

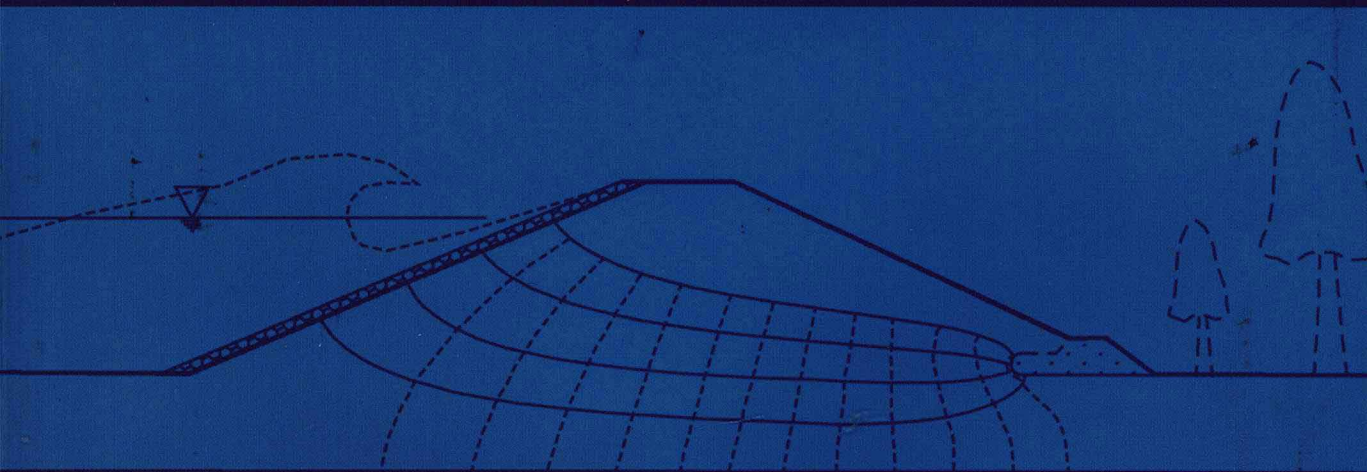
DIKES ENGINEERING MANUAL
Design, Construction, Management & Researches

堤防工程手册

设计 · 施工 · 管理 · 科研

主编 毛昶熙 等

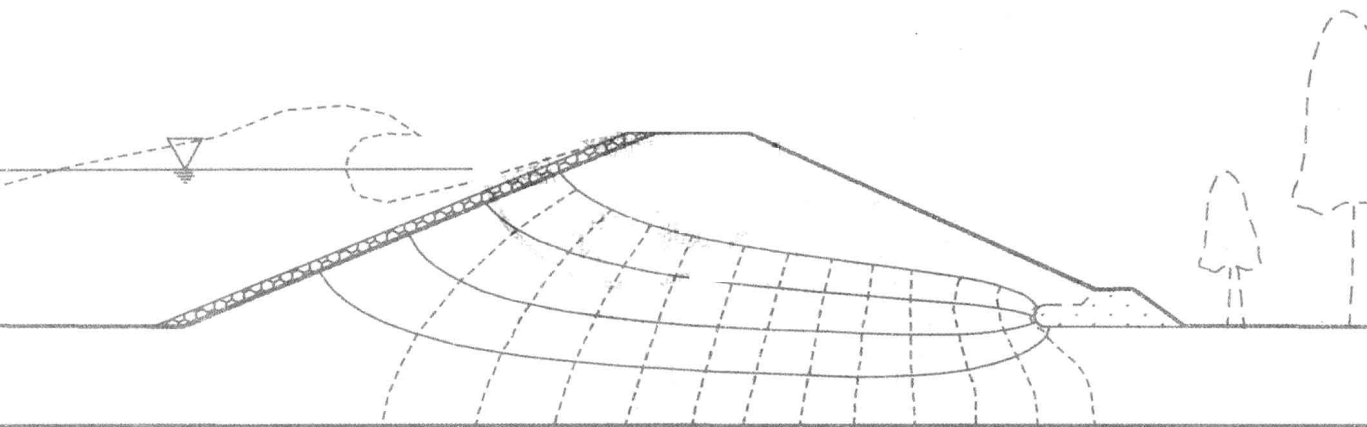
Mao Chang-xi et al.



