

SOIL MECHANICS Work Team at Hohai University

SOIL MECHANICS



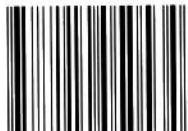
人民交通出版社
China Communications Press

www.dayi100.com

组稿编辑：陈志敏
文字编辑：边 金
美术编辑：姚亚妮

读者信箱：czmxc@263.net

ISBN 7-114-05053-4



9 787114 050534 >

ISBN 7-114-05053-4

定价：26.00 元

SOIL MECHANICS

SOIL MECHANICS Work Team at Hohai University

人民交通出版社

www.day100.com

内 容 提 要

教育部倡导在具备条件的高等院校中进行双语教学,许多院校都做了有益的探索和尝试。有些院校直接采用外文原版书进行教学,反馈意见各不相同。由于我国土木工程专业高等教育模式与国外存在较大差别,编制适合国内学生特点的本土英文版教材,成为国内院校的迫切需要。基于此,河海大学土木工程学院的几位教授在国内土力学教材的基础上,参照国外英文版图书的编写方式和风格,同时考虑国内学生的使用特点,精心编译而成此书。本书共分八章:第一章 土体的物理性质和岩土工程的分类;第二章 渗流;第三章 地基中的应力;第四章 地基的压缩和固结;第五章 土的抗剪强度;第六章 土压力理论;第七章 边坡稳定分析;第八章 地基承载力。每章后均附有习题、符号说明和部分专业英语词汇的汉译,供学生在使用本书时练习、参照。

本书可供高等院校土木工程专业及相关专业在开设土力学双语教学课程时使用。

图书在版编目(CIP)数据

土力学/施建勇等编著. —北京:人民交通出版社,
2004.8

ISBN 7-114-05053-4

I. 土… II. 施… III. 土力学-高等学校-教材
-英文 IV. TU43

中国版本图书馆CIP数据核字(2004)第035429号

书 名:SOIL MECHANICS

著 者:SOIL MECHANICS Work Team at Hohai University

责任编辑:陈志敏

出版发行:人民交通出版社

地 址:(100011)北京市朝阳区安定门外外馆斜街3号

网 址:<http://www.ccpres.com.cn>

销售电话:(010)85285838, 85285995

总 经 销:北京中交盛世书刊有限公司

经 销:各地新华书店

印 刷:北京牛山世兴印刷厂

开 本:787×1092 1/16

印 张:22

字 数:372千

版 次:2004年7月第1版

印 次:2004年7月第1版第1次印刷

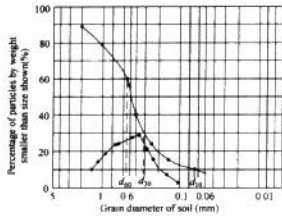
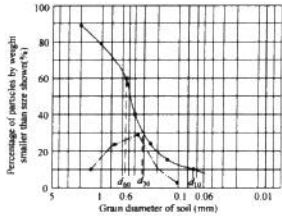
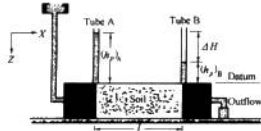
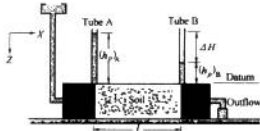
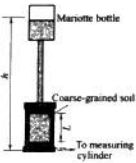
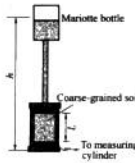
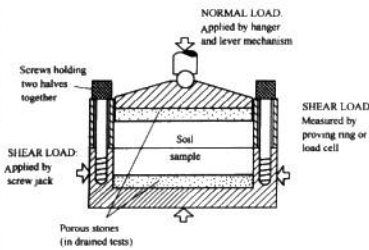
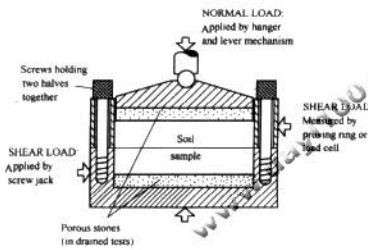
书 号:ISBN 7-114-05053-4

