INTERNATIONAL SYMPOSIUM ON
DAMS FOR A CHANGING WORLD
-Need for Knowledge Transfer across the Generations & the World
Kyoto, Japan June 5, 2012

Initiatives for Knowledge Succession in Dam Engineering

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ABSTRACT:
Many dams have been built in Japan, but only a few new large dams have been constructed in recent years due to financial deterioration and lack of suitable dam sites. In contrast, there has been an increase in flood control projects by redeveloping or renovating old dams which were built under existing river plans to cope with the increasing number of storm disasters. Knowledge of dam construction has been handed down from generation to generation in regional development bureaus and municipal governments. But in near future, it will need to be shared nationwide including new technologies such as for renovating dams. Advanced dam control methods and effective human resources development are also needed to respond to increasing storm events. This paper describes how the Ministry of Land, Infrastructure, Transport and Tourism and related institutes are maintaining and succeeding knowledge of dam engineering, developing human resources and contributing to the international community.

Keywords: dam engineering, knowledge succession, information sharing, training

1. INTRODUCTION

There are about 3,000 dams over 15 m high in Japan as of 2012. Of these, 525 have flood control functions and are controlled by regional branches of the national government (92 dams), Japan Water Agency (22 dams) and municipal governments (411 dams). Today, 126 flood control dams are being built, including 40 by the national government, 7 by the Japan Water Agency and 79 by municipal governments. The roles of the national government, Japan Water Agency and municipal governments are prescribed by the River Act, Act on Advancement of Water Resources Development and Act on Japan Water Agency as building and controlling dams that affect: dams which are important from the aspect of flood control in the major river systems in Japan (Class A river systems), important dams on designated seven river systems for water resources development , and other dams, respectively.

Although many dams have been built in Japan, no new dam construction project has started since 2004 due to the changing situation, such as financial deterioration and lack of suitable sites for building dams because dams have already been built on most suitable sites. Indeed, 105 dam projects have been cancelled since 2000, resulting in a sharp reduction in large dam projects from 316 in 2000 to 119 in 2012.

In contrast, there has been an increase in projects for redeveloping and renovating old dams built under existing river plans, to enhance flood control against storm disasters, which have become increasingly severe. For example, in 2006 a storm with a maximum cumulative rainfall of 1,200 mm flooded the Sendai River in Kagoshima Prefecture and inundated more than

2,000 houses. To prevent recurrence, a project to redevelop the Tsuruda Dam, which was completed in 1956 for flood control and power generation, was started in 2007 with a budget of 46 billion yen to improve its flood control capacity.

In Japan, there are few sites remaining that require knowledge for constructing large dams. Therefore, knowledge should be shared not only within single regional development bureaus and municipal governments, but throughout Japan. Engineers who have conventional knowledge should be given opportunities to learn new technologies such as for renovating old dams, as an increasing number of sites will require new technologies.

Effective development of human resources on dam control skills is also needed as older experts retire and as national and regional administrative bodies reduce personnel. Also, advanced technologies for controlling dams during storms need to be developed.

2. KNOWLEDGE SUCCESSION IN DAM ENGINEERING

2.1. Knowledge succession on dam construction

Japan has maintained and transmitted knowledge on dam constructions by using various technical standards and engineers' know-how in actual dam construction, developing new technologies using knowledge acquired at the sites, developing experts who have advanced knowledge, and using the knowledge at subsequent dam construction sites, thus forming a cycle of knowledge. However, technical information and human resources which support this cycle of knowledge have shrunk and become regionally unbalanced due to a decline of dam construction sites. On the other hand, engineers must learn how to design and construct dams under new and difficult conditions in large-scale dam renovation projects for strengthening flood control, such as additional construction of outlets accompanying changes in usage of reservoir capacity, etc. which are increasing to make effective use of the existing stock of dams. A requisite cycle of knowledge needs to be kept to handle new issues, to build and control dams safely, economically and effectively at existing and future sites, and to maintain and transmit knowledge on dam construction broadly.