中国水利水电出版社
www.waterpub.com.cn

堤防工程手册

主编 毛昶熙 等



中国水利水电出版社
www.waterpub.com.cn

内 容 提 要

本书是一本较全面系统论述江河湖海的堤防设计、管理、施工、科研等方面中有关防渗、防冲、防浪、风险和环境等技术性问题的学术专著,重点介绍江海堤防的设计条件、计算方法、结构型式、堤基管涌发展和堤身滑坡沉降破坏机理、土堤与泵闸建筑物衔接的防渗设计措施、渗流控制及堤岸抗冲防浪等适应性护坡工程措施以及防洪抢险、除险加固技术等。本书是在广泛收集国内外有关文献资料的基础上,扼要整编成比较全面、便于查考、有选择空间的实用性现代化手册。

本手册可为大堤的防汛决策、安全管理及除险加固建设提供科学依据,可供同类型土石坝、水库岸坡、边坡工程等工作人员使用,也可供从事有关局部冲刷、河道整治、海港淤积等方面的科研人员和教学工作者参考。

图书在版编目(CIP)数据

堤防工程手册 / 毛昶熙等主编. -- 北京: 中国水利水电出版社, 2009.9
ISBN 978-7-5084-6875-4

I. ①堤… II. ①毛… III. ①堤防—防洪工程—技术手册 IV. ①TV871-62

中国版本图书馆CIP数据核字(2009)第181277号

书 名	堤防工程手册
作 者	主编 毛昶熙 等
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 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	北京市兴怀印刷厂
规 格	184mm×260mm 16开本 40印张 948千字 1插页
版 次	2009年9月第1版 2009年9月第1次印刷
印 数	0001—3000册
定 价	130.00元

凡购买我社图书,如有缺页、倒页、脱页的,本社营销中心负责调换

版权所有·侵权必究

《堤防工程手册》编写审校工作人员

主 编 毛昶熙（南京水利科学研究院）
 段祥宝（南京水利科学研究院）
 李思慎（长江科学院、长江重要堤防隐蔽工程建设管理局）
 汪自力（黄河水利科学研究院）

编审人员

章 序	编 写 者	审阅者
第 1 章	毛昶熙 李思慎	牛运光
第 2 章	顾淦臣 李思慎 吴昌瑜	逯宝玉
第 3 章	毛昶熙 段祥宝	吴世余
第 4 章	毛昶熙 段祥宝 毛佩郁	陈椿庭 顾淦臣
第 5 章	毛昶熙 段祥宝 毛 宁	余广明
第 6 章	毛昶熙 段祥宝 谢兴华	吴世余
第 7 章	李思慎 王满兴 关德斌 彭国强 兰华林 张宝森	白永年 杜玉海
第 8 章	汪自力 岳瑜素 许雨新	刘贵芝
第 9 章	张宝森 汪自力 许雨新	陈士俊
第 10 章	姜树海 范子武	吴时强

工作人员 吴金山 谢罗锋 程 璐

序 一

Preface I

修建江河湖海堤防工程是人们防御洪水灾害的主要工程措施。为加强对堤防工程的研究，水利部结合“国际减灾十年活动”拟定了“堤防渗流控制与防冲”课题及“海堤防浪防冲防渗”课题，由南京水利科学研究院主持，长江科学院、黄河水利科学研究院等单位协作。课题以长江、黄河等七大江河和东南沿海主要堤防的调查资料为基础，通过理论分析、模型试验，在堤防渗流理论、防冲、防浪和崩岸治理等方面取得了很多实用性成果，并汇编成册，出版了《堤防渗流与防冲》一书。现在的这本《堤防工程手册》就是以此汇编成果为基础，经过进一步研究和加工整理编写而成的。

