

中国水工程安全与病害防治技术丛书

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# 水工程安全与病害防治技术概论

The General of  
Water Works Safety  
and Prevention  
Technologies

钮新强 杨光荣 陈雯 等 编著



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## 内 容 提 要

本书系“中国水工程安全与病害防治技术丛书”之一，是另外7本丛书分册陆续出版后的汇总与精炼。

本书共7章，第1章～第3章为基础单元，论述了概念加固和整体性理论在水工程加固中的应用等基础理论；第4章在安全巡检、观测及健康检测前提下，给出了各类水工程安全评估标准；第5章～第7章分别简述了水工程结构、地质和时效三大缺陷及其加固技术。

本书理念新颖，技术实用，实施有效，可供从事水工程、岩土工程以及公路交通、铁道桥隧、石油化工、矿山能源和水资源等领域的规划、设计、施工、监理、管理人员以及中职、中专与高等院校的有关师生应用参考。

## Abstract

The General of Water Works Safety and Prevantion Technologies (The General for short), one of The Series of Safety and Disaster Prevention for Water Works in China, is the collection and concision of other 7 series published successively.

The General is composed of 7 chapters. Chapter 1, 2 and 3 are the bases, where the basic theories such as the application of conception reinforcement and integration theories to water Works reinforcement are discussed; in Chapter 4, the safety assessment standards of all kinds of water Works are put forward on the basis of safety tour inspection, observation and healthy examination. In Chapter 5, 6 and 7, the 3 defects of water Works such as the defect in structure, defect in geology and defect in effectiveness, as well as its reinforcement technologies are expounded.

With novel ideas, practical technologies and effective implementation. The General may serve as reference for the planners, designers, operators, supervising engineers and managers, as well as the teachers and students in secondary professional schools, secondary specialized schools and university in the fields of water engineering, geotechnical engineering), highway traffic, railway bridge and tunnel, petrochemical industry, mine, energy and water resources.

## 编 著 者 的 话

在江河湖海与地下水源上开发、利用、控制、调配和保护水资源的各类建筑物，称为“水工程”。

水工程包括挡水建筑物诸如闸、坝、堤、海塘等；泄水建筑物诸如溢洪道、泄洪隧洞等；输水建筑物诸如渠道、输水隧洞、管道等；治导建筑物诸如丁坝、顺坝等；专用建筑物诸如水电站及扬水站的厂房、船闸及升船机、防波堤及码头、鱼道、筏道以及给水的过滤池等。

水工程的一个共同点，就是必须承受水的各种作用诸如静水压力、动水压力、渗流压力和水流冲刷等。

根据中华人民共和国水利部《2005 年全国水利发展统计公报》，全国已建各类水闸 39839 座，其中大型水闸 405 座；各类水库大坝 85108 座，其中大型水库大坝 470 座；江河堤 277500km；海塘 10000 余 km，它们对国民经济的发展发挥了重要作用，为水文明进步作出了有益贡献。

由于水工程基础和建筑物本身存在地质缺陷和结构缺陷，设计欠妥、施工材料选择不当、施工质量不佳、运行条件变化、运行年限增加、运行管理存在问题以及地震等不利因素日益凸现，致使约占水工程总量 30%~40% 的水工混凝土建筑物存在不同程度的病害，有的已严重影响工程正常运行，威胁着人民生命与财产的安全，党中央国务院对此给予高度的重视。

2006 年中央经济工作会议强调，集中力量用两三年的时间基本完成全国大中型和重点小型病险水工程的改造，以求“一定不能出现垮坝等重大安全事故”，确保“以人为本”构建和谐社

会的自然生态与人文环境的平衡。

“中国水工程安全与病害防治技术丛书”编写宗旨是密切配合党中央国务院这一重大战略部署进行的一项有意义的工作。旨在“十五”期间共 3259 座病险水工程除险加固总结的基础上,以“概念加固”新思维,采取集体讨论、分工合作的方式,编著了《水工程安全与病害防治技术概论》、《水工程安全检测与评估》、《水工程概预算的原理与应用》、《水工程结构缺陷一般加固技术》、《水工程地质缺陷常用加固技术》、《病险水工程碳纤维补强加固技术》、《病险水工程裂缝修补技术》和《病害水工程维护与管理》共计 8 册一套系列丛书。