The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) introduced a new system in 2011 to share and maintain knowledge on dam construction in liaison with the Water and Disaster Management Bureau, the National Institute for Land and Infrastructure Management (NILIM), the Public Works Research Institute (PWRI), and the Regional Development

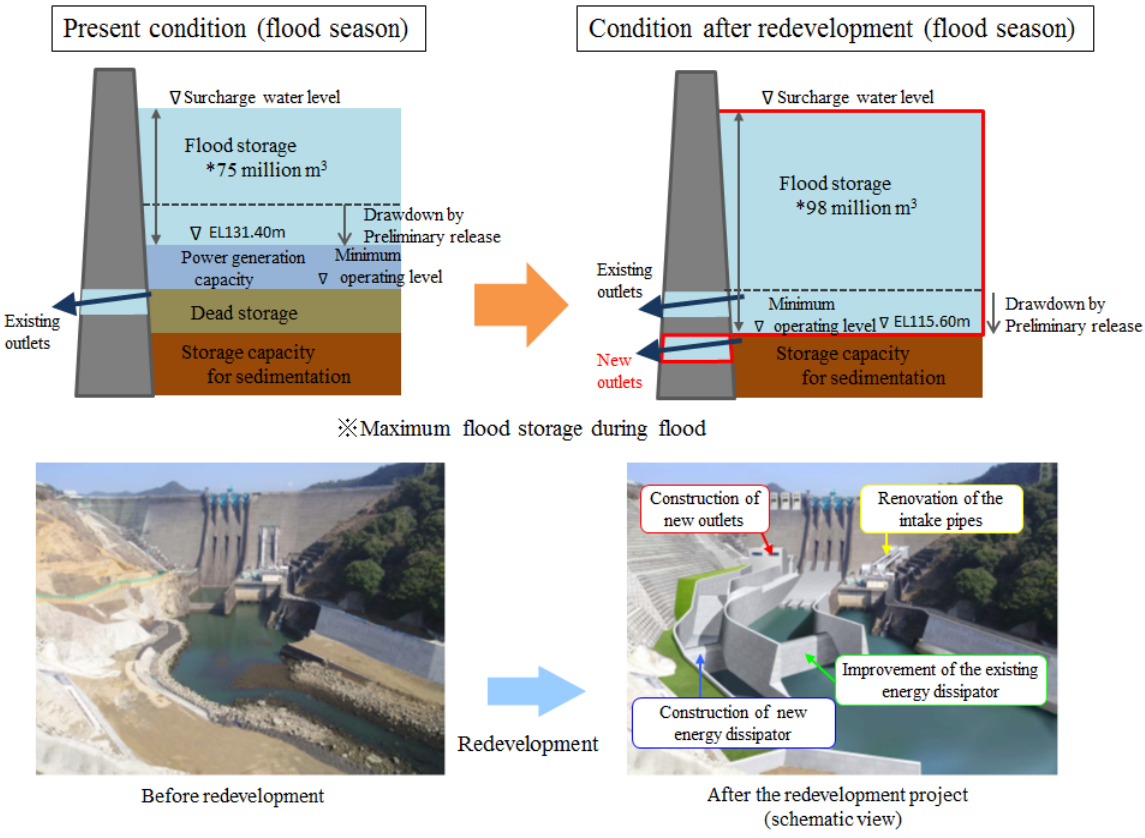

Figure 1. Example of dam redevelopment (Tsuruda Dam Redevelopment Project)

Bureaus.

2.1.1. Study Group on Dam Engineering

Each regional development bureau has taken independent actions to share technical information from dam construction projects within their areas and train personnel, such as by holding study meetings and conducting field surveys. However, with the reduction in dam construction sites, some regional development bureaus are struggling to continue such activities by themselves. The MLIT, the NILIM, the PWRI and the Regional Development Bureaus therefore established a Study Group on Dam Engineering and started various activities with the following objectives.