《堤防工程手册》的编写出版，历时十余载，收集了中外大量文献资料，整编了近年来堤防工程研究的主要成果。该书内容丰富，较全面地论述了江河湖海的堤防设计、管理、施工等方面中有关防渗、防冲、防浪、风险和环境等技术性问题，重点介绍江海堤防的设计条件、计算方法、结构型式、堤基堤身破坏机理、渗流控制及堤岸抗冲防浪等适应性工程措施以及防洪抢险、除险加固技术等，具有很强的实用性。该书的出版对于提高我国堤防工程技术水平将会起到很好的推动作用，对堤防的设计、管理、施工和科研也具有较高的参考价值。

水利部国际合作与科技司

2008年12月

序 二

Preface II

Water defenses have been constructed since centuries in China and many other countries all over the world. However, in the recent decades the demand for a more accurate design remains a topical issue. This concerns designing in the most economical way, while in recent years the focus has also shifted to give values and functions not concerned with water retention a more important place (ecological, cultural and social issues) . The developments in the field of research, calculation methods and norm calculations are continuing, which has lead to a string of publications over recent decades. The good example of that is a large number of various guidelines documents in The Netherlands, Germany, United Kingdom, Japan and USA. However, the good Manual in the field of river and coastal dikes and other defense structures was still missing in China. The existing Manuals needed an upgrading.

Water defenses have also a very high priority within the Chinese Government, especially after the major floods in the Yangtze Basin in 1998. This flood can be treated as a turning-point in the Chinese strategy on flood management. Dikes to protect land from the annual floods in China date back centuries and in some places more than 2,000 years. Since the creation of the People's Republic, these incomplete and poorly maintained dikes have been strengthened and extended. At the same time, there has been rapid growth in the value of assets protected by the dikes and this demands much higher levels of protection. In the past, a breach of a dike might destroy a low-value field crop and inundate houses and public buildings. But now, the property at risk includes modern factories, processing plants, and high-value commercial real estate, and potential high crop losses. **The Government's strategy** for tackling the flood problem has evolved over the years. Its main elements are, among others:

—Construction of Dikes and Protection of Riverbanks Against Erosion,

—Urban Flood Protection,
—Creation of Flood Detention Areas for Temporary Storage of Flood Waters,
—Construction of Dams on the Rivers to Reduce Downstream Flows, and Improved Drainage Systems Behind the Dikes to Mitigate Flooding Caused by Rainfall.

The realization of these goals needs proper knowledge and guidelines for implementation.

Construction of a dike (levee) requires that it is high enough to exclude an extreme flood or design storm conditions. The difference in height between a dike designed for a 50-year flood and a 1,000-year flood is relatively small on most rivers and coasts and the higher level is justified by the potential losses if the dike is overtopped and the consequences of that are severe (in terms of casualties or economic damage). Dikes are normally found on the natural riverbank some distance from the river and along the sea shores. Shore or bank erosion can cause shore/bank collapse and threaten the dikes. Usually, rock spurs are built to deflect the flow from the vulnerable section of dikes/banks, or revetments (rock, concrete blocks, mattresses, etc.) are placed to protect the shore or bank. The modern design approach is characterized by understanding the problem and making a proper choice from a number of suitable alternatives for solving of a certain problem. To tackle these problems in efficient way the actual domestic and international knowledge and techniques must be applied. This background clarifies why the need has arisen for a comprehensive book in the field of dikes/defense structures design, construction, and maintenance and management problems for civil engineering researches, designers and managers.

In 2003 Prof. Mao Chang-Xi published his excellent book on Seepage of Dikes and Scour Defence. It was compilation of his many years of research and experience, supplemented with some experience from abroad. However, as the title says, the content of this book was limited to seepage and scour. But the personal energy of Prof. Mao Chang-xi likes to be unlimited. A five years later a new, more complete document under his guidance is appearing, a **Dikes Engineering Manual**.

The present Dikes Engineering Manual focuses on all these problems discussed above and is of great importance for implementation of Government's

strategy on water defenses in China. This Manual is a compilation of contemporary research and experience in the field of dikes, shore protection and revetments by experts in China and abroad.

The Manual contains 10 main chapters covering the wide field of aspects related to river and sea dikes and coastal protection. The current publication captures and presents the most recent contributions by Chinese experts primarily from their own research and literature translated into design guidelines on river and sea dikes, bank and shore protection, closure works and revetments, including geotechnical aspects. Also maintenance, risk and safety assessment, and management aspects are treated in detail.

