普通高等教育土木与交通类“十三五”规划教材

岩土工程概论（中英双语）

主　编　刘爱华
副主编　唐丽燕　李　青　赖佑贤

中国水利水电出版社
www.waterpub.com.cn

普通高等教育土木与交通类“十三五”规划教材

岩土工程概论（中英双语）

主　编　刘爱华
副主编　唐丽燕　李　青　赖佑贤

中国水利水电出版社
www.waterpub.com.cn
·北京·

内 容 提 要

本教材既考虑岩土工程课程专业知识上的系统性，也兼顾科技英语学习的基本特点与要求，通过优化教材内容，实现专业知识的学习和科技英语能力的培养提高，达到双赢目标。内容涵盖岩土工程的基本分类方法与典型岩土工程，岩土材料的力学特性和测试方法，岩土工程相关计算理论、设计方法、施工技术和装备，岩土工程常见工程灾害与防治，数值化技术与岩土工程的关系以及学科领域的研究热点和前沿等内容。章与章之间既相互联系，又可自成一体，方便满足不同层次读者的需求。

本教材可作为高校土木、水利、建筑、交通及其他岩土工程类专业学生的双语教材，也可作为相关学科领域研究生以及工程技术与科研人员的学习参考资料。

图书在版编目（CIP）数据

岩土工程概论 : 汉、英 / 刘爱华主编. -- 北京 : 中国水利水电出版社, 2016.11
普通高等教育土木与交通类“十三五”规划教材
ISBN 978-7-5170-4915-9

Ⅰ. ①岩… Ⅱ. ①刘… Ⅲ. ①岩土工程－高等学校－教材－汉、英 Ⅳ. ①TU4

中国版本图书馆CIP数据核字(2016)第280665号

书　　名	普通高等教育土木与交通类“十三五”规划教材 **岩土工程概论（中英双语）** YANTU GONGCHENG GAILUN（ZHONGYING SHUANGYU）
作　　者	主编　刘爱华　副主编　唐丽燕　李　青　赖佑贤
出版发行	中国水利水电出版社 （北京市海淀区玉渊潭南路1号D座　100038） 网址：www.waterpub.com.cn E-mail：sales@waterpub.com.cn 电话：（010）68367658（营销中心）
经　　售	北京科水图书销售中心（零售） 电话：（010）88383994、63202643、68545874 全国各地新华书店和相关出版物销售网点
排　　版	中国水利水电出版社微机排版中心
印　　刷	北京瑞斯通印务发展有限公司
规　　格	184mm×260mm　16开本　15印张　397千字
版　　次	2016年11月第1版　2016年11月第1次印刷
印　　数	0001—3000册
定　　价	**38.00**元

主 编 简 介

刘爱华 男，1963 年 3 月生，湖南邵东人，博士、教授、博士研究生导师。国际岩石力学学会会员，中国岩石力学与工程学会工程实例委员会委员，企业安全生产标准化建设指导与评审专家。长期从事岩石力学计算方法与理论、岩土工程加固机理与灾害防治以及安全管理工程等领域的教学与科研工作。

1983 年毕业于中南矿冶学院（中南大学），1988—1995 年公派留学法国，获国立巴黎高等矿业学校硕士和博士学位，并在巴黎第十二大学完成博士后工作。留学法国期间，主要研究方向为岩石力学与工程地质理论及其应用。1995—1997 年任职中南工业大学（中南大学），1996 年晋升为教授。1997—2004 年在美国工作，曾就职于 CPI 和 IBM 等公司。2004—2013 年任中南大学教授、博士研究生导师，2013 年 12 月调入华南农业大学水利与土木工程学院。