The first objective is to share information on dam construction throughout the nation across regional borders. The efforts by individual regional development bureaus for maintaining and transmitting knowledge on dam construction are to be united as a whole irrespective of regional boundaries. Dam construction sites will be used to share technical information not only for engineers in charge of the dam construction project but also engineers from other regional development bureaus.

The second objective is to accumulate technical information on dam construction. Because each dam is unique, dams cannot be designed and constructed by relying merely on technical standards even though there are diverse technical standards available; advanced technical judgment is required. Some experienced experts have given technical advice to regional development bureaus on dam projects mainly based on their personal knowledge, which may be lost when they retire or their number decreases, so it was decided to accumulate and keep the knowledge of the experts in the NILIM. The systematic organization of information on each dam design, problems encountered during construction, and solutions will also be useful when establishing and revising new and existing technical standards and guidelines.

The third objective is to develop human resources. Technical advice by experts with advanced knowledge and experience is indispensable in dam projects. Many dam construction offices set up their own technical committees and seek advice from such experts. Even when such experts retire and decrease in number, technical guidance must be continued. The Group therefore decided that the NILIM will centrally appoint knowledgeable and experienced experts as “dam engineering advisors” to help construction offices choose appropriate experts. This will also help develop the next generation of technical advisors.

2.1.2. Examples of activities

The redevelopment project of the Tsuruda Dam (Fig. 1) is the largest and most advanced project in Japan, involving restrictions on works due to water level changes of the reservoir, which remains in service during the work. To execute the works as scheduled, problems have to be solved quickly and the safety has to be checked properly and regularly.

Figure 2. Technical committee for the redevelopment of the Tsuruda Dam

Figure 3. Site investigation

Therefore, based on advice by NILIM, the Sendaigawa River Office of the Kyushu Regional Development Bureau, which is in charge of the project, set up a technical committee for the redevelopment of the Tsuruda Dam consisting of experts, to seek advice and opinions on various issues.

The Group decided to use the Tsuruda Dam project to help share information nationwide and among regional development bureaus. At the first meeting on November 17, 2011, 31 engineers were invited (Fig. 2) and investigated the site (Fig. 3). The advice given by the experts was collected by the Group and then shared among all regional development bureaus.

After that, the Shikoku Regional Development Bureau also held a study meeting at the Tsuruda Dam site in order that many engineers in the Bureau can share technical information on dam redevelopment project.

2.2. Knowledge succession on dam management

Dams are large structures and must be controlled safely,

otherwise a serious disaster could occur. The frequency of storms and flood events has increased in recent years due to abnormal meteorological conditions, and so the frequency of operating dam gates is increasing.

To prepare for storms, sections in charge of controlling dams monitor the dam body daily, checking for leakage, inspecting outlets, etc. according to prescribed rules and must quickly and properly operate the dams.

Citizens are also highly concerned about dams. The staff engaged in dam control must always learn new knowledge, study the effects on the downstream rivers and conduct emergency drills.

To develop human resources who can meet social demands, the College of Land, Infrastructure, Transport and Tourism and Japan Construction Training Center run training courses on the latest technology.

2.2.1. Training program on dam control

The College of Land, Infrastructure, Transport and Tourism runs a training program on dam control every year as a part of technological training on dams.

(1) Objectives of the program:

Acquisition of comprehensive knowledge on dam control and other skills to cultivate the ability to:
1) Execute works by systematic acquisition of knowledge on dams,
2) Control dams and risks, and
3) Solve problems on dam control.

(2) Targets:

Technical staff in charge of dam control and projects of MLIT and other ministries and agencies, prefectural governments, ordinance-designated cities, and incorporated administrative agency, who meet either of the following criteria:
1) Section chief of an office, or equivalent position
2) Person having the capacity equivalent to 1)
In fiscal 2011, 23 persons underwent the program.

(3) Contents:

The contents of the program are listed in Table 1 and include a wide range of knowledge including dam redevelopment, mainly dam control (Fig. 4). To improve their knowledge, the trainees hold group discussions on fixed subjects (Table 2).