Considering the history and expertise of China in this technology, it is particularly notable that the main author and other contributors represent probably the greatest reservoir of such expertise and technology. Hence, this Manual must be considered a keystone for the agencies, engineers or other persons responsible for the planning, design and assessment of measures for the protection and maintenance of river and coastal areas.

The breadth and scope of material covered with regard to the subject is extensive. The author has organised the book in a logical manner beginning with an introductory chapter on the present ranking of dikes and coastal defences and design standards in China.

The concepts and practices of dike construction, flood and coastal defences are presented in a historic perspective continuing to the present. This sets the stage and basis for the more definitive technical chapters that follow, chapters which discuss in detail the various technical aspects of the broad subject of dikes and revetments:

- Chapter 1 Ranking, Design Standards, Alignment and Types of Dikes;
- Chapter 2 Engineering Geology of Dike Subgrade and its Treatment Measures;
- Chapter 3 Earth Dikes of River and Lake;
- Chapter 4 Collapse of Riverbank or Dike and Protection Measures;
- Chapter 5 Sea Dikes;
- Chapter 6 Urban Dikes;
- Chapter 7 Construction Works to Strengthen Dikes;
- Chapter 8 Measures of Flood Fighting;
- Chapter 9 Safety Management of Dike Engineering;

Chapter 10 Method of Risk Assessment for Dikes.

Each of the chapters is supported by practical examples and extensive references.

The process of improvement of design techniques has been accelerated by a number of serious flood disasters in recent years all over the world. The aim of this Manual is to provide the reader with the overview of the present state of the dike engineering. It contains the inventory and the evaluation of the recent literature and experience in this field. Although in recent years great progress has been made in this field, our knowledge and understanding of the complex nature of dike and bank processes is still limited. Therefore, the engineer can also use up-to-date equipment and advanced research techniques like scale and prototype models and mathematical models to get a better insight into behavior of these structures.

There is much similarity in processes and design approach both for river bank and shore protection as well as for river and sea dikes. Most failure modes are common for both areas; however, the consequences can be quite different. The failure of a dike may lead to flooding and inundation of the land behind, which is usually not the case in case of bank erosion. However, bank erosion, when close to the dikes, may also induce (be a reason) for a dike failure. Therefore, the content of this Manual is of value for both fields.

As already mentioned, the breadth and scope of material covered with regard to the subjects is extensive. In this Manual, among others, such specific items are treated as hydraulic loading, risk and failure modes of dikes and banks, seepage, scour, calculation of dike height and cross-section, stability of various types of revetments and alternative systems, and many other design considerations. The civil engineering branch is still little acquainted with the possibilities of geosynthetics and other alternative materials. Therefore, it is of value that also these new developments and applications are treated in this Manual. It can also be mentioned that the Netherlands, similar to China, has a long history of coping with floods and has many achievements in this field. This probably explains the fact that the recent Dutch books and technical reports are frequently cited or used as references in this Manual.

The language barrier is still the main obstacle in dissemination of foreign know-how to working-level (i. e. design offices) in China. Therefore, this publication which includes a large number of research results and experiences from

foreign countries is an important step in improving this situation. However, to try to bridge the gap between China and outside world, it would also be useful to translate this Manual into English to provide the opportunity for foreign colleagues to make acquaintance with Chinese approaches and research results.

The close foreign cooperation is also of importance because the flood problems are common problems all over the world and the developments in the field of research, calculation methods and design standards are continuing. International cooperation in this field is beneficial for all countries in efficient treating these common problems.

This Manual is the result of cooperation between the Nanjing Hydraulic Institute and many other Chinese Institutes, and it was possible due to support of the Chinese Ministry of Water Resources and Ministry of Communication.

This Manual is intended both for practicing engineers and for the post-graduate students. It provides the better insight into the latest developments in the subject. Hence, it must be considered a keystone for the engineer or other person responsible for the planning, design and assessment of measures for the protection and maintenance of water defenses.