曾获教育部 1995 年度“优秀青年教师资助计划”、国家教委优秀留学人员基金、IET 等多种奖励。主持或承担过多项基金研究和横向科研项目，曾担任“973”项目子课题负责人 1 次以及“973”项目研究骨干 1 次；科研成果获得过省部级科技进步特等奖、一等奖、二等奖等奖励；教学研究成果获得过校级教学成果一等奖及省级教学成果二等奖。已出版著作 4 部，发表科研论文 80 多篇，获国家发明专利授权 1 项。

E-mail：alexliu@163.com

Editor in chief

Liu Aihua, male, born in March 1963, Shaodong, Hunan, is a Ph. D, Professor, Ph. D tutor. Professor Liu is a member of the International Association of Rock Mechanics, committee member of the Real Engineering Cases Association of Rock Mechanics and Engineering in China, and expert both in construction and evaluation of enterprise safety production standardization. His major research fields include calculation methods and theories of rock mechanics, reinforcement mechanisms of rock and soil engineering, and safety management engineering.

Mr. Liu graduated from Central South Institute of Mining and Metallurgy (Central South University) in 1983 and obtained a Bachelor's Degree in Mining Engineering. Mr. Liu had a long experience of overseas studies. He studied in Ecole Nationale Superieure des Mines de Paris, France, from 1988 to 1993, and obtained Master's Degree (1989) and Ph. D Degree (1993) in Rock Mechanics and

Engineering Geology, then completed a post-doctoral work at the University of Paris Ⅻ (1993—1995). Mr. Liu had worked at Central South University of Technology (Central South University) from 1995 to 1997, and was promoted to Professor in 1996. From 1997 to 2004, Mr. Liu had accumulated some good working experiences both in CPI and IBM in USA. Then Mr. Liu came back to Central South University in 2004 and worked as Professor and Ph. D tutor. Since December 2013, Mr. Liu has been working at the College of Water Conservancy and Civil Engineering, South China Agricultural University.

Mr. Liu was awarded as outstanding young teacher for the year 1995 by the National Ministry of Education. He was also awarded by the State Education Commission Outstanding Overseas Ph. D Students Fund, IET and other incentives. Mr. Liu Chaired or undertook a number of provincial and ministerial fund research projects and enterprise scientific research projects, served as the team leader for a "973" sub-project once and the "973" project main researcher once, won the provincial and ministerial scientific and technological awards many times, including grand prize, first prize, second prize, etc. won also a second prize in the provincial teaching achievement awards. Mr. Liu has published 4 books and more than 80 research papers, and owns 1 national invention patent as well.

E-mail: alexliu@163.com

PREFACE 前言

世界上以英语作为官方语言的国家多达171个，占国家总数的88.6%。在国际交流日益频繁和广泛深入的今天，作为世界上使用最广泛的语言——英语，其影响力早已席卷全球。英语的作用远远超出了作为一种语言在人民生活的方方面面所发挥的沟通交流作用，还关系到科学技术的革新、人类文明的进步以及世界的协同发展。在各行各业竞争越来越激烈的国际大环境下，具有较强的英语听说读写能力并能自如地将这种能力用于工作和生活之中，是决定一个人，尤其是高层次人才能否在事业和生活上更容易地获得较大成功的重要因素之一。因此，改变传统的教育理念，在人才培养过程中强调知识的活学活用，树立能力培养优先原则，发挥高等院校在人才培养上的优势，把年轻一代培养成具有扎实理论基础和系统专业知识的，具有国际视野和较强的使用专业外语进行学术交流沟通、自身能力培养和提高的卓越学习型人才，是新时期教育工作者义不容辞的职责。

随着改革开放的全方位深化与持续，高等院校教育教学改革也在加紧推进，培养国际化专业人才已经成为一种现实需求。在高校人才培养大纲中增设一定数量的双语专业课程，正在成为一种可以有效提高工科类学生专业英语听、说、读、写能力的重要手段，而且越来越受重视。事实上，在高校设置一定数量的双语教学课程既获得了教育管理部门的政策鼓励，也越来越受到广大师生的认可。然而，目前国内专业性较强的双语教材总量较少，既考虑专业知识的系统性，又兼顾科技英语学习技巧和专业英语能力培养的优秀双语教材就更少。

