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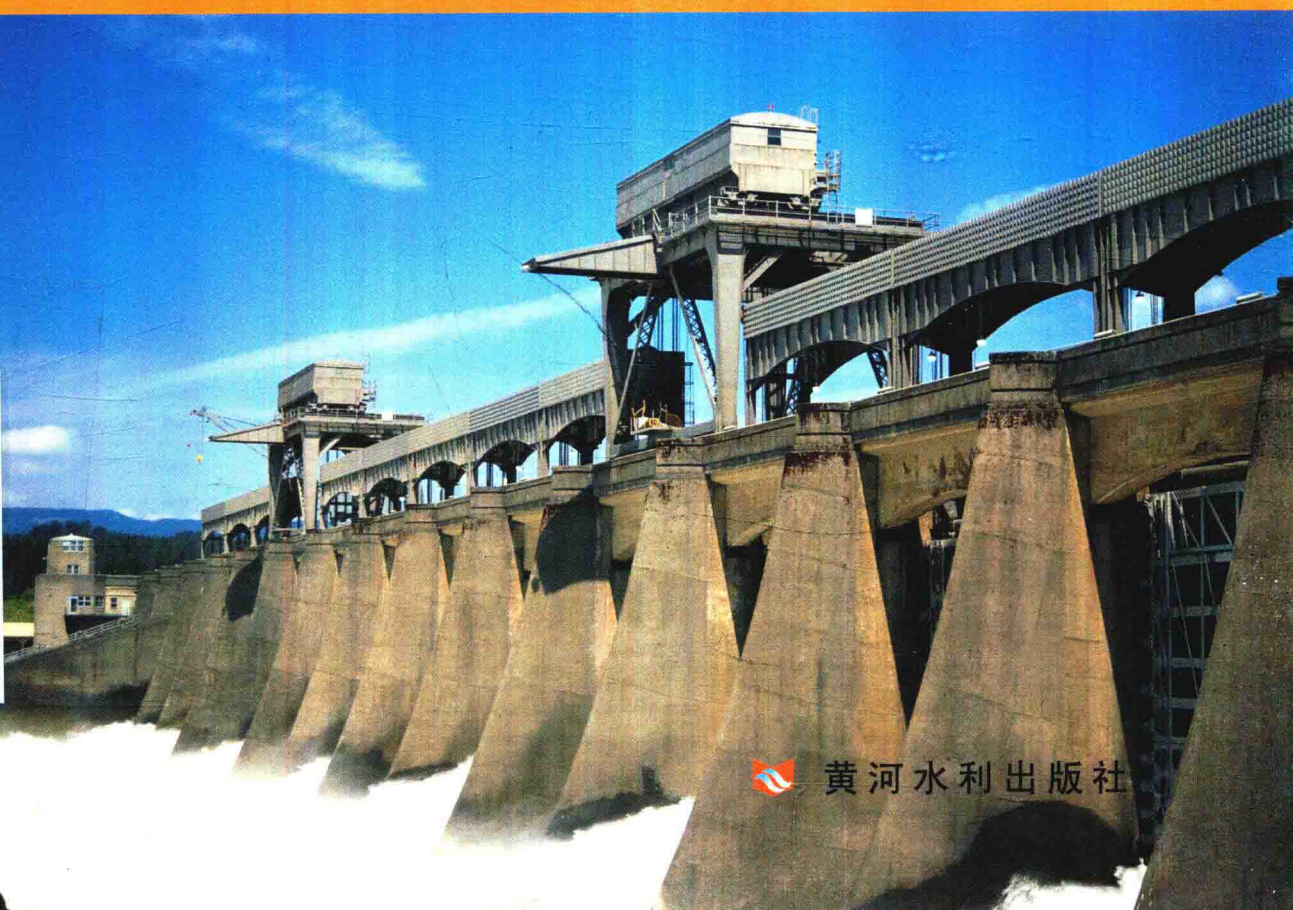
任智锋 汤慧卿 李润芝 张宁 翁建平 徐丽 译



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Synopsis

The book introduces technical problems on dam security observation scientifically. For concrete dam, earth rock dam, bank of near dam region, water conveyance structure, and outlet structure, several plans, are resented. For example, observation item optimizing, test point optimizing, reasonable distribution, and facility selection. Moreover, the book introduces security observation designs of seven typical concrete dams and earth rock dams. Then, it shows evaluation of above designs. Based on past experience of dam security observation designs, advanced new technology and means are generated. Of course, it has tight relationship with practical engineering. As a result, based on the principle (practical, reliable, advanced, economic), design is optimized. Purposes, such as damsecurity observation, gaining profit, improving technology level of design and construction, could be achieved.