各册分别介绍了除险加固技术的简史、现状、技术基础理论、设计计算经验公式、施工工艺流程与工艺、安全、质量检测与评估、施工采用的材料与主要设备,以及病害水工程的技术维护与科学管理方法等。书前汇集了相应术语与符号,书尾载有相关工程应用典型案例。丛书内容新颖简明,文字通俗易懂,集知识性、实用性与可操作性于一体,可谓当今水工程安全与病害防治技术小百科。

“兴建容易修补难”,这是先人为我们总结出来的至理名言。“中国水工程安全与病害防治技术丛书”的出版发行,既有助于近期全国大范围除险加固水工程施工,又前瞻性地为“概念加固”理论发展提供了上升平台。

**编著者**

2007 年 5 月

## **Authors' Statement**

“Water works” is defined as all kinds of structures constructed for the development, utilization, control, operation and protection of water resources in rivers, lakes, and oceans and underground water head.

Water works include water retaining structures, such as sluice, dam, levee, seawall; water release structures, such as spillway, spillway tunnel; water conveyance structures, such as channel, conveyance tunnel, pipeline; river control structures, such as groin, longitudinal dike; and special structures, such as power house, ship lock, ship lift, breakwater, dock, fish way, log chute, filter basin for water supply of hydropower station and pumping station.

A common feature of water works is it has to endure all kinds of actions, such as hydrostatic pressure, hydrodynamic pressure, seepage pressure and current erosion.

According to the 2005 Statistic Bulletin about National Water Resources Development, 39839 water gates has been constructed nationwide, including 405 large ones; 85108 dams and reservoirs, including 470 large ones; levees of 277500 km; seawalls of more than 10000 km. All those constructed structures have played an important role in the development of national economy, greatly contributing to the progress of water civilization.

As more and more unfavorable factors appear in the foundation of water works and structures gradually, including inherent

geological and structural defects, faulty designs, inappropriate construction materials, low quality of construction, changes in operation conditions, increased years of operation, problems in operation management and earthquake, some hydraulic concrete structures accounted for 30% ~ 40% of total amount of water works have various damages at different level, which have seriously affected normal operations, and threatened the safety of people's lives and properties. However, the Communist Party and the Government have attached great importance to those situations.

It was emphasized on 2006 Central Working Conference for Economy that we should concentrate ourselves to basically complete the reconstruction of medium, large and important small sick water works in 2 or 3 years' time in order to avoid fatal safety accidents with a firm hand, such as dam breach, ensuring a balance between natural ecology and culture environment for a harmonious and human oriented society.

The compiling of the Series of Safety and Disaster Prevention for Water Works in China is a significant task closely following the important strategy of the Central Government and the State Council. Based on the summarized experiences drawn from the risk removing and reinforcement of 3259 sick and risk water works during the "Tenth Five" program, with the new view of "Conceptional reinforcement", through group discussions, separated work and cooperation, we compiled the series of 8 volumes, including the General of Water Works Safety and Damage Prevention Technologies, Detection and Assessment of Water Works Safety, Principles and Application of Water Works Estimation, General Reinforcement Technology for Hydraulic structural Defects, Common Reinforcement Technologies for Geolog-



ical Defects of Water Works, Reinforcement Technologies by Carbon Fiber for Sick and Risky Water Works, Crack Repairing Technologies for Sick and Risky Water Works, and Maintenance and Management of Sick Water Works.

In each volume, the authors respectively introduce risk removing and reinforcement technology, including its development history, current situation, technological foundation theory, calculation formulas, construction flow, technics, safety, quality test and assessment, materials and equipments during construction, as well as the methods of technical maintenance and scientific management for sick water works. The corresponding terms and symbols were listed at the beginning and typical application cases of relevant works was listed at the end of each book. The series is concise and easy to understand. At the same time, it combines technology with practice and the feature of operation. It can be regarded as a technical encyclopedia for the safety and damage prevention of water works.

“Easy to construct but difficult to repair” is wisdom that our ancestor summarized for us. The publication of the series is not only beneficial for the risk removing and reinforcement construction of water works nationwide recently, but also provides a rising space in a forward-looking way for the development of conception reinforcement.