岩土工程类专业涵盖的范围较广，土木工程、岩土工程、水利水电工程、城市地下空间工程、建筑、交通、桥隧、港口码头等均与岩土工程关系密切。《岩土工程概论》是高校岩土工程类专业学生的重要专业基础课程。在专业课时被严重压缩的高校教学改革大环境下，将《岩土工程概论》设置成双语课程，既能教给学生有关岩土工程学科的系统专业基础知识，同时也能更有效地提高学生学习英语的兴趣，扩展学生专业词汇量，掌握常见科技英语表达模式，培养大学生专业科技英语的综合运用能力，为实现国际化人才的培养目标服务。基于该课程的教学改革项目“工程类本科生专业英语实际运用能力培养模式创新研究（GDJG20142093）”获2014年度广东省高等教育教学改革立项，为本教材的编写提供了支撑。

本书主编刘爱华教授长期从事岩土工程领域相关研究与教学工作，并获得过湖南省第十届高等教育教学成果二等奖，先后为本科生及研究生开设过《有限单元法及应用》《职业安全管理工程》及《岩土工程概论》等双语课程，能较好地把握专

业双语课程在学习内容和形式上的特殊要求。华南农业大学水利与土木工程学院每年向8个土木工程专业班和3个水利水电工程专业班超过300名的学生开设了本课程，教学效果良好。

《岩土工程概论》(General Introduction to Geotechnical Engineering) 以大学土木、水利、建筑、交通及其他岩土工程类本科学生为主要使用对象，兼顾研究生以及相关工程领域的科研与技术人员学习参考之需要，既考虑该课程专业知识上的系统性，同时兼顾科技英语学习的基本特点与要求，以中、英双语形式系统介绍岩土工程专业基础知识。本教材能帮助读者在学习岩土工程专业知识与技术的同时，在科技英语的听、说、读、写等综合能力上也得到同步锻炼，取得进步。

《岩土工程概论》(General Introduction to Geotechnical Engineering) 在内容设置上进行了大胆的组合与优化。教材内容涵盖了岩土工程的基本分类方法与典型岩土工程，岩土材料的力学特性和测试方法，岩土工程相关计算理论、设计方法、施工技术和装备，岩土工程常见工程灾害与防治，数值化技术与岩土工程关系以及学科领域研究热点和前沿等方面内容。章与章之间在内容安排上既相互联系，又可自成一体，能方便满足不同层次读者的需求。

在书稿出版之际，特别感谢慧眼独具的中国水利水电出版社提供的合作平台与大力支持，感谢广州市水电建设工程有限公司为书稿出版给予的支持，感谢黄莉、欧阳帆、汪丽娜、闫晓满和邹家强等在书稿撰写过程中付出的辛勤劳动。双语书稿有其特殊性，可参照的经验和样本较少，加上作者水平所限，书中难免有疏漏之处，敬请广大读者批评指正。

作者

2016年5月31日

CONTENTS 目录

Chapter 1

Introduction to Geotechnical Engineering

岩土工程简介

1.1 Definition 定义

【Text】

Everything you see around you is supported by soil or rock. Anything that is not supported by soil or rock, either floats, flies or falls down.

Civil engineering is a professional engineering discipline that deals with the design, construction, and maintenance of the physical and naturally built environment, including works like roads, bridges, canals, dams, and buildings. Civil engineering is the oldest engineering discipline after military engineering, and it was defined to distinguish non-military engineering from military engineering. It is traditionally broken into several sub-disciplines including environmental engineering, geotechnical engineering, geophysics, geodesy, control engineering, structural engineering, transportation engineering, earth science, atmospheric sciences, forensic engineering, municipal or urban engineering, water resources engineering, materials engineering, offshore engineering, quantity surveying, coastal engineering, surveying, and construction engineering. Civil engineering takes place on all levels: in the public sector from municipal through to national governments, and in the private sector from individual homeowners through to international companies.

