Dams in Japan
Overview 2015

JCOLD

JAPAN COMMISSION ON LARGE DAMS

Japan Commission on Large Dams

History

In 1931, three years after the International Commission on Large Dams (ICOLD) was established, Japan joined ICOLD as the Japan National Committee on Large Dams. In 1944, Japan withdrew from ICOLD during the World War II, then rejoined in March 1953. On September 13, 1962, the Japan Commission on Large Dams was established, and in January 2012, it became a General Incorporated Association.

Membership

The members of JCOLD are incorporated bodies involved in dam construction. They include government bodies concerned with dam construction, electric power companies, survey and research bodies, academic associations, industrial associations, construction consultants, construction companies, and manufacturers (75 members as of January 2015).

Operation

JCOLD is involved in operations such as surveys, research, international technology exchanges, etc. concerning large dams and related facilities (below, "large dams"), in order to improve the design, construction, maintenance, and operation of large dams and to contribute to the development of the Japanese economy. Responsibilities include:

Collection of information, surveying, and research concerning large dams

(1) Exchange of technology and guidance concerning large dams

(2) Participation in ICOLD, assistance with its activities, and international exchange of technology concerning large dams

(3) Introduction of and spreading awareness of the achievements of surveys and research concerning large dams

(4) Other activities necessary to achieve the goals of JCOLD

In recent years, JCOLD has actively conducted a program of surveys and research on methods of harmonizing dam development with the environment and on ways to mitigate their environmental impacts to achieve the sustainable development of dams.

Organization

Under the leadership of the Chairman, there is a Planning Committee, Technical Committee, and Administrative Office. These committees undertake work in their respective areas.

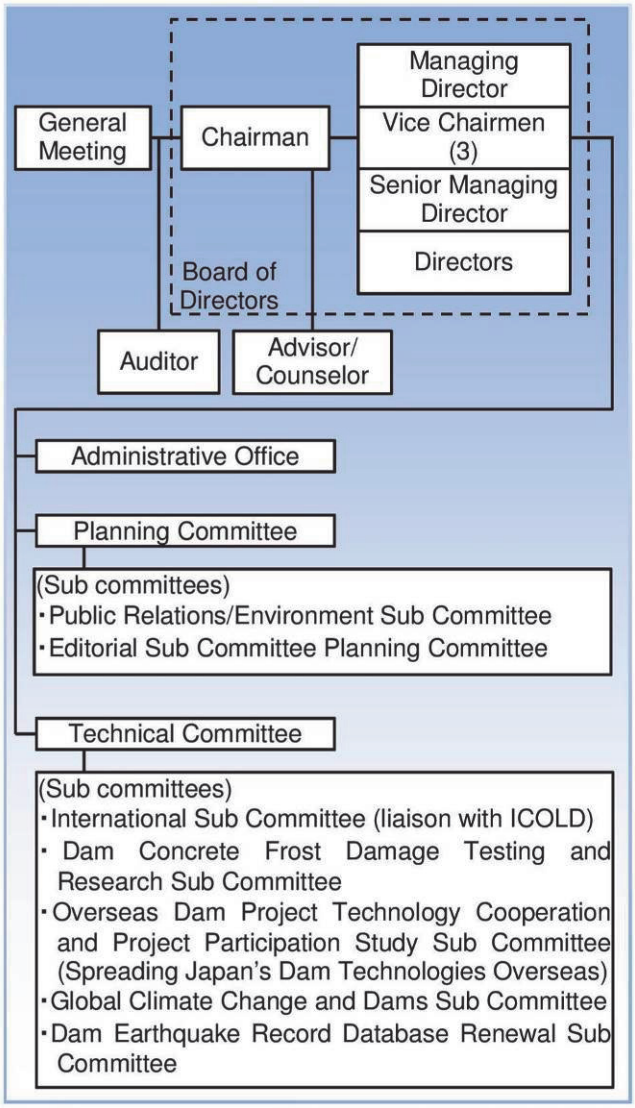


Figure-1 Organization Chart of JCOLD

Publication

JCOLD publishes its Journal, Large Dams, four times a year (January, April, July, October), which is distributed to members and subscribers. At ICOLD Congresses held once every three years, JCOLD publishes Current Activities on Dams in Japan in English, which introduces the state of dams and dam technologies in Japan, and distributes it to Congress participants (1997, 2000, 2003, 2006, 2009 and 2012).

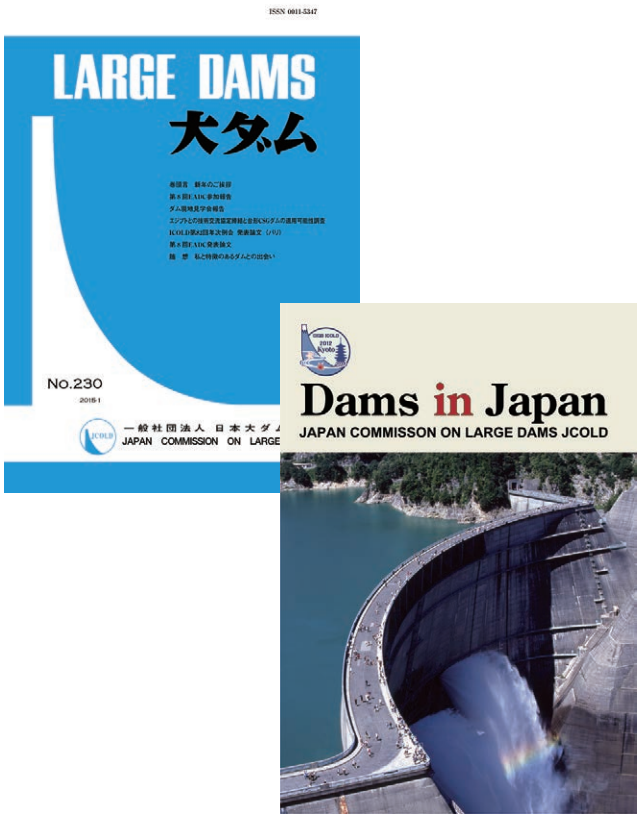


Figure-2 Large Dams and Dams in Japan

Annual lecture meeting

Dam Technology Lectures and Discussion Meetings

(Held jointly with the Japan Association of Dam & Weir Equipment Engineering)

At the meeting, the results of surveys and research by the various JCOLD technical Sub committees, papers presented to the ICOLD Congress, and results of activities by the Japan Association of Dam & Weir Equipment Engineering are reported widely to people concerned with dams. In addition, the lecturers and participants in the Technology Lecture and Discussion Meeting discuss the reports in order to improve the technologies, maintenance, and operation of dams.

Figure-3 Dam Technology Lecture and Study Meeting

Study Tour

To increase mutual awareness among engineers, including JCOLD members and others concerned with dams, on improving dam and hydroelectric power plant technologies and the construction of dams, JCOLD holds tours of dams and hydroelectric power plants still under construction with the cooperation of various organizations.

Figure-4 Tour of the site of the Ooitagawa Dam (2014)

Contribution to ICOLD

JCOLD submitted 358 ICOLD Congress Papers until now. In addition, Many Japanese engineers participate in ICOLD Annual Meeting and Congress.

JCOLD participates in 22 technical committees at Annual Meeting and exchanges technical information.

JCOLD held Annual Meeting in 1960(Tokyo) and 1984(Tokyo), and Congress in 2012(Kyoto).

Susumu NAGATA(1957-1960), Masayoshi NOSE (1966-1969), Shigeru ICHIURA (1982-1985), Kyohei BABA (2001-2004), Norihisa MATSUMOTO(2007-2010) and Tadahiko SAKAMOTO(2011-2014) served as a vice president of ICOLD.

Table-1 Number of participants from Japan

Year	Host country (Host city)	Number of participants from Japan
1998	India (New Delhi)	43
1999	Turkey (Anatolia)	56
2000	China (Beijing)	87
2001	Germany (Dresden)	60
2002	Brazil (Iguazu)	47
2003	Canada (Montreal)	49
2004	South Korea (Seoul)	143
2005	Iran (Tehran)	77
2006	Spain (Barcelona)	107
2007	Russia (St. Petersburg)	79
2008	Bulgaria (Sofia)	63
2009	Brazil (Brasilia)	46
2010	Vietnam (Hanoi)	75
2011	Switzerland	70
2012	Japan (Kyoto)	398
2013	USA (Seattle)	73
2014	Indonesia (Bali)	79

Table-2 Number of submitted papers

Year	No.	Host country (Host city)	Number of submitted papers
1933	1	Sweden (Stockholm)	3
1936	2	America (Washington)	5
1955	5	France (Paris)	4
1958	6	America (New York)	13
1961	7	Italy (Rome)	8
1964	8	United Kingdom (Edinburg)	13
1967	9	Turkey (Istanbul)	11
1970	10	Canada (Montreal)	8
1973	11	Spain (Madrid)	12
1976	12	Mexico (Mexico)	9
1979	13	India (New Delhi)	11
1982	14	Brazil(Rio de Janeiro)	12
1985	15	Switzerland(Lausanne)	17
1988	16	United States(San Francisco)	22
1991	17	Austria(Vienna)	29
1994	18	South Africa(Durban)	25
1997	19	Italy(Florence)	28
2000	20	China(Beijing)	16
2003	21	Canada(Montreal)	20
2006	22	Spain(Barcelona)	23
2009	23	Brazil(Brasilia)	15
2012	24	Japan(Kyoto)	37

Dams in Japan

Development of dams

In Japan, the major purpose of dams was irrigation from ancient times to the end of the feudal period in the mid nineteenth century. The Sayama-ike irrigation pond (Osaka Prefecture), which is considered to be Japan's oldest dam, was completed in 616, and is recorded in the official historic documents.

As Japan was modernized and urbanized after the Meiji Revolution (1867), Japan started to build dams with modern technology, to meet the increased demand for water and electric power. In 1900, the Nunobikigohonmatsu Dam (Hyogo Prefecture) was completed as water supply dam. As for hydropower, the Chitose No.1 Dam (Hokkaido) was first completed in 1910. Later, multi-purpose dams with flood control capacity were constructed, with the first, the Kodo Dam (Yamaguchi Prefecture), completed in 1940.

To make more efficient use of water resources and control of flood, comprehensive projects are promoted under the concept of integrated development of river systems. Also, in recent years, redevelopment projects, such as raising the height of dams, excavating reservoirs, and upgrading discharge facilities, are being carried out more and more.

Figure-5 Nunobikigohonmatsu Dam

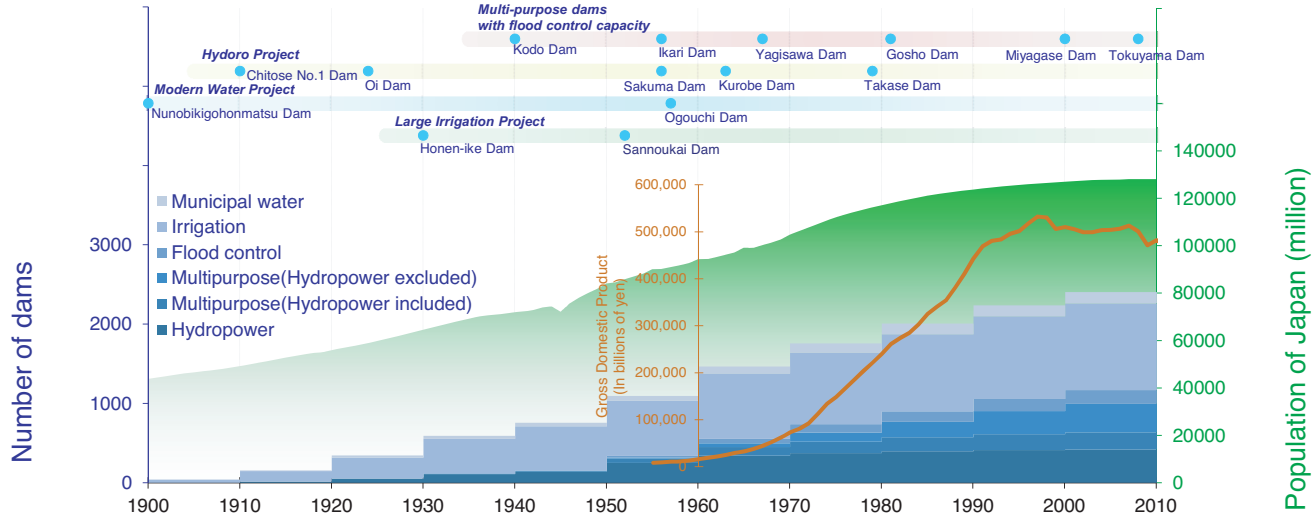


Figure-6 Development of Dams, Economy of Japan and Population

Major dams in Japan

There are many dams over 100 meters high in Japan, though, their reservoir capacities are smaller than those of other dams around the world, reflecting the geographical features of Japan (narrow islands and steep terrain).

Table-3 Ranking of dams by height in Japan

	Dam name	Type	Height (m)
1	Kurobe Dam	Arch	186
2	Takase Dam	Rockfill	176
3	Tokuyama Dam	Rockfill	161
4	Naramata Dam	Rockfill	158
5	Okutadami Dam	Gravity	157
6	Miyagase Dam	Gravity	156
7	Urayama Dam	Gravity	155
8	Nukui Dam	Arch	156
9	Sakuma Dam	Gravity	155.5
10	Nagawado Dam	Arch	155

Table-4 Ranking of dams by reservoir capacity in Japan

	Dam name	Reservoir capacity (million m^3)
1	Tokuyama Dam	660
2	Okutadami Dam	601
3	Tagokura Dam	494
4	Yubari Shuparo Dam	427
5	Miboro Dam	370
6	Kuzuryu Dam	353
7	Sakuma Dam	343
8	Ikehara Dam	338
9	Sameura Dam	316
10	Hitotsuse Dam	261

Figure-7 Tokuyama Dam

Figure-8 Yubari Shuparo Dam

Hydroelectric power plants in Japan

The output of hydroelectric power plants in Japan accounts for about 19% of all electric power sources, and pumped storage hydroelectric power occupies top 10s of the electric power output rankings.

Table-5 Electric power output ranking of Conventional hydropower plants

	Hydroelectric power plant	Electric power output (MW)	Dam name
1	Okutadami	560	Okutadami Dam
2	Tagokura	400	Tagokura Dam
3	Sakuma	350	Sakuma Dam
4	Kurobegawa-Daiyon	335	Kurobe Dam
5	Arimine Daiichi	265	Arimine Dam
6	Tedorigawa Daiichi	250	Tedorigawa Dam
7	Miboro	215	Miboro Dam
8	Shinojiya	206	Miyanaka Dam
9	Hitotsuse	180	Hitotsuse Dam
10	Shinanogawa	177	Nishiotaki Dam

Table-6 Electric power output ranking of Pumped Storage hydropower plants

	Hydroelectric power plant	Electric power output (MW)	Dam name (upper reservoir / lower reservoir)
1	Okutataragi	1,932	Kurogawa Dam / Tataragi Dam
2	Okukiyotsu-Daini	1,600	Kassa Dam / Futai Dam
3	Okumino	1,500	Kaore Dam / Kamiosu Dam
4	Shintakasegawa	1,280	Takase Dam / Nanakura Dam
5	Okouchi	1,280	Ota Dam / Hase Dam
6	Okuyoshino	1,206	Seto Dam / Asahi Dam
7	Tamahara	1,200	Tamahara Dam / Fujiwara Dam
8	Matanogawa	1,200	Doyo Dam / Matanogawa Dam
9	Omarugawa	1,200	Ouseuchi Dam / Ishikawauchi Dam
10	Shintoyone	1,125	Shintoyone Dam / Sakuma Dam

Figure-9 Okutadami Dam

Figure-10 Kurobe Dam

Introduction to Dam Technologies in Japan

Trapezoidal CSG dam

The trapezoidal CSG dam developed in Japan is a new type of dam which combines the characteristics of a trapezoidal Dam and the CSG (Cemented Sand and Gravel) construction method. It rationalizes the construction of dams in three ways: "Rationalization of materials: because the dam body materials require less strength, the required performance of the material is low and there are few restrictions on the selection of materials," "Rationalization of design: The trapezoidal shape improves seismic stability, and so the strength required of the dam body materials is lower," and "Rationalization of construction: Construction work can be executed rapidly by simplified construction facilities."