**Compilers**

May 2007 in Wuhan

# 前 言

水，对人类栖息的地球而言，正面临着越来越严重的危机：水资源短缺、水环境污染、水生态退化、水土流失和水灾害频发。

在人口日益增长而水资源恶化的形势下，人类以其聪明才智面对现实迎接挑战：以“科学发展观”，针对水资源丰沛的河流，采用工程与非工程的措施变革水流态、强化水功能，在保护水资源的同时，合理开发利用水资源诸如兴建与加固已有防洪和发电的水库大坝，最终达到“人水和谐”的目标。

水电是世界上能够进行商业开发的第一大清洁能源，可再生、无污染、运行费用低，便于进行电力调峰，有利于提高资源利用率和经济社会的综合效益。在地球传统能源日益紧张的情况下，世界各国普遍优化开发水电，大力利用水能资源。目前，水力发电满足了全世界约 20% 的电力需求，有 55 个国家一半以上的电力由水电提供，其中 24 个国家这一比重超过了 90%。中国不论是已探明的水能资源 5.42 亿 kW 蕴藏量，还是可能开发的 4.02 亿 kW 的水能资源，都居世界第一位。水能资源在中国能源发展战略中具有重要的作用，同时，水工程的建设及其加固工程也在世界水工程领域独树一帜、与时俱进。

中国于 1978 年年底实行改革开放以来，30 年的水电建设以超过每 10 年翻一番的速度稳固发展。至 2008 年底，全国水电装机容量达到 1.72 亿 kW，居世界第一位；占全国发电总装机容量的 21.6%，仅次于以煤发电，居全国第二位。预计 2020 年，

中国水电装机容量将达到 3 亿 kW，平均每年新增 1200 万 kW。

中国经济已进入新的发展时期，在国民经济又好又快的持续增长、工业现代化进程加快的同时，资源和环境制约趋紧，能源供应出现紧张局面，生态环境压力持续增大。据此，一方面加快西部水力资源开发、实现西电东送，解决国民经济发展中的能源短缺问题，改善生态环境，促进区域经济的协调和可持续发展；另一方面，分期分批地适时对病害水工程作加固处理，以保证水工建筑物的安全和健康，并延缓水库大坝等的使用寿命。截至 2008 年 12 月 28 日，“全国病险水库除险加固专项规划”项目共 6240 座，其中大型水库 86 座、中型水库 1096 座、小型水库 5058 座。已开工加固的水库有 3217 座，其中大型水库 50 座、中型水库 532 座、小型水库 2635 座，占专项规划总数的 51.6%。“开工率低、加固项目建设进度滞后仍是目前病险水库除险加固项目建设中存在的突出问题”（水利部 2009 年 1 月 7 日《关于全国病险水库除险加固专项规划项目开工情况的通报》）。水利部要求，“各地要继续高度重视，进一步落实责任，强化措施，加强对病险水库除险加固工作的指导、协调和监督检查，确保专项规划项目的顺利实施”。预测表明，到 2030 年左右，我国水电开发终将告一段落，随之而来的是，现有 60 年和未来 20 年左右的水工程将全部进入加固处理阶段，相应加固技术也将及时跟进与创新以满足现实与未来的需要。“中国水工程安全与病害防治技术丛书”正是该加固技术的一套新著。

《水工程安全与病害防治技术概论》系“中国水工程安全与病害防治技术丛书”之一，它是在另外 7 本“丛书”分册陆续出版后的汇总与精炼。本书共分 7 章：第 1 章为绪论，给出了病险水工程的概念、分类、现存的主要问题及决堤溃坝警示，以及中国水工程安全与病害防治技术简况；第 2 章为概念加固与概念设计加固应用；第 3 章为整体性理论及其水工程加固应用；第 4 章为水工程安全检测与评估；第 5 章～第 7 章分别为水工程结构缺

陷加固技术、水工程地质缺陷防渗加固技术和水工程材料时效缺陷试验研究及处置。第1章~第3章为基础单元,为水工程安全与病害防治技术作理论铺垫;第4章是全书的中心,在“安全巡检、安全观测、安全与健康检测”前提下给出了各类水工程安全评估;最后3章是全书的重点,以“三种缺陷(结构、地质与时效等缺陷)”分别概述了相应的加固技术。

