

Seepage of Dikes

Seepage of Dikes & Scour Defence
& Scour Defence

毛昶熙 段祥宝 毛佩郁 等

堤防渗流与防冲

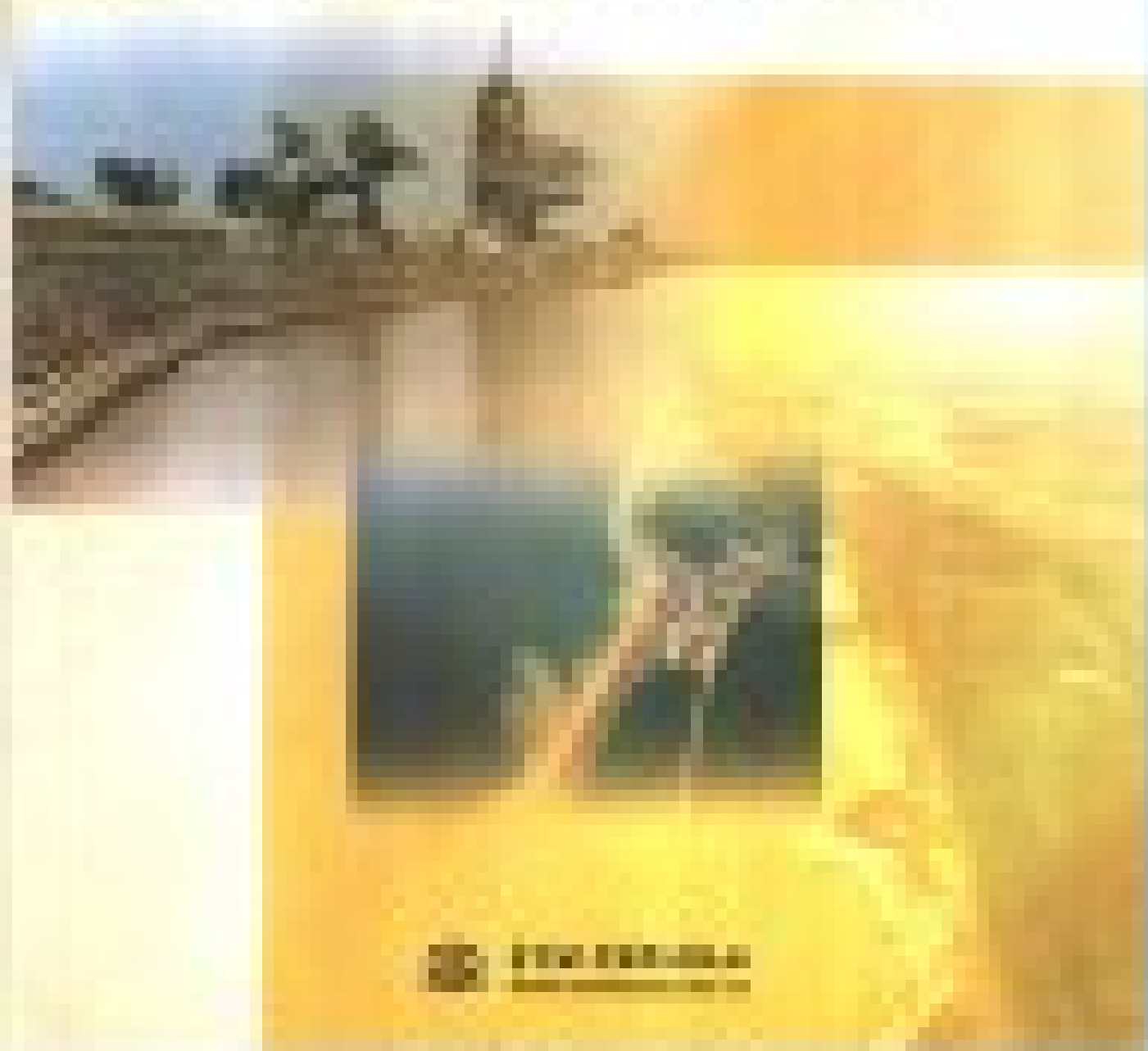


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堤防渗透与防冲



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毛昶熙 段祥宝 毛佩郁 等



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内 容 提 要

本书是研究江海堤防渗流、冲刷和防冲防浪的比较系统全面的卷册,是一部理论结合实践的、论述渗流与防冲的堤防研究专著。内容包括江海堤防的调研分析,堤防的设计计算方法,优选结构型式和稳定性分析,河湾防冲抛石护岸与崩岸治理,海堤防浪护坡设计,局部冲刷公式推广应用以及堤防加固工程的实例分析等论文 30 余篇。为江河湖海堤防工程的管理、设计、施工和科研提供了地下水与地表水及其相互作用下的设计方法和研究途径;可供从事堤防建设、防洪抢险、堵口截流、河湾冲淤、河道整治等工作参考。