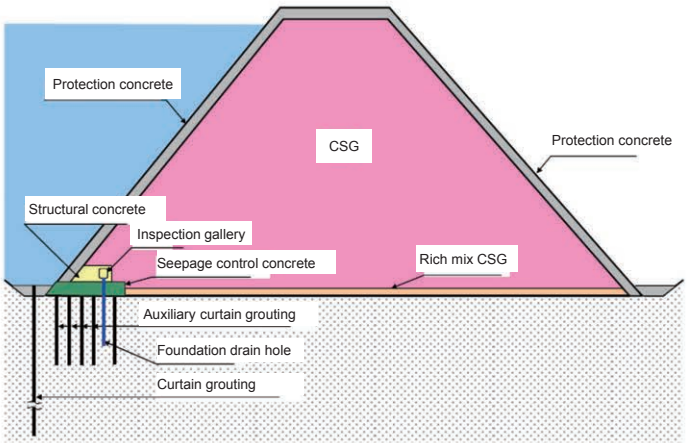


Figure-11 Concept of Trapezoidal CSG dam

Figure-12 Tobetsu Dam

Electric power production by pumped storage of seawater

The Okinawa Yanbaru Seawater Pumped Storage Hydroelectric Power Plant in Okinawa Prefecture, which is the world's first seawater pumped storage hydroelectric power plant and where the Pacific Ocean is the lower reservoir and an artificial upper regulation pond is the upper reservoir, generates pumped storage electric power using seawater. Its penstock, pump turbine, and generator are all installed underground. Its normal effective head is 136m, and its maximum discharge is 26 m^3/s. The maximum output of the power plant is 30 MW, and when the upper reservoir is full, it can operate continuously at maximum output for six hours.

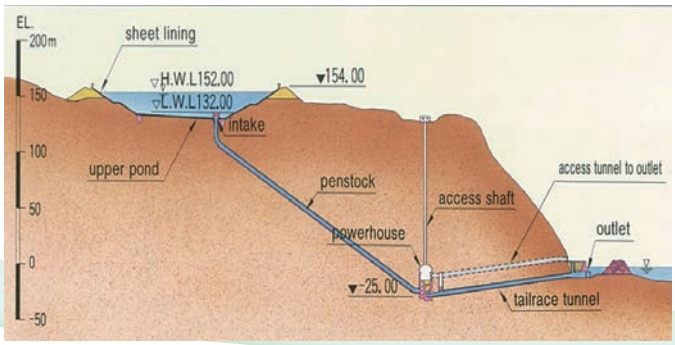


Figure-13 Profile of Seawater Pumped Storage Power Plant

Figure-14 Okinawa Yanbaru Seawater Pumped Storage Power Plant

RCD (Roller Compacted Dam Concrete) method

This method is executed by spreading extremely dry and lean concrete with a small cement content with a bulldozer, then compacting it with a vibrating roller. Level differences are not formed on the placed surface, so it is classified as a planar method, like the expanded layer method. Using machinery such as bulldozers and vibrating rollers permits larger volumes to be placed faster than conventional column block method, thus not only reducing the construction term and cost, but also improving work safety.

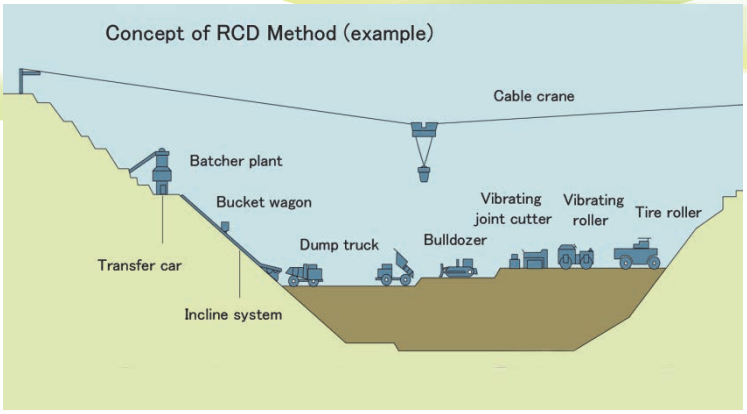


Figure-15 Concept of RCD Method

Figure-16 Yunishigawa Dam

Total sediment management

In Japan, sediment management based on the concept of integrating the process from the headwaters to the coast of a river basin is applied in order to stably maintain river courses, ensure the functions of dams and other structures, conserve the coast and mitigate impacts on the ecosystem.

At dams, sediment control projects and sediment check dams restrict the inflow of sediment into dam reservoirs from the river basin, and the quantity of sediment flowing into reservoirs is lowered by constructing flushing bypass tunnels, discharging sediment from reservoirs by flushing pipelines, etc.

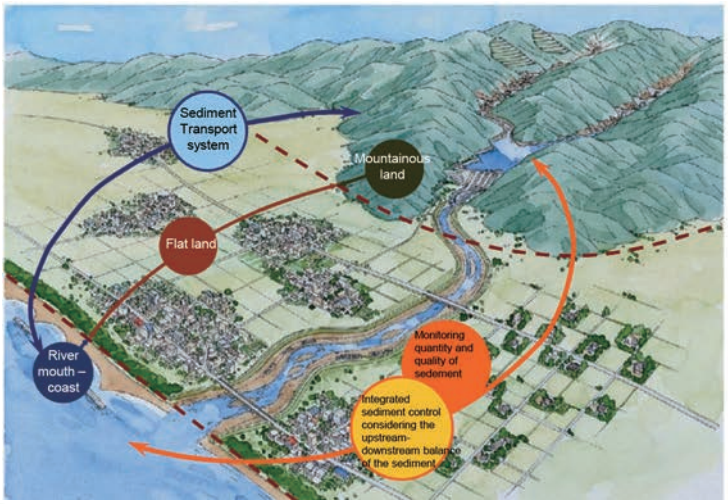


Figure-17 Concept of Total sediment management

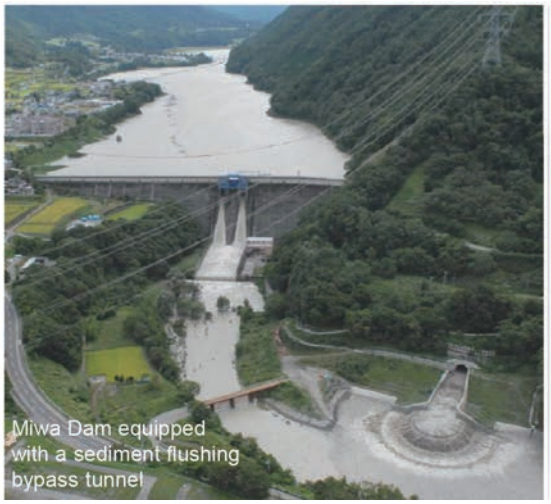


Figure-18 Miwa Dam

Preservation measures of dam reservoirs

Water quality is one of the important elements which should be preserved in dam reservoirs. This water quality issue is closely associated with the size of the dam reservoir, a natural phenomenon, operation of the dam reservoir, and the structure of the dam, etc.

Therefore, water quality preservation measures for the dam reservoir is conducted as well as controlling outflow of pollutant and nutrient salts from the catchment area.

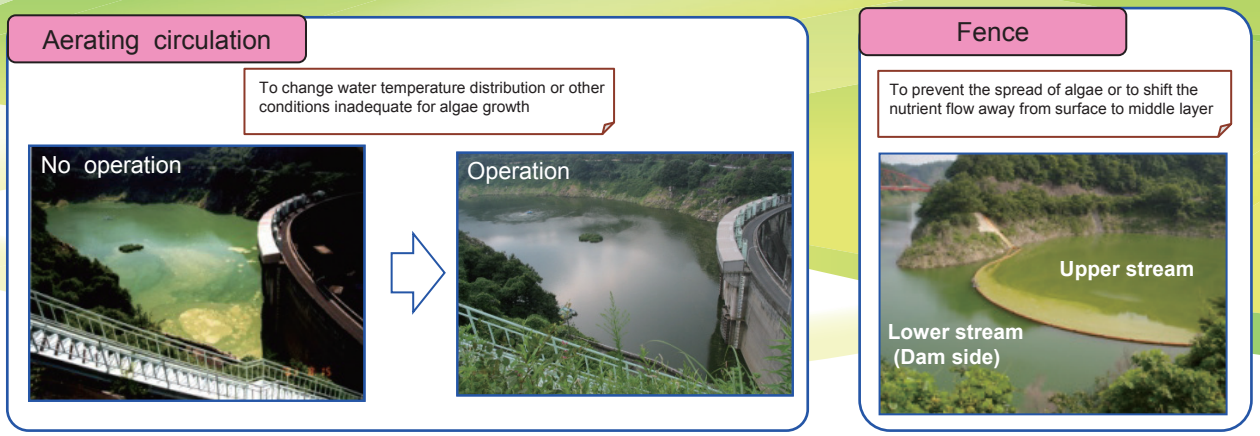
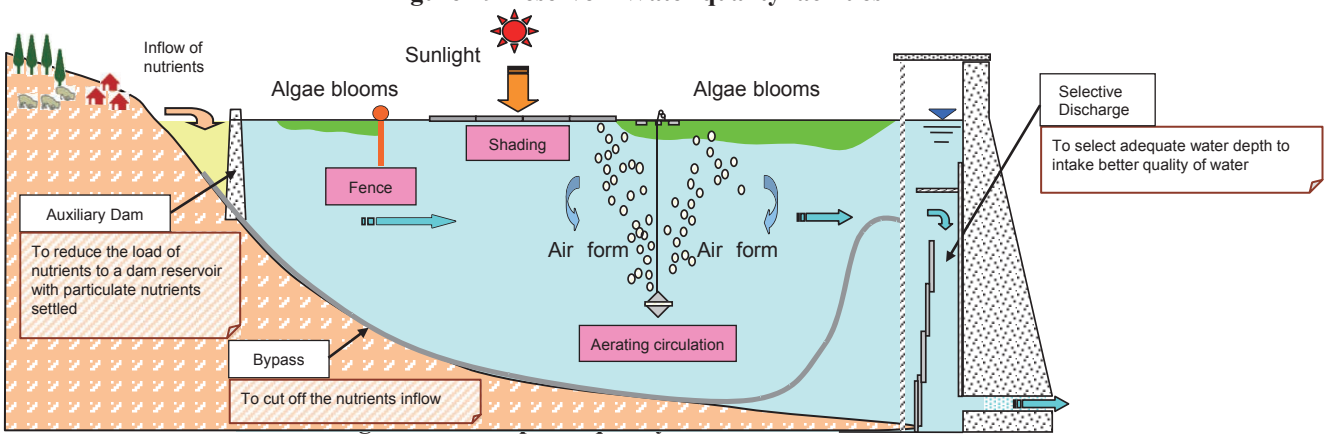


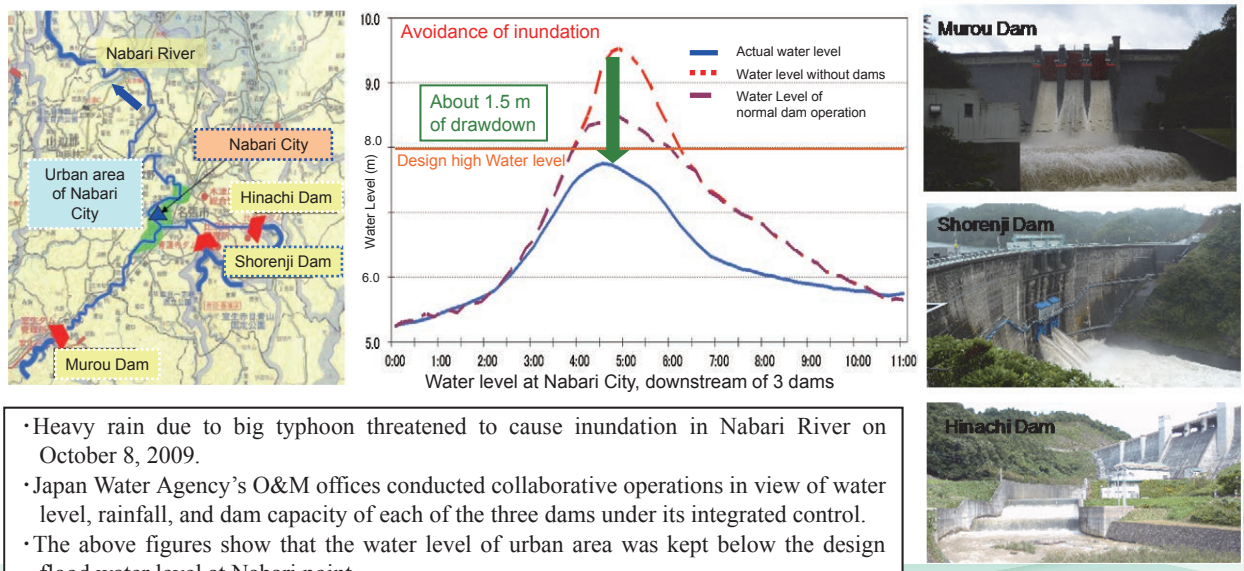
Figure-19 Reservoir Water quality facilities



Advancement of flood control operation

Recently, flood disasters caused by heavy rains occur frequently in Japan. It is set that the flood control operation of the dam should work most effectively for design flood scale and design wave form. However, as the rainfall is a natural phenomenon the rainfall condition varies from time to time.

Therefore, the appropriate operation is conducted at all times, making use of the rainfall prediction technologies and flood outflow analysis model and maximizing the flood control capacity of the dam so that the prevention or mitigation of flood damages can be achieved in the downstream areas.



- Heavy rain due to big typhoon threatened to cause inundation in Nabari River on October 8, 2009.
- Japan Water Agency's O&M offices conducted collaborative operations in view of water level, rainfall, and dam capacity of each of the three dams under its integrated control.
- The above figures show that the water level of urban area was kept below the design flood water level at Nabari point.

Figure-21 Flood control through integrated and collaborative operation of three dams

Papers in ICOLD & Other Technical Publications

Papers in ICOLD

Theme 1 Safety supervision and rehabilitation of existing dams

A. ICOLD 81st Annual Meeting International Symposium in Seattle Aug. 2013

New exterior deformation monitoring method for embankment dams using synthetic aperture radar (SAR)

H. Satoh, T. Kobori, T. Sasaki, Y. Yamaguchi, T. Iwasaki, N. Mushiake and K. Honda

The total number of dams that have been constructed and projected for construction since 1900 in Japan is approximately 2,500. Among these, as of the year 2020, nearly 1,500 dams will reach or surpass the age of 50 years, accounting for 58% of the total. Because the number of dams that have behaved stable over an extended period since completion is increasing, the exterior deformation measurement of embankment dams for the safety management often runs into difficulties due to time-consuming surveying procedures and high labor costs. Moreover, during an emergency such as a large earthquake, it is difficult to secure adequate surveyors in a disaster area to carry out temporary inspections, and taking measurements of exterior deformation in such a state of disaster presents a potential risk on the safety for workers. For these reasons, there is a strong demand for a means of conducting a rapid and safe measurement of the exterior deformation of embankment dams. In this paper, on the basis of data collected by Synthetic Aperture Radar (SAR) satellite that has been adapted to carry out disaster assessments, a basic examination was carried out regarding the applicability of SAR to the exterior deformation measurement of embankment dams. No measurement facilities are needed for SAR, and it results in cost reduction of data acquisition for exterior deformation measurement of embankment dams. This paper presents, not only the results of the examination, but also a brief outline of the principal concept of SAR, since the SAR-based approach is a new technique in the field of dam instrumentation. Exterior deformation of a rockfill dam with a height of 66m was measured by SAR in about four years just after the completion, the result by SAR was compared with that by GPS, and we found that the tendency of settlement of a dam body was well reproduced.