Geotechnical engineering is obviously the branch of civil engineering concerned with the engineering behaviour of earth materials. In the other words, Geotechnical engineering is specialized in civil engineering field research about the engineering properties of soil and rock mass and its application.

Geotechnical engineering mainly includes the following main aspects: soil science, geology (including hydrology), engineering survey, foundation (foundation treatment, foundation engineering), tunnel excavation, foundation pit excavation, excavation engineering, supporting engineering (foundation pit supporting, slope supporting and debris flow control), engineering detection and monitoring etc. Actually, the above problems can be summed up in the three eternal classic problems in soil mechanics: slope stability, soil pressure and bearing capacity of foundation.

Geotechnical engineering is thus an area of civil engineering concerned with the rock and soil that support civil engineering systems. Knowledge from the fields of geology, material science and testing, mechanics, and hydraulics are applied by geotechnical engineers to safely and economically design foundations, retaining walls, and similar structures. Environmental concerns in relation to groundwater and waste disposal have spawned a new area of study called geo-environmental engineering where

biology and chemistry are important. Some of the unique difficulties of geotechnical engineering are the result of the variability and properties of soil. Boundary conditions are often well defined in other branches of civil engineering, but with soil, clearly defining these conditions can be impossible. The material properties and behavior of soil are also difficult to predict due to the variability of soil and limited investigation. This contrasts with the relatively well defined material properties of steel and concrete used in other areas of civil engineering. Soil mechanics, which describes the behavior of soil, is also complicated because soils exhibit nonlinear (stress-dependent) strength, stiffness, and dilatancy (volume change associated with application of shear stress).

【Key words】

soil *n*. 泥土
rock *n*. 岩石
civil engineering 土木工程
geotechnical engineering 岩土工程
environmental engineering 环境工程
structural engineering 结构工程
offshore engineering 近海工程
coastal engineering 海岸工程
municipal or urban engineering 市政工程
geology *n*. 地质学
foundation *n*. 地基（基础）
excavation *n*. 开挖
supporting *n*. 支护
slope stability 边坡稳定
soil pressure 土压力
bearing capacity 承（载）量（能力）
groundwater *n*. 地下水
waste disposal 废物弃置（场）
variability *n*. 变化（性）
boundary condition 边界条件
investigation *n*. 调查
nonlinear *adj*. 非线性的
strength *n*. 强度
stress *n*. 应力
stiffness *n*. 刚度
dilatancy *n*. 膨胀性

【Translation】

Everything you see around you **is supported by** soil or rock. Anything that is

not supported by soil or rock, either floats, flies or falls down.

我们周围能见到的所有东西都是为岩土所支撑的。不被岩土所支撑的东西要么浮在水面，要么飞在空中，要么坠落地下。

Civil engineering is a professional engineering discipline that deals with the design, construction, and maintenance of the physical and naturally built environment, including works like roads, bridges, canals, dams, and buildings. Civil engineering is the oldest engineering discipline after military engineering, and it was defined to distinguish non-military engineering from military engineering. **It is traditionally broken into** several sub-disciplines including environmental engineering, geotechnical engineering, geophysics, geodesy, control engineering, structural engineering, transportation engineering, earth science, atmospheric sciences, forensic engineering, municipal or urban engineering, water resources engineering, materials engineering, offshore engineering, quantity surveying, coastal engineering, surveying, and construction engineering. Civil engineering **takes place on all levels: in the public sector** from municipal through to national governments, **and in the private sector** from individual homeowners through to international companies.