The book is available for technicians of water resources and hydropower engineering design, construction, observation, scientific research, operation, management, facility production. Moreover, it could be used for staff of university as well.

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Brief Introduction of the Writer

Zhao Zhiren as a professor of engineering, a senior researcher, and an honorary doctorate who was born in Suzhou, Anhui, graduated from Beijing College of Water Resources and Hydropower. He worked at IWHR and BIDR. Now he is a chief engineer of Tianjin Dam Security Observation Research Centre and a senior consultant of the State Power Corporation Automation Research Institute, MWR Water Conservancy Hydrological Automation Research Institute, Xinjiang Institute of Water Resources and Hydropower Research.

Mr. Zhao has prizes for progress in science and technology from nation, ministry of water resources, ministry of power industry, ministry of water conservancy, and Tianjin. He also has prizes of excellent academic papers, from Chinese Hydraulic Engineering Society and China Society for Hydropower Engineering, and prize of excellent science technology book, from ten provinces in Northern China.

Important publications are listed: *Observation Technology of Concrete Dam External Part* from water resources and electric power press, *Observation Technology of Concrete Dam Internal Part*, *Theory and Application of Dam Security Observation* from Tianjin science and technology press, Observation and analysis of Sanmenxia dam. Mr. Zhao is one of main writers of *Technical Specification for Concrete Dam Safety Monitoring* (SDJ336 - 89). In the same time, there are over 120 academic papers and 20 translation papers on *Journal of Hydraulics*, *Journal of Geotechnical Engineering*, *Memoir of ICOLD*, *Hydraulic Electrogenerating*, *Water Resources and Hydropower Engineering*, *Dam observation and Geotechnical Tests*, *Water Conservancy and Hydropower Translation* etc.

Mr. Zhao worked for over 20 large and medium projects security observation, such as Liujiaxia, Yuqiao Reservoir, Malaysia Penang Reservoir etc. He played roles as design, construction, observation, analysis, scientific research, and manufacture. More than that, he worded for over 10 nation or province science and technology projects which are key points or projects withfund. He, as expert, worked for over 30 projects on safety appraisal, investigate, or bid elevation. For example, Three gorges dam, Xiaolangdi dam. In dam security observation area, he has creationary achievement as well as outstanding contribution.

Awards are listed: medals of Tianjin seventh and eighth five-year plans in 1987 and 1995, special government allowance in 1992, certificate and allowance of expert from Tianjin in 1994, national water resources system advanced worker from ministry of personnel and ministry of water resources in 1995, safety appraisal expert certificate of reservoir dam from ministry of water resources in 1997. In 1999, he was employed as panel member of dike hidden danger and dangerous case test technology. In 1993, he was invited for lectures and study visit in USA and Canda.

The Original Writer's Preface

In recent years, as an important portion of hydraulic and hydropower engineering project, the dam safety monitoring is getting more and more extensive importance by the domestic and international dam field, related meetings about discussion of dam safety monitoring issues are also attracted much attention by professionals, at the same time, specializing in dam safety monitoring research and design staff have been also rising trend year by year. It is important to ensure the safety of dam operation, produce the best project benefit and improve the design and construction technology level.

Dam safety monitoring design will guide and control the safety monitoring works execution, the effect and function of safety monitoring is closely related to the quality of the design. Unfortunately, no publication which is specialized in introduction of the dam safety observation design issued so far at home and abroad, most practitioners will accumulate experience gradually on their own groping or teacher's guidance. In view of this, I am on the occasion of my retirement, use my spare time to compile this book, designed to provide Technical Monograph about a more comprehensive, systematic discussion of security monitoring design for safety monitoring professionals, especially the design staff, in their actual work as reference. The passage of time, this book since the first issue in the country has been 14 years, the reaction is still relatively good, that this book can be combined with actual engineering, more practical, after hearing the news, I personally feel gratified at it, that did not waste of my effort and realized the original intention of this book.