印 数:0001~2000册

定 价:26.00元

(如有印刷、装订质量问题的图书由本社负责调换)

www.day1700.com

页码	误	正
9	第 9 行...curve dotted...	...curve and dotted...
9	 <p>FIGURE 1-4 Particle size distribution analytical curves</p>	 <p>FIGURE 1-4 Particle size distribution analytical curves</p>
61	 <p>FIGURE 2-3 Head loss due to flow of water through soil</p>	 <p>FIGURE 2-3 Head loss due to flow of water through soil</p>
66	 <p>FIGURE 2-6 A constant-head apparatus</p>	 <p>FIGURE 2-6 A constant-head apparatus</p>
209	 <p>FIGURE 5-5 The direct shear test apparatus</p>	 <p>FIGURE 5-5 The direct shear test apparatus</p>


CONTENTS

CHAPTER 1 PHYSICAL PROPERTIES AND ENGINEERING CLASSIFICATION OF SOIL

1.1	Formation of Soil	1
1.2	Components of Soil	3
1.2.1	Solid Phase	4
1.2.2	Liquid Phase	13
1.2.3	Vapor Phase	16
1.3	Soil Fabric	16
1.3.1	Interaction between Soil Particles	16
1.3.2	Soil Fabric	18
1.4	Physical Features and Indexes of Soil	21
1.4.1	Basic Physical Indexes	21
1.4.2	Calculated Physical Indexes	23
1.4.3	Conversion between Physical Indexes	26
1.5	Relative Density of Cohesionless Soil, Consistency of Cohesive Soil and Soil Compaction	31
1.5.1	Relative Density of Cohesionless Soil	31
1.5.2	Consistency of Cohesive Soil	33
1.5.3	Soil Compaction	38
1.6	Soil Classification	43

CHAPTER 2 WATER FLOW THROUGH SOIL

2.1	Introduction	59
2.2	Driving Potential—Total Head	60
2.3	Darcy's Law	61
2.3.1	Darcy's Law	61
2.3.2	Validity of Darcy's Law	63



2.4	Determination of the Coefficient of Permeability	65
2.4.1	Empirical Relationships for k	65
2.4.2	Determination of k in the Laboratory	66
2.4.3	Pumping Test to Determine k in the Field	68
2.4.4	The Coefficient of Permeability of Soil Layers	70
2.5	Two-Dimensional Flow of Water through Soil and Flow Net	71
2.5.1	Laplace's Equation for Two-Dimensional Steady Flow	71
2.5.2	Flow Net	72
2.6	Effective Stress and Pore Water Pressure in soil	74
2.6.1	The Principle of Effective Stress	74
2.6.2	Effective Stresses due to Hydrostatic Stress Fields	75
2.6.3	Effects of Seepage	76
2.7	Seepage Force and Critical Hydraulic Gradient	78
2.7.1	Seepage Force	78
2.7.2	Heaving, Boiling, and Piping	79
2.7.3	Critical Hydraulic Gradient	79

CHAPTER 3 STRESSES IN SOIL

3.1	Introduction	88
3.2	Effective Overburden Pressure in the Ground	90
3.3	Contact Pressure between the Foundation and the Ground	93
3.3.1	Contact Pressure due to Vertical Centric Load	95
3.3.2	Contact Pressure due to Vertical Eccentric Load	96
3.3.3	Contact Pressure due to Inclined Eccentric Load	97
3.4	Stress Increase in the Ground	98
3.4.1	Stress Increase in Spatial Problems	99
3.4.2	Stress Increase in Plane Problems	118
3.4.3	Effective Overburden Pressure of Embankment and Contact Pressure between Embankment and Ground	128

