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REPORT ON A SYSTEM FOR CHECKING SAFETY OF DAM BODY AND RESERVOIR SLOPE DURING FIRST FILLING AND THE OCCURRED LANDSLIDE *

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1. INTRODUCTION

It is fortunate that, in the modern history of Japan, there have been no major dam disasters. There are two reasons for this. Firstly, technical standards that are thought to be strict even when compared to others around the world have been established by river administrators and have been carefully observed. Secondly, a system is in place that prohibits the construction of dams unless various types of technical reviews such as bedrock inspections are conducted at the site. Moreover, first filling process is also required, in which the rate of reservoir level rise and fall and the observation and monitoring systems are carefully controlled. In first filling process, the dam is filled with water on a trial basis after the dam construction has been completed and before the dam is put into service, and the behavior of the dam body, the foundation and the ground around the reservoir and so on is monitored carefully. If a problem is discovered during this stage, countermeasures will be taken immediately. The dam is not

* *Présentation d'un système de vérification de la sécurité du corps du barrage et des talus de la retenue lors de la première mise en eau et du glissement de terrain.*

approved as being complete and cannot be put into service unless first filling has been concluded successfully.

This paper introduces the first filling system in Japan and reports about the first filling method of Takizawa Dam, for which the first filling was actually implemented. It also reports the detailed observation of the dam body and natural ground, etc. during the first filling, as well as the deformation in the surrounding ground that occurred during first filling and the measures taken to cope with it and so on.

2. OVERVIEW OF TAKIZAWA DAM

Takizawa Dam is a concrete gravity dam located in the city of Chichibu, Saitama Prefecture, on the upper reaches of the Ara River System. The Ara River System has a river basin area of approximately 3,000 km2. With the nation's capital, Tokyo, located in its lower reaches, it is one of Japan's major river systems in terms of population and assets located within the flood susceptible area. Use of the water from this river system is highly advanced. Figure 1 shows the location of Takizawa Dam

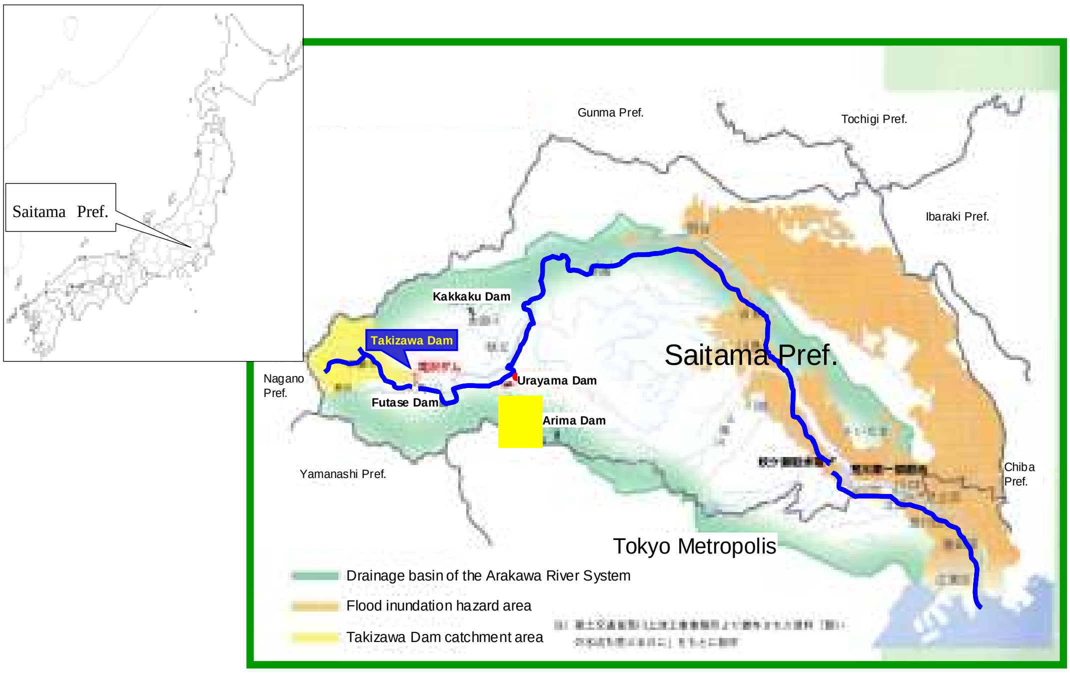

Fig. 1
Location of Takizawa Dam
Localisation du barrage de Takizawa

2.1. OBJECTIVES OF PROJECT

- Flood control

Of the design flood of 1,850 m^3/s at the dam location, flood control of 1,550 m^3/s is conducted to reduce the flood discharge in the downstream section of the Ara River.