Safety and soundness evaluation of existing concrete gravity dams focusing on change of vibration characteristics

M. Kondo, T. Sasaki, T. Kobori and T. Kashima

To evaluate the structural safety and soundness of existing dams those are expected to fulfill their functions for the very long-term, the effects of deterioration due to aging and damage that might be occurred caused by past strong or repetitive unusual loads such as seismic motions should be adequately considered. However, it is not easy to identify the location or degree of these deterioration or damage such as mostly invisible cracks inside the dam body or below water level.

In order to provide a primary assessment of safety and soundness of existing dams effectively and find dams which require more detailed investigation by performing various non-destructive or destructive inspections, an evaluation method that focuses on the change of vibration characteristics of a dam body is discussed in this paper.

Firstly, the effects of deterioration and damage on the natural frequencies of a concrete gravity dam are estimated by using numerical analyses considering the situation that we usually have no long-term measurement data on vibration characteristics of actual existing dams. In the analyses, we assumed several types of crack along the horizontal lift joints that might have the most effect on the stability of dam body, and simulated its dynamic behaviors during a large earthquake including propagation of assumed existing cracks. From the analyses, it revealed that the effects on the vibration characteristics of dam body vary depending on the location and degree of assumed cracks.

Secondly, the possibility to estimate the location and degree of deterioration or damage by focusing on the change of natural frequencies of dam body is discussed referring to the results of numerical analyses and some examples of microtremor measurements performed at actual concrete gravity dams. The natural frequencies of actual dams based on the microtremor measurements are estimated by calculating the ratio of Fourier spectrum for a vibration waveform obtained at the upper part of dam to that obtained at dam foundation. To distinguish the effect of deterioration or damage from other factors such as the change of water level that affect on natural frequencies was found to be important.

Lastly, a future direction to lead these evaluations of the safety and soundness of existing dams to a process in risk assessment that should be essential to rationalize resource allocations is also discussed.

Investigation on riprap deterioration and evaluation of its influence on slip stability for a rockfill dam

H. Sakamoto, T. Sasaki, Y. Yamaguchi, T. Ookawa, and T. Shimoda

Recently, it is strongly demanded to extend the life of dams and their appurtenant structures. Although rockfill dams are considered more durable structures against deterioration, there are some cases in which the riprap materials have been deteriorated, and this phenomenon has harmful influence on the dam stability. To prioritize the urgency of repair against those deteriorations, it is important to evaluate their influence on the safety. However, there are not any technical standards for investigation on riprap deterioration. Under these circumstances, the case studies on deterioration investigation of riprap could be important and valuable information.

In this paper, we introduce the case studies on deterioration investigation at Midorikawa dam, rockfill dam with a height of 35m, a crest length of 244m , and dam volume of 376,400m^3, constructed in 1971 in Kumamoto-ken, Japan.. In Midorikawa

dam, riprap was constructed with 5 kinds of large size rock materials and the thickness of riprap is 1m. At the dam site, monthly mean temperature of the minimum temperature month is 3.6 to 11.6 degree Celsius, and the difference value of monthly mean temperature between the maximum month and the minimum month is 21.0 to 26.0 degree Celsius during 1981-1985.

The deterioration investigations of riprap were conducted in 1979, 1985, and 1987. Many field investigations and laboratory tests were conducted, for example, degree of weathering investigation, density and water absorption test of riprap material and rock material, trench investigation, and soon.

Moreover, we evaluate the influence of dam surface deterioration on the sliding stability from numerical analysis results. In the simulation we apply the modified seismic coefficient method, and assumed that the deteriorated parts of design section were lost and changed the deteriorated ranges to evaluate its influence on the stability.

From the results of those investigations and analyses, the following are confirmed . The degrees of riprap weathering differ from the location on the dam, upstream or downstream faces and elevation. Duration of sunshine and difference of riprap materials are considered as factors of the difference of degree of riprap weathering. Although the riprap material in upper part didn't have so good durability against weathering, the rock materials which placed beneath the riprap have hardly been deteriorated or weathered. In this case study, the deeper the deteriorated range becomes, the lower the sliding safety factor becomes. But, the reduction is not as large as the stability is greatly affected.

Application of the GPS automatic displacement measurement system for monitoring exterior deformation of embankment dams

Y. Yamaguchi, T, Kobori, T Sasaki, T. Iwasaki, T. Masunari and N. Shimizu

The measurement of exterior deformation is one of the most important measuring items for safety management of embankment dams. By using targets installed on the crest and slopes of embankment dams, their exterior deformation has been measured by conventional surveying methods.

According to the Japanese dam safety management standard, the measurement frequency of exterior deformation of embankment dams is set as once a week at the period of the first filling of reservoir, that is, the first term of dam management, and once every three months in the third term that is the final management stage when behavior of the dam and its foundation come to be stable. But, because the surveying work is relatively time consuming one, rapidly responding after a large earthquake or in other emergencies is a big challenge. Particularly in Japan, on March 11, 2011, the Mw9.0 the 2011 off the Pacific coast of Tohoku Earthquake occurred, and an old earthfill dam to form an irrigation pond breached. Therefore, a rapid measurement of deformation behavior immediately after the large earthquakes became an urgent issue in Japan.

The global positioning system (GPS) is a system that can perform surveys quickly in relatively low cost. The GPS is a weather-proof positioning system using satellites, which is well known for its role in car navigation and in surveying applications.

We enthusiastically made the research to develop the GPS automatic displacement measurement system for measuring exterior deformation of embankment dams. At present, this system has already been installed at many embankment dams, and even at a few concrete gravity dams. We have already submitted and presented some papers on this topic at the ICOLD congresses and symposiums step by step.

In this paper, we systematically summarize the results of our previous studies and other researchers' studies on this topic. This paper consists of several chapters, such as "GPS Automatic Displacement Measurement System", "Improvement of Measurement Accuracy", "Development and Improvement of Installation Method to Embankment Dams", "Emergency Response and Information Sharing" and "Case Studies at Actual Dams". In addition, we introduce the outlines of engineering manual on this technology, which we are preparing.

Maintenance of the spillway concrete deteriorated by alkali-aggregate reaction in the Terauchi Dam

S. Ichikawa, S. Inoue and K. Nagata

Deterioration in concrete structures has a variety of causes. In order to maintain a structure over a long period of time, it is necessary to grasp its soundness. In case that the structure has deteriorated, its owner/manager has to investigate the cause of deterioration, evaluate how fast the structure will get worse, and take appropriate measures.

The Terauchi Dam is a rock-fill type dam with the height of 83 meters and 18 million cubic meters in storage capacity, located in the Chikugo River system in northern part of Kyushu island, Japan, owned by the Japan Water Agency (JWA). 34 years have passed since its completion, as of 2012. It has concrete structures: spillway, and intake facilities. These structures were constructed using concrete that had been produced in ready-mixed concrete plant. The reason was because there was a ready-mixed concrete plant with the ability for necessary production near the dam.

At over ten years from the completion, cracks were observed for the first time on the side wall of spillway, and they have grown wider along with the passage of time.

According to the results of study and analysis, alkali-aggregate reaction (AAR) was identified as the cause. Results of the promoting expansion test revealed that further deterioration is anticipated due to AAR.

Therefore, in the Terauchi Dam, in order to extend the life of the structure, repair work was carried out in 2010 to suppress the deterioration due to further progress of AAR. The repair work comprises: carbon fiber sheet bonded to the concrete surface as a primary measure; and then surface of carbon fiber sheet coated for water shielding.

This paper discusses: the state of deterioration of the spillway concrete; its cause identified by research and analysis; selected measures for repair work and to hold current deterioration state; and a plan for future maintenance, in the Terauchi Dam.

Measurement of pore water pressures in rockfill dams by wireless pore water pressure transducers

Y. Hayashida, R. Towmezuka, Y. Kohgo, I. Asano, S. Masukawa and H. Tagashira

It is very important to measure pore water pressures within embankments and foundations in order to monitor the stabilities of fill dams. In the measurement of pore water pressures, conventional pore water pressure transducers were connected with cables to the data loggers located on the grand surfaces. The cables were utilized to transfer measurement data and supply power sources. However, the conventional transducers have following

drawbacks: (1) to reduce stabilities of embankments, (2) to become a cause of breakdown of transducers, (3) to be an obstacle against construction, and (4) to need an excess cost to install cables. In order to improve these drawbacks, we have been developing wireless pore water pressure transducers. In this transducer, low frequency electromagnetic waves and the latest digital transfer technique were used. The wireless transducer system consists of mainly two parts: transducers and a receiver. The transducer consists of a pore water pressure transducer, an antenna, electric circuits (control and data logging system) and batteries. The purposes of this paper are to introduce the wireless transducer and to verify the performance of the transducers installed within embankments of dams. The specifications of the transducer are a) more than 100 m underground-communication, b) more than 10 years life to confirm measurement of data from construction and first reserving phase to steady state phase of dam's behavior, and c) the water pressure resistance was more than 3MPa etc. To confirm the term b) above is more difficult than others. We performed a series of accelerated capacity tests of batteries and confirmed that it would run for ten years under a condition: once a day measurement frequency and 1 time/week data communication frequency. This time we could get long term measurement data from the real dams. From the results, the transducers had a tendency that the lifetime was shorter than the estimated values. Then, after five and half years, these were out of order and not able to perform data communication. We examine the reason they were out of order from the capacity test of their batteries and voltage data of batteries measured in site.

From the results, we clarified that capacity of battery was sufficient but the inner resistance of battery was increasing according to the elapsed time. If the inner resistance of battery increases, the voltage descent will happen when the high electric current is required, for example, in a data communication procedure. Then we set the batteries in parallel to moderate the effect of voltage descent. Improved transducers can reduce the increase of inner resistance values according to the elapsed time comparing with test models. Then we verify the long term performance of the transducers depended on not only capacity but also inner resistance of batteries.

Evaluation of freeze and thaw durability of dam concrete based on the long term exposure test

M. Satou, T. Imaoka, Y. Yasuda and S. Kinoshita

To keep the freeze and thaw durability is important for the concrete in a cold weather region. Moreover, in order to perform maintenance management efficiently, the suitable evaluation and prediction of frost damage are required.

Usually, the frost durability of concrete is evaluated by the freezing and thawing accelerating test that repeats freezing and thawing cycle to concrete specimens. However, few studies have been done to investigate the relation between the durability by an accelerating test and the durability in actual environment. So, it is difficult to predict the deterioration based on the result of a freeze and thaw accelerating test.

To identify the relationship between the resistance to freezing and thawing of dam concrete in cold areas, the long-term exposure test using large scale concrete blocks which are cubes 1m on a side at Okutadami dam has been done since 1963. Okutadami dam which is located in heavy snowfall area in Japan is a concrete gravity dam for power generation completed in 1960.

In this long-term exposure test, dynamic modulus of elasticity of large scale concrete blocks has been measured by ultrasonic method at annual intervals.

When renewal construction of the power plant was carried out, concrete cores were taken from Okutadami dam, which were about 40 years after completion. And to obtain information for the deterioration prediction due to the frost damage, physical properties of concrete cores that were collected from the dam and large scale concrete blocks were evaluated.

In this report, the result of analysis of concrete cores which are exposed to severe environment for about 40 years is described. And comparison between the result of the long-term exposure test and the result of having analyzed the concrete core is conducted. In addition, the relation between the exposure period and the frost deterioration depth is studied.

B. ICOLD 82nd Annual Meeting International Symposium in Bali Jun. 2014

Study on Enhancement of Hydroelectric Power Generation by Utilizing Plain Dam

K. Asai, S. Mitsuishi, N. Kawamoto, T. Izumiya and Y. Sasaki

In Japan hydroelectric power is sustainable, renewable and pure domestic energy with low CO2 emissions. It needs further progressive enhancement in the future. In Japan, while it has been difficult to construct a new dam due to the environmental impacts and financial tightening, plain dams known as retarding basins are recognized as effective solutions for flood control because they are friendly to the environment basically with no submergence, no separation of rivers and no change of water level.

In this study, hydroelectric power generation utilizing plain dams is examined considering the actual circumstances in Japan. Although plain dams are only used for flood control at present, we attempt to utilize them for water resources here, namely for enhancement of hydroelectric power generation. In particular, increasing electric power at downstream power plants is calculated by properly discharging stored water of plain dams in accordance with river flow regimes.

In this paper, we investigate potential of power sources development by modeling water use calculation utilizing plain dams on the basis of the data and theoretical analysis of the Shinano River, which is the longest river in Japan with a large scale of hydroelectric power generation. The simulation indicates that construction of plain dams at Tategahana area where embankment collapses frequently have caused flooding, makes it possible to supply up to around 56,000 households electrical power and its effect of CO_2 reduction is equivalent to a 55,000 ha forest. In comparison to hydroelectric power, which takes part in the planning of a multipurpose dam, it costs less; besides the effects of increasing volumes of electric power generation are caluculated by sensitive analysis comprising various river flow regimes and respective scales of plain dams.

Trends of annual behavior of operating concrete dams

M. Nonaka, T. Sano, K. Otagaki and N. Sato

Water resources Engineering Department of Japan Water Agency collects and management all the dam behavior data of own dams.

This paper discusses about trends of behavior of concrete dams by focus on the results of annual behavior data. Japan Water Agency has 20 concrete dams, those heights range from 24m to 156m and the operation periods range from 5 to 54 years. Contents are observation data such as dam displacement, water leakage of dam body and uplift pressure.

Maximum annual dam displacement range has correlation with dam height. Main factor of displacement at dam foundation is variation of water level. Some dams show the large quantity of water leakage temporarily in the winter season. Finally, the uplift pressures differ substantially in the situation of selecting the basic drainage apertures to observe at a same time.

This database is useful for safety verification in the situation of large earthquake and heavy flood. Additionally, database can be used for improving the management method and predicting the future behavior of every concrete dams.

Emergency response against water quality accident to secure safe water supply for capital area

S. Ojima and Y. Murakami

Japan is one of the countries where people drink tap water directly. Therefore, careful water resources management is required especially in supplying drinking water. On May 17, 2012, formaldehyde (HCHO in chemical formula), one of harmful substance, was detected as exceeding the limit for drinking water regulation near capital area of Japan, and, eventually, water supply for around 360 thousand houses was stopped in Chiba Prefecture, next to Tokyo metropolis.

Japan Water Agency (JWA) is in charge of operation of water resources management facilities in major river basins in Japan such as dams, weirs and canals, etc. Therefore, JWA worked together with river administrator against the water quality accident through emergency operation which aimed at reducing consistency of causative substance of HCHO and to prevent expansion of troubles. Emergency discharge from upstream dams, stopping water delivery through canals which connects 2 river basins, etc. were implemented as emergency operation. Finally, most of water supply service area did not suffer from water quality accident, but very urgent decision and operation were required at that time.

Through the experience of the water quality accident and emergency operation, JWA learned importance of 1) appropriate information sharing and 2) grasping the potential risk in the basin in advance. In addition, JWA reminded that enhancing the capacity of risk management is essential to achieve the mission of "to deliver safe water stably" as an organization working in the field of water supply service since water quality accident, in general, are directly link to citizens' daily lives and one trouble can give impact into wide area through the network of rivers, canals and also installed water supply facilities.

Effects of reservoir water level and temperature on vibration characteristics of concrete gravity dam

T. Kashima, T. Sasaki, M. Kondo and Y. Enomura

To evaluate seismic performance of dams against large earthquakes, it is necessary to select physical properties of dam and its foundation appropriately so that their actual dynamic behaviors during earthquakes are well reproduced.

Focusing on vibration characteristics such as natural frequencies obtained from analysis results of earthquake motion records observed at each dam are one of the most popular and practical way to identify values of various properties such as the elastic modulus of dam body.