CHAPTER 4 COMPRESSION AND CONSOLIDATION OF SOIL

4.1	Introduction	137
4.2	Soil Compressibility Characteristics	140



4.2.1	Fundamental Concept	140
4.2.2	The Oedometer Test	141
4.2.3	Compressibility Parameters	144
4.3	Calculation Formulae of Soil Compression with Zero Lateral Strain	147
4.4	$e-p$ Curve Method for Foundation Settlement Calculation	151
4.5	$e-\log p$ Curve Method for Foundation Settlement Calculation	161
4.5.1	Effect of Stress History on the Compressibility of Clays	161
4.5.2	Derivation of the In-Situ Compression Curve	164
4.5.3	Calculation of Foundation Settlement	170
4.5.4	Discussion	175
4.6	Terzaghi's Theory of One-Dimensional Consolidation	176
4.6.1	One-dimensional Consolidation Analogy	177
4.6.2	One-dimensional Consolidation Theory	180
4.6.3	Degree of Consolidation and its Application	184
4.7	Determination of Coefficient of Consolidation	189
4.7.1	The Log Time Method (Due to Casagrande)	190
4.7.2	The Root Time Method (Due to Taylor)	191
4.7.3	In-Situ Value of C_v	193
4.8	Secondary Compression	195

CHAPTER 5 SHEAR STRENGTH OF SOIL

5.1	Introduction	203
5.2	Friction Model in Physics and the Mohr-Coulomb Failure Criterion	203
5.2.1	Friction Model	203
5.2.2	The Mohr-Coulomb Failure Criterion	204
5.2.3	Failure Envelop	206
5.3	Shear Strength Test	208
5.3.1	The Direct Shear Test	208
5.3.2	The Triaxial Compression Test	210
5.3.3	The Unconfined Compression Test	215
5.3.4	The Vane Shear Test	215

www.EngineeringBooksPdf.com

5.3.5	Special Test	216
5.4	Pore Pressure Coefficients in the Triaxial Test	217
5.4.1	Coefficient B —Increment of All-round Pressure	218
5.4.2	Coefficient A —Increment of Difference of Main Principal Stresses	218
5.4.3	Pore Water Pressure during Triaxial Test	219
5.5	The Shear Strength Characteristics of Soil	219
5.5.1	The Shear Test Results of Sand	219
5.5.2	The Shear Test Results of Clay	221
5.5.3	Residual Strength	225
5.5.4	Sensitivity of Clay	227
5.5.5	Creep of Clay	227
5.6	Stress Paths and Concept of Critical State	229
5.6.1	Stress Paths	229
5.6.2	The Concept of Critical State	232

CHAPTER 6 EARTH PRESSURE ON RETAINING STRUCTURES

6.1	Introduction	242
6.2	Earth Pressure at Rest	244
6.3	Rankine's Lateral Pressure	246
6.3.1	Rankine's Theory of Active Earth Pressure	246
6.3.2	Rankine's Theory of Passive Earth Pressure	247
6.3.3	Backfill-Partially Submerged Cohesionless Soil Supporting a Surcharge	249
6.3.4	Cohesive Soil with Horizontal Backfill	251
6.3.5	Rankine's Active and Passive Pressure with Sloping Backfill	255
6.4	Coulomb's Earth Pressure Theory	257
6.4.1	Coulomb's Active Pressure	257
6.4.2	Graphic Solution for Coulomb's Active Earth Pressure	259
6.4.3	Active Force on Retaining Walls with Earthquake Forces	261
6.4.4	Coulomb's Passive Pressure	265
6.5	Active Thrust on the Bracing Systems of Open Cuts	267



6.6	Summary and General Comments	270
-----	------------------------------	-----

CHAPTER 7 SLOPE STABILITY

7.1	Introduction	274
7.2	Slopes in Cohesionless Soil	277
7.2.1	Slopes in Cohesionless Soil in General Cases	277
7.2.2	Slope with Seepage	278
7.3	Slopes in Cohesive Soil—Total Stress Analysis	280
7.3.1	Slope Failure Mechanism in Cohesive Soil	280
7.3.2	Total Stress ($\varphi_u = 0$) Analysis	281
7.3.3	Location of the Most Critical Circle	283
7.3.4	Simplified Chart Method	285
7.4	Swedish Method of Slices	287
7.4.1	Method of Slices	287
7.4.2	Total Stress Method	287
7.4.3	Effective Stress Method	289
7.5	Bishop's Simplified Method	292
7.6	Slope Stability in Practical Problems	295
7.6.1	Slope in multi-layered Soils or with Surcharge	295
7.6.2	Slope in Cohesive Soil with Steady Seepage	297
7.6.3	Effects of Earthquake on Slope Stability	300
7.7	Simplified Method for Compound Slip	302
7.8	Discussion	303
7.8.1	Critical Stage of a Practical Slope	303
7.8.2	Usage of Shear Strength of Soil	305
7.8.3	Allowable Factor of Safety	306