2.2.2. Practical training on dam operation

The Japan Construction Training Center runs a training

Table 1. Subjects of dam control technologies

Lecture	Hours	Lecture	Hours	Lecture	Hours
Future flood control measures	1.5	Dam structure standards	1.5	Storms and disaster information	1.5
Flood control to cope with climate change	1.5	Design and construction of dams	4.0	Weather and forecasting	1.5
Dam control and water source management	1.5	Design and construction of water works	2.0	Measures during storms	1.5
General dam control	3.0	Process of dam construction and cost control	1.5	Risk control and public relations	2.0
Water resource planning	1.5	Redevelopment and renovation of dams	2.0	Practice of dam operation	3.5
Directions of flood control policies	1.5	Seismic verification of dams	1.0	Group discussion on project studies	11.0
Comprehensive sediment control	1.5	Landslide survey and prevention	2.0	General discussion on project studies	2.5
Enactments related to dams	1.5	Environment around dams	2.5	Compliance	1.0
Dams and water rights	1.5	Operation and maintenance of mechanical facilities	1.5		
Present states of river control and topics	1.5	Operation and maintenance of telecommunication facilities	1.5	Entrance and completion ceremonies	2.0
Trends of dam technologies and topics	1.5			Total	64.0

Figure 4. A lecture

Table 2. Project studies

1	Reduction of dam management costs and rationalization
2	Effective use of existing dams in high water management
3	Ensuring a correct understanding of dam functions and effects
4	Directions of dam redevelopment and renewal
5	Revitalization of economy in water source areas

Figure 5. Dam simulator

course for persons engaged in dam control to provide the latest information on dams and deepen their technical knowledge. For those in charge of operating dam gates, a special training course is given by using a dam simulator (Fig. 5), which involves predicting and calculating the inflow and calculating the discharge, to help operators appropriately manage dam gates.

The main training using the dam simulator is outlined below:
1) Practical training of dam operation (10 times a year, total of 60 trainees, 3 days per training)
Special operation skills (during abnormal floods) and skills for preparing references are taught to inexperienced dam operators.
2) Training of chief dam control engineers (lecture, 5 days, about 115 trainees)
Knowledge and skills necessary for safe dam control are taught to chief dam control engineers (under Article 50 of the River Act).
3) Dam control for managers, (3 days, about 20 trainees)
Necessary knowledge about safety control of dams and operation of dam simulators is taught to managers (control managers, branch managers, etc.).
4) Chief dam control engineers (practical training, 20 times a year, 120 trainees in total, 3 days per training)
Skills of dam operation using the dam simulator are taught to candidates of chief dam control engineers under Article 50 of the River Act.
5) Dam control (5 days, about 30 trainees)
Technical knowledge necessary for dam control, environmental control of reservoirs, hydraulics, functions of structures and dam operation using the dam simulator are taught.

Of the classes, the practical training of dam operation deals with floods exceeding the design level. On the first day, a lecture is given on the rules for operating dams, an outline of special operation, methods of preparing justification for switching to special operation, and other procedures necessary for flood control to improve basic understanding. The trainees then practice operations using the dam simulator.

On the second and third days, trainees prepare justifications for switching to special operation by manual calculation by assuming a computer malfunction, check the contents and switch to special operation.

Each group consists of three persons: group leader, person in charge of monitoring hydrological data and operator, who take turns.
The group leader unites the group, makes decisions, gives instructions, prepares operation plans during a flood based on meteorological data, and prepares a justification for switching to special operation (together with the other members).
The person in charge of monitoring hydrological data collects hydrological data, receives and sends the data, and calculates the inflow and discharge.
The operator gives warnings, operates the gates, and prepares operation records.

The Japan Construction Training Center also offers courses for dam control engineer tests (practical training), training programs for dam construction engineers, and comprehensive training on dams.

