

中国水工程安全与病害防治技术丛书

8

病害水工程维护与管理

Maintenance and
Management
of Sick
Water Works

易晶萍 李飞 胡春燕 张正清 吕国梁 陈彦生 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，主要介绍了在“概念加固”理念下，以“整体性理论”整合我国病害水工程维护与管理的新进展。

全书共6章，第1章为绪论，概述了我国病害水工程维护与管理简史以及“健康维护、精细管理”新思维；第2章为病害水工程维护与管理理论概要，重点概述了安全健康智能诊断原理与失败学的基本涵义；第3章汇集了病害水工程安全监控检测；第4章为病害水工程维护与管理要点；第5章介绍了病害水工程养护与修理新进展；第6章为病害水工程维护与管理典型案例。

本书概念清新、内容翔实。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、冶金矿山的科技管理人员和中职、中专与高等院校的有关师生参考。

Abstract

It is one of the book series, *Safety and Disaster Prevention for Water Works in China*, mainly introduce and summarize the new progress in the field of maintenance and management of risky water engineering based on “integrity theory” under direction of “conception reinforcement” idea.

It consists of the 6 chapters. The first one, namely the introduction, provides a brief history on maintenance and management of risky water engineering in China as well as the newly - advocated thinking— “effective maintenance and precision management”. The second, i. e. theoretical outline on the maintenance and management, focuses on principles of intelligence diagnosis on safety and health and the outline of failure science. The third compiles safety monitoring items and contents of risky water engineering. The fourth sums up the key points of maintenance and management of risky water engineering. New developments in maintaining and repairing of risky water engineering are introduced in the fifth chapter. The sixth collects typical cases of maintenance and management of risky water engineering in an all - round way.

The book, characterized by its clear concepts and substantial contents, can be used as reference for scientific and technical professionals, who get engaged in water engineering, geotechnical engineering, highway traffic, railway, bridges, tunnels, petroleum, chemical industry as well as metallurgic mining, and teachers and students concerned in secondary technical schools and universities.

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“一定不会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、施工技术流程与工艺、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 Chinese 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 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 Committee of the Chinese Communist Party 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 "TenthFive" program, with the new viem of "Conception al 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 Reinforce-

ment Technologies for Geological 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

前 言

从哲学的角度来看,病害水工程的维护与管理应当在科学发展观的指导下,成为促进水工程哪怕是已经存在病害的水工程与时俱进地在下列诸主题上凸显创新和进步。

1. 保持和稳固水工程的理性增长

在国家水资源保护与利用的前提下,水工程规模和数量的增长,应以切实提高人民福祉为宗旨,在合理的承受范围之内,满足人们在自控、自律等理性约束下的需求,来维护已存在病害的水工程复苏,并理性控制新建的水工程的增长数目与速度。

2. 寻求水工程生态环境与社会经济发展的平衡

水工程尤其是病害水工程的维护与管理,必须紧紧围绕水资源的综合利用、节能降耗大做文章,既要及时对已占水工程总量近40%的病害水工程进行修理加固,又要合理规划兴建一批生态环保良性的水工程。

3. 体现“以人为本”的要求

这是病害水工程维护与管理的核心。在哲学上形式表现为维护修理水工程,进而保护水工程所控制的水资源,而水资源的保护与利用的出发点和落脚点最终是人们实现水资源共享,根本在人。任何工程、各种资源,均“以人为本”为最高服务目标。

4. 节约和保护自然水资源

这是病害水工程维护与管理的作用所在。所谓节约就是不浪费;所谓保护就是不破坏。节约和保护自然水资源既在总量上不损失,又在水质上不污染。对病害水工程的修理加固作用,就是维持、扩大和保护自然水资源的基本功能。

5. 大力提高水工程（含及时修理加固好的病害水工程）的维护和管理水平

一方面追求水工程总体效益诸如社会的、人文的、经济的和生态环保的综合效益；另一方面要在维护与管理理念、组织、制度等多方面创新。

6. 推动科技进步与自主创新

病害水工程的维护和管理科技进步，主要体现在下列关键技术上：

（1）水工程老化病害机理、堤防崩岸机理、超薄防渗墙防渗机理、高边坡工程破坏机理、地下厂房围岩加固机理等分析需深入浅出地普及与规范化。

（2）水工程健康监测新技术的开拓创新。包括光纤监测技术、智能型分布式自动化监测系统、高精度、强抗干扰的小量程钢弦式孔隙水压力计、泄水建筑物长期动态观测及数据分析评估、网络技术、大坝工作与安全性能评价专家系统、堤防安全监测技术、水工程工情与水情自动监测系统、设计施工参数分析系统、高速与超高速水力学试验等。