CHAPTER 8 BEARING CAPACITY OF FOUNDATIONS

8.1	Introduction	312
8.1.1	General Requirements of Foundations	312
8.1.2	Modes of Shear Failure	313
8.1.3	Various Definitions	315
8.2	Allowable Bearing Capacity Determined from Plastic Zone	315

8.3	Prandtl's Theory	319
8.4	Terzaghi's Soil Bearing Capacity Formulas	321
8.4.1	Rough Base	321
8.4.2	Smooth Base	325
8.4.3	General Method for Shallow Foundations	326
8.4.4	Skempton's Values of N_c for $\varphi_u = 0$ Soil	327
8.4.5	Hansen's Recommendations	328
8.4.6	Eccentric Loads	330
8.5	In-situ Bearing Tests	330
8.5.1	The Plate-Bearing Test	331
8.5.2	The Standard Penetration Test	331
8.5.3	The Cone Penetration Test	332
8.6	Code Recommendations for Bearing Capacity	334
8.7	Factors Influencing Bearing Capacity	334
8.7.1	Type of Soil and its Properties	335
8.7.2	Width of the Footing	336
8.7.3	Depth of Foundation	336
	REFERENCES	340

www.day100.com

PHYSICAL PROPERTIES AND ENGINEERING CLASSIFICATION OF SOIL

1.1 Formation of Soil

Soil, which is a complex mixture of inorganic matters that may or may not contain decomposed organic residues and other substances and which blankets the crust, is formed by the process of weathering, that is, disintegration and decomposition of rock and mineral at or near the earth surface through the action of many naturally physical or mechanical and chemical agents into smaller and smaller particles. The two latter kinds of weathering process are concomitant and occur simultaneously.

The destructive process in the formation of soil from rock may be either physical or chemical. The physical process may be erosion by the action of wind, frost, rain or snow, or the action of various forces by the impact of wave and earthquake, or the variation of temperature and freezing and thawing in the rock. These processes caused cracks in the whole rock, and disintegration and fracture and debris came into being. For example, the thermal stress caused by the cooling of rock mass or the change of temperature in the ground surface nearby can cause cracks in rock mass. Rain in these cracks can cause these cracks open after freezing and expansion. Rock mass can disintegrate into debris, and debris becomes smaller and smaller in the same process. In dry land, the impact of sandstone and gravel can also cause cracks in rock mass. The weathering action can only change the sizes and shapes of particles and can't change the mineral composition of rock. The chemical process results in changes in the mineral form of the

parent rock due to the action of oxygen, carbon dioxide and water (especially if it contains traces of acid or alkali). In general, natural soil is not only the result of physical weathering but also the result of chemical weathering.

On the basis of its origin, soil can be divided into two large groups, those that consist chiefly of the results of chemical and physical rock weathering, and those that are chiefly of organic origin. If the products of rock weathering are still located at the place where they originated, they constitute residual soil. Otherwise they constitute transported soil, regardless of the agent that performed the transportation.

Residual soils are those which have been left in place as a result of decay of the underlying parent rock. Residual soils that have developed in semiarid or temperate climates are usually stiff and stable and do not extend to great depth. However, particularly in warm humid climates where the time of exposure has been long, residual soils may extend to depth of hundreds of meters. They may be strong and stable, but they may also consist of highly compressible materials surrounding blocks of less weathered rock. Under these circumstances they may give rise to difficulties with foundations and other types of construction. Residual soils are usually encountered in south of the terminal moraine. In glaciated areas residual soils are buried by glacial drift because there may be more than one terminal moraine. The parent materials for residual soils are igneous rocks such as granite or basalt, and sedimentary rocks such as limestone, sandstone, and shale.

Transported soils are those which have been transported by flood, wind and glaciers as a result of decay of the underlying parent rock. Transported soils are mainly the following kinds:

Alluvial Soils: Alluvial soils occur in former and present flood plains and deltas, and often form very thick deposits.