- Stabilization of vested water supply and preservation of river environment

A flow rate is secured so as to stabilize the vested water intake in the Ara River littoral zone, preserve the river environment and so on.

- New water use (domestic water)

A total intake of up to 4.60 m^3/s can be obtained (up to 3.74 m^3/s as domestic water for Saitama Prefecture and up to 0.86 m^3/s as domestic water for Tokyo).

- Power generation

A maximum output of 3,400 kW of power is generated using the water discharged from the dam.

2.2. OVERVIEW OF FACILITY

Dam type:	Concrete gravity dam
Dam body volume:	Approximately 1,670,000 m^3
Dam height:	132 m
Crest length:	424 m
Catchment area:	108.6 km^2 (reservoir area: 1.45 km^2)
Normal water level:	Elevation 565.0 m (October - June of following year), elevation 537.0 m (July - September)
Surcharge level:	Elevation 565.0 m (July - September)
Lowest water level:	Elevation 495.0 m
Reservoir capacity:	63,000,000 m^3
Effective capacity:	58,000,000 m^3

3. CONCEPT OF FIRST FILLING AND FIRST FILLING PLAN FOR TAKIZAWA DAM

An accident occurring at a dam will have an enormous impact on the residents living in downstream areas, so ensuring dam safety is of critical importance. Particularly when constructing dams in a densely populated country like Japan, ensuring safety is the issue that is given priority above all others. From this standpoint, first filling is required for all dams constructed in Japan, and a dam is not completed until it has been subjected to first filling.

3.1. OVERVIEW OF FIRST FILLING PROCEDURES

The procedures for first filling are determined by the Ministry of Land, Infrastructure and Transport which functions as the river administrator. An overview of these procedures is presented below.

« Chapter 1:General provisions »

This stage establishes the objectives for the enactment of first filling procedures and the definition of first filling. The definition states that "first filling is a procedure conducted prior to the transition to normal management, in which the reservoir level is raised and lowered within the range below the surcharge level in order to confirm the safety of the dam, the foundation ground and the ground around the reservoir.

« Chapter 2: First filling procedure »

For first filling, a first filling plan and procedures for operations during the construction work must be prepared and these must be approved by the Ministry of Land, Infrastructure and Transport, etc.

« Chapter 3: Basic policy for first filling»

The range within which the reservoir level is raised during first filling is the range up to the surcharge level that represents the highest reservoir level for dam operation. As a rule, the reservoir level is lowered within the range from the surcharge level to the normal reservoir level. However, in cases in which there is a landslide where countermeasures have been provided within the reservoir or the like, the reservoir level is reduced to the level at which safety can be ensured.

The reservoir level raising and lowering tests are normally conducted in non-flood season in order to secure the flood control capacity.

Normally the speed at which the reservoir level is lowered is kept to 1 m / day or less to lighten the burden on the observation and monitoring organization during the first filling process.

In addition, for flood control during first filling, separate operational procedures for use during construction are prepared and flood control is conducted in accordance with these procedures.

Reservoir level that can keep a flood control capacity for the target flood(hereinafter referred to as “flood control reservoir level”) is established for dams for which first filling must be conducted with particular care, such as special types of dams that have been subjected to special foundation treatment and so on. In general, even when flood control has been conducted in accordance with operational procedures during construction for a 20 year flood (a flood with a probability of occurrence of 20 years), the level should be set such that the reservoir level that has been previously experienced + 1 m is never exceeded.

« Chapter 4: First filling plan »

When conducting first filling, a first filling simulation based on the actual flow status for a period of the past 10 years or more at the location of that dam must be conducted, and a first filling plan must be established. In addition, an appropriate measurement and monitoring plan must be drafted to ensure the safety of the dam body, the foundation ground and the ground around the reservoir during the first filling process.

« Chapter 5 : Implementation of first filling »

During first filling, the reservoir level is maintained at the surcharge level for a period of at least 24 hours, and the safety of the dam body, the foundation ground and the ground around the reservoir is checked with even greater accuracy.

