GEOTECHNICAL ENGINEERING HANDBOOK

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Preface

My aims in writing this book have been twofold: firstly to provide a text covering the more common aspects of site investigation procedure and geotechnical design practice; secondly to collect together a large number of design charts and tables which are commonly used in geotechnical engineering. It is intended primarily for use by practicing engineers and postgraduate and final year undergraduate students specialising in geotechnical engineering. I have assumed the reader will be familiar with the principles of soil mechanics.

The majority of the book is in the form of Data Sheets, each sheet or group of sheets covering a specific topic for easy reference. I have aimed to include sufficient design charts and tables for it to be used as a design manual and reference book for most straightforward projects.

Early chapters explain how to plan a site investigation, with information on such topics as the extent of boring, pitting and sampling required; boring, sampling and testing techniques and how these relate to site conditions and to the information needed for design work. The more common field and laboratory test procedures are described and the advantages, limitations and problems which can arise are discussed. Standard methods of describing and classifying soils are given. A chapter on site instrumentation gives the operating principles of extensometers, settlement gauges, pressure cells and piezometers, with discussion of the uses and accuracy of each type of instrument.

Later chapters are devoted to analysis and design. A chapter on seepage analysis describes the use of flow nets and electrical analogue paper. Modes of failure of soil slopes and the principles of slope stability calculations are discussed, with design charts for simple cases. Methods of calculating consolidation settlements for both cohesive and granular soils are described, whilst tables and charts of influence factors enable stresses and displacements beneath foundations to be calculated using elastic theory. Design procedures are given for spread and pile foundations, earth retaining walls and pavement thickness design.

In preparing this book I am particularly indebted to my colleagues Mr. D.O.M. Davies and Dr. M.V. Symons for their many helpful discussions and their work in checking the script, also to Miss L.M. Thomas whose skill and patience in typing the manuscript has never ceased to surprise me.

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1-4	Based broadly on classification systems proposed in *The Engineering Classification of Residual Tropical Soils,* A.L. Little, Proceedings of the 7th International Conference on Soil Mechanics and Foundation Engineering (Mexico, 1965); *The Logging of Rock Cores for Engineering Purposes,* British Geotechnical Society Engineering Group Working Party Report, Quarterly Journal of Engineering Geology, vol. 3 (1970); and *Tropical Lateritic Materials and their Use in Mechanically Stabilised Pavements,* D.W. Farthing, unpublished dissertation, Dept. of Civil Engineering, University of Salford (1972).
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SYMBOLS AND ABBREVIATIONS

A	area.
a	length, layer thickness coefficient, slice width.
AASHTO	American Association of State Highway and Transportation Officials.
ALD	average least dimension.
ASTM	American Society for Testing and Materials.
B	width of footing, width of sample.
b	width or half width of loaded area, slice width.
BS	British Standard.
C	cohesion force.
C_a	adhesion force.
C_r	resultant thrust.
c	cohesion, elastic rebound of piles.
c'	effective cohesion.
$\bar{c}$	average cohesion or average undrained shear strength.
c_a	adhesion.
c_v	coefficient of consolidation.
c_1	Hazen's formula factor.
CBR	California Bearing Ratio.
cm	centimetre.
D	diameter, depth, particle size.
d	diameter, depth, derivative.
∂	partial derivative.
dia	diameter.
deg	degrees.
E	Young's modulus, horizontal thrust between slices or wedges for slope stability analysis.
e	voids ratio, coefficient of restitution, distance, exponential constant (2.718281).
F	shape factor, factor of safety, force.
F_M	moment coefficient for lateral thrust on piles.
F_δ	deflection coefficient for lateral thrust on piles.
f	fall of rammer, coefficient of variation of soil modulus.
ft	foot.
G	shear modulus.
G_s	specific gravity of soil solids.
g	gram.
GW	groundwater level.
H	height, thickness, head of water.
$\bar{H}$	average thickness.
H_c	head in constant head permeability test.
h	height, depth of water in aquifer, hydraulic head.
ht	height.
hz	hertz (cycles per second).
I	influence factor.
I_E	exit hydraulic gradient.
i	hydraulic gradient, angle of incidence.
i_c	critical angle of incidence.
K	bulk modulus.
K_a	coefficient of active earth pressure.
K_h	coefficient of horizontal earth pressure.
K_o	coefficient of earth pressure at rest.
K_p	coefficient of passive earth pressure.
K_s	coefficient of earth pressure, undefined state.
K_v	coefficient of vertical earth pressure.
k	coefficient of permeability, coefficient of frictional loss.
kg	kilogram.
km	kilometre.
kN	kilonewton.
L	length of sample, test section, pile, etc.
l	litre.
ℓ	length of loaded area.