The values estimated in this way, however, are affected by fluctuations of the reservoir water level and the temperature. The vibration characteristics, that reflect the stiffness of dam, may also provide an effective barometer to monitor the structural soundness of dam body. The effects of reservoir water level and temperature should be taken adequately into consideration to detect the sign of deterioration due to aging.

In this paper, the effects of reservoir water level and temperature on the vibration characteristics of dam body such as natural frequencies is investigated by using many earthquake motion records, which were observed at a dam and includes a strong motion record during a large-scale earthquake. The estimated natural frequencies are also compared with those estimated from analysis results of microtremor measurement conducted at the foundation and on the crest of the same dam.

As a result, it revealed that the natural frequencies of the dam are obviously affected by temperature fluctuation and the change of natural frequencies accompanied with the temperature change is larger than that of reservoir water level in view of the circumstances of the interested dam. The reason of these behaviors is discussed by using a numerical simulation of a model dam considering transverse joints.

Evaluation and prediction of frost damage of the Nagawado based on the standardized freezing and thawing cycle method

R. Doi and T. Kurose

The Nagawado dam is an arch dam located in a cold-district in the central Japan.

The dam was developed in 1960's. About 50 years have already passed since commencement of the dam operation. Because of its climatic location, the dam surface is subject to cold ambient air and frequent cycles of freezing and thawing in the winter. The safety management of the dam includes inspections, surveys and investigations of the dam concrete surface. Some deterioration of the concrete was observed at the surface due to the frost damage in recent years. Concrete core samples were collected from the surface in order to evaluate depth of the frost damage. Distributions of relative dynamic elastic modulus were measured by velocities of ultrasonic wave for each core sample. We confirmed the deterioration is very limited less than 1 cm deep from the surface. Furthermore, thermometers were newly installed 1cm deep from the surface to monitor temperature history through a winter season. Thermal distribution in the concrete depth and its time history were evaluated by an unsteady heat conduction analysis and the monitored data by the new and existing thermometers. The frost damage in future was evaluated based on the standardized freezing and thawing cycle method. We judged the dam concrete will be sound and stable in the long term considering statistical confidence interval of the prediction.

C. ICOLD 25th Congress in Stavanger Jun. 2015

A consideration of tecnological development of small-low earthfill dams and expansion of rational use of reservoirs

M. Matsuura and Y. Mineno

Japan has 2,723 dams with the height of embankment 15 m or more, of which 1,816 are less than 50 m, and 1,188 (43.6%) are small scale dams less than 30 m high, so about a half of the total are low embankment height dams. The reasons for this are the national land conditions which result in small river basins with rapid flow, the demand for water resources with branch points for irrigating dispersed agricultural land, and the fact that 70% of the population lives and farming is carried out on just under 20% of the national land consisting of weak and low lying plains.

This document summarizes the progress of technical development of small scale fill dams in Japan and their construction results. The technical issues are rational renewal of aging existing dams, methods of expanding reservoirs to deal with increasing water demand, design concepts for foundations that are weak and subject to liquefaction, the effective utilization of heterogeneous soil materials that can be obtained near dams, and ensuring seismic resistance under these conditions.

For specific discussions, we indicate herein the results of implementation of dam construction in which the reservoir bottom was excavated and the excavated soil was used for embankment of the dam while ensuring water supply. This is an example of renewal, integration, and expansion of old small scale irrigation dams (TAMEIKE) without changing the dam embankment height and the flood water level. Next, issues such as material control, construction specifications, performance monitoring during construction, monitoring during flooding, etc., are discussed based on the results of trial constructions, additional measures, embedded instruments, and other methods, in order to reduce the cost by using volcanic ash loam which is distributed around the dam site as the sole material.

Development of emergency power unit for gates

S. Kasahara, Y. Kiyonaga, Y Harada, A. Shimomura and N. Ishikawa

In case of power failure or equipment breakdown at dam outlet facilities caused by large-scale disaster, it is anticipated that the dam function might be lost due to inoperability of gates, and that might bring significant damage to downstream areas. Many of the current dam outlet facilities use hydraulic opening/closing equipment, and current measures that are taken against disasters include duplication of power source and hydraulic circuit as well as installation of backup power generator unit. However, power failure, damage of hydraulic pipes up to actuators such as hydraulic cylinders, or breakdown of hydraulic control equipment can incapacitate the operation of the facilities. Furthermore, operation by backup engine requires knowledge of hydraulic circuits in order to carry out manual operation of various valves in the hydraulic units. The calm and reliable operation is difficult in the so-called “panic state”.

The authors developed an emergency hydraulic power unit that can address current risk management issues, aiming at installing the “small, lightweight, easy-to-operate and reliable emergency hydraulic unit” on site.

Retrofitting and change in operation of cascade dams to facilitate sediment sluicing in the Mimikawa river basin

T. Sumi, T. Yoshimura, K. Asazaki, M. Kaku, J. Kashiwai, and T. Sato

With the huge sediment production in mountainous areas due to the Typhoon Nabi disaster in the Mimikawa River Basin in 2005, full-scale countermeasures to deal with reservoir sedimentation became necessary. To that end, the “Mimikawa River Basin Integrated Sediment Flow Management Plan”, which took into consideration the entire river basin from the mountainous areas to the sea, was compiled in 2011 by the Miyazaki Prefecture. Sediment sluicing operation at a group of dams in the main river in the Mimikawa River Basin will play a central role in this plan, and is scheduled to commence in FY2016. Sediment sluicing operation is planned for Yamasubaru, Saigou and Oouchibaru Dams in the Mimikawa River, which are administered by Kyushu Electric Power Company (KEPCO). In order that water level can be lowered sufficiently at times of river flooding during typhoon period, crest gate retrofitting work on Yamasubaru and Saigou Dams is currently being carried out.

This paper reports on related matters including the following, 1) the necessity for sediment flow management at dams in the Mimikawa River Basin, 2) the appropriateness of choosing sediment sluicing at dams as a measure to manage sediment flow, 3) numerical simulation carried out with the objective of confirming the effect of sediment sluicing and formulating optimal rules for operation, 4) hydraulic model studies carried out to determine functional characteristics of sediment sluicing operation, 5) details of dam retrofitting work and innovative techniques to prepare for sediment sluicing, 6) assessment of environmental impact below dams after commencement of sediment sluicing operation and 7) adoption of auxiliary methods for sediment flow management being carried out in advance of commencement of sediment sluicing operation.

Theme 2 New Construction Technology

A. ICOLD 81st Annual Meeting International Symposium in Seattle Aug. 2013

The application of automatic grouting control system on mix proportion at the Oyama Dam

T. Maeda, T. Matsunaga, Y. Matuoka, and K. Tsushima

The Oyama Dam is a concrete gravity dam with the height of 94 meters and 19.6 million cubic meters in storage capacity, located in the Chikugo River system in northern part of Kyushu island, Japan, owned by the Japan Water Agency (JWA). Construction project is at its final stage. First impoundment has started in May 2011. Geological composition of the dam site and its neighboring area includes Pliocene of Neogene to Pleistocene volcanic rock and volcaniclastic rocks. It features the complex geological structure that is characteristic of areas covered with relatively new terrigenous rocks. The foundation rock consists mainly of Shakadake volcanic rocks - andesitic lava spewed from the volcano which was active about 3.1 to 4.1 million years ago. It has a complex hydro-geological structure, and there also exist highly permeable zones in more than 50 meter depth of the foundation rock, in addition to near surface area.

Time and project cost management for the curtain grouting was a critical challenge for the overall construction project. The depth for curtain grouting at the Oyama Dam is, 190 meter from the surface of foundation rock at the maximum, which is twice as long as the dam height, while that of abut is set four times deeper than dam height of those areas. The design of curtain grouting was conducted based on the results of detailed geological survey.

This paper focuses on grouting works in the Oyama Dam, especially on the automatic grouting control system. The automatic grouting control system on mix proportion was adopted as one of the methods to execute grouting works effectively at the Oyama Dam. The system comprises a set of special grouting machine and software. The density of cement milk set the system depending on the grouting situation. It enables to change cement milk density automatically and continuously, based on status of grouting. Comparison of the system with the conventional one is discussed for its evaluation. The evaluation results revealed that: (i) the system achieved 40% reduction of grouting time that conventional one; (ii) quality of grouting results, or reducing Lugeon value, is as same as conventional one; and (iii) unit injected cement volume with the system is also as same as that of conventional one.

Design and construction for the particular treatment of ground foundation on the soil with high water pressure

Y. Kobayashi, M. Miyamaru, T. Oogomori and Y. Kuninaka

Fujinami Dam is a central core type rockfill dam, built in Kose River which is a left-side tributary from the middle of Chikugo River.

The ground soil under the riverbed had over 0.2 MPa of high water pressure. There was the high permeable Andesite layer with many open cracks underneath the riverbed, and the layer was connected to the reservoir of Gousho Dam on the right hand side of Fujinami Dam. The seepage fracture by ground water such as heaving and/or piping was considered because of the high water pressure in the soil layer underneath Fujinami Dam. Therefore, those two particular ground treatments below were performed to control the soil permeability.

In order to prevent the ground heaving, the influence of water pressure was shut off by building a waterproof wall under the right-side riverbed by vertical curtain grouting perpendicular to the center line of the dam. There were so permeable portions at the Andesite rock with cracks (Lu > 1,000) that the grouting was unable to be performed by the normal top-down method. The cement grout could not stay at the right position by using top-down grouting and too much volume of cement was considered to flow out into lower layers, therefore, the Vertical Curtain Grouting was built up from the less permeable lower layer by Bottom-up grouting method. This bottom-up grouting achieved the efficient improvement at the right position of the underground soil with adequate cement volume.

The other treatment to prevent the ground water piping at the soil foundation was the Thick Blanket Grouting. The blanket grouting was performed to the depth of 20m although that is normally performed up to the depth of 5m to 10m.

With those two types of grouting countermeasures, the safety against the seepage fracture of ground water at the dam foundation was assured at Fujinami dam.

B. ICOLD 82nd Annual Meeting International Symposium in Bali Jun. 2014

Technical Issues on Detailed Design of RCC dam for the Dasu Hydropower Project, Pakistan

J. Fukuwatari, H. M. F. Ahmed, I. Araki and M. Iijima,

In spite of chronic load-shedding due to lack of electric power, which is one of the mostserious socio-economic issues of Pakistan, there is huge hydropower potential

originating from glaciers in the north-west region of Pakistan where the Himalayas, the Karakorams and Hindu Kush Mountains meet. Already, Tarbela Hydopower Project (3,478 MW) built in 1976, one of the largest hydropower stations in Pakistan, utilizes the flow of the Indus River originating in the north-west mountainous area. Moreover, Pakistan Water and Power Development Authority (WAPDA) plans another five large hydropower projects along the upstream stretch of the Tarbela HPP: namely, Bunji HPP, Diamer-Basha HPP, Dasu HPP, Pattan HPP, and Thakot HPP from the upstream.

Dasu HPP is located 200 km upstream of Tarbela or 350 km north of Islamabad, the capital city. It is composed of a concrete gravity dam and an underground powerhouse with 12 generators with each 360 MW capacity, 4,320 MW in total. Main specifications of the dam are 242 m height, 570 m length and 4.1 million m3 volume of RCC.

The detailed design and bid preparation were completed by the consultants of the project. This paper describes the challenging design concept of the RCC dam due to issues such as: i) dynamic

analysis and countermeasure for safety against large earthquakes, ii) design of flushing facility for sedimentation, iii) RCC mix proportion with natural pozzolan.

2D/3D linear and non-linear dynamic analyses were conducted to evaluate safety for the maximum credible earthquake (MCE). Low Level Outlet (LLO) in the dam and two flushing tunnels on the right bank for flushing of sedimentation was designed based on sedimentation analysis along the Indus River. Natural pozzolan from gracial deposits will be used as the cementitious material instead of flyash or blast-furnace slag, due to their non-availability.

Development of Cruising RCD Construction Method

Y. Yamaguchi, T. Fujisawa , H. Yoshida and T. Sasaki

RCD construction method is a rationalized construction method for concrete dams which was originally developed in Japan in 1970's. RCD and RCC have common concept in construction procedure, but RCD gives us higher quality in compacted concrete than RCC. RCD construction method has been applied to about 40 concrete gravity dams in Japan, and has achieved reduction of the construction period, the labor cost, the environmental issue, and the hazard in safety for the constructor. However, under the current social and economic conditions, it is necessary to develop technologies to achieve further rationalization, by shortening the work period, lowering the labor requirements, and achieving greater efficiency in order to cut costs. We are now continuously developing technologies to raise efficiency and speed than by the conventional RCD method.

The conventional RCD construction method has two major problems to be solved for the further rationalization: alternate placement of RCD and external concretes to completely integrate two concretes and setting of cross-forms along transverse joints at the stopping of RCD concrete placement in a lift. In the newly developed method, "cruising RCD constrution method", RCD concrete is placed prior to external concrete placement. The above methodogical change gives us the following advantages.

1) The RCD concrete and the external concrete can be placed independently each other, and the efficiency of concrete placing works will be greatly improved.

2) The placement of RCD concrete can be stopped and restarted without cross-forms.

The new method have already been apllied to three large concrete gravity dams in Japan, and high-speed construction has been achieved.

The Japan Dam Engineering Center led the development and application of the cruising RCD method, and published "Engineering Manual for Cruising RCD Construction Method Technology".

In this paper, we will introduce an outline of this technology including application cases.

Theme 3 Flood, Spillways and Outlet Works

A. ICOLD 81st Annual Meeting International Symposium in Seattle Aug. 2013

Risk analysis of flood control method utilizing rainfall prediction

S. Mitsuishi, T. Sumi, T. Ozeki and T. Yagami

There has been a steady increase of extreme floods in Japan, where hydropower and irrigation potential has already been developed and most of the dam building activity is slowing down. For solving problems, the strategy should mainly focus on improvement and modernization of existing dams, improving the efficiency and saving water using modern technology. Rainfall prediction technology has progressed remarkably with numerical climate model. By utilizing this development, effective flood control operation which differs from existing dam operation rules has been conducted at some dam sites.

This flood control measure takes into consideration for risks caused by errors of rainfall prediction, that is, it assumes the occurrences of floods due to the shortages of flood control volume or unfilled water use volume after the flood. Therefore it is an urgent challenge to prescribe newly proper operation measure based on these risks into dam operation rules for manipulating precise dam operation constantly.

This study analyzes the errors of rainfall prediction by using Japan Meteorological Agency's MSM(Meso Scale Model) and GSM(Global Spectral Model), the accuracy of which have been considerably improved in recent years. Namely, the volume of rainfall prediction is divided into basin areas ,rainfall duration and weather factor, and then it is compared with the actual rainfall volume on the ground-based observations. In addition, for permissible estimated errors in dam operation, several numerical values are assumed while referring to the river planning or the high standard safety guidelines in space development plans and some other advanced designs. This enables us to estimate the approximate value of potential upper and lower limits of rainfall in dam management using rainfall prediction.

Furthermore, we conduct simulations concerning a group of dams in Kizu river, one of the Yodo River systems, where effective flood control was implemented in the past by over-cut, with using these upper limit on the rainfall prediction and sensitivity analysis of the over-cut volume. The dam operation adapted in practice is verified by estimating the amount of damages in the downstream river sections. This method should be verified by further various flood cases in future and be expected to be established as a stable and feasible technique which will enable every operator to practice with over-cutting flood control operations which reduce outflow discharge more than regulated.

New methods to increase the reservoir capacity and upgrade the discharge functions

S. Takasu, T. Ikeda, H. Yoshida and H. Kawasaki

In many dams, in order to make more efficient uses of limited reservoir capacities, outflow discharge control and preliminary release have been carried out using installed gates. However, in case of the dams of flood control use with small catchment area, it is often difficult for the proper gate operation, because the rainfall runoff time is short. For example, there is occurred insufficiency of flood control by missing the opportunity of preliminary release

caused by the delay of gate operation, and events of losing safety of the dam body caused by increase of reservoir water level over the usually control maximum level. In addition, the costs would be increasingly required for maintenances or replacements of many aging gates.