3.2. FIRST FILLING PLAN FOR TAKIZAWA DAM

A first filling plan was drafted, following the former "Procedures for Implementation of First filling (draft) (October 1, 1999). Top priority was given to checking the safety of the dam body, the foundation ground and the ground around the reservoir, and the plan was determined so as to prevent the first filling period from being unduly extended and to enable the benefits of the dam to be produced quickly.

Table 1 shows the basic approach for first filling at the beginning.

Table 1
Basic Approach for First filling Plan (Initial)

Item	Basic Approach
Establishment of design year	Based on the daily average flow data for the 20 years between 1984 and 2003, the 10th year (1993) was established as the design year.
Start of first filling	October 1 (non-flood season)
Range for reservoir level raising	Surcharge level(elevation 565.0 m)
Range for reservoir level lowering	Down to the lowest elevation at which reservoir level control is possible (elevation 485.0 m: foundation elevation of the lowest intake of selective intake facility) in order to check the safety of landslides in the area around the reservoir
Speed of reservoir level raising	Out of consideration for safety with respect to landslides in the area around the reservoir, 1 m / day or less is used as the basic speed over the highest experienced reservoir level(however, this does not include the reservoir level increase when flood control is implemented)
Speed of reservoir level lowering	1 m / day or less (does not include cases in which the reservoir level must be decreased, etc. after flood control has been implemented)
Maintenance of reservoir level	24 hours at surcharge level (elevation 565.0 m)
Flood control method	During flood season (July 1 - September 30), the emergency spillway is kept fully open up to a design maximum flood of 300 m^3/s, or until discharge from the emergency spillway begins, and the discharge operation is conducted so the water level increase in downstream areas does not exceed 30 cm in 30 minutes. Subsequently, all gate operations are suspended (the gate is kept open) and natural regulation is conducted. During non-flood season (October 1 - June 30), if the reservoir level is below the upper limit for flood control reservoir level (elevation 549.1 m), flood control is conducted in the same manner as in flood season. If the reservoir level is at or above the upper limit of flood control reservoir level (elevation 549.1 m), the emergency spillway is closed completely, and flood control is conducted basically using the "inflow = discharge" operation.
Storage restrictions during flood season	During flood season (July 1 - September 30), a flood control reservoir level is established as described bellow, and long time storing that exceeds this reservoir level is not conducted.

Table 1 (suite)

Establishment of flood control reservoir level	Flood control reservoir level is set as a initial reservoir level, so that the peak reservoir level does not exceed the highest experienced level + 1 m when flood control is conducted in accordance with the "flood control method for flood season" for 20 year flood waveform (peak flow rate 1000 m3/s) having the same shape as the design high water waveform (100 year flood).
Upper limit for flood control reservoir level	Out of consideration for ensuring the certainty of flood control operations, during the flood season the emergency spillway is kept fully open at all times (natural regulation method). Accordingly, upper limit for flood control reservoir level is set to an elevation of 549.1 m, so that the discharge from the emergency spillway (full open) dose not begin during the operation up to normal spillway discharge of 300 m^3/s for 100 year flood in accordance with the “flood control method for flood season”.
Lower limit for flood control reservoir level	Lowest reservoir level at which reservoir level control is possible: foundation elevation of the lowest intake of selective intake (485.0 m)
Discharge to downstream areas	During the first filling operation, necessary discharge within the inflow range (water for unspecified use) is conducted so as not to adversely impact the river environment and vested water use downstream from the dam. The quantity discharged to downstream areas during first filling is set to a maintenance flow discharge of 0.49 m^3/s (year-round) directly downstream from the dam site after the dam has been put into operation.

4. LANDSLIDE AREAS AROUND RESERVOIR

4.1. OVERVIEW OF LANDSLIDES

The geology in the area surrounding Takizawa Dam consists primarily of the Nakatsugawa Group faults in the Chichibu belt (Carboniferous period, Paleozoic era - Jurassic period, Mesozoic era) and the Otaki Group faults in the Shimanto belt (Cretaceous period - Jurassic period, Mesozoic era). Of these two, many of the landslides in the area of the Takizawa Dam reservoir are recognized to be caused by the Otaki Group faults that comprise the majority of the reservoir area. Fig. 2 shows the distribution of landslide blocks in the area of the Takizawa Dam reservoir.