《水工程安全与病害防治技术概论》一书,采取集体讨论分工合作的方式进行编著。全书由钮新强、杨光荣、陈雯、颜国红、胡军、徐学军、郭玉、董建军、孟祥芳和陈彦生编著。其中钮新强撰写前言和第1章绪论;杨光荣执笔撰写第2章概念加固与概念设计加固应用和第3章整体性理论及其水工程加固应用;陈雯执笔撰写第4章水工程安全检测与评估;颜国红执笔撰写第5章水工程结构缺陷加固技术;胡军执笔撰写第6章水工程地质缺陷防渗加固技术;徐学军执笔撰写第7章水工程材料时效缺陷试验研究及处置和附录1~附录2;孟祥芳执笔编写术语表和附录3;郭玉、董建军和陈彦生参加了部分章节的编撰。全书由郭玉、董建军和陈彦生共同策划,由陈彦生统稿。书中的英文“内容提要”、“前言”、“目录”和“后记”由刘文翻译。

在《水工程安全与病害防治技术概论》的编著中,引用和参考了水利部及其下属的长江、黄河、淮河、海河、松花江、辽河、珠江七大流域机构,以及国家电力公司、中国工程院和四川、湖北、湖南、重庆、云南、上海、辽宁、广东、广西、新疆、青海、山东、江苏等省(自治区、直辖市)的有关信息资料,在此一并表示谢意。

限于编著者的水平,书中难免有不当或欠妥之处,敬请读者不吝指正。

**编著者**

2009年10月

## Preface

For the earth where the human beings inhabit, water crisis is becoming more and more serious, such as the shortage of water resources, the pollution of water environment, the degeneration of water ecology, the loss of soil and water and the recurrence of water disaster.

With the increase of population and the deterioration of water resources, the human beings face reality and receive challenges with their intelligence and ability. Persisting in the scientific outlook on development, we take the structural and nonstructural measures to transform flow pattern and strengthen water function for the rivers with abundant water resources. While protecting, water resources are utilized and developed reasonably, for example, the reservoirs and dams for flood control and hydropower generation have been constructed and reinforced, so as to achieve the purpose of harmony between human and water.

Hydropower is the first clean energy that can be developed commercially in the world, which is reproducible, pollution-free, low operation cost, convenient for electric power peak regulation and beneficial for the improvement of resources utilization ratio and comprehensive eco-social benefit. Under the situation of increasingly lack of traditional energy, all the countries in the world give priority to the development of hydropower and make full use of hydropower potential. At present, the hydropower generation can satisfy 20% of the power demands in the world, half of the power depends on hydropower in 55 countries

and it accounts for 90% in 24 countries. Both the hydroenergy potential ( $5.42 \times 10^8 \text{ kW}$ ) and the developable hydropower ( $4.02 \times 10^8 \text{ kW}$ ) in China rank first in the world. In China, the hydro-energy resources play an important role in the energy development strategy, and the construction and reinforcement of water projects keeping pace with the times are unique in the field of water project in the world.

Since the reform and opening up in the end of 1978, the hydropower development in China doubled per 10 years within the 30 years. By the end of 2008, the hydropower installed capacity reached  $1.72 \times 10^8 \text{ kW}$ , ranking first in the world and accounting for 21.6% of the total power generation capacity in China only less than that of coal power generation. It is expected that the hydropower installed capacity will reach  $3 \times 10^8 \text{ kW}$  in 2020, with an average increase of 12000000kW every year.

The Chinese economy has entered a new period, with the continuous growth of national economy and the acceleration of industry modernization, the restriction of resources and environment becomes more serious, the energies are in short supply and the pressures on ecological environment increase unceasingly. Therefore, on the one hand, the development of hydropower resources in Western China has been accelerated to achieve the west-to-east electricity transmission, so as to solve the problems of energy shortage, improve ecological environment and promote harmonious and sustainable development of regional economy. On the other hand, the defective and dangerous water projects have been reinforced by stages, so as to ensure the safety and health of hydraulic structures and prolong their service lives. By the end of Dec. 28 of 2008, 6240 reservoirs were involved in the *Specific Plan of Reinforcement and Danger Re-*