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序（一）

中国洪水灾害集中在东部平原区，修建江河湖海堤防工程是中国防御洪水的主要工程措施。为加强对堤防工程的研究，水利部结合“国际减灾十年活动”拟订了“堤防渗流与防冲”的课题，由南京水利科学研究院主持，并与长江科学院、黄河水利科学研究院等协作单位共同进行研究。该课题研究以长江等七大江河和东南沿海三省（市）主要堤防现场调查为基础，进行了理论计算、模型试验，并在堤防渗流理论、防冲和崩岸治理等方面提出了计算方法和治理方案。该课题及其随后补充的“海堤防浪防冲防渗”课题的研究成果汇编成为现在《堤防渗流与防冲》一书。

我们相信本书的出版将会对中国堤防渗流与防冲技术的深入研究起到促进作用，对堤防的设计、管理、施工和科研也具有参考价值。

水利部建设与管理司

2002 年 12 月

序 (二)

Preface

In China dikes have been used to protect the land from the annual floods for many centuries and in some places date back for more than 2,000 years. Since the creation of the People's Republic, these incomplete and often poorly maintained dikes have been strengthened and extended. At the same time, there has been rapid growth in the value of the assets protected by the dikes and this demands much higher levels of protection. In the past, a breach of a dike might have destroyed a low-value field crop and inundated houses and public buildings. Now however, the property at risk includes modern factories, processing plants, and high-value commercial real estate as well as potentially high crop losses. The Chinese Government therefore gives very high priority to the water defences, especially since the major floods in the Yangtze Basin in 1998.

The Government strategy for tackling the flood problem has evolved over the years. Its main elements include:

- the construction of dikes and the protection of riverbanks against erosion,
- urban flood protection,
- the creation of flood retention areas to provide temporary storage for flood waters,
- the construction of dams across some rivers to reduce downstream flows, and
- improved drainage systems behind the dikes to mitigate flooding caused by rainfall.

The construction of a dike (levee) requires that it should be high enough to preclude extreme flooding. For most rivers the difference between the height of a dike designed for a 50-year flood and that of a dike to withstand a 1,000-year flood is relatively small and the higher construction level is justified by the potential losses if the dike is overtopped. Dikes are normally sited on the natural riverbank at some distance from the riverbed. A common problem is seepage through the foundation material. This is known as "piping," and can lead to loss of material such that the bank and the dike collapse and are then overtopped. This problem can usually be treated by adding material to the inside (land side) face of the dike at the site where seepage appears, or by diminishing the seepage by placing cut-off walls in the core of a dike. Bank erosion can cause the collapse of the bank and threaten integrity of the dike. Usually, rock spurs/groynes are built to deflect the flow

away from the vulnerable section of riverbank or revetments (for example rock, concrete blocks, mattresses) are placed to protect the bank. Dams too are subject to seepage, scour and problems that give rise to the need for slope protection.

The modern design approach is characterized by first acquiring a thorough understanding of the problem and then making an appropriate choice from a number of suitable alternatives/possible solutions. To tackle these problems efficiently both domestic and international knowledge and techniques must be applied. This background illustrates why need has arisen for a comprehensive book encompassing the fields of dike design, seepage and scour problems to assist civil engineering researchers, designers and managers.

This book on 'Seepage of Dikes and Scour Defence' focuses on these problems and is of great importance in the implementation of Government strategy on water defences in China. It is the result of cooperation between the Nanjing Hydraulic Institute and the Yangtze River and the Yellow River Institutes and other similar bodies/organisations, and its publication was made possible by the support of the Chinese Ministry of Water Resources.

The process of improving design techniques has been accelerated by the need to combat a number of serious flood disasters in recent years all over the world. The aim of this book is to provide the reader with an overview of the present state of the dike engineering. It contains an inventory and evaluation of the recent literature and experience in this field.

Although great progress has been made in this field in recent years, our knowledge and understanding of the complex nature of dike and bank processes is still limited. However the engineer can now use up-to-date equipment and advanced research techniques like scale and prototype models and mathematical models to gain greater insight into the behaviour of these structures.