Probably in June of 2016, I was still in the vacation period at my daughter's home in the United States, one backbone technician from Hydraulic Department, who is my colleague of the China Water Resources Bei Fang Investigation, Design & Research CO. LTD (BIDR), contacted me through various ways, and expressed the thought that he and his several colleagues want to translate the Chinese version *Dam Safety Monitoring Design* into English in their spare time, they hoped to get my support. I was surprised to hear that. Firstly, they are all backbone in the work, they are very busy, the translation of this book with spare time will spend a lot of energy. Secondly, the publishing will also cost a sum of money. But I was touched by their professionalism finally. Because everyone knows that, in terms of economic efficiency, publishing a book, for the individual, is to 'pay' not to 'earn', under today's money-driven society, they go so far as to sacrifice their spare time to rest, burn the midnight oil to work on the translation with no compensation, this spirit is admirable and I agreed their request without hesitation, and promise to support them.

About the audience, they think this book is rather practical, it sums up a lot of engineering experience, and is recommended by many staff who engaged in safety monitoring design. In recent years, with the increased influence of China's hydraulic and hydropower industry at abroad, many domestic design institutes have undertaken a lot of foreign hydraulic and hydropower engineering design tasks, at the same time, safety monitoring design tasks increased correspondingly. As the

similar books is so limit at home and abroad, translating this book into English is not only benefiting to improve the English level of the designers, but also facilitating the direct communication with the foreign profession.

It should be noted that several young colleagues who participated in the translation work are bachelor or master degree, with many years design experiences. They worked for assignment of translation, proofreading and strict compilation. In order to avoid technical mistakes, I have pointed out the issues in the original book and the key points which should be paid attention to during translation. However, since English is not our mother language, it is difficult to achieve "perfect, infallible", but it should be said the results is quite well, basically expressed the original meaning, especially in the technical aspects.

A few words as preamble, after publication, if it is practical, except for appreciating the translator, I should give thanks for the publishers and all other people who support the publication. I expect this book to achieve the desired expectation, this will also comfort myself as original author.

Original Author Zhao Zhiren

Preface

As an important part of water resources and hydropower engineering, dam security observation aroused wide concern in the field of dam construction. There are 13 international dam conferences since 1964. The conference is convened per 3 years. 12 of them have relationship with dam security observation. It plays essential roles for dam security, gaining profit, improving technology level of design and construction.

Security observation is in the control of dam security design. Effect and role have tight relationship with observation design quality. As vice director of CSHE dam security committee, director of dam security observation design and construction committee, director of dam security observation & management of Tianjin Society of Hydroelectric Engineering, the author hosted several national conferences on dam security observation. Many technical problems are discussed and solved. For example, national dam security observation design and construction colloquium, convened in 1997, said that design, construction and facility are leader, guarantee and key respectively. More than that, national dam security observation design and construction seminar, convened in 1999, said that design should be optimized, construction should guarantee quality, and facility should be reliable. National dam security observation apparatus and automation technology colloquium & exhibition, convened in 2001, said that design principle should be practical, reliable, advanced and economic.

Because of efforts from several aspects, above principle and conclusion are carried out in security observation design. Therefore, design level is improved. In the same time, new technology, new method, and new facility are applied. Although many achievements have been obtained, there are some problems and shortage. Nowadays, the main problem is unreasonable design of observation item and test point. More than that, method is not advanced. Facility cannot be selected properly, which is not able to get key point. Therefore waste of manpower, material resources, and fund cannot be avoided. It has an effect on authenticity and reliability, so actual problem, about dam observation, cannot be solved. There are not any special books on dam security observation design in the world. A book, which introduces dam security design entirely as well as systematically, is necessary. This book filled the blank. It is available for security observation technician, especially for observation designer.

The purpose of this book is enhancing pertinence and representativeness of observation design. Moreover, it improves economical efficiency and rationality. As results, technology level and design quality of observation design could be enhanced. Principles, such as practical, reliable, advanced, and economic, should be carried out during design optimizing. Via this book, the author aims at improving dam security observation and having positive effects on hydropower engineering construction and management.