*moval of Defective and Dangerous Reservoirs*, including 86 large – sized ones, 1096 medium – sized ones and 5058 small – sized ones. Among them, the reinforcement of 3217 reservoirs has started, including 50 large – sized ones, 532 medium – sized ones and 2635 small – sized ones and accounting for 51.6% of the total. The low operating rate and lagged reinforcement construction are the outstanding problems in the construction of reinforcement and danger removal of defective and dangerous reservoirs (according to the *Notification of Commencement Situation for Specific Planning Project of Reinforcement and Danger Removal of Defective and Dangerous Reservoirs* issued by the Ministry of Water Resources on Jan. 17 of 2009). It was required by the Ministry of Water Resources that, “great importance shall be attached to the work, duties shall be fulfilled and measures shall be intensified further throughout the country, so as to strengthen the guidance, coordination and supervision of reinforcement and danger removal of defective and dangerous reservoirs and ensure the smooth implementation of specific planning project”. It is predicted that the hydropower development in China shall be completed in 2030; consequently, the water projects in the past 60 years and over the next 20 years will enter the stages of reinforcement and the corresponding reinforcement technologies will be followed up and innovated timely in order to meet the demands at present and in the future. The Series of Safety and Disaster Prevention for Water Works in China is just a new book about the reinforcement technologies.

The General of Water Works Safety and Prevantion Technologies (The General for short), one of The Series of Safety and Disaster Prevention for Water Works in China, is the collection and concision of the other 7 books published successively.

The General is composed of 7 chapters. Chapter 1 gives an introduction on the concept, classification, existing key problems and bitter lessons, as well as the past, present and future of water works. Chapter 2 describes the application of conception reinforcement and conceptual design reinforcement. Chapter 3 discusses integration theories and their application to water works reinforcement; Chapter 4 involves the safety detection and assessment. In Chapter 5, 6 and 7, the structural defect reinforcement technologies, the geological defect seepage - control and reinforcement technologies and the test research and solution of material effectiveness defect are expounded respectively. The first three chapters are the bases that provide theoretical basis for the water works safety and defect control technologies. Chapter 4 is the center, where the safety assessment standards of all kinds of water Works are put forward on the basis of safe tour inspection, observation and healthy examination. The last three chapters are the emphases, where the reinforcement technologies for 3 defects of water Works in structure, geology and effectiveness are described correspondingly.

The General is compiled by Niu Xinqiang, Yang Guangrong, Chen Wen, Yan Guohong, Hu Jun, Xu Xuejun, Guo Yu, Dong Jianjun, Meng Xiangfang and Chen Yansheng by means of collective discussion and teamwork. The "Foreword" and "Chapter 1 - Introduction" are written by Niu Xinqiang; Chapter 2 and 3 respectively entitled "Application of Conception Reinforcement and Conceptual Design Reinforcement" and "Integration Theories and their Application to Water Works Projects" are written by Yang Guangrong; Chapter 4 "Safety Detection and Assessment of Water Works Project" is written by Chen Wen; Chapter 5 "Water Project Structural Defect Reinforcement Technologies"



by Yan Guohong; Chapter 6 “Water Works Project Geological Defect Seepage – control and Reinforcement Technologies” by Hujun; Chapter 7 “Test Research and Solution of Water Works Project Material Effectiveness defect” and Appendix 1 and 2 by Xu Xuejun; the “Terminology” and “Appendix 3” by Meng Xiangfang; Guo Yu, Dong Jianjun and Chen Yansheng take part in the compilation of some chapters. The book is planned by Guo Yu, Dong Jianjun and Chen Yansheng together, and Organized by ChenYansheng. The “Abstract”, “Foreword”, “Contents” and “Postscript” are translated by Liu Wen.

In the compilation of General, we cite and refer to some relevant information and data from the Ministry of Water Resources and its subordinate organizations of 7 river basins (Changjiang River, Yellow River, Huaihe River, Haihe River, Songhua River, Liaohe river, Pearl River), the State Power Corporation and Chinese Academy of Engineering, as well as the information of the provinces, autonomous regions and municipalities as Sichuang, Hubei, Hunan, Chongqing, Yunnan, Shanghai, Liaoning, Guangdong, Guangxi, Sinkiang, Qinghai, Shandong and Jiangsu. Here we express our heartfelt thanks.

Due to the limited level of compilers, some unintended mistakes are difficult to be avoided, we hope that the readers will kindly point out.

**Complier**

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