In Japan, there are many dams with small catchment area because of its complicated geographical features, and these dams of flood control use with operation of the gates have above problems. For this reason, after the around 1970, dams adopting preliminary release method has been no longer constructed and dams adopting free flow flood control method needing no gate operation has increased. The dam adopting free flow flood control method has defect of needs more flood control storage than the one adopting gate control method, but almost all the dams with small catchment area lower than the 100km2 have been adopted free flow flood control method because of certainty and ease of flood control.

On the other hand, almost all the dams constructed before around 1970 are installed flood control gates and there are quite a few dams conducting severe operation of the gates or preliminary release. For the measures to resolve these subjects, the modification to the dam adopted free flow flood control method removing gates or abolishing preliminary release method is considered. To increase flood control storage, reallocation of storage capacity, raising of dam body and excavation of reservoir bed are considered. The amount of required flood control storage increase is often small for dams in Japan and there are possibilities to take measures of reallocation storage capacity and several meters raising of the dam body.

In this paper, we clarify the subjects of operation on the dam with small catchment area, and shows some cases which were changed to the type of natural regulation method abolishing preliminary release, by raising the dam body and increasing the reservoir capacity.

Temporary Stream Diversion For The Oyubari Dam Redevelopment Project

M. Yamamoto, J. Tamura and H. Kuroki

This paper discusses issues and solutions associated with upstream water diversion and dam construction including flow diversion structure design and construction method. In order to meet increasing water demand and to prevent flood damage, the Oyubari Dam Redevelopment Project was undertaken. The project increases storage volume and level of an existing reservoir by constructing a new dam, Yubari Shuparo Dam, 150 m downstream from existing Oyubari Dam. Yubari Shuparo Dam is planned to be 110 m high with a crest length of 390 m, and volume of 9,400,000 m^3 when completed. The total capacity of the new reservoir is 427million m3, which is about five times greater than that of the existing dam. Yubari Shuparo Dam will serve multiple purposes ncluding flood control, maintenance and improvement of functions of river, irrigation, i water supply, and hydropower. It is scheduled for completion in 2015, the old reservoir will be incorporated into the new reservoir after completion.

Meanwhile Oyubari Dam is primarily used for irrigation and hydropower generation. For these purposes, water must be constantly released from the reservoir to downstream during the construction of Yubari Shuparo Dam. In addition, existing power stations must be protected from flooding. Therefore, diversion structure are required a large cross-sections. Four diversion conduits of 5.0m wide and 8.5m high each, have been provided to handle the peak flow of 1,300m^3/s from Oyubari Dam.

B. ICOLD 82nd Annual Meeting International Symposium in Bali Jun. 2014

Clarification on Hydraulic Characteristics of Labyrinth Spillway with Large Discharge Capacity Applied to Nam Ngiep 1 Hydropower Project

Y. Aosaka, M. Asano and J. Mizuta

Labyrinth spillways increase discharge capacity effectively compared to a straight overflow spillway arrangement with the same crest width. A main dam and are regulation dam are constructed for power generation of the Nam Ngiep 1 hydropower project, located in the Lao People's Democratic Republic. A labyrinth spillway is applied to the re-regulation dam. The design of the spillway has met the hydraulic requirements of the re-regulation dam with cost efficiency.

Recently, hydraulic characteristics of labyrinth spillways have been investigated in the world and there are a lot of references for design. Hydraulic model tests, however, were conducted due to the unique characteristics of the labyrinth of the re-regulation dam as follows:

1) The downstream and upstream overflow walls need to be inclined to ensure the stability of the spillway because of the large scale of height and overflow depth of the spillway.

2) The labyrinth has one of the largest discharge capacities per unit of the world and there are few precedent structures with similar size.

3) The performance of the spillway would be influenced by fluctuation of river water level downstream of the structure.

The hydraulic characteristics of the labyrinth spillway have been investigated through the hydraulic model tests to identify and resolve technical issues by refining the physical configuration of the spillway as followings.

1) The shape of crest is modified to prevent turbulent.

2) Air pipes are installed to prevent negative pressures.

The appropriateness of the application of labyrinth to the re-regulation dam has been verified with the hydraulic requirements satisfied.

Maximum flood inflow could increase due to heavy rains by the global warming.

Labyrinth spillways could be an effective way of increasing discharge capacity to the dams located with geometric constrain, and thus could be applied to other projects including existing dams to improve discharge capacity.

C. ICOLD 25th Congress in Stavanger Jun. 2015

Ohno Dam's Operation Results For Redusing Inundation Damage In Excess Inflow Situation

J. Kashiwai, T. Kubozono and T. Takada

If a gated dam has the purpose of flood control, operation mode should be changed from flood control to overtopping prevention mode in an excess flood inflow situation. The judgment of the changing mode and the decision of increasing way of outflow to connect both operations, mainly depend on a dam manager in Japan.

Ohno dam had experienced many flood control operations till 2012 and contributed to reduce the disaster damages of flooding. At the flood in Oct. 2004, the water level went up to lowest water level for the operation of overtopping prevention. From the experience of the operation of the flood in 2004, Ohno dam learned not only the importance of flexible operation considering flooding situation at downstream areas but the necessity of more practical rules against excess floods.

For the operation rule against excess floods, Ohno dam picked up the idea presented by the Public Works Research Institute Japan and prepared prototype rule for Ohno dam in 2012. The idea is to present minimum outflow, which can prevent overtopping, in the condition of inflow and water level at a point. The minimum outflow is obtained through the simulation of gate operation under the conditions related with hydrograph of inflow, gate movement, increasing rate of outflow and so on.

After the preparation of the prototype rule, the Ohno dam tried to examine the practical use of the new rule, and met the typhoon that caused excess flood in Sep. 2013 under examination situation. The operation was carried out with referring to the minimum outflow table, which was printed out, and obtained good results. Effectiveness of the minimum outflow table was confirmed through the actual operation.

Study on flood control effect of Abugawa dam on the flood in July 2013 and improvement measures

S. Mitsuishi, K. Asai, Y. Akamatsu, N. Kawamoto and Y. Hirano

The purpose of this paper is to verify the flood control effect of Abugawa Dam on the occasion of heavy rain disaster in Yamaguchi-Shimane area in Japan dated July 28, 2013 and, to suggest improvement ideas for dam operations.

Abugawa Dam stored about 1271m3/s flood water at the peak of inflow and had a remarkable flood control effect by lowering water level at Nakatsue datum point by 3.4m. While the upper branch river areas suffered immense damages, no damage was caused in Hagi City which is located downstream of the dam. The cause of this fact is that the average rainfall was much less than the flood control plan though partial guerilla-like rainfall was observed in the upper stream. Therefore, it is possible to conclude that the dam is useful to local and short guerilla-like rainfalls.

At this flood, the reservoir level of the dam was lower than the flood season control level by about 5m, thus the adjustment operation was executed. Nevertheless, a large volume of over storage was generated as it took 3 hours to open dam gate after the decision of discharge. If a large scale flood which exceeds the flood control plan occurs in the future, the operation prescribed under the proviso clause is taken and it can lead to tremendous damages. In order to execute adjustment operation smoothly and stably, the introduction of water level threshold discharge method is effective and, as an aid to judge the commencement time of the operation, utilization of critical flow is highly suggested.

As it took 1 hour to convey necessary information to the authorities concerned in addition to 2 hour reserved time, both of which are required by the operation regulations, 3 hours in total were spent before the actual gate opening at this flood and, this is the main cause for the over storage. There is room for improvement of this operation by adopting one time distribution of written information by facsimile etc. and, by reducing the reserved time before gate opening to more than 1 hour.

When a large scale flood which exceeds the flood control plan occurs in the future, an adequate preemptive discharge becomes necessary from the view point of realizing the dam's maximum flood control function and avoiding the operation prescribed under the proviso clause. Considering the data of MSM rainfall prediction published by Japan Meteorological Agency, there was also room for discussing preemptive discharge.

Strengthening the flood discharge capacity of Kanogawa dam

Y. Nishizawa, H. Yoshida, T. Ikeda and N. Yasuda

The Ministry of Land, Infrastructure, Transport and Tourism has planned a large-scale tunnel spillway with inner diameter of 11.5 m and total length of approximately 450 m in order to drastically strengthen the flood discharge capacity of Kanogawa Dam. This tunnel spillway will have the following four unique technical features. Firstly, because the gate and control house will be installed near the outlet of the tunnel spillway, the tunnel will be a pressure tunnel acted on throughout its length by maximum external water pressure of about 0.9MPa dependent on the ground water level of the natural ground and by maximum internal water pressure of about 0.4 MPa dependent on the reservoir water level. Secondly, its maximum discharge flow rate will be 1,000 m3/s, and its maximum flow velocity will be as high as 10 m/s or more. Thirdly, in order to minimize the impact on the downstream river course, the stepped energy dissipator adopted is a contractive type. Fourthly, in order to install an inflow channel and vertical shaft inside the reservoir of Kanogawa Dam and to excavate the tunnel in the natural rock on the right bank of the reservoir, measures to prevent leaking from the reservoir was an important matter that was thoroughly investigated.

Flood control for typhoon 18 at the Yodo river system in 2013 - avoidance of catastrophe through coordinated operation of 7 dams -

M. Kanmurii, H. Morita, H. Takezawa, T. Aoyama and H. Miura

On September 16, 2013, the heavy rains of typhoon 18 caused an overflow in a section of at the most 400m on the right embankment of Katsura River downstream area close to confluence point of the 3 rivers, the Katsura River, Uji River, and the Kizu River in Yodo River System.

At this time, the Hiyoshi dam upstream was utilizing its dam capacity to the fullest and was storing floodwater to implement

flood control (disaster prevention operations) and also even at the Uji River, the Seta River Barrage was completely closed and the Amagase Dam was undertaking flood control and additionally, the dam group upstream of Kizu river (Takayama Dam, Murou Dam, Shorenji Dam, Nunome dam and Hinachi Dam) were also coordinating to lower the water level at the confluence point of the 3 rivers.

Because it was possible to utilize all the facilities in Yodo River System to full capacity for flood control, the overflow downstream of the Katsura River was held to a level where stacked sandbags were able to avoid the worst case of collapse of embankment.

The flood response this time, through the close coordination adjustments and the high level of technical skills demonstrated by the dam operations and maintenance offices, the dam integrated management offices, the Kinki Regional Development Bureau, and the Kansai Regional Bureau of Japan Water Agency (JWA), the collaboration of 7 dams in Yodo River System were able to undertake the unprecedented operation and demonstrates the very significant effect of the dams and the operation of the dams can be thought to have prevented a mayor disaster.

Hydraulic model test of "ski jump spillway with multi flip buckets" applied to the nam ngiep 1 hydropower project

Y. Aosaka, M. Hanamoto and M. Asakawa

A main dam and a re-regulation dam are constructed for power generation of the Nam Ngiep 1 hydropower project (Project), located in the Lao People's Democratic Republic. A main powerhouse and a re-regulation powerhouse are to be constructed near the main dam and the re-regulation dam, generating electricity which is to be sold to Thailand and Lao People's Democratic Republic. The topography around the main dam has characteristic of narrow gouge and lots of deposits including big boulder on the river bed. Considering these conditions, ski jump spillway with multi flip buckets ("Multi Flip Bucket Type"), which ensures the sufficient function as energy dissipator, is adopted for the spillway of the main dam in order to improve its economy. Multi Flip Bucket Type has multi chute with different elevation and angle for discharging water to disperse the diving points. It can mitigate the impact of diving water to prevent the increase of the tail water level and the decrease of energy generation due to moved river deposits.

Hydraulic model tests have been carried out to confirm the hydraulic characteristics of the spillway of the main dam. The application to the Project is verified considering the following issues;

Design of the spillway gates, chutes, guide walls, aeraters, flip buckets and deflector for appropriate diving point, stable discharge, and reduction of splash is carried out.

Width, angles, radius, and elevations of flip buckets are determined to minimize the scoring and deposition of riverbed, and to prevent the increase of the tail water level. Additionally, the effect of pre-excavation of downstream riverbed is evaluated.

Among other things mentioned above, detailed results of the hydraulic model tests for determining flip bucket angle and movable bed to evaluate the impact to the tail water level are mentioned in this paper.

Multi Flip Buckets Type is economically advantageous compared to hydraulic jump type and is more effective for the energy dissipator, and has less impact to downstream riverbed. Multi Flip Buckets Type can be applied to the dams on narrow rivers where ordinary ski jump spillway cannot be applied.

Theme 4 Earthquakes and dams

A. ICOLD 81st Annual Meeting International Symposium in Seattle Aug. 2013

Reproduction analysis for deformation behaviour of an earth core rockfill dam under construction during large earthquake

S. Yoshida, H. Satoh, T. Sasaki and Y. Yamaguchi

For the risk management of dams, the evaluation of the seismic safety of dams is important and it can be used to decide the priority for the seismic reinforcement of existing dams. According to "Guidelines for Seismic Performance Evaluation of Dams against Large Earthquakes (Draft, March 2005)" issued by the River Bureau of the Ministry of Land, Infrastructure, Transport and Tourism in Japan, the sliding deformation is the key factor in the evaluation of seismic performance of embankment dams. This stands on the empirical knowledge that a settlement due to shaking down during a large earthquake is considered to be a part of consolidation settlement in advance and has a minor effect on the seismic performance compared to the sliding deformation.

During the Iwate-Miyagi Nairiku Earthquake in 2008, large settlement without sliding was observed at Isawa earth core rockfill dam of dam height 132m under construction located in Iwate Prefecture, Japan. (Dam height at the time of the earthquake was about 84m)

Thus, the settlement due to shaking down due to the large earthquake motions should be also paid attention for the seismic performance of dams and the evaluation method of such deformation is strongly needed.

In this study, we show the overviews of the damage of the rockfill dam during Iwate-Miyagi Nairiku Earthquake, and conducted reproduction analysis for deformation behaviour. For the analysis, the dynamic characteristics of construction materials were evaluated from the results of cyclic triaxial tests under various conditions. In addition, we conducted the sliding displacement analysis using Newmark method.

We conducted dynamic laboratory tests for construction materials and evaluated differences of dynamic properties due to the saturated or unsaturated conditions. And we calculate settlements induced by large earthquake motions based on the cumulative damage theory and evaluated differences of behaviour due to saturated or unsaturated conditions. Confirmation of reproducibility was executed by comparing results of analysis and the measured differential settlement data.

We found that the reproducibility of the settlement due to shaking down was fine in the case of using the dynamic strength properties of saturated conditions in core material and the dynamic strength properties of unsaturated conditions in other zone materials. Results of the sliding displacement analysis using Newmark method was not generated sliding displacement. It was the

comparable as the actual phenomenon of the dam during the earthquake.

Modified seismic coefficient method by recent seismic records prioritizing embankment dams for detailed safety evaluation against large earthquakes

K. Aoi, T. Sasaki, H. Satoh, H. Sakamoto and Y. Yamaguchi

Recently in Japan, large-scale earthquakes have frequently occurred, so seismic performance evaluation of dams, which store huge amount of water in their reservoirs, has become more important. Because there are more than 1,500 existing embankment dams in Japan, concurrently conducting of seismic performance evaluations by the dynamic analysis is difficult for all of embankment dams in a short period and with the limited budget. In order to determine the priority of implementation of detailed seismic performance evaluations for existing embankment dams, it is necessary to study simple and practical seismic performance evaluation method.