There is much similarity between the processes and design approaches to river bank and dike (levee) protection. Most failure modes are common to both areas, although, the consequences may be quite different. The failure of a dike may lead to inundation of the land behind it, while this does not usually occur in the case of bank erosion. However, when it occurs close to the dikes, bank erosion may also induce/initiate dike failure. For this reason this book is of value to those operating in both fields.

The breadth and scope of the material covered is extensive. Among the subjects included in this book, such specific items as hydraulic loading, failure modes of dikes and banks, seepage, scour, the calculation of dike height and cross-sections, the stability of various types of revetments and alternative systems, and many other design considerations are treated. The part which refers to the seepage problems is partly based on the previous book "Numerical Computation in Seepage Flow and Programs Application (1999)", but has been upgraded and extended to cover new techniques, especially with reference to the

use of suspension-type cut-off walls under dikes (levees). Because the civil engineering branch is not yet fully acquainted with the possibilities of geosynthetics, especially in the field of dike and foundation reinforcement, filters, alternative revetments (geomattresses), and of construction elements (geotubes and geocontainers), the treatment of these new developments and applications is of particular value.

Like China, the Netherlands has a long history of coping with floods and has many achievements in this field, so it will come as no surprise that recently published Dutch books and technical reports are frequently cited/referred to and are included in the bibliography in this book. As the language barrier is still the main obstacle to the dissemination of foreign know-how to working practice (i. e. design offices) in China, this publication, which includes a large number of research results and experiences from foreign countries, is an important step towards improving this situation. However, to bridge the gap between China and the rest of the world it would also be useful to translate this book into English, thus providing an opportunity for foreign colleagues to become acquainted with Chinese approaches and research results. Close international cooperation is also important because flood problems are common throughout the world and there are continuous developments in the fields of research, calculation methods and design standards. International cooperation in this field is beneficial to all countries in their efforts towards the efficient treatment of these common problems.

This book is intended for the use of both practising engineers and post-graduate students and should give them better insight into the latest developments in the subject. Hence, it must be considered a keystone for the engineer and to others who may be responsible for the planning, design and assessment of measures for the protection and maintenance of water defences.

Krystian W. Pilarczyk

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Sept. 2002

Editor's Preface

Among the natural disasters, flood ranks the first both at home and abroad. China has suffered flood since the ancient time. In history, there is a saying "If one wants to govern the world in safety, he must first control flood". So incorporating with the activity of "International Disaster Mitigation for Ten Years" proposed by the United Nations, the Ministry of Water Resources drafted a key topic of <Seepage Control and Scour Defense for Dike>, which was be studied by Nanjing Hydraulic Research Institute with the cooperation of Hydraulic Research Institute of the Yangtze River and Hydraulic Research Institute of the Yellow River, in view of dike engineering relevant to flood control and disaster mitigation. Later on, a research topic of "Wave, Scour and Seepage Control of Sea Dike" was supplemented with respect to more comprehensive study of dikes. Since 1994, investigation has been conducted for the national important rivers and seas with the analysis and summarization of existing problems. In view of these problems, relevant studies were carried out with the association of practical situations. 30 reports about the research achievements were submitted in the past 8 years, which laid a foundation for the compilation of <Manual of Dike Design> in the work plan of the research topic. Based on the wish of the early exchange of research achievements in favorable to flood control and disaster mitigation, relevant papers are compiled into this book, i. e. <Seepage of Dikes and Scour Defense> for persons who are engaged in the river and sea dike works. However, it is a pity that the ongoing study of "Model Tests of the Identification Method of 'Innocuous Piping' of Beijiang Dike" is not collected in this book.

The first four Chapters of this book are "Investigation with Analyses for River dikes", "Seepage Computation with Analysis and Design and Construction for River Dikes", "Case Study on Engineering Measures of River Dikes to be Strengthened and Dike Breach Analysis" and "Analysis with Experiment for Scour and Anti-scour of Dikes and River Banks" respectively. Chapter 5 is about the investigation with analysis, structural types and stability of revetment blocks of sea dikes. Chapter 6 is the general report of research topic "Seepage of Dikes and Scour Defense". In addition, Previous research achievements closely related to the topic, namely, <Synthetic Study for Local Scour> and English papers of related topics published in the last decade in view of dike seepage, scour defense, wave protection, dumped riprap and local scour near hydraulic structures are collected in this book as Appendix A and Appendix B separately for references in order to provide more substantial contents and be beneficial to wide exchange.

Relevant contents of the recent Dutch famous book of (Dikes and Revetments) are introduced in the specific chapters and sections of this book as well. Prof. Pilarczyk, famous dike expert and Editor-in-chief of that book, is willing to write a preface for this book at invitation. The editor would like to express deep gratitude to him.