土木工程是一门专门处理道路、桥梁、运河、水坝和建筑物等工程的设计、施工以及工程完成后周边环境维护等工作的工程学科。土木工程是继军用工程之后最为古老的工程学科，用以区分军用工程和非军用工程。传统上将土木工程细分为环境工程、岩土工程、地球物理、大地测量、控制工程、结构工程、交通工程、土壤学、大气科学、法律工程学、市政工程、水资源工程、材料工程、海洋工程、数量测量、海岸工程、测量、建筑工程等子学科。土木工程涵盖各个层面：在公共领域，可以从市政府到国家机构；在私营层面，则可以从私营业主到国际化企业。

Geotechnical engineering is obviously the branch of civil engineering concerned with the engineering behaviour of earth materials. In other words, geotechnical engineering **is specialized in** civil engineering **field research about** the engineering properties of soil and rock mass and its application.

显然，岩土工程是土木工程中与土工材料工程性质密切相关的一个分支。换句话说，岩土工程专注于土木工程领域关于岩土体工程性质研究及其应用。

Geotechnical engineering mainly includes the following main aspects: soil science, geology (including hydrology), engineering survey, foundation (foundation treatment, foundation engineering), tunnel excavation, foundation pit excavation, excavation engineering, supporting engineering (foundation pit supporting, slope supporting and debris flow control), engineering detection and monitoring etc. **Ac-**

tually, the above problems can be summed up in the three eternal classic problems in soil mechanics: slope stability, soil pressure and bearing capacity of foundation.

岩土工程主要包括以下几个方面：土壤学、地质（包括水文）、工程勘察、基础工程（地基处理，地基工程）、隧道开挖、基坑开挖、开挖工程、支护工程（基坑支护、边坡支护和泥石流治理）、工程检测和监测等。事实上，上述问题完全可以归结为土力学中最经典的三大问题：边坡稳定性、土压力和地基承载力。

Geotechnical engineering is thus an area of civil engineering concerned with the rock and soil that support civil engineering systems. Knowledge from the fields of geology, material science and testing, mechanics, and hydraulics are applied by geotechnical engineers to safely and economically design foundations, retaining walls, and similar structures. **Environmental concerns in relation to** groundwater and waste disposal **have spawned a new area of study called** geoenvironmental engineering **where** biology and chemistry are important. Some of the unique difficulties of geotechnical engineering are the result of the variability and properties of soil. Boundary conditions are often well defined in other branches of civil engineering, but with soil, clearly defining these conditions can be impossible. The material properties and behavior of soil are also difficult to predict due to the variability of soil and limited investigation. This contrasts with the relatively well defined material properties of steel and concrete used in other areas of civil engineering. Soil mechanics, which describes the behavior of soil, is also complicated because soils exhibit nonlinear (stress-dependent) strength, stiffness, and dilatancy (volume change associated with application of shear stress).

因此，岩土工程属于与岩土体密切相关的土木工程领域，并为土木工程体系提供支撑。岩土工程师们运用地质学、材料科学与测试技术、力学和水力学等方面的知识进行基础工程、挡土墙工程和其他类似构筑物的安全而又经济的设计。此外，与地下水和废物处理有关的环境问题催生了一个新的研究领域，称为环境岩土工程，生物和化学知识在该领域至关重要。岩土工程中的一些独特的难题源自土体的多样性及其性质。在土木工程的其他分支中，边界条件往往是很好定义的，但对土体而言，明确定义这些边界条件可能是行不通的。同样，由于土体的多样性以及有限的调查数据使得土体的材料性质和特性也难以进行准确预测。这一点与土木工程其他领域中用到的钢材和混凝土的材料性能能获得比较明确的定义相比较，差别明显。描述土体性质的土力学，也因为土体具有非线性强度（与应力相关）、刚度和剪胀性（体积随施加的剪应力而变化）而变得复杂。

Civil engineering is a branch of engineering that deals with the design and construction of structures that are intended to be stationary, such as buildings and houses, tunnels, bridges, canals, highways, airports, port facilities, and road

beds for railroads.