A general survey identified 79 landslide blocks for the landslides in the area of the Takizawa Dam reservoir. Of these, 43 blocks are affected by filling. A committee of landslide specialists was established to select the special blocks, that were considered to be particularly important in terms of dam planning due to their size and placement etc, among these landslide blocks. This committee provided guidance and advice regarding the mechanism of landslides and a general study of countermeasures. In September 1995, the "Study of Landslides Near Reservoirs and its Countermeasures (Japan Institute of Development and Construction Engineering under the supervision of the Water Resources Development Division, River Bureau, Ministry of Construction in those days)" was established. Based on the work of the committee and this study, the landslide blocks were inspected in detail and countermeasures were studied. Measures were actually implemented for 18 blocks and were not implemented for 25 blocks.

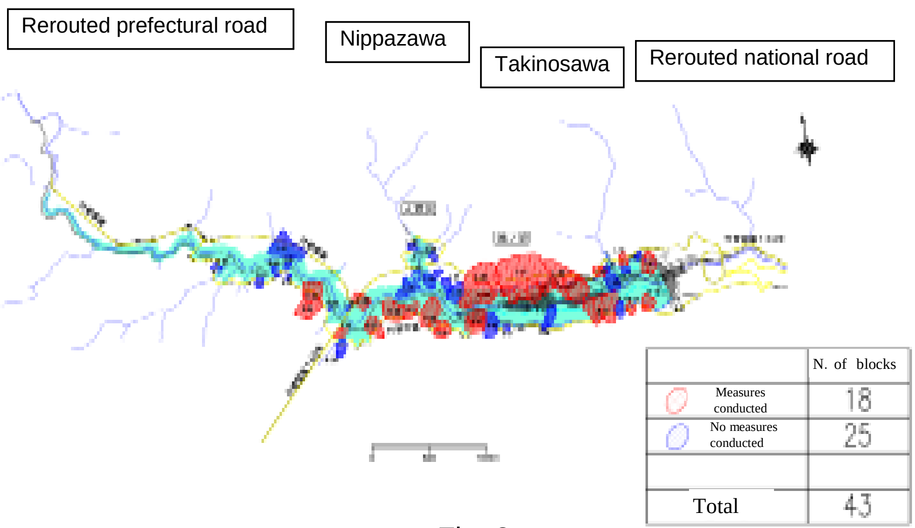

Fig. 2

Distribution of landslide blocks in the area around the Takizawa Dam Reservoir

Répartition des zones de glissement de terrain autour du barrage de Takizawa

4.2. From the general inspection of landslides to the design of countermeasure

Fig. 3 shows the process from general inspection of landslides to the design of countermeasure for the landslides at Takizawa Dam.