Any engineer or agency that has coastal or flood control interests should be aware of this volume and include it in its technical library. It should stand as a classic reference in the field for years to come. This Chinese Manual is valuable supplement to the actual US Coastal Engineering Manual (CEM2006) and European Manual on Use of Rock in Hydraulic and Coastal Engineering (RM2007) . This Chinese Manual will be of great value not only for Chinese users but also for international consultants and contractors operating in China. Therefore, an English translation of this Manual would be very welcome.

Krystian W. Pilarczyk

Former Manager of Research and Development in Hydraulic Engineering,
Hydraulic Engineering Institute, Dutch Public Works Department, Delft,
the Netherlands

Dec. 2008

自 序

Editor's Preface

洪水灾害在国内外都是居自然灾害中的首位，为防范江河洪水泛滥成灾和潮水侵袭为患，人们自古以来多修筑堤防保障沿岸人民生命财产的安全，而且随着社会经济的发展，沿着江河湖海的地区日趋重要，堤防建设加固减灾的要求更加迫切。因此水利部结合当时联合国号召“国际减灾十年活动”拟定了专项课题“堤防渗流控制与防冲”和随后补充的课题“海堤防浪防冲防渗”，由南京水利科学研究院和长江科学院、黄河水利科学研究院等协作单位共同进行此项防洪减灾的堤防工程研究，并在协议中规定编写《堤防工程手册》，举办学习班广泛交流，谋求有助于提高设计管理水平，达到防洪减灾的目的。

堤防课题研究从1994年开始，对全国性的重点江海堤防进行调研总结，分析存在的问题，然后有针对性地进行试验研究。1998年长江特大洪水，再及时沿江调研查看渗流、管涌、崩岸、溃口等险情，并对险情问题及其相应的防渗、防冲、防浪措施以及当时感兴趣的垂直防渗墙措施，进行核算分析和试验研究，提出成果报告30余篇发表于中英文刊物，并再整编，于2003年出版了《堤防渗流与防冲》一书，为编写本手册创造了条件。接着又结合北江大堤进行了无害管涌和发展性管涌的试验研究，提出成果报告6篇发表于《水利学报》，并引起了众多研究兴趣和讨论，从而为编写本手册提供了更多的新内容。在这10余年来的成果报告基础上，再参照国内外的最新堤防规范、手册及有关文献资料，我们协作编写完成了这本《堤防工程手册》，希望能达到开始拟订的该项研究课题的愿望。

本手册编写的主导思想是“实用性、全面性、先进性”。编写取材力求实用和合理先进，避免过多的数学推导，注明资料来源，便于查考。介绍公式图表及方法措施，按其合理性、先进性编排，注明年代及其发展进程，便于比较选用。考虑到全面性，也把现行的规范、手册中的有关公式图表罗列其中。关于编写内容，主要是“工程技术”，在工程方面分类为江河湖海堤防及

城市堤防。在技术方面包括有设计、施工、管理和科研。具体章节是第1~6章和第10章主要是计算分析设计方面；第7章主要是加固堤防施工方面；第8章、第9章主要是维护管理方面；至于被视为优化设计先导的科研，则主要是介绍在设计方面的章节，必要时加以评述和讨论，让设计者能够结合具体问题选用比较可靠、适宜的设计计算方法和公式，以及寻找优化设计的科学研究途径。

在本手册编写过程中，笔者深感知识有限，再邀请协作单位以外的专家教授参加编写，并推荐文献资料来弥补编写内容之不足。成稿后除互相交流意见外，再分章邀请富有研究和实践经验的专家教授审阅修改，最后会审，再交付出版，力求质量有所提高，避免错误。希望它能在当今如此众多出版物的环境下，不被视为滥竽充数。

本手册编审历经10余载，领导更换和财务、出版制度的改变，对编写进程不无影响。虽有难度，协作的同志们仍愿坚持完成任务，付之以无偿无私的劳动智慧，对此深表敬意。同时也迎来了水利部国际合作与科技司和南京水利科学研究所的资助以及出版社的支持，使得最初拟订这项堤防研究课题，要出版这本《堤防工程手册》广泛交流的最终目标，顺利成为了现实，对此深表谢意。再者水利部主管部门和堤防专家学者 K. W. Pilarczyk 应邀阅后为本手册写序推荐，在此致以衷心的感谢。