Wind-borne Soils: Under this group two kinds of soil material may be included, namely: loess and dune sand. Wind-borne soils are ones which have been transported and laid down by atmospheric currents such as wind. Loess is wind-blown silt or silty clay, light in color, porous and coherent. Loess as construction material is relatively unknown to engineers. Loess often may turn out to be a very dangerous material for dams, highways, and a support of foundations, particularly when wetting. Dunes develop when and where loose sand is exposed to wind



www.Engineering100.com

(sandy shores of lakes, rivers, seas).

Glacial Soils; Glacial soils are those which have been transported and deposited by glaciers. The principal glacial deposits are of the Pleistocene Epoch. The glacial ice sheet filled up river valleys with the so-called glacial drift. Glacial drift is the glacial deposit from all types of the superficial materials of rock debris of any sort, handled in any way, by the continental glacier—for example by erosion, transportation, deposition from ice, or running meltwaters emanating from the ice. The glacial deposits may be sorted, assorted, or stratified. These deposits consist of boulders, rock fragments, gravel, sand, silt, and clay in various proportions. One of the engineering aspects of glacial soils relative to foundation engineering is the thickness of the glacial drift. On ridges of bedrock the glacial drift may be thin, whereas in preglacial valleys the glacial drift may be thick. Excavation operations in glacial till (unsorted, unstratified, unconsolidated, heterogeneous material) in a dense state require a power shovel or explosives. Ordinarily, however, excavations in glacial till present no problem.

Marsh Soils; Marsh soils denotes soil deposit in muckland. They are a mixture of finely particled, inorganic soil and black, decomposed organic matters.

1.2 Components of Soil

The composition of natural soil may include solid particles and voids between particles, where the voids are filled with water and gas. As the mixture of solid particles, water and gas, soil falls into three phases; (1) solid mineral particles, which called solid phase; (2) water in various forms and states, which called liquid phase; and (3) gaseous inclusions, which called vapor phase. When the hole of the soil framework is all filled with water, this kind of soil calls saturated-soil; When the hole of the soil framework contains the air only, this kind of soil calls dry-soil; When the hole of the soil framework contains air and water, this kind of soil belongs to three mutual department and calls wet-soil, and it was founded above underground water level and below ground surface.

Research shows that the various components proportion of three phases will affect the engineering properties of soil, which will be discussed as the following.

1.2.1 Solid Phase

1. Soil-forming mineral

The mineral components which form soil particles vary with the mineral components of parent rock and weathering. Soil-forming minerals include two major types; one type is original mineral, which includes quartz, feldspar, isinglass, hornblende and pyroxene. The soils formed through physical weathering consist of single or combined original minerals commonly. The particles present the characteristics such as coarseness, roundness, piece form or plank form in size; and weakly water-absorbing, stable property, without plasticity in property which are similar with the parent rock. Another type is secondary mineral, which is formed through chemical weathering of original mineral, and has the components different from parent rock. Secondary mineral consists mainly of clay mineral, where kaolinite, illite, montmorillonite are familiar. The particles forming secondary mineral present very small in size and flaky and needle in shape, which result in the characteristics of unstable property, strong water-absorbing (especially for the particles consisting of montmorillonites), volume-expanding and plasticity.

2. Crystal structure of clay mineral

Clay mineral, the most one of the secondary mineral and the main constituent part of clay particle group, is made of aluminosilicate mineral which is produced mainly from the decomposing of various silicate minerals. Clay mineral is classified as crystal and non-crystal by structure, whereas crystal component is most. Crystal means that atoms and ions regularly arrange in space. Various geometrical array forms call crystal structure, and the minimal cell of crystal structure calls crystal cell. Clay mineral forms soil depending on the basic composing of silicon-oxygen tetrahedral unit and aluminum (magnesium)-oxyhydrogen (oxygen) octahedral unit. The silicon-oxygen tetrahedron unit, comprising a central silicon ion with four surrounding oxygen ions, shows in Fig. 1-1a). The tetrahedron units combine to form a silica sheet as shown in Fig. 1-1b). Note that the three oxygen ions located at the base of each tetrahedron are shared by the neighboring tetrahedra. The aluminum (magnesium)-oxyhydrogen octahedral unit, consisting of a aluminum ion at the center and six oxygen ions at corner, shows in Fig. 1-2a). The combina-