Some parts of this book acquired funds from MWR scientific and technological key project and investigation design research project. It is supported by MWR international cooperation and science

technology department, GIWP, and TIDI.

Chusheng Cao, director of TIDI expert committee, former chief engineer, CAE academician, China engineering design master, professor of engineering, professor of Tianjin University, checked this book. Thank him sincerely.

During publishing, it is supported by TIDI. Many thanks for the help.

Due to restriction of author's knowledge, there would be some mistakes. Please pick them out.

Author

December 2002

Contents

Chapter 1

Overview

1.1 General Principle

1.1.1 Design Purpose

1.1.1.1 Ensure Safe Operation of Structure

A set of monitoring system that is designed to monitor the performance of building and foundation is the essential measure to ensure safe operation of structure. Based on it, unusual occurrence could be found out easily and respective analysis and treatment could be adopted in time, thus serious accident and disaster could be prevented. Meanwhile, based on obtained monitoring data, future performance and development tendency could be forecasted. It could provide scientific basis for safety impoundment, appraisal and reinforcement of dam.

1.1.1.2 Achieve Project Benefits

According to observation results, building and foundation should be regarded as unity. Security degree should be determined in different conditions. Building and foundation should be able to control project operation. Water level should be adjusted properly. Reservoir operation should be paid enough attention so that achieving benefits in safe condition. And huge investment, caused by strengthening, could be avoided.

1.1.1.3 Examine Design and Improve Design Ability

Hydraulic structure design has obtained lots of experience. Having said that, however, many influencing factors should be studied. In the design, unknown factors are usually decided based on experience or assuming. Existed projects are real models. They are able to show influencing factors and examine validity of design. So design could be more reasonable, impeccable and innovative. Technical level could be improved as well.

1.1.1.4 Improve Construction and Accelerate its Progress

Construction observation result reflects construction quality and condition, which offers data about construction improvement. Most new construction techniques and methods would be accepted and spread after actual fruits were demonstrated to be reasonable. Observation data is able to tell applicability, advantage and improving approach of construction method.

1.1.2 Design Requirement

1.1.2.1 Ensure Pertinence and Practicability

Engineer should be familiar with project, such as project scale, structure design method, hydrology, weather, landform, geology and existed problems. Observation design should have clear purpose. To be pointed out, project features and key zones should be taken into consideration together. It should have clear purpose, well applicability, highlighted key point and proper arrangement. Each phase of design should be optimized in order to gain better observation result with little investment.

1.1.2.2 Fully Reliability and Integrality

Observation system design needs general plan which is optimum plan based on reliability, continuity and integrality demonstration. Of course, it is via several different observing methods. This plan should satisfy requirements of construction period, storage period and operating period observation. For different buildings and parts, different methods should be carried out. These methods should be under a general plan and carried out step by step.

1.1.2.3 Advanced Observation Methods and Apparatus

Observation method and instrument should satisfy the requirements of accuracy. Based on former experience, advanced techniques should be applied. Structure data should be updated timely. For data which is key point of project safety and does not workable for manual test, automatic system could be used for observation and transmission.

1.1.2.4 Necessary Economy and Rationality

Observation should be simple. Test point should be selected and construction should be convenient. Observations of deformation, seepage and stress should be matched with each other. Of course, they should satisfy future observation data analysis. Observation results are able to achieve expected aim. At the same time, observations should be economic enough so that investment could be as less as possible.

According to *reference* [1], observation design must be carried out by design group with corresponding qualification certificate.

1.1.3 Design Preparation

1.1.3.1 Understanding Observation Theory and Methods

Designer should understand basic knowledge of observation, observation facility function and test theory. What is more, these facilities should be used properly during design arrangement. Features and relations of deformation, seepage and stress observations should be known well. Requirements of observation data analysis should be taken into consideration and data should be fully utilized.

1.1.3.2 Being Familiar with Project Design Data

Instructions, drawings, experiments and calculation results of structure design and construction design

should be known well. Furthermore, project features, key problems, plan and requirements of water storage operation should be understood as well. As a result, mission and scale of observation system could be determined.

1.1.3.3 Mastering Main Content of Observation Design

During feasibility study phase, general design plan of security observation system, observation items, quantity and investment of facilities should be proposed. Of course, it should obey design optimization.