由于本手册内容广泛，还有一些类同土石坝、水闸、水库岸坡、河道海港整治等方面的工程技术问题。错误难免，甚望指正。

毛昶熙

2009年3月

作者简介

毛昶熙，河南豫北内黄人，抗日战争期间先后求学于西北农学院、工学院水利系，1941年毕业于西北工学院（原北洋工学院，现天津大学），获得李仪祉奖学金，留校任助教。一年后报名到抗战前沿参加南阳地区灌溉工程设计施工，并在黄河水利专科学校任讲师，抗战胜利复员改为中原工学院（合并于河南大学）任副教授。主要教课是曾参与助写的刘德润编著《普通水力学》（1945再版）。1948年初来南京中央水利实验处任副研究员。1949年新中国成立后留用，迄今未能如愿离开南京，任教授级高工，从事科研未有间断。

20世纪50年代配合治淮工程等做水工模型试验，随后将做过的40余项试验加以分析总结编写为《闸下消能初步综合研究》和《水工建筑物下游局部冲刷综合研究》等篇获得水利部进步奖和科学大会奖，并由水利出版社于1956年和1959年出版交流。1954~1956年为适应科研队伍迅速发展，连续三届办水工试验学习班，在水工室领导下负责组编教材《水工模型试验》，经过整编精简，于1959年由南京水利科学研究院、北京水利科学研究院合编出版，1985年再版。

20世纪50年代后期开始转向负责渗流研究工作，在两位苏联专家指导下，于1957年首建了渗流实验室，进行了多项工程渗流问题研究，总结性的报告《研究渗流的三向电模拟试验》，被水利部选为有创新成果，于1965年译成英文，派员带往在巴基斯坦召开的国际学术会议交流，并预约专著《电模拟试验与渗流研究》，因文革延误于1981年出版。为引进国外先进技术，组织翻译了英、法、德、日、俄五国文字的当代优秀文献资料，从1959年到1983年会同南科院情报室编排出版了《渗流译文汇编》计12辑。其中“有限元法”经过渗流组协作攻关，20世纪70年代初，在国内首先成功应用到渗流计算中，编印成册《渗流计算程序汇编》在1983年召开的首届全国渗流学术会议上公开交流；同时举办渗流计算程序应用学习班积极推广，逐步取代了习用半个世纪的电模拟试验。随后于1999年整编补充出版了专著《渗流数值计算与程序应用》，进一步促进工程渗流的发展。

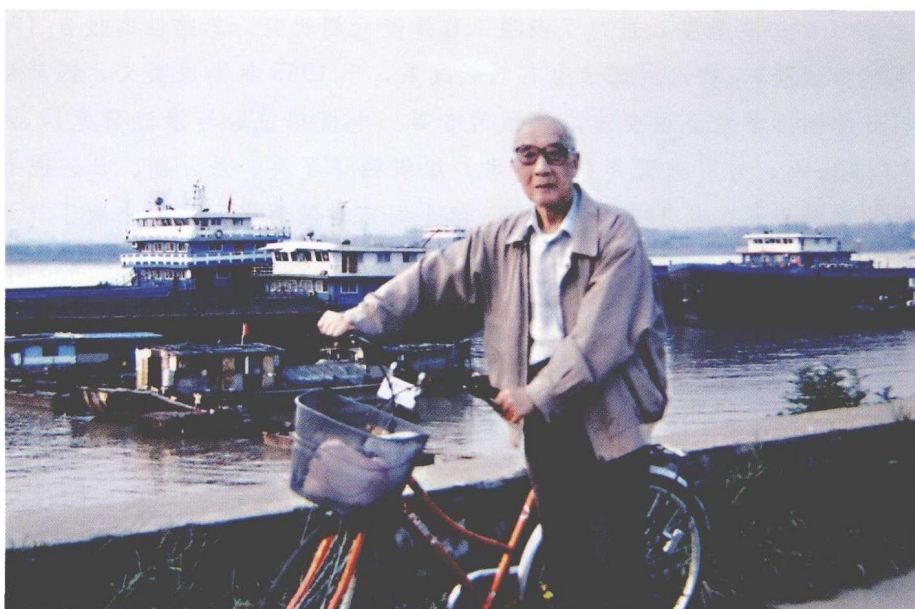
20世纪80年代初期水利部令组团出国渗流考察，先后于1983~1984年赴匈牙利、罗马尼亚、德国和美国，考察访问了各著名科研机构 and 大学的发展概况，取得不少新技术资料和计算程序，并建立了联系，为研究生选题和国外学术交流创造了有利条件。1986年水利电力部首批科研基金项目批准了“闸坝下游消能冲刷综合研究”专题，开展了黏土冲刷试验研究，并编《闸坝工程水力学》讲义，应邀为江苏、内蒙

