SOIL MECHANICS Work Team at Hohai Uni versity

SOIL MECHANICS

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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

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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。

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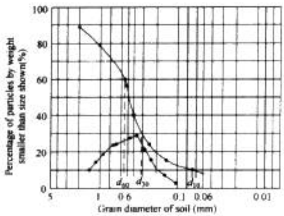
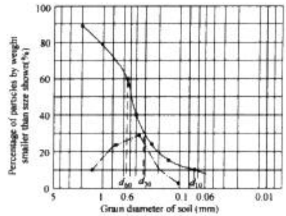
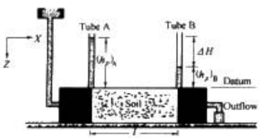
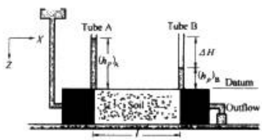
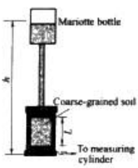
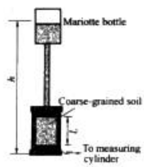
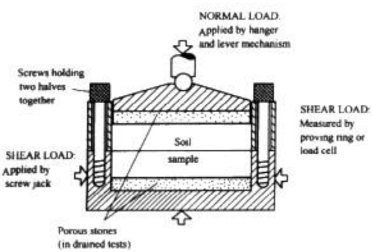
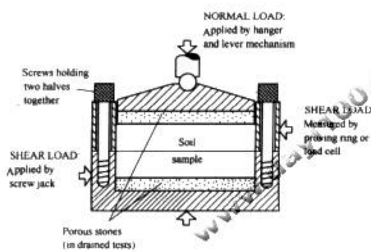
9	 FIGURE 1-4　Particle size distribution analytical curves	 FIGURE 1-4　Particle size distribution analytical curves
61	 FIGURE 2-3　Head loss due to flow of water through soil	 FIGURE 2-3　Head loss due to flow of water through soil
66	 FIGURE 2-6　A constant-head apparatus	 FIGURE 2-6　A constant-head apparatus
209	 FIGURE 5-5　The direct shear test apparatus	 FIGURE 5-5　The direct shear test apparatus

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CHAP 1

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 debrises 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 induded, 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, particulary when wetting. Dunes develop when and where loose sand is exposed to wind (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 characteritics 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-oxgen 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-

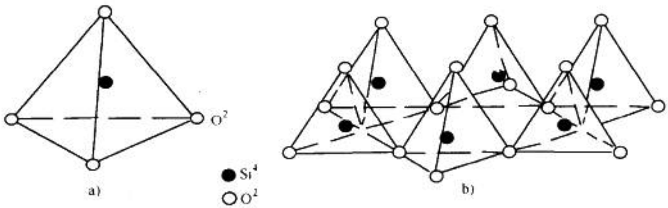

FIGURE 1-1 Basic unit and structure of aluminium

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 tetra hedron 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 kalium ion.

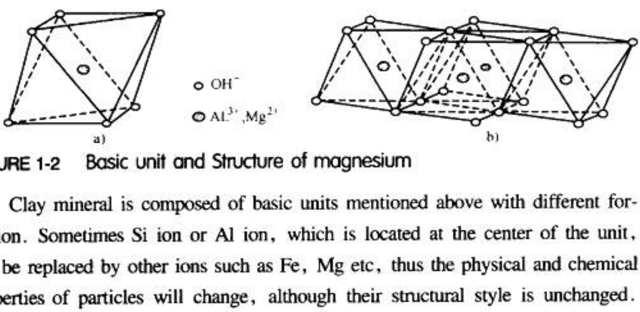

FIGURE 1-2 Basic unit and Structure of magnesium

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 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(SL 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.