During preliminary design phase, security observation system general design plan, test point arrangement, communication and network structure should be updated. Main facilities quantity and project estimate budget should be determined approximately.

During bidding design phase, observation items installation specification should be proposed. Instrument upgrading list, software, buildings, test order of main observation items and project estimate budget should be determined.

During construction phase, construction detail drawing, manufacturing drawing, facility assembling accuracy and requirements should be proposed. It should be based on observation system design or technical requirements.

During impoundment phase, observation working scheme and main observation technical index should be determined. At the same time, dam operating condition should be evaluated as well.

During operation phase, observation data analysis, security examining and authenticating affairs should be carried out. Furthermore, observation system should be updated.

1.2 Observation Items

1.2.1 Content of Item

1.2.1.1 Security Observation Range

Reference [1] item 2 said, 'A dam includes permanent water retaining structure, matched outlet structure, water conveyance structure and ship passing structure etc.' *Reference* [2, 3] general provision also has related rules. Therefore, in this book, dam could be considered as all kinds of hydraulic structures and bank slope near the dam zone. All of them are within the range of security observation.

1.2.1.2 Field Inspection Item

In writer's opinion, structure security observation consists of field inspection and apparatus inspection. Furthermore, field inspection has two parts, i. e. walkaround inspection and field examine. Simple measuring tools or temporary apparatus should be used for structure inspection. In behaviour or quantity, problems could be seen.

Items of field inspection can be seen from Table 1.1. In principle, all the structures should be inspected as Table 1.1. In this table, '√' item must be examined and others could be examined up

to actual condition. If necessary, it could be modified.

Table 1.1 Field inspection items

Category	Item	Earth rock dam	Rock – fill dam	Concrete dam	Sluice, spillway	Tunnel, underground power house	Reservoir
Hydrology	Erosion	√			√	√	
	Plant	√			√		√
	Lair	√					
	Sedimentation	√	√	√	√	√	√
	Frost			√	√	√	√
Deformation	Crack	√	√	√	√	√	√
	Breakdown	√	√		√		√
	Landslide	√	√	√	√	√	
	Upheaval	√	√				
	Diastrophism	√	√	√			
Seepage	Leakage	√	√	√	√	√	√
	Drainage	√	√	√	√	√	
	Piping	√					
	Wet spot	√					
	Muddiness	√	√	√	√	√	
Stress	Carbonization			√	√	√	
	Rusting			√	√	√	
	Weathering			√			
	Exfoliation			√		√	√
	Softening			√			
Water flow	Scour	√	√	√	√	√	√
	Flow state			√	√	√	√
	Cavitation			√	√	√	
	Attrition			√	√	√	
	Atomization				√	√	
	Vibration				√	√	

1.2.1.3 Apparatus Observation Item

Apparatus includes apparatus monitoring and data analysis. Independent variable and dependent variable of structure are under long term continuous observing via special stable facilities. It is quantitative. Based on calculation and analysis about observation data, working condition should be known well.

According to different grades, observation items are listed in Table 1.2. In this table, '√' item must be examined and others could be examined up to actual condition. And rockfill dam includes facing dam.

Table 1.2 Apparatus observation items

Category	Item	Classified by projects						Classified by grades			
		Earth rock dam	Rock-fill dam	Concrete dam	Sluice, spillway	Tunnel, underground power house	Reservoir	1	2	3	4
Hydrology	Water level	√	√	√	√	√	√	√	√	√	√
	Precipitation	√	√	√	√		√	√	√		
	Wave	√					√				
	Sluicing			√	√	√		√			
	Air temperature	√	√	√	√			√	√	√	
	Water temperature			√				√	√		
Deformation	Surface	√	√	√	√	√	√	√	√	√	
	Interior	√									
	Foundation			√				√	√		
	Crack	√	√	√	√	√		√	√	√	√
	Joint		√	√		√		√	√		
	Slope	√	√	√	√		√	√			
Seepage	Dam body	√	√	√				√			
	Dam foundation	√	√	√	√			√	√	√	
	Seepage around dam	√		√				√	√		
	Seepage discharge	√	√	√	√	√	√	√	√	√	√
	Underground water					√	√	√			
	Water quality	√	√	√	√			√			
Stress	Soil										
	Concrete							√			
	Rebar		√	√		√		√	√		
	Steel plate							√			
	Interface	√									
	Temperature			√				√	√		
Water flow	Intensity of pressure				√	√		√			
	Flow velocity				√	√					
	Aeration										
	Energy dissipation				√			√			
Earthquake	Vibration										

1.2.2 Test Order of Items

1.2.2.1 Field Inspection Category

Ⅰ Daily inspection

Based on project condition and features, reasonable inspection system should be built up. It should include inspection time, zone, content and requirements. Furthermore, daily inspection route and procedures should be determined, which would be carried out by experienced staffs.