3. CONTRIBUTIONS TO OVERSEAS COUNTRIES

The International Centre for Water Hazard and Risk Management under the auspices of UNESCO (ICHARM) in PWRI runs a master course entitled "Water-related Disaster Management Course of Disaster Management Policy Program" in liaison with the Japan International Cooperation Agency (JICA) and National Graduate Institute for Policy Studies to technical administrative officials of developing countries, mainly in Asia. To date, 41 have obtained the master degree on disaster management, and 19 fifth-generation students are studying today (Table 3).

Table 3. Students of the master course "Water-related Risk Management Course of Disaster Management Policy Program"

Country / Year	Bangladesh	Bhutan	China	Colombia	Ethiopia	Fiji	Guatemala	India	Indonesia	Japan	Laos	Malaysia	Maldives	Myanmar	Nepal	Netherland	Pakistan	Philippines	Sri Lanka	Tajikistan	Thailand	Tunisia	Vietnam	Total	Master degree
2007-2008	2		3					1		3					1									10	10
2008-2009	2		2		1				1						1						2			9	7
2009-2010	2		1		1				3	1				1				1	2		1			13	12
2010-2011	2		2	1			1		1					1	3		1							12	12
2011-2012	2		2			1			2						2		6	1	1			1	1	19	
Total	**10**		**10**	**1**	**2**	**1**	**1**	**1**	**7**	**4**				**2**	**7**		**7**	**2**	**3**		**3**	**1**	**1**	**63**	**41**

Table 4. Syllabus of Dam Engineering Course

1: Outline of Dam Engineering
2: Planning and Operation of Flood Control
3: Earthquake Engineering for Dams
4,5: Environmental Impact of Dams (1), (2)
6,7: Sediment Management in Reservoirs (1), (2)
8,9: Dam Construction (1), (2)
10: Dam Management
11: Effective Use of Existing Dams
12: Roles of Dams in the 21st Century
13: Visit to Dam Experimental Laboratory
14, 15: Presentation of Dam Country Reports

A 15-class course entitled "Sustainable Reservoir Development and Management" has been held since the program was started. The contents of today's course are shown in Table 4. This comprehensive course covers not only the basic aspects of dam design, construction and operation but also applied aspects such as the environmental impacts of sedimentation and management after construction. As described in the syllabus, the roles of dams in combating climate change are taught. Lecturers are experts of the PWRI, Japan Dam Engineering Center and university professors.

Excursions to dams in Japan are included in the course, and students have visited the Isawa and the Obara Dam, which are under construction, and the Ikari and the Kawaji Dam, which share their free reservoir capacities to control floods and improve the hydrological regime (Fig. 6).

Dams are the mainstays of flood control in Japan. There may be limits to applying the knowledge directly in other countries, but ICHARM aims to help communicate the importance of dam engineering to students from developing nations.

4. CONCLUSIONS

This paper outlined issues of dam engineering and succeeding knowledge on dam construction. It also reviewed the contents of training programs for maintaining and improving the dam control skills of dam control engineers. A project for contributing internationally by sharing technical information was also outlined.

Japan's knowledge for constructing and controlling dams should be used not only in Japan but also throughout the international community, and must be continually improved through detailed studies. The activities in Japan for transmitting knowledge on dam construction to the next generation, where the construction of large dams is decreasing, will assist countries and areas that are in a similar phase.

It is hoped that this report will contribute to the maintenance, succession and improvement of dam engineering around the world.

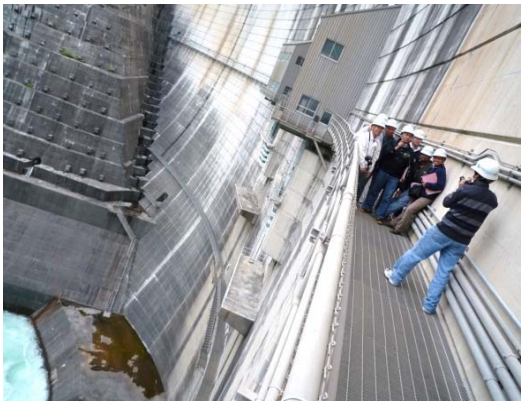

Figure 6. Visit to the Kawaji Dam