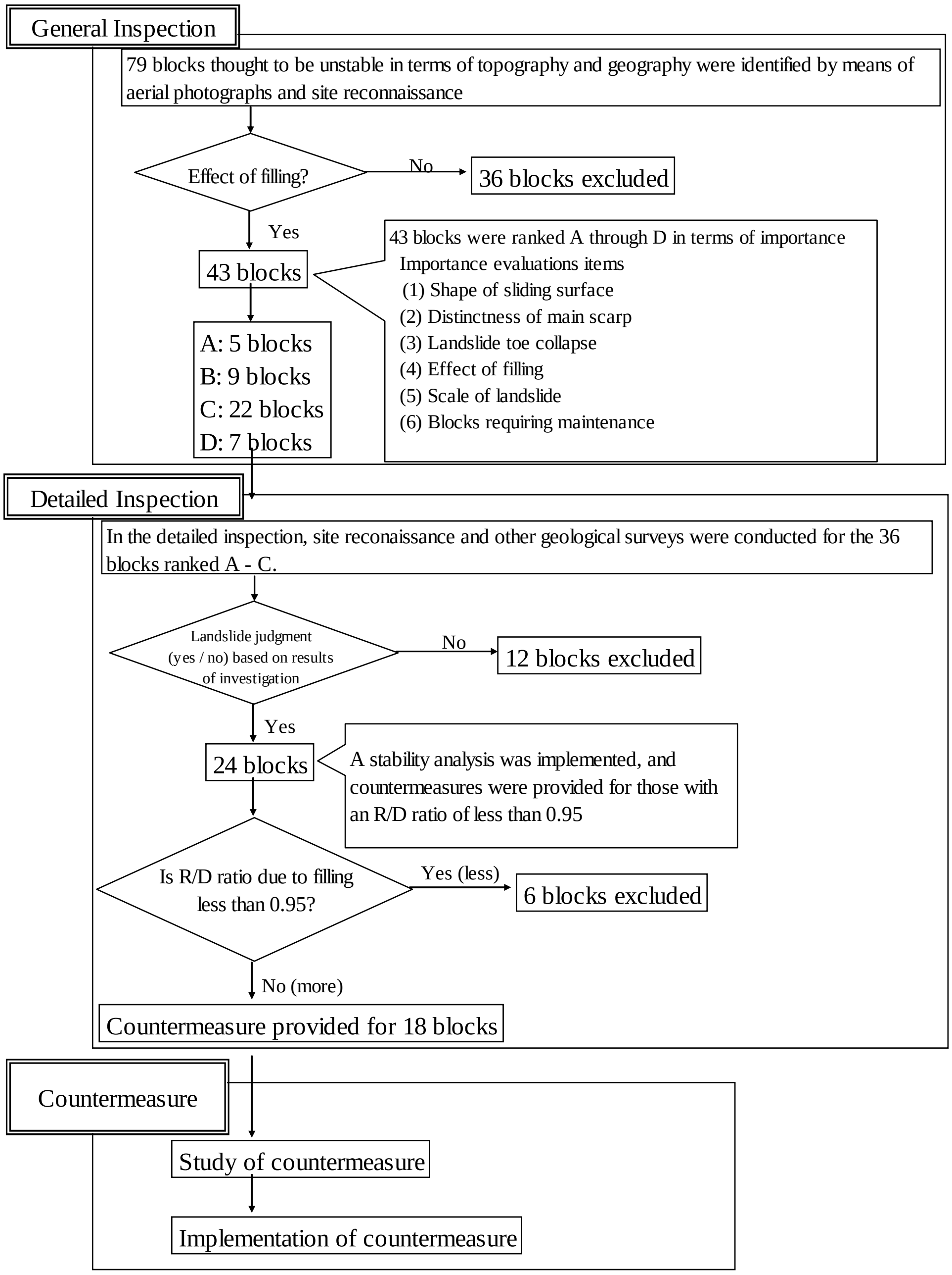

Fig. 3

Planning for implementation of landslide countermeasures

Planification de la mise en œuvre des contre-mesures pour traiter les zones de glissement de terrain

4.2.1. General inspection

79 landslide blocks were identified from a reading of aerial photographs taken in FY 1998 (1/8,000 and 1.20,000) and from site reconnaissance. Each of these blocks was rated A - D in terms of importance, based on evidence of the

impact of filling, the type of slip surface, the distinctness of the main scarp, the presence of landslide toe collapse, the effect of filling, the scale of the landslide and the effect on the block requiring maintenance.

4.2.2. Detailed inspection

Of the 79 locations identified in the general inspection, site reconnaissance and boring and other geological surveys were conducted for the 36 blocks rated A - C. This was done to study the causes of landslides and determine whether any had occurred. For the blocks at which landslides may occur, a stability analysis was conducted with respect to the equilibrium between the resistance force (R) and displacement force (D) acting on the landslide block as a result of filling. If the R/D ratio was less than 0.95, the landslide block was selected as one requiring countermeasure. 18 blocks were selected in this manner.

Table 2
Conditions for stability analysis

Item	Landslide Stability Analysis	Colluvial Soil Slope Analysis
Stability analysis method	Slice method (reference water surface method)	Posit an arbitrary slip circle within the colluvial soil slope and conduct repeat slip circle calculations (trial slip circle calculations), and adopt a slip circle that has an R/D ratio of less than 0.95 and produces maximum deterrent force.
Current R/D ratio	1.00	
Estimation of soil strength constant	Back calculation method Thickness of landslide layer and cohesion of slip surface Vertical layer thickness of landslide Cohesion C' where Cohesion C' maximum 25 kN/m^2	(1) Determine internal friction angle ø' from current slope gradient. (2) Assume C' = 0 and conduct repeat slip circle calculations for current slope prior to filling. (3) Use C' such that R/D ratio is 1.00.
Unit weight of soil masses	γt=18kN/m^3(1.8tf/m^3)	
Range of fluctuation for reservoir level	Surcharge level Reservoir level	Surcharge level Reservoir level
Groundwater level	If groundwater level data is available, use maximum groundwater level. If groundwater level data is not available, set groundwater level lower than slip surface.	
Residual pore water pressure	50%	50%

A different analysis method was used for the stability analysis depending on whether the slope had a slip surface formed as a result of a landslide or was colluvial soil in which no clear slip surface has been formed. Table 2 (above) shows the conditions for stability analysis.