lb	pound.
LL	liquid limit.
log	logarithm.
LS	linear shrinkage.
M	moment.
m	metre, moisture content, mass or weight.
m_v	coefficient of compressibility.
max	maximum.
m/c	moisture content.
MDD	maximum dry density.
min	minute, minimum.
ml	millilitre.
MN	meganewton.
N	normal solution, normal force, number of blows per 300mm for SPT, number of blocks for Newmark chart, newton.
N_c	bearing capacity factor, correction factor for Newmark chart.
N_q	bearing capacity factor.
N_γ	bearing capacity factor.
Nm	newton-metre.
O	oxygen.
OMC	optimum moisture content.
P	pressure, load.
P_a	active thrust.
P_h	horizontal thrust.
P_p	passive thrust.
P_v	vertical thrust.
p	pressure.
p_a	allowable bearing pressure.
p_c	pressure behind braced excavation in clay.
p_{nu}	net ultimate bearing pressure.
p_o	overburden pressure.
p_s	pressure behind braced excavation in sand.
p_u	ultimate bearing pressure.
pen	penetration (bitumen grade).
pH	acidity ($-\log_{10}$ hydrogen ion concentration).
PI	plasticity index.
PL	plastic limit.
Q	load.
Q_b	ultimate end bearing load of a pile.
Q_s	ultimate skin friction and adhesion load of a pile.
Q_u	ultimate load capacity of a pile.
q	pressure, rate of flow.
R	resistance, thrust, radial distance, effective radius to source of flow, reduction factor, regional factor.
R_T	thrust on tie rods.
r	radius, angle of refraction.
r_u	pore water pressure ratio.
r_{ue}	critical pore water pressure ratio for Bishop and Morgenstern slope stability curves.
RC	rapid curing.
S	sulphur, settlement of plate or footing, spacing of piles, surcharge weight, sliding force, soil support value.
s	undrained shear strength, set.
SC	slow curing.
sec	second.
$\underline{SN}$	weighted structural number.
$\overline{SN}$	structural number.
SPT	standard penetration test.
sub	submerged.
T	basic time lag, stiffness factor, thrust.
T_v	time factor for consolidation settlement.

t	time, metric ton (1000kg).
t_{50}, t_{90}	time for 50%, 90% consolidation (etc.).
ton	long ton (2240lb).
TRRL	Transport and Road Research Laboratory.
u	pore water pressure.
V	volume, vertical load, flow.
vol.	volume.
W	weight.
w	weight of soil, width/length ratio of flow net.
w_s	weight of sand.
wt	weight.
X	vertical shear forces between slices for slope stability analysis.
x	horizontal co-ordinate direction, depth to point of contraflexure in sheet pile retaining walls.
y	horizontal co-ordinate direction, depth to point of zero shear force in sheet pile retaining walls.
z	vertical co-ordinate direction, depth, drawdown depth, length of drainage path.
z_c	critical depth in clays, above which active pressure is zero.
α	exponent, angle, slope angle, factor.
β	angle, slope angle.
γ	bulk density, shear strain.
γ_d	dry density.
γ_{sub}	submerged density.
γ_w	density of water.
δ	angle, angle of friction at interface, deflection, derivative.
ε	strain, movement of shear box.
Θ	bulk stress.
θ	angle.
λ	Lame's constant, Meyerhof's shape factor.
µm	micron (0.001mm)
ν	Poisson's ratio.
π	ratio of circle circumference/diameter (3.14159265).
ρ	settlement, Rowe's reduction factor.
ρ_{oed}	settlement calculated from oedometer test results.
Σ	summation.
σ	normal stress.
σ_1	maximum principal stress.
σ_3	minimum principal stress.
τ	shear stress.
ϕ	angle of shearing resistance.
ϕ'	effective angle of shearing resistance.
"	inch
$>, \geqslant$	greater than, greater or equal.
$<, \leqslant$	less than, less or equal.
$\simeq$	approximately equal.
▼	water surface level.

CONTENTS

Chapter 1

SOIL DESCRIPTION AND CLASSIFICATION

ENGINEERING SOIL

For civil engineering purposes, soil may be taken to include all material formed from aggregates of rock particles which can be separated by gentle mechanical means and excavated without blasting. This description will include many materials which are classified geologically as rocks and geologists often refer to soil defined in this general way as'regolith'. As rocks slowly weather into soils and soils are gradually transformed into rocks, so the distinction between the two is often vague.

Soils may be divided into two major groups: transported and residual. Transported soils predominate in temperate latitudes and residual soils are more common in tropical regions.

A broad classification of soil types according to their geological origins is given in Data Sheet 1-1.

SOIL DESCRIPTIONS

Soil descriptions are made from field observations and from disturbed and undisturbed samples taken from cuttings, excavations and boreholes.

Descriptions are usually based on particle size and plasticity and should contain information on some or all of the following properties, as appropriate:

(1) field strength or compactness,
(2) structure (bedding, discontinuities etc.) and state of weathering,
(3) colour,
(4) particle shape and composition,
(5) soil name, based on particle size,
(6) reference to inclusions.

Properties should be described in approximately the order given above. The directions and examples given in Data Sheet 1-2 summarise the information to be included and show the order and style of descriptions which are usually used. Some of the properties to be included in descriptions are discussed more fully in Data Sheet 1-3.

Soil descriptions based on particle size are often misleading when applied to residual soils or weathered rock, and Data Sheet 1-4 shows how this type of material may be described and classified.

The format of soil descriptions and the amount of information given will depend on the nature of the soil, the effort spent on the site investigation, the nature of the project and the style of reporting required by organisations involved. The aim should be to give reasonably detailed and consistent descriptions which convey the nature of the soils being described but descriptions should not be so long or so stylised that they are difficult to follow.

Often, similar material will be encountered in a number of pits