An Introduction to

Soil Mechanics and Foundations

THIRD EDITION

C. R. SCOTT
B.A., M.I.C.E., M.I.Struct.E.
Senior Lecturer in Civil Engineering, The City University, London

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Preface

This book is mainly intended to meet the needs of undergraduate students of Civil Engineering. A certain amount of factual information, in the form of design charts and tables, has been included. I hope, therefore, that the book will prove to be of use to the students when their courses are over, and will help to bridge the awkward gap between theory and practice.

In preparing the first edition of this book, I had two principal aims: firstly to provide the student with a description of soil behaviour—and of the effects of the clay minerals and the soil water on such behaviour—which was rather more detailed than is usual in an elementary text, and secondly to encourage him to look critically at the traditional methods of analysis and design. The latter point is important, since all such methods require certain simplifying assumptions without which no solution is generally possible. Serious errors in design are seldom the result of failure to understand the methods as such. They more usually arise from a failure to study and understand the geology of the site, or from attempts to apply analytical methods to problems for which the implicit assumptions make them unsuitable. In the design of foundations and earth structures, more than in most branches of engineering, the engineer must be continually exercising his judgement in making decisions. The analytical methods cannot relieve him of this responsibility, but, properly used, they should ensure that his judgement is based on sound knowledge and not on blind intuition.

In this third edition, a few minor alterations have been made to take account of recent research. The main changes, however, concern the core of the book, consisting of Chapters 5 to 8. These have been largely rewritten to place the study of soil strength and consolidation more firmly in the context of plasticity theory. Substantial changes have also been made in Chapters 9, 10 and 11 to allow a fuller discussion of the methods of analysis of lateral earth pressure, bearing capacity of foundations and the stability of slopes.

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Contents

List of symbols

The symbols used in the text conform, as far as possible, with the recommendations of BS 1991: Part 4: 1961. Other symbols have been chosen to conform generally with established usage. The reader should notice that, in conformity with BS 1991, the bulk density (γ) has, throughout this book, been defined as the weight density or unit weight (that is, the gravitational force per unit volume, measured here in kN/m^3). The significance of the more important symbols is given below.

A	air void ratio: area: pore pressure coefficient.
A_f	pore pressure coefficient A at failure.
a	area.
B	breadth: pore pressure coefficient.
b	breadth.
C_c	compression index: coefficient of curvature.
C_s	swelling index: compressibility of the soil skeleton.
C_u	uniformity coefficient.
C_v	compressibility of the pore fluid.
c	apparent cohesion (in terms of total stress).
c'	apparent cohesion (in terms of effective stress).
c'_e	Hvorslev's effective cohesion.
c'_r	residual value of apparent cohesion (in terms of effective stress).
c_u	apparent cohesion under undrained conditions (in terms of total stress).
c_v	coefficient of consolidation.
c_s	coefficient of swelling.
c_w	adhesion between soil and a retaining wall.
D	depth: diameter.
D_f	depth factor.
D_{10}	effective particle size.
d	depth: diameter: length of drainage path.
E	Young's modulus.
e	void ratio.
e_c	critical void ratio.
F	factor of safety.
F_c	factor of safety with respect to cohesion.
F_ϕ	factor of safety with respect to friction.
f	plastic potential function.
G_s	specific gravity of soil particles.
H	height.