古、山东等省（自治区）举办学习研讨班讲授交流。此后为水利部培训人才举办了多届“土坝渗流分析”、“闸坝工程水力学”等研讨班，并整编教材，主编出版了专著《渗流计算分析与控制》（1990 第 1 版，2003 再版）和《闸坝工程水力学与设计管理》（1995）。同时也参编《水工设计手册》（1984）、《土工原理与计算》（1980，1996 再版）、《中国水利百科全书》（2004）渗流章节等。

20 世纪 90 年代中期接受水利部重点防洪课题“堤防渗流与防冲”研究项目，经过江海堤防调研分析和科研试验，于 2003 年出版了初步成果《堤防渗流与防冲》一书。现在出版这本《堤防工程手册》是完成课题要求的最后一项。

从 1942 年开始在《水利》、《工程》等当代刊物上发表论文迄今百余篇，其中参加国际性学术会议的英文稿十余篇；并有数篇获得国家、部、省及水利学会的奖励。负责项目《土坝渗流安全分析》获得首届国家科技进步三等奖，参加“七五”攻关项目中的《复杂岩基渗流计算》获得国家科技进步一等奖等。这些成果都是文中署名写作同志们的集体智慧的结晶。

致力于科研、教学、培训等水利技术事业迄今 68 载，在科研道路上，不问窗外事，似乎平坦，却是崎岖坎坷的奋斗历程。68 年来，以不曾担任行政官职为慰。学术性职称，曾有中国水利学会工程管理专业委员会副主任，水力学、岩土专委会委员及渗流学组顾问，省水利学会水力学专委会主任等。也曾为北京水科院、黄河水科院、淮委安徽省水科院等聘请为水工渗流顾问。



作者 2006 年 10 月在长江大堤上

目 录

序一
序二
自序

第1章 堤防级别、设计标准、选线及类型	1
1.1 堤防工程的级别与防洪设计标准和防护区	1
1.1.1 堤防级别、防洪标准与防护对象	1
1.1.2 防护区的确定	2
1.2 堤防工程的防洪标准与设计洪水	4
1.2.1 防洪标准与设计洪水的确定	4
1.2.2 防洪标准的提高趋向	5
1.3 堤防安全加高与超高	7
1.4 堤防工程的安全性要求	8
1.5 堤防选线及堤距	9
1.6 堤防的类型布局	10
1.7 堤防结构类型	12
参考文献	15
第2章 堤基的工程地质及地基处理	16
2.1 地质年代和地层系统	16
2.1.1 概述	16
2.1.2 长江堤防地基的地层系统	18
2.1.3 黄河堤防堤基的地层系统	19
2.1.4 淮河堤防地基的地层系统	21
2.1.5 珠江堤防地基的地层系统	21
2.1.6 海河堤防地基的地层系统	22
2.1.7 辽河堤防地基的地层系统	22
2.1.8 嫩江堤防地基的地层系统	23
2.1.9 松花江堤防地基的地层系统	23
2.1.10 湖堤海堤的堤基地层系统	24
2.2 各种地层土类的物理力学性质	24
2.2.1 江汉平原冲积土及荆江大堤地基土的物理力学指标	25