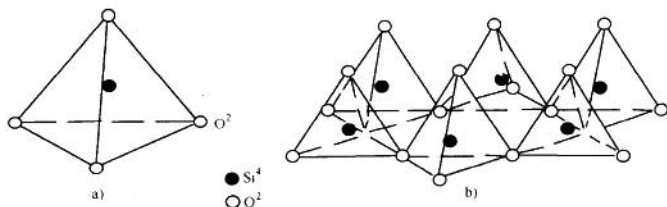


FIGURE 1-1 Basic unit and structure of aluminium

tion of the aluminum octahedral units forms a gibbsite sheet, shown in Fig. 1-2b). Kaolinite is the outcome of feldspar erosion by the action of wind, and it consists of a structure based on a single sheet of silica tetrahedron combined with a single sheet of alumina octahedrons. Montmorillonite has a basic structure consisting of a sheet of alumina octahedrons and combined with two sheets of silica tetrahedrons, and there is a very weak bond between the combined sheets, so the space between the combined sheets is occupied by water molecules and (exchangeable) cations. Considerable swelling of montmorillonite can occur due to additional water being adsorbed between the combined sheets. Illite has the same basic structure as Montmorillonite, but there is a very strong bond between the combined sheets due to the existing of potassium ion.

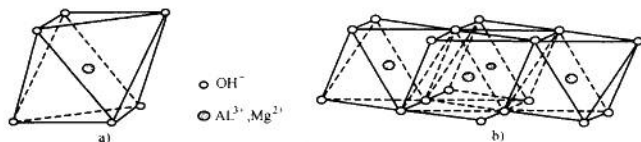


FIGURE 1-2 Basic unit and Structure of magnesium

Clay mineral is composed of basic units mentioned above with different formation. Sometimes Si ion or Al ion, which is located at the center of the unit, can be replaced by other ions such as Fe, Mg etc, thus the physical and chemical properties of particles will change, although their structural style is unchanged. This phenomenon is called isomorphous replacement or homeotype replacement.

3. The size and gradation of solid soil

As mentioned above, the size of solid particles relates to the soil-forming minerals, and the particle sizes reflect the property of soil at some degree. As a natural

www.bay100.com

production, soil consists of countless particles which have different shapes, so it is unnecessary and impossible to study the size of particles. An alternative method used in engineering is classifying the particles which have the similar size and property as grain group. The grain group which are used commonly in engineering is boulder grain, cobble grain, sand grain, silt grain, clay grain, colloidal grain.

The definition for grain group varies with countries, even departments in a country. Table 1-1 shows the definition in 《Soils test regulation(GB 237—1999)》 by The Ministry of Water Resources of the People's Republic of China.

Table 1-1 Classes of the grain group defined by The Ministry of Water Resources of the People's Republic of China

Generic terms of soil particles	Division of soil particles		Range of particle size (mm)
Huge particle group	Float stone(block stone)group		$d > 200$
	Pebble (macadam)group		$200 \geq d > 60$
Gross particle group	Pebble particle (breccia)	Coarse gravel	$60 \geq d > 20$
		Middle gravel	$20 \geq d > 5$
		Fine gravel	$5 \geq d > 2$
	Grains of sand	Coarse sand	$2 \geq d > 0.5$
		Middle sand	$0.5 \geq d > 0.25$
		Fine sand	$0.25 \geq d > 0.075$
fine particle group	Silt		$0.075 \geq d > 0.005$
	Clay		$d \leq 0.005$

The particle content of grain group in soil is defined as the ratio of mass of total particles and that of dry soil in percent style. The particle size distribution is described as the percentage by mass of particles within the different size range, which represents the property of soil. A well grading soil can reach a high degree of density after compacting, thus, which exhibits weak permeability, high strength and low compressibility. Whereas, the poor grading soil has the opposite properties.