（3）深覆盖层闸、坝、堤、塘地基渗流控制技术。包括“概念加固”理念下，水工程“整体性理论”的完整防渗体系设计、防渗效果检测技术、开发新型优质的防渗材料以及拓展适应大变形的高抗渗塑性混凝土等。

（4）碾压混凝土坝及面板胶结堆石坝缺陷修补加固技术。包括水工程抗震技术、水工程地震反应及安全监测、抗震加固技术应用以及碾压混凝土及面板胶结堆石坝结构缺陷的修理与加固新技术创新等。

（5）水工程高边坡加固技术。包括陡倾角高边坡工程中的岩石水力学影响、直立船闸高边坡稳定加固评价、高边坡监测信息反馈加固设计理论与方法的创新等。

（6）水工程地下硐室群围岩加固。包括硐室群布置优化、硐口边坡稳定、硐室群施工顺序与施工技术优化、盾构关键技术、

有压隧洞经济合理衬砌结构优化,应力场与渗流场的耦合研究以及监测、预警、预报系统的建立等。

(7) 建立全国/流域水工程安全监测与评估管理信息系统。包括其管理“硬件”布网、管理“软件”开发,适时病害险情预警、预报系统和应急处理方案、水工程保护的水资源质量与安全持续可发展监测、排污、消毒和合理调度等。

(8) 逐步健全水工程/水资源/生态环境/人文环境的协调机制。包括病害水工程的合理、有效维护、规范水工程报废标准与拆除措施、定期对其做出风险评估与应对处治措施等。

病害水工程的维护与管理目的,集中而言有3个:一是明确水工程退役评估所需的基本信息;二是对拟拆除水工程所要开展的工程、环境和经济评估的措施;三是比较研究水工程退役的具体技术方案和评估退役水工程之投资与效益。3个目的综合链紧紧扣在水工程退役评估上,其最终结果同样有3个:一是评估的水工程继续运行,并在继续运行中加强维护与管理;二是水工程部分功能将退役,并对没有退役的部分功能继续维护与管理;三是整个水工程全部功能退役。

《病害水工程维护与管理》一书旨在达到上述3个目的的前提下,分别对病害水工程是否退役在工程、环境与经济三方面评估作“整体性理论”整合,而重点放在病害水工程安全评估所应对的维护与管理上。书中理论概要及有关新思维是病害水工程维护与管理必须考量的内容,也是探索我国病害水工程维护与管理规律的必经之路,为此,在第1章和第2章概述其要点,抛砖引玉,以飨读者。其他各章则总结了我国病害水工程维护与管理的新进展和新经验。

《病害水工程维护与管理》一书,采取集体讨论、分工合作的方式编著。全书由易晶萍、李飞、胡春燕、张正清、吕国梁、郭玉、董建军和陈彦生编著。其中,易晶萍执笔撰写前言、术语、绪论、病害水工程维护与管理理论概要和病害水工程安全监控检测;李飞执笔撰写病害水工程维护与管理要点;胡春燕执

笔撰写病害水工程养护与修理；张正清执笔撰写病害水工程维护与管理典型案例 6.1~6.5 和附录 1~附录 3；吕国梁执笔撰写病害水工程维护与管理典型案例 6.6~6.8 和附录 4~附录 6；郭玉、董建军和陈彦生参加了部分章节的撰写。全书由郭玉、董建军和陈彦生共同策划，陈彦生统稿。书中的英文由刘运飞和王九程翻译。

在《病害水工程维护与管理》撰写过程中，引用或参考了水利部、国家电力公司、住房和城乡建设部、交通运输部、铁道部、中国工程院等单位以及浙江、广东、福建、辽宁、吉林、山西、北京、江苏、安徽、河北、新疆、甘肃、湖北、湖南和河南等省（自治区、直辖市）的信息资料，在此一并表示感谢。

限于编著者的水平，书中难免有不当欠妥之处，恳请读者不吝斧正。

编著者

2009 年 3 月

Preface

In terms of philosophy, maintenance and management of risky water works, in accordance with scientific outlook on development, is expected to keep pace with times and bring into full play innovation and progress in the following aspects for water engineering, including risky ones.

1. Maintain rational development of water engineering

The development of water engineering in size and number should consider protection and utilization of water resources as precondition, and aim at improving welfare of people actually. Meanwhile, within their reach water engineering are required to meet people's needs under control of people's self - discipline, contribute to recovery of risky water engineering, and bring their numbers and growth under proper control.