Ⅱ Annual inspection

During flood season, dry season, frost period and ant damage period of each year, comprehensive or special inspection should be carried out by operating staffs. Of course, items of inspection have been ruled. Based on daily inspection, necessity of field inspection should be determined.

Ⅲ Special inspection

Some special conditions, such as flood, earthquake, accident etc., have serious impact on operating security. Field inspection should be carried out by competent department, i. e. walkaround inspection and field inspection.

1.2.2.2 Apparatus Observation Phases

Ⅰ Construction phase

It is from observation facilities established to fist water retaining.

Ⅱ Storage period

It is from fist water retaining to reservoir water level reaching normal water level, which is within 3 years. If the reservoir is emptied and filled up again, it should be observed as storage period. If the water level cannot reach normal water level within 3 years, observation should be regarded as operating period.

Ⅲ Operation period

It is normal usage period after water storage phase.

1.2.2.3 Field Inspection Frequency

According to categories, field inspection frequency could be selected, which can be seen from Table 1.3.

Table 1.3 Field inspection frequency

Category	Construction period	Storage period	Operation period
Daily inspection(time per year)	10 - 4	30 - 8	4 - 2
Annual inspection(time per year)	4 - 2	8 - 4	3 - 2
Special inspection	If necessary	If necessary	If necessary

Ⅰ Daily inspection method

Its major part is walkaround inspection. Except for eye-measurement, some other methods are listed: hammer, drill rod, steel ruler, magnifier, telescope, counting cup, litmus paper, elasticity tester, camera, video recorder, closed circuit, diver etc.

Ⅱ Annual and special inspection methods

It includes walkaround inspection and field inspection. Field inspection is nondestructive examination

which consists of high pressure ground penetrating radar, electromagnetic profiler, resistivity imaging instrument, infrared temperature sounder, ultrasonic detector, acoustic detector, underwater TV detector, diving instrument, underwater ship etc.

1.2.2.4 Apparatus Inspection Frequency

Table 1.4 shows manual test frequency in normal condition. For special condition which influences project security or automatic observation condition, test number should be added. Hydrology and hydraulics test frequency is based on actual necessity, so it is not listed in the Table 1.4.

Table 1.4 Apparatus inspection frequency

Category	Item	Construction period	Storage period	Operation period
Deformation	Exterior	4 – 2 /month	10 – 4 /month	6 – 2/year
	Interior	10 – 4 /month	30 – 10 /month	12 – 4/year
Seepage	Seepage	10 – 4 /month	30 – 10 /month	6 – 3/month
	Water quality	6 – 3/year	12 – 6 /month	12 – 3/year
Stress	Stress	6 – 3/month	30 – 4/month	12 – 4/year
	Temperature	15 – 4 /month	30 – 4 /month	6 – 2/month

1. In construction period, dam body filling is fast. Deformation and stress observation frequency could be at upper limit.
2. In water storage period, impounding phase could select upper limit. After that, relative stable phase could use lower limit.
3. In operation period, test result, varying significantly, could make use of upper limit. While, it could select lower limit in stable condition. When project is in face of extension, rebuilding, water level raising, and refilling in empty reservoir, observation should be regarded as in construction period or in water storage period.

Because of some reasons, test number or test items should be decreased or stopped. It should be reported to department in charge. These reasons are listed as following: reservoir is full of sediment, it is discarded, reservoir purpose is changed, and operation condition is stable.

1.3 Limit Requirements

1.3.1 Deformation Observation

1.3.1.1 Deformation Symbol

Deformation symbol can be seen from Table 1.5. Design should pay attention to it so that more suitable methods and facilities can be obtained.