The “Draft of Guidelines for Seismic Design of Embankment Dams” (hereinafter referred to as the “Draft of Guidelines”) was drawn up in June, 1991, as a seismic performance evaluation method for rockfill dams. The Draft of Guidelines was established as the future design method for new dams, but it can be used for relatively evaluation of the seismic safety of existing dams. In the Draft of Guidelines, a modified seismic coefficient method is proposed as a seismic performance evaluation method for rockfill dams in Japan with a height less than 100m, in which the vertical distribution of seismic force was determined with taking the seismic response of dam body into account. The seismic force coefficient was formulated through the examination and analysis of only eight seismic motions recorded at dam sites during actual relatively large earthquakes, and it is same regardless of dam height and slopes of surfaces. But, since the implementation of the Draft of Guidelines, a number of seismic motions have been recorded at many dam sites in Japan. Based on many recent seismic motions obtained at dam sites from 1966 to 2008, we examine the seismic force coefficient corresponding to the dam height that can also be applied to rockfill dams with a height greater than 100m. In addition, we investigate the effects of gradients of upstream and downstream surfaces on the values of the seismic force coefficient. Based on the results, we propose a revised seismic force coefficient which will be utilized in design method of new dams and simple seismic performance evaluation of existing dams.

Study On Behavior Of Afrd During Earthquake And The Conducted Reinforcement

T. Tsukada, H. Yamamoto, Y. Shimada and Y. Uchita

The Yashio dam is the upper dam of Shiobara pumped strage power plant. It’s a 90.5m high asphalt concrete facing rockfill dam. Two cracks occurred at the facing along the abutments of left and right bank and leakage increased in the 2011 Touhoku Earthquake. We stopped leakage by repairing in the short period. The maximum acceleration values were about 50 cm/sec^2 at the bed rock and 250 cm/sec^2 at the crest respectively. They were less than the acceleration we considered at the design stage by the 2-D numerical dynamic analysis and 3-D model vibration test. We studied to pursue the mechanism of occurring and development of the cracks by analysis of the measured acceleration and 3-D numerical dynamic analysis and so on. After the studies, we found that the cracks occurred by the concentration of strain at the concrete joints on the crest of the dam. We also studied toughness of asphaltic concrete facing with crack and confirmed the flexibility of the reinforced structure, that we supposed by the results of many tests, against the large deformation during earthquake. We used the low elastic asphalt that was developed for ensure the flexibility at the low temperature and the asphalt impregnated nonwoven fabric sheet that was developed for prevention of development of underlayer cracks. We summarized important considerations on the structure and procedure in case that the facing has damage.

Earthquake resistant evaluation of dam and spillway gate to large-scale earthquakes

H. Doi, Y. Otubo and A. Nakano

From the viewpoint of ensuring soundness and accountability for facilities of hydroelectric power plants against large-scale earthquakes which have occurred frequently in Japan, it is imperative that seismic performance of each facility should be evaluated. The Kansai Electric Power Co., Inc. gives higher priority to evaluate soundness of dams, spillway gates, head tanks, penstocks and aqueducts, taking into account of possible impacts to third parties when an accident occurs.

We have performed seismic evaluation for about 40 concrete gravity dams with a height of more than 15 m, supposing the maximum scale earthquake motion which possibly occurs in the future, namely "Level 2 earthquake motion". In the seismic performance evaluation against such large-scale earthquakes, it is important to apply a simulation model that can reproduce actual behavior more precisely.

Although it is assumed that actual behavior of concrete gravity dams in large-scale earthquakes is controlled by such factors as interaction of each dam block, restricted effects by surrounding foundation rock, etc., those factors cannot be reflected in conventional two-dimensional dynamic analysis. Three-dimensional dynamic analysis has been introduced to the dams that show high tensile stress. For establishing a proper three-dimensional model, it is required to determine specific parameters through identification analysis by using recorded earthquake data.

Seismic observation devices at an existing dam body and spillway gate have been set for two years. The three-dimensional analysis model that can properly reproduce observed seismic responses has been developed by using measured seismic waves.

In this paper, we discuss the following items: 1) earthquake resistant evaluation of a dam using the developed three-dimensional analysis model, and 2) behavior of the dam and the spillway gate during the large-scale earthquakes in consideration of integrated behavior of the dam blocks and their surrounding foundation rocks.

B. ICOLD 82nd Annual Meeting International Symposium in Bali Jun. 2014

A practical consideration on the damage to small and old irrigation dams by the 2011 Tohoku Earthquake

K. Ueda and M Matsuura

In Japan, numerous small dams have been constructed and operated for the irrigation of paddy since ancient times. Taking into consideration of the increase of the numbers of aging dams in the world, the practical engineering learnt from the experience through the ages in Japan should be the matter of importance. Under this circumstances, the catastrophe that is '' The 2011 Tohoku Earthquake'' occurred in Japan. The agricultural facilities including small and old dams were severely damaged although large high dams adhering to the sophisticated design standard have not suffered severe damage. In three disaster-stricken prefectures, 12,521 small and old dams are still in use for irrigation. It is reported that approximately 1,784 dams –about14 %out of total – were damaged and about 500 dams within the 1,784 were damaged so seriously as to need immediate care. Approximately 860 items of defects were found at 500 dams. Most of them are slides, cracks, opening, swell, depression, subsidence and displacement on embankments and appurtenances. The on-site conditions and assumed causes of these defects stated above should be practically examined in this paper , referring to several case studies..

The practical knowledge obtained may contribute to proper remedial designs and provide important clue to the appropriate revision of standards or criteria of not only small and old dams but also large high dams in some cases. This knowledge is also considered to be very useful for the structural integrity as well as for the appropriate operation and maintenance of aging dams around the world.

Dynamic analysis of seismic behavior of raised concrete gravity dam during large earthquake

M. Kondo, T. Shida, T. Sasaki and Y. Enomura

To meet changing needs for flood control and/or water use in river basin, raising existing dam can be one of the most effective solutions. Meanwhile, evaluating the structural safety of dam against large earthquakes has become to be required more strongly for both new dam construction projects and existing dams. Dam raise projects increasing its height are notexceptions.

In this paper, seismic behavior of raised concrete gravity dams during large earthquakes are investigated by using numerical simulationsincluding non-linear dynamic analysis considering crack propagation accompanied withtension softening of dam concrete.

The analyses revealed that the estimated damage into dam body of raised concrete gravity dam are not the same as newly constructed damwith the same shape and it depends on the height of dam raising and reservoir water level under the construction work to raise. Based on these results, it was pointed out that when evaluating the effects of seismic motion on a raised concrete gravity dam by using dynamic analysis, its construction process and conditionfor dam raisingworksincluding placing new concrete and actual reservoir water level under raising worksshould be taken into consideration

Seismic analysis of concrete gravity dam installing new outlet works conduit into existing dam body

T. Shida, M. Kondo, T. Sasaki and Y. Enomura

To meet changing needs for flood control or water use in river basin with effective use of existing stock, installing new or additional outlet works into existing dam body by drilling can be one of the most effective solutions in terms of both cost and impact on natural environment.

Meanwhile, seismic safety of existing dam against large earthquakes has become to be required more strongly.

In this paper, seismic behavior of a concrete gravity dam during large earthquakes are investigated focusing on damage to dam body around new or additional outlet works conduit which is installed into existing dam body by using numerical simulations including non-linear dynamic analysis considering crack propagation accompanied with tension softening of dam concrete.

The analyses revealed that the estimated damage into dam body around the new or additional conduit is not the same as the case of newly constructed dam with conduits. It means that when evaluating the safety of dams installing conduit into existing dam body by using numerical analyses, construction process that includes drilling, lining and reservoir water level under and after construction works should be taken into consideration. From the analyses, it was also revealed that reinforcing steel around the new conduit is effective in diminishing crack opening and extension into existing dam body.

Effects of limited number of slip circles and arbitrary slip circles on sliding deformation of embankment dams due to earthquakes based on Newmark's method

S. Fujikawa, H. Sato and Y. Enomura

For the risk management of dams, the evaluation of seismic performance of dams is important. According to "Guidelines for Seismic Performance Evaluation of Dams against Large Earthquakes (Draft)" issued by the River Bureau of the Ministry of Land, Infrastructure, Transport and Tourism in Japan in March 2005, sliding deformation is identified one of the most important issues in the evaluation of seismic performance of embankment dams. To calculate sliding deformation, static analysis of embanking and impounding processes is firstly performed to evaluate static stress distribution.

Seismic response analysis is secondly performed and finally sliding deformation analysis is conducted. To evaluate sliding deformation due to earthquakes, Newmark's method is widely used in the sliding deformation analysis of embankment dams. In the sliding deformation analysis, number of slip circles is generally restricted due to capacity of computer and a few dozens of slip circles has been used in many previous researches. However, similar to the static sliding stability analysis, method for arbitrarily searching a circle of maximum sliding deformation is desirable in Newmark's method. Therefore, we conducted a research to investigate the effects of limited number of slip circles and arbitrary slip circles on sliding deformation analysis of embankment dams due to earthquakes based on Newmark's method for a model dam of an earth core rockfill dam (ECRD).

We compared the results between limited number of slip circles and arbitrary slip circles of the sliding deformation analysis, and we confirmed that the amount of maximum sliding deformation of arbitrary slip circles was larger than that of limited number of slip circles.

Rational, organized, and successful emergency operation against disaster – case of the historic earthquake in Japan

S. Takagi, H. Izume, K. Someya and H. Ootaka

On March 11, 2011, historic earthquake with magnitude 9.0 hit Japan. To manage necessary response to serious earthquake disaster, the head office of Japan Water Agency (JWA) and each branch offices set up Emergency Operation Centers based on "Emergency Operation Plan" immediately after the earthquake. Based on the detailed rules of Emergency Operation Plan and related manuals, JWA conducted emergency facility inspection and information collection just after the earthquake.

On each dam where the earthquake motion above the regulated standard was observed, primary and secondary emergency inspections were carried out within 3 hours and 24 hours after the earthquake respectively. As a result, it was confirmed that there was no safety problem in any of dams.

On the other hand, damages disrupting the function of the water resource management facilities - barrage, levee and canals - located in the Tone River and Lake Kasumigaura basin have occurred.

Therefore JWA conducted necessary operation to prevent the damage from spreading, emergency rehabilitation works at damaged sites, information release to related organizations such as water user organizations, preparation of the documents for rehabilitation works, etc. In addition, regular meetings in HQ EOC (Headquarter Emergency Operation Center) were organized with the participation of all board members and Director Generals of all the departments of JWA to collect and share information, and to command emergency response and rehabilitation.

Considering the lessons learned through the experience, JWA is going to review existing plans and manuals for risk management and disaster prevention duties as follows; 1) database compilation of main facilities, 2) revision of BCP (business continuity planning), 3) promoting arrangement of cooperation agreement at the disaster with local firms, 4) accumulation and brushing up of technology on emergency recovery and 5) implementation of more practical disaster drill.

Cracking on embankment dam body due to recent large earthquakes and direct and splitting tensile strength tests for earth-core material

H. Sato and Y. Enomura

The 2011 Tohoku Earthquake and other large earthquakes which have occurred in recent years in Japan have caused relatively large cracks on the crests of many embankment dam bodies. Immediately after the 2011 Tohoku Earthquake, special safety inspections were carried out at over 300 dams in the affected area. As a result of special safety inspections, more than 10% of all inspected dams reported some damages. This ratio rose to 18% for embankment dams. Damage to embankment dams included relatively wide and/or long cracks mainly on the crests of earthfill dams. After the 1995 Kobe Earthquake, cracks were also observed on the crest of the Kinjoike pond, an old agricultural pond with a height of 15m located about 30km from the epicenter. The width of the crack on the crest was narrow about 1cm, but the crack from the crest extended deep into the dam body when the dam body was excavated to perform repairing work while checking the cracks. However, no sliding deformation was observed at the Kinjoike pond. Results of safety inspections of embankment dams after large earthquakes in Japan have raised awareness of the importance of evaluating cracks of embankment dam bodies. It is necessary to evaluate the tensile strength of dam body materials of embankment dams, but almost no tensile strength tests using dam body materials of embankment dams have been carried out. In this paper, we firstly introduce cracking on embankment dam bodies due to recent large earthquakes. Next, we report the results of laboratory direct and splitting tensile tests using core material of an existing rockfill dam. When the degree of compaction of specimens is 95%, the direst tensile strength ranges from 25 to 30kPa, and the splitting tensile strength ranges from 20 to 25kPa.

Probabilistic Seismic Risk Analysis using Dam Distance Attenuation Formula in Japan"

H. Kawasaki, N. Matsumoto and I. Suetomi

On the present seismic safety verification of dams in Japan, the acceleration time history as an input-motion is created by calculating the acceleration response spectrum to the scenario earthquake considered to have the maximum influence in the dam-site foundation by the distance attenuation formula.

Since this deterministic method is not premised on probability, it is not suitable for the risk assessment which is judged with the probability and the suffered damage.

Then, we tried to evaluate the acceleration in dam foundation by the probabilistic method in this paper. Earthquakes are classified into the earthquake which cannot specify the epicenter in the outskirts of Japan, and the earthquake which can specify the epicenter. The former occurred at random, and the latter made the model for generating repeatedly at a comparable interval. Thus the probabilistic hazards at the dam site foundations were evaluated.

Using these earthquake models, in several representative dam-sites, acceleration calculations by the distance attenuation formula were performed, and the earthquake hazards at the dam-site foundations were evaluated probable.

Although these results are exemplary, it will be useful for the accuracy improvement of the dam seismic analysis in Japan. Moreover, the characteristic of the dam-site foundations can be clarified more by comparison with the stochastic seismic hazard map by J-SHIS (Japan Seismic Hazard Information Station) which shows the earthquake hazard of the ground surface.

Attenuation Relationship of Earthquake Motion at Dam Foundation in Consideration of The 2011 Tohoku Earthquake

T. Ito and T. Sasaki

Estimation of input earthquake motion is very important aspects of the seismic design and inspection of seismic tolerance of dams. Generally, characteristics of earthquake motion at some geographical point are affected by three element combinations, which are earthquake source mechanisms, transmission path properties, and local site conditions. There are three basic approaches to estimate site-specific earthquake motions: theoretical, semi-empirical, and empirical methods. The hybrid method is a combination of theoretical and semi-empirical approaches. With enormous develop of computer simulation

ability, the theoretical, semi-empirical, hybrid approaches are rapidly evolving. However their results should still be examined by empirical approach from the viewpoint of accuracy checking.

We have presented several papers about attenuation equations of acceleration response spectra for the dam foundations in the past. In the first paper, attenuation equations were derived from the statistical analysis of horizontal-direction ground motions recorded at 91 dams sites for 63 earthquakes from 1974 to 2000. Since the first paper, we have proposed vertical-direction attenuation relationships, and made the brush-up and modification for these attenuation relationships.

In this paper, we propose the latest attenuation relationships derived from the statistical analysis of 794 horizontal-direction and 394 vertical-direction ground motions recorded at 239 dams sites for 91 earthquakes from 1974 to April, 2011 including The 2011 Tohoku Earthquake (March 11th, 2011 Mw9.0)

Vibration model tests on the seismic characteristics of raised fill dams

H. Tagashira, Y. Hayashida, S. Kuroda and S. Masukawa

Dynamic centrifuge model tests and 1G shaking table model test were carried out in order to investigate the seismic characteristics of raised fill dams.

Four types of dam body model were made: type A of the existing dam, type B of a trapezoidal embankment made of the raised new dam body material, type C of a raise fill dam without the middle layer (transition layer) between existing and raised new dam bodies and type D of a raised one with the middle layer. They were made of No.6 silica sand with 5% of water content and three kinds of relative density: 50% for the existing dam body, 75% for the middle layer and 95% for the raised new dam body. Five sine waves with maximum acceleration of 100, 200, 300, 400 and 500 cm/s2 were input in order.

As a result, the following characteristic phenomena were recognezed; larger settlement at the raised new dam body crest than that at the existing dam body crest, horizontal displacement of the raised new dam crest toward the existing dam crest, local intense variation of displacement and maximum response acceleration amplification factor at the boundary between the two dam bodies or at the middle layer, and local displacement intensity reduction effect of the middle layer.