4.2.3. Study of countermeasure

Design safety factors for landslide countermeasures are established as shown in Table 3 in accordance with the block requiring maintenance and the scale of the landslide. The deterrent force of the countermeasure is determined by the R/D ratio of the landslide block that has been reduced by filling and by the design safety factor that is established for each block. The countermeasure method is determined through consideration of the effect, cost etc. as judged from the size of the deterrent force and the location of the landslide block.

Table 3
Design safety factors

Blocks requiring maintenance	Importance	Scale of landslide			
		Extremely large	Large	Medium	Small
		2 million m^3 or greater	More than 400,000 m^3 but less than 2 million m^3	More than 30,000 m^3 but less than 400,000 m^3	30,000 m^3 or less
Landslide that affects a dam facility	Major	1.15	1.20	1.20	1.20
Landslide that affects facilities in the area of the reservoir (national / prefectural road)	Major	1.10	1.10	1.15	1.15
Landslide that affects facilities in the area of the reservoir (management road)	Medium	1.05	1.10	1.10	1.10
Landslide that affects facilities in the area of the reservoir (municipal road)	Minor	1.05	1.05	1.05	1.05
Other landslide occurring at a reservoir slope (Other)	Minor	1.05	1.05	1.05	1.05

4.3. CHANGES IN TAKIZAWA DAM FIRST FILLING PLAN

The first filling for Takizawa Dam began on October 1. 2005. The first filling at Takizawa Dam confirmed a deformation in the slope around the reservoir in November 2005. The plan was changed after the discovery of the slope deformation as compared to one before the slope deformation was discovered. Prior to the discovery of the slope deformation, manual gate operations were conducted to restrict the discharge capacity to a reservoir level rise or fall of no more than 1 m / day, under a basic policy of not allowing discharge to downstream areas that exceeded the design effluent flow (300 m3/s). Moreover, when water was discharged, the discharge operation made sure that the rise in the water level in downstream areas did not exceed 30 cm in a 30-minute period. When conducting discharge that exceeded the design effluent flow, the gates were not operated and natural discharge was conducted, and an upper limit was established for flood control reservoir level.

Due to the discovery of the slope deformation during first filling, however, the method of operation was changed. This was done from the standpoint of controlling to the greatest extent possible the rise in the reservoir level accompanying flood control, and from the need for discharge operations to maintain the reservoir level (elevation 537.0 m) at the flood control starting flow volume (100 m3/s) even after the transition to normal dam management. The method was changed as follows:

1 The gates for the emergency spillway are opened completely.
2 Within the limits of the discharge capacity, operation is conducted based on inflow = discharge.
3 The upper limit for flood control reservoir level is set to elevation 555.0 m (elevation of emergency spillway crest 555.90 m - 90 cm), out of consideration for the volume stored during the gate operation interval and so on.

As a result of these changes, it is possible that the discharge volume will be greater than that in accordance with the flood control method in the initial first filling plan, but this will be dealt with by upgrading the patrol organization so that it will be more thorough than it was before the slope deformation was discovered.

Moreover, not imposing storage restrictions up to flood control reservoir level in flood season (elevation 555.0 m) and allowing long time storing offers the following advantages as compared to the method used prior to the change:

① Compared to non-flood season, the reservoir level increase per day is greater, and safety with respect to the reservoir level increase for landslides in the area around the reservoir can be confirmed under more severe conditions.
② It is possible to begin reservoir level lowering trials quickly after the

surcharge level is reached, so safety with respect to landslides in the area around the reservoir can be confirmed at an earlier stage, enabling subsequent dam operations to have an effect.

③ If there is a need for separate landslide measures due to the results of reservoir level lowering trials, a rapid response would be possible.

There was a concern that the reservoir level would rise rapidly during flood season as a result of these changes, so the stability of the landslide slope was rechecked. As a result, there were judged to be no circumstances that would cause major instability in the slope, and it was determined that continued thorough slope monitoring would enable long time storing during flood season.

Table 4 shows the initial and changed first filling plans. Fig. 4 shows an outline of the discharge equipment.