Heartfelt thanks are expressed to the Construction and Management Department of the Ministry of Water Resources and Nanjing Hydraulic Research Institute for their recommendation to write preface and financial support and to the Chinese Hydraulic and water Power Press for the smooth publication of this book.

Due to the wide aspect involved and the research achievements of stages, viewpoint of this book need to be further studied and verified by practical works in future. If readers find mistakes in this book, please do not be hesitated.

Mao Changxi

Dec. 2002

自 序

洪水灾害在国内外都是居自然灾害中的首位，而我国又是自古以来的水患大国，历代都有“治水治天下”之称。因此水利部结合当时联合国号召的“国际减灾十年活动”拟订了“堤防渗流控制与防冲”重点课题让我院（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。

随后又补充“海堤防浪防冲防渗”的课题研究，使堤防研究课题内容更为广泛全面。从1994年开始，经过全国性的重点江海堤防调研，总结分析存在的问题。然后结合实际进行针对性研究，历时八载，提出了成果报告30篇，为课题计划最后编写“堤防设计手册”创造了条件。为使研究成果早日得到交流，使其能有助于防洪减灾的愿望，先将成果汇编成册，定名《堤防渗流与防冲》，提供从事江海堤防工作者参考。遗憾的是，正在研究的“北江大堤无害管涌”试验研究尚未能列入此书。

本书前四部分为江河大堤的调研分析、计算分析与设计施工、加固工程与溃口分析、堤岸冲刷与防冲及其试验等。第五部分为海堤调研分析及结构型式和护坡块体稳定性分析等。第六部分为堤防课题研究的总报告。此外，为了充实出书的内容和更有利于广泛交流，还把与课题密切相关的过去研究的成果“局部冲刷综合研究”和最近十年内发表过的有关堤防渗流、防冲、防浪和抛石护岸及建筑物附近局部冲刷等的英文文章作为附录，供参考。

书中海堤部分还介绍了荷兰最近的名著《堤防与护坡》的部分有关内容，主编该著作的著名堤防专家学者 Krystain W. Pilarczyk 教授应邀愿为即将出版的本书写序推荐，作者深表谢意。

本书脱稿后，受到了水利部建管司写序推荐和南京水利科学研究院的推荐和资助以及中国水利水电出版社的支持，得以顺利出版，作者衷心感谢。

由于本书内容广泛，研究成果尚属阶段性，有赖进一步深入研究和工程实践的检验，不当之处，甚望读者指正。

毛昶熙

2002年12月于南京

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- 24 Calculation of scour depth around groyne head and size of riprap in closure work Mao Peiyu, Duan Xiangbao, Mao Changxi (271)
- 25 Preliminary study results about regulation of river bank collapse (English abstract,p. 285) Mao Changxi, Duan Xiangbao, Mao Peiyu (276)
- 26 A General formula for local scour Mao Changxi (286)

Chapter 5 Investigation with Analysis and Study for Sea Dikes

- 27 Investigation report for present conditions of sea dikes along South-east Sea

- Mao Changxi, Duan Xiangbao, Mao Peiyu (293)
- 28 Computational analysis on structural type of sea dikes and its sliding stability
(English abstract, p. 324)
..... Mao Changxi, Duan Xiangbao, Mao Peiyu, Zhang Shijun, Zhou Ji (316)
- 29 Analysis on stability of revetment blocks of sea dikes
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- 30 Brief introduction of stability analysis and calculation in design
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Chapter 6 General Research Report of Topic "Seepage of Dikes and Scour Defence"

- 31 General Research Report of Topic "Seepage of Dikes and Scour Defence"
..... Mao Changxi (387)

Appendix A Synthetic Study for Local Scour(Russian abstract, p. 452)

- Mao Changxi (417)

Appendix B English papers of related topics published in the last decade

- A General formula for local scour below hydraulic structures Mao Changxi (459)
- Calculation of scour depth around groyne head and riprap stone size at
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- Study on breakwater stability under waves induced seepage flow
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- Analysis of slope stability of earth dam under seepage flow by F. E. M.
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- Effects of suspension-type cutoff walls on seepage flow under levees
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- Experimental study on rock riprap used in river bend anti-scour and bank
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- About research problems on the flood dangers occurred along Yangtze
River in year 1998 Mao Changxi, Duan Xiangbao, Mao Peiyu (510)
- Structural types of sea embankment and their stability analysis
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