C. ICOLD 25th Congress in Stavanger Jun. 2015

Effects of new modified seismic force coefficients on minimum sliding safety factors of existing rockfill dams

H. Sato, K Aoi, H. Sakamoto, T. Sasaki and Y. Yamaguchi

In 1991, The “Draft of Guidelines for Seismic Design of Embankment Dams” was drawn up in Japan. The Draft of Guidelines was established as both a future design method for new dams and a seismic performance evaluation method for existing dams. In the Draft of Guidelines, a modified seismic coefficient method was proposed as the seismic performance evaluation method for embankment dams in Japan with a height less than 100 m, in which the vertical distribution of seismic force was determined with taking the seismic response of a dam body into account. Based on seismic response analysis using 55 observed seismic records, we have been proposed revised seismic force coefficients which can be applicable to embankment dams higher than 100 m. In this paper, to investigate the effects of the seismic force coefficients on minimum safety factor, we conducted stability analysis for 12 existing rockfill dams by the modified seismic coefficient method using seismic force coefficients defined by the Draft of Guidelines and our proposed coefficients. The minimum safety factors using the revised seismic force coefficient are almost same or larger than those using original one. We think we propose better seismic force coefficients which consider the nonlinear behavior of higher embankment dams during earthquakes.

Effect of initial shear stress on strength reduction of compacted soil during undrained cyclic loading

K. Ueno, Y. Mohri, T. Tanaka and F. Tatsuoka

A great number of Irrigation earth dams designed and constructed not following the modern design codes exhibited excessive deformations by strong seismic loads. Damages occurred more frequently in the upstream slopes than in the downstream slopes because of the reduction of undrained shear strength in the saturated zone by undrained cyclic loading. This phenomenon has to be taken into consideration to properly evaluate the residual deformation of irrigation earth dams during a seismic event. In view of the above, the authors developed a modified version of the Newmark method (so-called Modified Newmark-D method) that takes into account the continuous degradation of undrained shear strength by undrained cyclic loading. The undrained shear strength degradation is strongly affected by dry density, and by the ratio of Initial shear stress to initial effective normal stress, which is different depending on the direction of failure plane and the location in a given embankment. If effects of dry density have been partly studied, the effects of initial shear stress on the strength reduction characteristics are little known.

In this study, the dependency of strength reduction characteristics on the initial shear stress was evaluated by performing of a series of triaxial tests on saturated specimens compacted to a relatively low dry density. Results show that the cyclic shear stress amplitude needed to generate a given strain at a given number of loading cycle decreases with an increase in initial shear stress. This result indicates that the strain when subjected to same seismic loads becomes larger with an increase in the initial shear stress. On the other hand, the undrained shear strength that has decreased by the same strain generated by undrained cyclic loading becomes larger with an increase in the initial shear stress. However, with an increase in the initial shear stress, the undrained shear strength becomes smaller than the initial shear stress more easily. Therefore, the residual deformation by the same seismic loads increases with an increase in the initial shear stress.

Evaluation of seismic performance of the interface of a composite dam against large scale earthquake motion

A. Nakamura, N. Yasuda, T. Kinoshita and H. Etoh

This paper sets large-scale earthquake motion (Level 2 earthquake motion) for a large-scale composite dam in order to evaluate seismic performance, mainly near the interface of its embankment dam and concrete dam. In the part near the interface, the embankment dam and concrete dam, which have different response characteristics, are connected, so a detailed

three-dimensional model was prepared and three-dimensional FEM dynamic analysis of the composite dam under Level 2 earthquake motion was carried out to evaluate its seismic performance. As the Level 2 earthquake motion, the lower limit acceleration response spectrum (equivalent to maximum acceleration of 300 cm/s^2) was set by using the specific attenuation formula for dams to obtain the acceleration response spectrum of the maximum assumption earthquake (MAE) and by performing a comparative study.

The results of the dynamic analysis revealed that the range where tension occurred was distributed near the upstream end and downstream end of the interface, but near the normal water level, it was not continuous in the upstream-downstream direction, so the watertightness is not harmed. Similarly, the occurrence of slippage of the interface surface is distributed from the upstream end to the downstream end of the interface, but it is not continuous in the upstream-downstream direction near the normal water level, so its watertightness is not affected. The local safety factor FS of element against shear failure of the core falls below FS = 1.0 near the normal water level, but for elements continuous in the upstream-downstream direction, FS rarely falls below FS = 1.0, and then for only a very short duration. Therefore, a sliding plane is not formed, and the watertightness is verified.

Review of material properties of rockfill dams and effects of shear strength of rock material on sliding deformation"

S. Fujikawa, H Sato and Y. Enomura

The "Guidelines for Seismic Performance Evaluation of Dams against Large Earthquake (Draft)" were issued in 2005. According to the seismic performance evaluation of embankment dams, the plastic deformation on embankment dam caused by sliding is an important evaluation value. However, to estimate the sliding deformation with actual embankment dams during an earthquake precisely, a lot of time and costs are required to conduct laboratory tests and natural period identification analysis. Therefore, in the future, simple and relatively precise evaluation method is required to conduct a number of seismic performance evaluation for embankment dams. n this paper, the material properties of rockfill dams managed by the MLIT or Japan Water Agency was reviewed. Representative values were set based on the reviewed results, and sliding deformation analysis calculated by an earth core rockfill dam model with the height of 100 m to study about the effects of shear strength of rock material on the sliding deformation. As a result, it was found that the input acceleration assumed the maximum sliding deformation of 1 m necessary for safety during an earthquake according to The Guidelines (Draft) is about 5 m/s^2.

Theme 5 Sedimentation and reservoir environment

A. ICOLD 81st Annual Meeting International Symposium in Seattle Aug. 2013

Dredging of sediment deposited in Kurodakezawagawa No.1 dam

K. Kimata, N. Ishibashi and T. Ono

In many reservoirs in Japan, disorders of dam function occur at present due to increased amount of deposited sediments.

It has thus become an urgent issue to develop an efficient method of treatment of deposited sediments, such as maintenance of the function of flood control and water utilization, securement of storage capacity, supply of sediment to down streams in consideration of sediment transport systems as well as an efficient utilization of deposited sediments.

Kurodakezawagawa No.1 dam is located upstream of the spa town Sounkyo, sedimentation of the dam has been a problem.

Kurodakezawagawa No.1 dam has a small site occupation of only 260 m2 for dewatering facilities, where a filter press to secure a dewatering capacity of 13.5 m3/h could not be installed. In order to overcome this site condition, the Okumura system which continuously dewaters the slurry using a "screw press" was applied, which has the following features for construction.

From the view point of the construction scale of V = 5,400 m^3, the site conditions and the dewatering capacity, two screw presses were selected; φ1,000 mm (horizontal type) and φ500 mm (vertical type).

The above screw presses have exhibited the actual performance of 10.0 m^3/h and 3.5 m^3/h for the φ1,000 mm (horizontal type) and the φ500 mm (vertical type), respectively.

In order to maintain the strength stipulated in the particular specification (qc = 300 kN/m^2 or more) and the dewatering capacity, additives to be used in the dewatering process were selected after sampling in advance, while automatic control of cone index was applied.

A comparative study on settling rate evaluation for soil particles in reservoirs

H. Umino and N. Hakoishi

This study aims to present an appropriate method on settling rate evaluation for soil particles in reservoirs. In Japan, we conduct numerical simulation of sediment and turbidity in reservoirs before starting dam construction project and predict probable sedimentation and environmental impact. For the execution of numerical simulation on sediment in reservoirs, it is indispensable to decide the settling rate of soil particles. Laser diffraction method has been commonly used for grain size analysis and grain size is converted into settling rate by Stokes' Formula, nevertheless, it has been indicated that the settling rate calculated by this method differs from the actual one.

The authors conducted three types' settling arte analysis, i.e., settling cylinder method, centrifugal sedimentation method and laser diffraction method, then, these results were compared. The settling cylinder is a method to observe the turbidity of turbid water in a settling cylinder with time and this method could simulate the actual phenomena and could give reliable results. On the other hand, it needs a plenty of turbid water and took long time to get results. The centrifugal sedimentation is a method that shortens the time of settlement by using centrifugal power, but the upper range of analysis was only 50 □m and the equipment is not disseminated. The laser diffraction method has been regarded as the standard method.

Before starting settling rate analysis we obtained turbid water from a river while flooding. After conducting settling rate analysis we realized that the settling rate distribution analyzed by laser diffraction method showed the tendency that the settling rate

distribution was faster than other methods. We estimated that actual settling rate was slower than calculation of the Stokes' Formula because several particles formed flocks and each flocks was porous. The importance of evaluating effective flock density was regarded if flock size was converted into settling rate.

Through this study three points were concluded. (1) Settling cylinder method was the most reliable for evaluating the settling rate of fine particles. (2) Centrifugal sedimentation method could alternate the settling cylinder method. (3) In case of using laser diffraction method, similar settling rate distribution to settling cylinder method could be obtained by attaching ultrasonic distribution treatment.

Development of the burrowing type sediment removal suction pipe by laboratory experiments and field test

T. Sakurai and N. Hakoishi

The construction of a dam can interrupt the transport of sediment through the river. Decreased sediment supply downstream causes environmental problems related to the riverbed such as degradation, armoring, and fewer opportunities to renew the riverbed material. Furthermore, sedimentation causes a reduction in the reservoir storage capacity. Therefore, measures are required for sediment supply from the reservoir. In consideration of the conditions and time variation of the downstream riverbed environment, it is desirable to be able to control the timing of sediment supply and the quantity and quality (mainly particle size) of supplied sediment.

In the past, besides traditional measures such as excavating and dredging, sediment flushing with water level drawdown and sediment bypassing were developed and used in Japan. However, the conditions for applying these measures are restricted and it is difficult to control the exact quantity and quality of the discharging sediment by these methods. Then, the authors have been working to develop a new sediment supply measure. We set following objectives of development. (1) A change of reservoir operation is not required. (2) It is able to control a sediment discharge rate according to a water discharge rate. (3) Size of facility is small and economy. As a result of earlier studies, we proposed the "burrowing type sediment removal suction pipe method" using the differential water head energy between the upstream and downstream areas of a dam. We have carried out the laboratory experiments to examine the hydraulic characteristics of the pipe and to improve the pipe.

In this study, we carried out the field test to examine the applicability of the burrowing type sediment removal suction pipe. We did the field test using the 200 mm diameter suction pipe at the actual very small reservoir located in the mountainous area. And we compared the result of the field test and the past laboratory experiments (pipe diameter: 60 mm, 100 mm and 200 mm). As a result, we understood the hydraulic characteristics such as a relationship between velocity in the pipe and the sediment concentration, a water head energy loss of the pipe and so on. It is confirmed that the burrowing type sediment removal suction pipe could be applied to remove non-cohesive sediment material without debris in a small reservoir.

Countermeasures against reservoir sedimentation problems

S. Takasu, H. Kawasaki and T. Ikeda

Generalized countermeasures against reservoir sedimentation with a number of actual results are excavating or dredging of sedimentation deposits in the dam reservoir or sediment trap dam. And a part of excavated materials has been effectively using for aggregate resources.

Besides, we can enumerate some methods to discharge reservoir deposits to the downstream using natural river flow forces, such as a sediment bypass, sluicing/ flushing and a partial sediment removal. In these methods, sediment bypass and sluicing/ flushing have been studied for a relatively long years and increased their actual results to a limited extent in Japan.

The partial sediment removal is a method to remove sedimentation deposits around the intake with flow-water by operating the discharge facility: conduit or discharge pipe installed in lower level, under the situation of a high reservoir level. This method is called HSRS: Hydro Suction Removal System. The place to discharge sedimentation deposits is assumed at the downstream side of the dam or sediment bypass tunnel.

The method of HSRS is a sediment conveying system by sucking sedimentation deposits making water flow using differential water head of a reservoir. It is considered as an effective method to adopt a dam reservoir with high differential water head because it need no lowering the reservoir water level like as sluicing/ flushing and no long tunnel like as a sediment bypass from a upper-end of a reservoir.

We can enumerate representative two functions required for HSRS.

One is a function which could efficiently suck and discharge sedimentation deposits in the pocket assumed with predetermined capacity under the surface of sedimentation. The sediment in the pocket is considered of the flowing bed load or the deposits materials dredging and removed in the reservoir.

The other is a function which could suck and discharge flowing suspended sediment and wash load after the discharge of the sediment in the pocket. It belongs to a category of density flow functionally, but this system is considered having higher efficiency relatively because of that the suspended sediment density on the datum level in the middle part of the reservoir is thicker than near the dam body installed spillway.

However, it is still necessary to resolve many problems relation with these functions in advance of an actual adoption of this system.

In this paper, we evaluate its applicability comparing with other methods, and show subjects in an adoption of it, in and the latest countermeasures on it in Japan.

Reservoir sedimentation database and selecting suitable sediment management options in Japan

T. Sumi

Modern development of dams in Japan goes back to approximately 100 years ago. The original target was mainly the utilization of water for water supply and agriculture purposes. With subsequent economic development, however, several other targets were added to dam development, such as hydropower generation, industrial water use and flood control for mitigating flood damage in the developed cities on the downstream flood plain. At present, the multi-purpose dams make up the majority of the Japanese dams. Approximately 3,000 dams over 15 meters in height have been constructed so far in Japan, but the total reservoir storage capacity is only 23 billion m^3.

In Japan, following the widespread recognition of sedimentation problems, all dams having a storage capacity over one million m^3

have been obliged to report sediment condition to the authority every year since 1980s.

As of 2006, from 971 dams accounting for approximately 1/3 of all dams in Japan, annual changes in sedimentation volume and the shape of accumulated sediment were reported to the central government. It is probably only Japan that established such a nationwide survey system, and such accumulated considerably valuable records on a global basis.

Based on these data, we can estimate regional or river basin scale reservoir sedimentation progress such as total storage loss and its annual speed. Classification of reservoirs both by reservoir sedimentation index and reservoir turnover index can be useful to understand the current situation and selecting suitable management options.

In this paper, history of reservoir sedimentation survey in Japan will be explained and how we have established database and how we are trying to effectively utilize will be discussed. Additionally, data analysis on sedimentation profile and characteristics of deposited materials are also discussed.

Experimental study on the vertical multi hole suction pipe method by using water head"

K. Arakawa, M. Fukuhama and H. Katayama

The Japanese archipelago has a long history of orogenic activity. Because of this, there are many steep mountains in Japan. Also, there is heavy precipitation-in some areas up to 3,000mm per year. Therefore, the sediment yield potential is immense. In some dams, a specific sedimentation rate has reached 1,000 cubic meters per kilometer per year. Though the dams in Japan have approximately 100-year probable sedimentation volume, several decades pass after the dam's construction, there is a sizeable amount of sedimentation.

The sedimentation is a major issue for dam management as it severely affects the capacity of the reservoir. To address these apprehensions, some recent suction systems are being developed. These natural vacuums-which utilize the clean potential energy created by the difference of the water head in relation to the surface of the water reservoir-have a significant improvement on the removal of sediment.

We demonstrated and tested the "Multi Hole Suction" pipe method (MHS) with the suction pipe positioned horizontally to absorb the sedimentation by negative pressure. However, the location of the pipe is 5 meters below a thick layer of sediment we have experienced a phenomenon that prevented the required discharge rate of the sedimentation, as an arch action which prevents clumps of sediment from collapsing smoothly.

The aim of this study is to improve reliability for the suction sediment systems by eliminating the influence of the arch action. We came up with the "Vertical Multi Hole Suction" pipe method (VMHS) which sets the suction holes on a vertically plumbed pipe. The system is superior to the conventional one in that fluid containing the sediment flows in the same direction as gravity acts.

We made the experiment assuming a water level difference of 45m, with sediment particle size: d50=0.2mm, and density of sediment layer 15m. We designed control experiments in consideration of 4 factors: (1) the suction pipe diameter, (2) number of suction holes, (3) the diameter of the suction holes and (4) the characteristics of deposited sediment. Using a 1:30 scale model, we measured 3 values: (1) the velocity of flow, (2) the hydraulic pressure and (3) the sediment concentration.

We grasped an effect to give to the flow velocity distribution, the volume of sediment discharge, water head loss and so on. And, we considered how to use this method practically in a real-life situation.