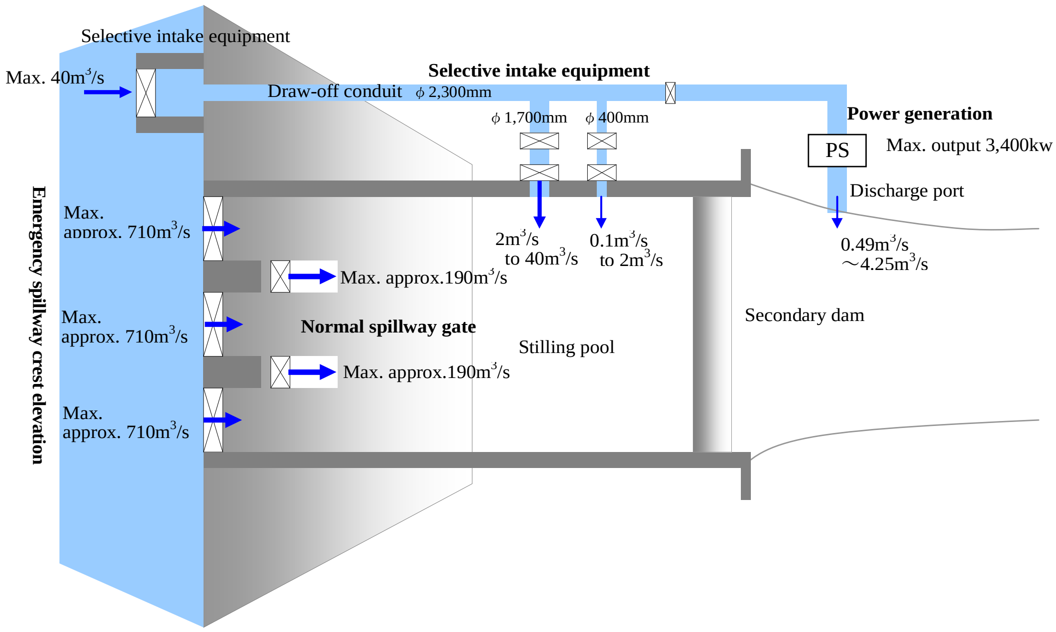

Fig. 4

Schematic of discharge equipment

Schéma d'équipement de décharge

Table 4
Comparison of initial first filling plan and changed one

Item	Initial first filling plan (October 1.2005 - August 17, 2006)	Changed first filling plan (August 18, 2006)
1. Speed of reservoir level raising	No more than 1 m / day at reservoir level not previously experienced (no restriction until elevation 485.0 m)	No more than 1 m / day at reservoir level not previously experienced (no restriction until elevation 503.0 m)
2. Speed of reservoir level lowering	No more than 1 m / day	(No change)
3. Reservoir level check range	Reduced to elevation 485.0 m after arrival at surcharge level	(No change)
4. Reservoir level maintenance period	1 day (24 hours) at surcharge level	(No change)
5 Downstream maintenance flow rate	0.49 m^3/s (within range of inflow volume)	(No change)
6. Operation in flood season	- Long time storing is restricted in flood season - Flood control reservoir level is set as a initial reservoir level so that the peak reservoir level does not exceed the highest experienced level + 1m when flood control is conducted in accordance with the “flood control method for flood season ”for 20 years flood (peak flow rate 1000 m^3/s) and reservoir level is kept this level. - Upper limit for flood control reservoir level: elevation 549.1 m Upper limit for flood control reservoir level is set so that the discharge from the emergency spillway (full open) dose not begin during the operation up to normal spillway discharge of 300 m^3/s for 100 year flood in accordance with the “flood control method for flood season”. - Lower limit for flood control reservoir level: elevation 485.0 m (foundation elevation of the lowest intake of selective intake facility) Note With regard to flood control, discharge is conducted in accordance with the "flood control method for flood season" up to the design maximum discharge of 300 m3/s or until discharge from the emergency spillway begins. Subsequently, operation of all gates is suspended (and the gates are kept open) and natural regulation is conducted.	- Long time storing is allowed in flood season - Reservoir level rise continues up to upper limit of flood control reservoir level (elevation 555.0 m), and reservoir level is maintained after water reaches upper limit of flood control reservoir level - Unscheduled inspection is conducted if reservoir level increase volume exceeds 1 m / day - Upper limit for flood control reservoir level: elevation 555.0 m Set to elevation 555.0 m (elevation of emergency spillway crest 555.90 m - 90 cm), out of consideration for the volume stored during the inflow calculation interval Note With regard to flood control, to ease the impact on the slope around the reservoir, an inflow = discharge operation is conducted within the limits of the discharge capacity. After the normal spillway has been fully opened, natural regulation is conducted.