2.2.2	黄河流域中西部及松辽平原西部堤防地基黄土的物理力学指标	26
2.2.3	膨胀土的物理力学指标	27
2.2.4	分散性黏土的物理力学性质	28
2.2.5	盐渍土的物理力学性质	29
2.2.6	软土地基的涵义、特征及物理力学指标	29
2.3	堤基主要病险问题	35
2.3.1	渗透变形	35
2.3.2	岸坡不稳定	37
2.3.3	沉降变形及滑动变形	38
2.3.4	穿堤建筑物的渗透破坏和过大沉降	39
2.3.5	地震灾害	40
2.4	堤防地基的容许承载力	41
2.4.1	概述	41
2.4.2	地基内各点的附加应力及自重应力	42
2.4.3	容许塑流区	47
2.4.4	确定塑性区开展的最小安全系数法	49
2.4.5	用有限元法计算塑流区开展范围	50
2.5	软土地基上堤坝的抗滑稳定和抗震稳定	52
2.5.1	改良圆弧法	52
2.5.2	软基上堤坝的极限高度	54
2.5.3	关于软基上堤坝极限高度公式的讨论	55
2.5.4	土堤的地震惯性力	57
2.5.5	软基堤防的抗震稳定计算	58
2.6	堤基加固技术简介	60
2.6.1	堤基防渗加固	61
2.6.2	软基承载力加强	62
	参考文献	66

第3章	江河湖土堤	67
3.1	土堤的破坏形式	67
3.2	渗流破坏力或作用力	70
3.2.1	渗流作用力及其分解	70
3.2.2	渗流的两个分力及其破坏性	72
3.2.3	渗透力与边界水压力的转换关系	73
3.2.4	单位土体渗流各力的图示与平衡算法	73
3.3	渗流控制	75
3.3.1	渗流控制要求	75
3.3.2	渗流控制措施	75
3.4	堤身结构设计	80

3.4.1	堤顶高程及结构	81
3.4.2	堤坡、戕台与护坡防冲及防渗	82
3.4.3	挖土筑堤标准	83
3.5	土堤稳定渗流安全验算	84
3.5.1	不透水地基上的土堤渗流安全计算 (堤内侧无水)	85
3.5.2	透水地基上的土堤渗流安全计算 (堤内侧无水)	89
3.5.3	堤内侧 (下游) 有水深时的渗流计算	93
3.5.4	透水堤基的防渗措施	96
3.5.5	覆盖土层下强透水堤基渗流计算	98
3.5.6	有减压沟的堤基渗流计算	101
3.5.7	有减压井列的堤基渗流计算	105
3.5.8	减压井各种水头损失的计算	106
3.5.9	堤内压土方案的渗流计算	110
3.5.10	有防渗墙的渗流计算	115
3.5.11	堤基各向异性、多层次的渗流计算	116
3.6	土堤非稳定渗流安全验算	118
3.6.1	洪峰过程堤身浸湿进展距离计算	118
3.6.2	洪峰过程透水堤基堤后渗流水量	122
3.6.3	典型洪峰 (正弦曲线) 过程的浸湿进展简化公式	122
3.6.4	洪峰过程堤防渗流关键值的经验公式	123
3.6.5	洪水回落时堤身流网与浸润线位置计算	125
3.6.6	渗流基本参数的选用	126
3.7	堤基管涌危险性验算	129
3.7.1	管涌险情发展与管涌定义	129
3.7.2	管涌发生与发展的临界坡降及允许坡降	130
3.7.3	管涌冲蚀发展过程与计算公式应用	132
3.7.4	洪峰在堤基渗流中传播迟后和衰减的计算	136
3.7.5	砂砾石地基的管涌临界坡降	139
3.7.6	控制管涌发展的措施及其安全判别式	144
3.7.7	管涌抢险措施	145
3.8	土堤抗滑安全验算	148
3.8.1	楔形体滑动土压力平衡法	148
3.8.2	滑坡计算垂直条分法 (圆弧滑动)	150
3.8.3	滑坡计算条分法存在的问题	152
3.8.4	滑坡计算有限元法	156
3.8.5	直线或折线的浅层滑坡及加筋抗滑计算	160
3.8.6	滑坡危险水位与骤降缓降问题及计算公式	163
3.8.7	安全系数与强度指标的选用	165