A study on sediment yield and transport properties at basin scale using a distributed rainfall and sediment runoff model

G. Nagatani, K. Ozawa, N. Mizuno, Y. Takata, H. Ishida and K. Takara

Large scale reservoir sedimentation by torrential rains causes the loss of the storage capacity of reservoirs in a short term. It is necessary to manage those sedimentation in order to obtain sustainable use of existing reservoirs. The purpose of this study is to predict accurately sediment yield and transport by torrential rains, using a distributed rainfall and sediment runoff model.

Sediment yield and sediment transport by water is closely related to rainfall and runoff processes. To simulate sediment yield and sediment transport, a model of the phenomena should involve runoff generation model by using physically-based hydrological model. Based on these considerations, distributed rainfall and sediment runoff model is developed as reservoir management technology. The model assumes that the flow lines are parallel to the slope and the hydraulic gradient is equal to the slope. The kinematic wave of the model does not consider the vertical water flow like infiltration effects. The input rainfall data is directly added to subsurface flow or surface flow according to the water depth on the area where the rainfall dropped. The model considers mixed grain sizes of sediment materials composing of riverbeds and slope-failure material from hill slopes.

The developed model is applied to the Tokai severe storm event in September 2000 at the Yahagi Dam (504.5 km^2), in Chubu, Japan. However, being strongly dependent on the initial conditions of river sediments, the model needs to understand the dynamics of sediment origin.

This paper clarifies the basin-scale dynamics of sediment during torrential rains, by improving the model to be able to identify the grain size of sediment movement due to each of the slope failure and the initial conditions of river sediments. The model represents the natural physical process of sediment movement from the sediment yield area to the dam reservoir. In addition, an approach for incorporating bed variation analysis in the reservoir should be included in further study.

B. ICOLD 82nd Annual Meeting International Symposium in Bali Jun. 2014

Development of the sediment removal suction pipe by laboratory and field experiments

M. Miyakawa, N. Hakoishi and T. Sakurai

The construction of a dam can interrupt the movement of sediment through the river. Decreased sediment downstream causes environmental problems related to the riverbed such as degradation, armoring, and fewer opportunities to renew the riverbed material. Furthermore, sedimentation causes a reduction

in reservoir storage capacity. Therefore, measures are required for sediment supply from the reservoir. Thinking of the conditions and time variation of the downstream riverbed environment, it is desirable to be able to control the timing of sediment supply and the quantity and quality (mainly particle size) of sediment.

The authors have been working to develop a new sediment supply measure to solve reservoir sedimentation problems and downstream riverbed environmental problems. As a result of earlier studies, we proposed a "burrowing type sediment removal suction pipe method", using the water head energy differential between the upstream and downstream areas of a dam. We have carried out laboratory experiments and field tests to examine hydraulic characteristics and applicability of the pipe. We compared the results of the laboratory experiments (with pipe diameter: 60 mm, 100 mm and 200 mm) and the results of the field tests (with pipe diameter: 200mm) at an actual small reservoir located in a mountainous area. As a result, the hydraulic characteristics such as the relationship between velocity in the pipe and the sediment concentration, water head energy loss in the pipe,etc. were found. It was confirmed that this kind of pipe could be applied to remove non-cohesive debris-less sediment material in a small reservoir.

Comparative study on settling rate evaluation for soil particles in reservoirs"

H. Umino and N. Hakoishi

This study aims to present an appropriate method on settling rate evaluation for soil particles in reservoirs. For the execution of numerical simulation on sediment in reservoirs, it is indispensable to decide the settling rate of soil particles. Laser diffraction method has been commonly used for grain size analysis and grain size is converted into settling rate by Stokes' Formula, nevertheless, it has been indicated that the settling rate calculated by this method differs from the actual one.

We obtained turbid water from a river while flooding, investigated and compared settling rate distribution by settling cylinder method, centrifugal sedimentation method and laser diffraction method. Settling cylinder method could give reliable results, but it needs a plenty of turbid water and took long time to get results. Centrifugal sedimentation method could shorten time for analysis, but the equipment for this method is not disseminated. The laser diffraction method has been regarded as the standard method. We estimated that actual settling rate was slower than calculation of the Stokes' Formula because several particles formed flocks and each flocks was porous.

Through this study three points were concluded. (1) Settling cylinder method was the most reliable for evaluating the settling rate of fine particles. (2) Centrifugal sedimentation method could alternate the settling cylinder method. (3) In case of using laser diffraction method, similar settling rate distribution to settling cylinder method could be obtained by ultrasonic distribution treatment.

The new practical method for screening musty-odor / non-odor species in Oscillatoriales (Cyanophyta)

F. Kimura, T. Homma, K. Ushijima, E. Furusato and Y. Tanaka

A musty-odor problem caused by cyanobacteria belonged to Oscillatoriales is not understood well enough in reservoirs. As one of the main causes, Oscillatoriales have morphological similar species including both some musty-odor producing species and others non-musty-odor producing species.

Therefore, the musty-odor producing species cannot be identified by the present morphological identification technique or the separation method of green / brown strains using the fluorescence microscope. Recently, Komárek and Anagnostidis have proposed the newly classification system of Oscillatoriales. It is revealed that the detailed classification research based on this classification system can determine the separation of musty-odor producing species / non-producing species. As a result, cases of successful separation of musty-odor / non-odor species in Oscillatoriales have increased.

However, classification and identification of Oscillatoriales based on the newly classification system is too hard to be directly applied in the regular phytoplankton monitoring, since it is performed by focusing on motility of trichome and detailed morphological characteristics at high magnification by microscope. Therefore, in order to implement the daily water quality management, the elucidation and measures of a musty-odor phenomenon in the dam reservoir, it is necessary to develop the simple method for identification of musty-odor species, which is based to the newly classification systems proposed by Komárek, et al. This paper introduces the consideration on the development of newly morphological identification method to discriminate the musty odor-species from Oscillatoriales. This method will be possible for reservoirs to predict risk of a musty-odor outbreak. This identification has been characterized by having adopted four new standards in a conventional standard. We assumed four conditions a classification standard about size and shape of a cell.

Water Quality Management by Free-selective Air-lock Intake

H. Kawasaki, H. Yamamoto and K. Kuwahara

Selecting the intake depth of the reservoir is beneficial for quality management of the reservoir and water supply. This paper presents a new selective intake system based on the air-lock method which can be operated and maintained easier than conventional systems.

Free-selective Air-lock intake systems (another name: Continuous Syphon) are rapidly extended for these ten years. Nowadays, they are in operation at 5 dams, and under construction at 2 dams in Japan. Firstly, this paper describes these situations.

Secondly, this paper describes the basic study to validate the shape of intake tube which decided by hydrologic accounting using hydraulic model experiment and numerical model simulation. The results of model studies are also evaluated by comparing with the measurement results of one of the system in operation.

Thirdly, this paper presents the design and construction case of this system in Yubari-Shuparo dam located in the north Japan, which is the latest and one of the biggest systems completed. Its maximum amount intake water is 83m^3/s and its range of intake depth is 45m.

Additionally, this intake system in Yubari-Shuparo dam enabled to intake water from one or more tubes simultaneously, using inverse V-shaped tubes which are placed at different elevations, while the other intake tubes are stopped by air-locking. Further, this system realized the high economic performance by no use of multistage metal gates which include parts to be frequently maintained such as rubber sealants and wire ropes, no use of heavy steel structures and hoist equipment, and no tower structure on the dam crest.

Integrated approach for environmental management in Tenryu river

Y. Kitamura

The impacts on the environmental condition in reservoir are unavoidable consequence of dam construction. The sedimentation, turbidity water and water quality are typical environmental issues for dams and reservoirs which have impact on the periphery of reservoir and downstream of dams irrespective of countries. These impacts are influenced from the upstream of dam, and influence to the downstream. Therefore the more integrated environmental management approach and consideration have been required for the whole river system, including not only the dam reservoir, but also up and downstream of dam.

The "Tenryu river natural resources reproduction committee" has been established on 2012 through three years preparation. The purpose of committee is the preservation, reproduction and creation for the environmental condition of Tenryu river, and is especially the reproduction of fishes resources and the improvement of environmental condition of river. The outstanding feature of the committee has the member of the fishermen's cooperative association, the academic experts, and the dam administrator. And the information/knowledge about the environment, and the needed technical development are exchanged cross-boundary of the participants.

The committee highlights about the "attached algae investigation and productivity of river evaluation", the "spawning bed investigation and creation method", and "information dissemination" for the downstream of Tenryu river from 2013.The attached-algae investigation shows the ecology environment and the productivity of river, and serves as a key for considering countermeasure among above themes. Moreover, the analysis of a fish catch and environmental items is important during evaluation of the productivity of a river. In this report the outline of new approach of the committee, and the field investigation and the evaluation technique are introduced about the fluvial environment management in Tenryu river.

C. ICOLD 25th Congress in Stavanger Jun. 2015

Investigation of The Recovery of Seaweed At Barren Ground by Deposition on Bottom of Dam Reservoir in Japan

Y. Sakai, T. Toyoda and S. Horiya

The increase of barren ground lead to a significant reduction in fisheries production and biodiversity in Japan. Iron is an essential micronutrient for algal growth. Macroalgae need high concentrations of iron as well as nitrogen and phosphorus. The speciation analyses of iron in Yoneoka reservoir and Ainumanai Dam in Japan was performed. As a result, rates of Fraction C corresponding to Fe-HS were in the range of 2.72–5.94 %. Dam iron humate elution unit (Unit A), dam humic substance unit (Unit B), and iron humate elution unit (Unit C) was effective for the growth of seagrass experimental sites at barren ground in Japan. And the growth effect of seaweed in Site B (Unit B) was highest among four sites.The change of iron humate concentration from July in 2010 to December in 2011 at four experimental sites took the almost the same tendency of increase and decrease. Si concentration at Site A, B, and C increased with time processing and was mainly low Si concentrations. In addition, phosphate concentration is suitable for fishery in Japan. From relationships between concentration of iron humate, Si, and P and growth area of seaweed at all experimental sites, the concentration of iron humate in May was considered to be effective for the growth of seaweed. Conclusively, we could propose the new barren ground reclamation method using deposition on bottom of dam reservoir in Japan.

Experimental study on the conditions for use of the "Vertical Multi Hole Suction pipe (vmhs)" method

Y. Numano, T. Nakamura and H. Katayama

Accumulation of the sediment in a dam reservoir reduces the flood control and water use functions of the dam and shortens the service life of the reservoir. The development of technologies to effectively and efficiently remove the sediment in reservoirs is thus called for. We have been researching and developing methods for sucking up sediments accumulated in dams by using water pressure (the MHS method) since 2001 to deal with this problem. Stationary hydraulic suction method including the MHS method provides high suction efficiency if the sediment to be sucked up mainly consists of sandy soil. The problem is that this suction becomes difficult when the ratio of sediment with low permeability and high viscosity such as silt and clay increases, because the sediment accumulated on the upper portion of the suction part becomes solidified and resistant to collapse. The authors therefore proposed the "vertical multi hole suction pipe (VMHS) method," in which sediment removal pipes were vertically installed to suck up sediment through suction holes on the side of the pipe while the pipe was horizontally installed in the conventional MHS method aiming to eliminate the phenomenon, in which the solidification of sediment in deep suction depths prevents the sediment from being sucked up, and to increase the reliability of suctions. The authors then assessed the basic suction performances of the method in model-based experiments by using silica.

This report aims to verify the limits of the use of the VMHS method when the sediment sucked up contains silt or clay components and to examine its countermeasures. The authors conducted indoor suction experiments using about a 1:10 scale model of the actual system. The experiment first examined conditions with which the method works using different sediment properties. The sediment deposited in dam sites contained a significantly high ratio of sandy soil. Sediment containing finer particles than silt was mixed with that sediment, and suction experiments were conducted using the ratios of the mixed fine particles as parameters. We used the average particle size of the 0.82 mm sediment and the ratio of 0.6% finer silt mixture than silt for dam sites, and the average particle size of the 0.24mm fine particles to be mixed with a 20% mixture ratio of particles that were finer than silt for mud conditioning. As a measure to improve the performance to suck up sediment containing silt and clay, the conventional suction holes were improved to a series of slit-type suction parts that extend from the surface of the sediment to the water column above the sediment. The experiment also verified the usability of this method. As a result, the suction was completed using a slit-type suction system with proper width to prevent high concentration of the sucked water if the mixture ratio of particles which were finer than silt was about 2%, even when the suction was interrupted with the conventional suction hole method.

Substantiative experiment al study of discharging sediments by the suction method utilizing the water head difference at the Yahagi dam

T. Sugita, M. Saiki, W. Nakane, I. Miyairi and K. Masui

The suctioning method of discharging sediments using the water head difference has been studied as a countermeasure against sedimentation at the Yahagi Dam. A field demonstration experiment was conducted to verify the performance of the method. A facility measuring a water head difference of 4.5 m, a sediment discharging pipe with diameter of 600 mm and total length of 47 m was installed near a check dam inside the reservoir of the Yahagi Dam, and a method using the mobile barge and applying the siphon principle was performed. Five different operation cases were analyzed in terms of the different soil types of sediments, the current velocity in the suction pipe, and the feature of suctioning operation. The state of sediment discharging in each case was checked, and the parameters necessary to confirm the equipment function and equipment design were estimated. The outline of the joint experiment and its results are given in this report.

Environmental study on flashing discharge in the river downstream from the Hitokura dam

M. Mori and S. Miyauchi

When a dam is built, it is known that the sand and soil from upstream rivers gathers at the dam, causing granulation of riverbed materials downstream. Indeed, granulated riverbed materials were found downstream of the Hitokura Dam. As a result, the river environment changed and the residents said that the fish population decreased after construction of the dam.

At the Hitokura Dam, flashing discharge procedure has been conducted since 2002 to supply sand and soil and to renew attached algae. To verify the effects of this procedure, we carried out physical and biological observations and made quantitative analyses of the improvement in granulation of the riverbed and the flaking and renewal of attached algae.

Other Technical Publications

"Engineering Manual for Design, Construction and Quality Control of Trapezoidal CSG Dam"

Japan Dam Engineering Center, June 2012

A trapezoidal CSG dm is a new type of dam intended to simultaneously achieve "rationalization of materials", "rationalization of design", and "rationalization of execution".

At the seepage control structure of the Taiho Dam (Okinawa General Bureau, Cabinet Office) and the Kawai Sub-dam of the Haizuka Dam (Chugoku Regional Development Bureau, Ministry of Land, Infrastructure, Transport and Tourism), testing, design, and execution were carried out based on the trapezoidal CSG dam theory, which applies a newly developed dam body design method, CSG strength setting method, and testing methods etc., successfully obtaining a vast quantity of information concerning execution and quality control. And following these two projects, preparations to build more trapezoidal CSG dams were made by studying design and execution plans for their main dam bodies, conducting laboratory tests, and performing trial field executions. In 2007, the Engineering Manual for Construction and quality Control of Trapezoidal CSG Dam was compiled based on these studies and tests.

Beginning in 2009, construction of the Tobetsu Dam (Hokkaido), the auxiliary dam of the Kasegawa Dam (Ministry of Land, Infrastructure, Transport and Tourism, Kyushu Regional Development Bureau), and the Okukubi Dam (Okinawa General Bureau, Cabinet Office) as full scale trapezoidal CSG dams began in succession based on the findings of these many past studies and projects. The construction of these dams has provided valuable knowledge concerning not only execution and quality control aspects, but also testing and design matters, at the same time as it has contributed to the development of new technologies and many innovations.

To encourage the wider construction of trapezoidal CSG dams and the further development of this technology by taking advantage of lessons learned from the costruction of these three dams, we have summarized the newest technology information including design, execution, and quality control to compile the new manual: Engineering Manual for Design, Construction, and Quality Control of Trapezoidal CSG Dam. We hope that everyone involved in the construction of trapezoidl CSG dams will refer to this volume as a useful source of information.

In conclusion, we wish to express our deep gratitude to everybody who has played a role in the development of trapezoidal CSG dams.