2. Try to strike a proper balance between ecological environment of water engineering and social economic development

Water engineering, especially maintenance and management of risky water works, must center on comprehensive utilization of water resources, energy saving, i. e. efforts should be made not only to maintain and reinforce risky water works accounting for 40% of the water works on time, but also to reasonably plan a number of environmentally - friendly water works.

3. Embody the idea of "putting people first"

The idea, the core of maintenance and management of risky water works, expresses itself from the angle of philosophy in maintaining and repairing of water engineering, and conserve wa-

ter resources under control of water engineering. The conservation and utilization of water resources is designed to meet with people's needs to share water resources, so people is its focus. All projects and all resources must take "putting people first" as their ultimate objective.

4. Economize and conserve natural water resources

The above point is the purpose of maintenance and management of risky water works. Economizing means no waste while conserving refers to no harm. The two points reflect themselves in no loss of water volume and no polluted water. The maintenance and reinforcement of risky water works is to maintain and enlarge basic functions of natural water resources.

5. Greatly enhance maintenance and management level of water works (including timely - reinforced risky ones)

On the one hand, efforts should be paid to comprehensive benefits of water works, including social, humanistic, economic, ecological and environmental ones; one the other hand, innovation should be made in ideas, framework and systems of maintenance and management.

6. Promote independent innovation and scientific and technological development

The advancement of the maintenance and reinforcement of risky water works should find itself expressed in the following key technology:

(1) An analysis should be made on water projects' aging mechanism, bank collapse mechanism, seepage - proofing mechanism of ultra - thin cut - off wall, failure mechanism of high slope projects, and underground workshops' adjoining rock reinforcement mechanism. The analysis needs to be standardized and popularized in a simple way.

(2) Innovation should be made on the new technology for water engineering' health monitoring. It involves optical fiber monitoring technology, intelligent distributed automatic monitoring system, small - range vibrating - wire pore pressure gauge with high precision and strong anti - interference, long - time dynamic observation and data analysis and assessment of discharge structures, network technology, evaluation expert system for dam operation and safety, monitoring technology of dyke safety, automatic monitoring system of water engineering' structural and water regime, analysis system of design and construction parameters, experiments on high - speed and super high - speed hydraulics, etc.

(3) Attention should be paid to foundation seepage control technology of deep - overburden floodgates, dams, dikes, ponds. It, under the direction of "integrity theory", contains the comprehensive anti - seepage system design as a part of the above - mentioned water projects' "conception reinforcement" idea, detection technology of anti - seepage effects, developing new anti - seepage materials with high quality, exploring high anti - seepage plastic concrete compatible with large deformation.

(4) Work should be done in repairing and reinforcing technology of defects of roller - compacted concrete dams and face rockfill dams. It comprises earthquake - proofing technique of water engineering, earthquake response and safety monitoring of water engineering, aseismic strengthening technology application, and technical innovation of repairing and reinforcing of structural defects of roller - compacted concrete and face rockfill dams, etc.

(5) Devotion should be made to high slope reinforcement technology of water engineering. It consists of rock hydraulic influence on anti - dip - angle high slope projects, evaluation on high slope stability reinforcement of vertical locks, innovation of

reinforcement design theory and methods of high slope monitoring information feedback and so on.

(6) Efforts should be made on adjoining rock reinforcement of underground chambers. It is made up of placement optimization of chambers, stability of chamber entrance slopes, sequence and technological optimization of chamber construction, key technology of shields, economical and reasonable lining structure optimization of pressure tunnels, coupling research on stress field and seepage field, establishment of monitoring and warning and forecasting systems of stress field and seepage field, etc.

(7) Establish safety monitoring and assessing management information system of water engineering throughout the nationwide basins. It is composed of management "hardware" layout, management "software" development, timely risk warning and forecasting system, emergency plan for risks, monitoring sustainable development of quality and safety of water resources conserved in water engineering, pollutant discharge, disinfection, proper allotment and so on.

(8) Gradually improve coordination mechanism among water engineering, water resources, ecological environment, and humanistic environment. It includes proper and effective maintenance of risky engineering, regulating out-of-service criteria and dismantling measures of water engineering, making risk assessments regularly as well as countermeasures, etc.

To sum up, there are three purposes of maintenance and management of risky water works. First, specify basic information needed for assessment on out-of-service water works. Second, make measures on working, environmental, and economic evaluation for dismantling water works. Thirdly, make comparative study on specific technological plans of retiring wa-