B Width of footing
c Cohesion
F_O Overall factor of safety
F_s Factor of safety
K_s Average coefficient of earth pressure
l Length of pile
N Number of SPT blows
n Number of piles
N' Corrected value of N
N_c, N_q, N_γ Bearing capacity factors
P Failure load on pile
Q Design working load
Q_a Allowable carrying capacity of pile
Q_{ag} Allowable carrying capacity of pile group

Q_e End bearing resistance
Q_f Negative skin friction
Q_s Shaft resistance
Q_u Ultimate carrying capacity of pile
Q_{ug} Ultimate carrying capacity of pile group
q_n Net ultimate bearing capacity
q_s Safe bearing capacity
q_{sn} Safe net bearing capacity
q_u Ultimate bearing capacity
SPT Standard penetration test
W_P Weight of pile
α Adhesion factor (Alpha)
δ Angle of friction between soil and pile (Delta)
η Efficiency of pile group (Eta)
ϕ Angle of friction
σ Safe bearing pressure of footing
σ_n Net bearing pressure of footing
$\bar{\sigma}'_o$ Average effective overburden pressure
σ'_o Effective overburden pressure

Chapter 10

c_u Shear strength
F Friction force
F_C Factor of safety with respect to cohesion
F_S Factor of safety
F_ϕ Factor of safety with respect to friction
L Length of slip surface
M_D Disturbing moment
M_R Resisting moment
N Normal (or radial) component of W
N_C Stability number
R Radius of slip circle
r_u Pore pressure ratio
S Shear force
T Tangential component of W
W Weight

Chapter 11

The comprehensive list of symbols for EC7 is given in *Eurocode 7. Geotechnical design Part 1: General rule*. Only some of the symbols, applied in this book, are reproduced here:

E_d Design value of the effect of actions
$E_{dst;d}$ Design value of the effect of destabilizing action
$E_{stb;d}$ Design value of the effect of stabilizing action
F_d Design value of an action
F_{rep} Representative value of an action
F_s Factor of safety

$G_{dst;d}$ Design value of destabilising permanent action
$G_{stb;d}$ Design value of stabilising permanent action
$Q_{dst;d}$ Design value of destabilising variable action
R_d Design value of resistance action
$S_{dst;d}$ Design value of destabilising seepage force
T_d Design value of total shear resistance
$U_{dst;d}$ Design value of destabilising pore water pressure
$V_{dst;d}$ Design value of destabilising vertical action
X_d Design value of a material property
X_k Characteristics value of a material property
γ_G Partial factor for a permanent action
$\gamma_{G;dist}$ Partial factor for a destabilising action
$\gamma_{G;stb}$ Partial factor for a stabilising action
γ_m Partial factor for soil parameters (material property)
γ_Q Partial factor for a variable action
$\gamma_{R;h}$ Partial factor for sliding resistance

Contents