土木工程是工程学的一个分支，涉及各类固定建筑物的设计和建造，包括大楼、房屋、隧道、桥梁、运河、高速公路、机场、港口设施以及铁路路基等。

Among its subdivisions are structural engineering, dealing with permanent structures; hydraulic engineering, dealing with the flow of water and other fluids; and environment/sanitary engineering, dealing with water supply, water purification, and sewer system, as well as urban planning and design.

土木工程的子学科又可分为结构工程，主要研究永久性建筑；水利工程，主要研究水和其他流体的输送；环境/卫生工程，主要研究水的供应、净化和排水系统，以及城市规划与设计等。

【Important sentences】

1. ... is supported by...
   ……被……所支撑。
2. It is traditionally broken into...
   传统上，被细分为……
3. It takes place on all levels: in the public sector..., and in the private sector...
   它涵盖各个层面：在公共领域，……；在私营层面，……
4. ... is specialized in... field research about...
   ……专注于……领域关于……
5. Actually, the above problems can be summed up in...
   事实上，上述问题完全可以归结为……
6. Environmental concerns in relation to... have spawned a new area of study called ... where... are important.
   与……有关的环境问题催生了一个新的研究领域，称为……，在这个该领域，……是至关重要的。(where 引导状语从句)

1.2 History 发展历程

【Text】

Humans have historically used soil as a material for flood control, irrigation purposes, burial sites, building foundations, and as construction material for buildings. First activities were linked to irrigation and flood control, as demonstrated by traces of dykes, dams, and canals dating back to at least 2000 BCE that were found in ancient Egypt, ancient Mesopotamia and the Fertile Crescent, as

well as around the early settlements of Mohenjo Daro and Harappa in the Indus valley. As the cities expanded, structures were erected supported by formalized foundations; Ancient Greeks notably constructed pad footings and strip-and-raft foundations. Until the 18th century, however, no theoretical basis for soil design had been developed and the discipline was more of an art than a science, relying on past experience.

Several foundation-related engineering problems, such as the Leaning Tower of Pisa, prompted scientists to begin taking a more scientific-based approach to examining the subsurface. The earliest advances occurred in the development of earth pressure theories for the construction of retaining walls. Henri Gautier, a French Royal Engineer, recognized the "natural slope" of different soils in 1717, an idea later known as the soil's angle of repose. A rudimentary soil classification system was also developed based on a material's unit weight, which is no longer considered a good indication of soil type.

The application of the principles of mechanics to soils was documented as early as 1773 when Charles Coulomb (a physicist, engineer, and army Captain) developed improved methods to determine the earth pressures against military ramparts. Coulomb observed that, at failure, a distinct slip plane would form behind a sliding retaining wall and he suggested that the maximum shear stress on the slip plane, for design purposes, was the sum of the soil cohesion, c, and friction $\sigma\tan\varphi$, where σ is the normal stress on the slip plane and φ is the friction angle of the soil. By combining Coulomb's theory with Christian Otto Mohr's 2D stress state, the theory became known as Mohr-Coulomb theory. Although it is now recognized that precise determination of cohesion is impossible because c is not a fundamental soil property, the Mohr-Coulomb theory is still used in practice today.

In the 19th century Henry Darcy developed what is now known as Darcy's Law describing the flow of fluids in porous media. Joseph Boussinesq (a mathematician and physicist) developed theories of stress distribution in elastic solids that proved useful for estimating stresses at depth in the ground; William Rankine, an engineer and physicist, developed an alternative to Coulomb's earth pressure theory. Albert Atterberg developed the clay consistency indices that are still used today for soil classification. Osborne Reynolds recognized in 1885 that shearing causes volumetric dilation of dense and contraction of loose granular materials.

Modern geotechnical engineering is said to have begun in 1925 with the publication of *Erdbaumechanik* by Karl Terzaghi (a civil engineer and geologist). Considered by many to be the father of modern soil mechanics and geotechnical engineer-