H_c critical height of an unsupported vertical bank.
h height: total hydraulic head.
I_σ influence coefficient for stress below a foundation.
I_ρ influence coefficient for settlement of a foundation.
i hydraulic gradient.
i_c critical hydraulic gradient for unstable upward flow.
K coefficient of lateral earth pressure.
K_a Rankine's coefficient of active earth pressure.
K_{ac}, K_{aq}, $K_{a\gamma}$ general coefficients of active earth pressure.
K_p Rankine's coefficient of passive earth pressure.
K_{pc}, K_{pq}, $K_{p\gamma}$ general coefficients of passive earth pressure.
K_0 coefficient of earth pressure at rest.
k permeability.
L length.
LI liquidity index.
LL liquid limit.
l length.
m_v coefficient of volume change.
N Taylor's stability number for earth slopes.
N_c, N_q, N_γ bearing capacity factors.
n porosity.
P force.
P_a active thrust of earth on a retaining wall.
P_p passive resistance of earth to a movement of a retaining wall.
PI plasticity index.
PL plastic limit.
p pressure: mean normal stress $(=\sigma_1 + \sigma_2 + \sigma_3)$.
p' mean effective stress $(=\sigma'_1 + \sigma'_2 + \sigma'_3)$.
p_a active lateral earth pressure.
p'_c preconsolidation pressure (spherical consolidation).
p'_e equivalent consolidation pressure (spherical consolidation).
pF soil suction.
p'_i initial value of p'.
p_p passive lateral earth pressure.
q rate of flow: deviator stress $\left(=\frac{3}{\sqrt{2}}\tau_{\text{oct}}\right)$.
q_a allowable bearing pressure of a foundation.
q_f gross ultimate bearing capacity of a foundation.
q_n net foundation pressure.
q_0 surcharge load on the ground surface.
RD relative density.
R_p overconsolidation ratio (spherical consolidation).
R_σ overconsolidation ratio (one-dimensional consolidation).
r radius.

r_u pore pressure ratio.
S_r degree of saturation.
SL shrinkage limit.
T torque: time factor: surface tension.
T_v time factor (one-dimensional consolidation).
t time.
U_v degree of consolidation (one-dimensional).
$\bar{U}$ mean degree of consolidation.
u pore pressure.
u_a pore air pressure.
u_w pore water pressure.
V volume.
V_s volume of solids.
V_v volume of voids.
v velocity: specific volume ($=1 + e$).
W weight.
w water content.
w_{sat} saturated water content.
X body force in the (negative) x direction.
Z body force in the (negative) z direction.

β slope angle: inclination of x axis to horizontal: dilatancy angle.
Γ specific volume at the critical state for $p' = 1{\cdot}0$.
δ angle of wall friction.
γ bulk density (weight density): shear strain.
γ' submerged density (weight density).
$\dot{\gamma}$ shear strain rate (with respect to time).
γ^p plastic shear strain.
γ_d dry density (weight density).
γ_f density of fluid.
γ_p density of soil particles.
γ_{sat} saturated density (weight density).
γ_w density of water (weight density).
ε normal strain.
ε^p plastic component of normal strain.
$\dot{\varepsilon}$ normal strain rate (with respect to time).
η dynamic viscosity: efficiency of a pile group.
κ slope of an overconsolidation line on the v: $\log_e p'$ plane.
λ slope of the normal (spherical) consolidation line on the $v : \log_e p'$ plane.
M slope of the critical state line in a plane of constant specific volume.
M_0 slope of the state boundary surface in a plane of constant specific volume.
μ coefficient of friction.

N specific volume for normal (spherical) consolidation at $p' = 1{\cdot}0$.
ν Poisson's ratio.
ρ surface settlement.
σ total normal stress.
σ' effective normal stress.
$\sigma_1, \sigma_2, \sigma_3$ principal normal stress components.
σ_a, σ_r axial and radial stress components in a triaxial compression test.
σ'_c preconsolidation pressure. (one-dimensional).
σ'_e equivalent consolidation pressure (one-dimensional).
σ'_i initial consolidation pressure. (one-dimensional).
σ_n component of stress normal to a surface of sliding.
σ_{oct} octahedral normal stress.
σ_v vertical component of normal stress.
τ shear stress components.
τ_f shear strength.
τ_{max} maximum shear strength.
τ_{oct} octahedral shear stress.
Φ potential function
ϕ angle of shearing resistance (in terms of total stress).
ϕ' angle of shearing resistance (in terms of effective stress).
ϕ'_{cv} angle of shearing resistance at constant volume (in terms of effective stress).
ϕ'_e Hvorslev's effective angle of internal friction.
ϕ_u angle of shearing resistance for undrained conditions (in terms of total stress).
ϕ'_r residual angle of shearing resistance (in terms of effective stress).
ϕ_μ angle of friction at an intergranular contact.
χ coefficient defining effective stress in partially saturated soils.
Ψ stream function.