Table 4 (suite)

7. State of the outlet works when flood	- Draw-off equipment can discharge up to 40 m^3/s - Normal spillway: fully closed status (operated up to max. discharge of 300 m^3/s) - Emergency spillway: fully open (natural discharge system)	- Draw-off equipment can discharge up to 40 m^3/s - Normal spillway: fully closed status (operation until fully open: can discharge up to 594 m^3/s [EL. 555.9 m]) - Emergency spillway: fully open (natural discharge system)
Note - Normal spillway: high-pressure radial gate (peak inflow 1,850 m3/s -> maximum discharge 300 m^3/s) - Emergency spillway: radial gate (design flood discharge 2,400 m3/s = normal spillway 300 m^3/s + emergency spillway 2,100 m^3/s)		

5. SAFETY MANAGEMENT DURING FIRST FILLING

5.1. Dam body safety management

Dam behavior can be evaluated quantitatively through measurements conducted with instruments of various types. To evaluate dam safety, however, instrument measurements must be combined with patrols that visually inspect the dam body and foundation ground. The purpose of the dam body and foundation ground patrol inspections is to determine the dam behavior that cannot be observed by instrument measurements alone, and to check for turbidity in leaking water (discharge water) from the foundation drain holes and the like, cracks in the dam body, water leakage from unexpected locations and so on. Another purpose of patrol inspections is to confirm that the instruments are still in good working condition. Table 5 shows the measurements conducted with the primary purpose of dam safety management.

Table 5
Measurements conducted for the primary purpose of dam safety management

Measurement	Equipment	No. of Units	Measurement Frequency	Notes
Seepage	Seepage (triangular weir)	2	Once per day	Automatic measurement
	Foundation drain hole	78	Once per day	Manual measurement
	Joint drain hole	28	Once per day	Manual measurement
Uplift pressure	Bourdon tube pressure gage	78	Once per day	Manual measurement
Deformation	Plumb line (normal)	1	Once per day	Automatic measurement
Earthquake ground motion	Strong-motion seismograph	3	During an earthquake	Automatic measurement

Table 6
Measurements conducted for the primary purpose of dam construction management and study

Measurement	Equipment	No. of Units	Measurement Frequency	Notes
Dam body internal pressure	Temperature sensing strain gage	66	Once per week	Automatic measurement
	Effective stress gage	4	Once per week	Automatic measurement
	Stress meter	5	Once per week	Automatic measurement
	Non-stress meter	6	Once per week	Automatic measurement
Dam body internal temperature	Thermometer	4	Once per week	Automatic measurement
Foundation ground temperature	Thermometer	5	Once per week	Automatic measurement
Leakage	Measurement holes (upstream / downstream passageway)	5	As needed	Manual measurement
Uplift pressure	Bourdon tube pressure gage	5	As needed	Manual measurement
	Pore water pressure meter	1	Once per week	Automatic measurement
Seismograph	Strong-motion seismograph	2	During an earthquake	Automatic measurement

In addition, the instruments shown in Table 6 (above) are buried underground for the purpose of construction management during placement of the dam body concrete as well as investigation and verification of the safety of the dam body with respect to long-term temperature stress. Observations using these instruments were continued during the first filling process.

5.2. Slope safety management

Slope management was performed during first filling regardless of whether measures for landslides were conducted. For the landslides for which countermeasures were provided, monitoring to detect slope deformation and determine behavior was conducted in order to judge the effectiveness of the countermeasures. With regard to landslides for which no countermeasures were provided, the slope behavior was monitored and safety was checked, and observations that took into consideration the occurrence of new landslides (for which advance prediction is difficult) were also conducted. At the management stage following the completion of first filling, monitoring and measuring were continued at locations where they were judged to be needed, such as the blocks for which countermeasures had been taken and that would have a major impact on the dam, reservoir and surrounding area.

Of the landslide blocks identified in the general inspection, monitoring was conducted for all except those blocks that would not affect filling.

5.3. Progress of slope displacement and countermeasure

As there are many landslide blocks in the area around the Takizawa Dam reservoir, monitoring of the behavior of the dam body and of deformations in the reservoir slope was an important concern in the first filling process.

First filling at Takizawa Dam began on October 1.2005. However, one month later (November 2005), patrol inspections of the reservoir discovered cracking in four locations of the slope on the left bank of the reservoir approximately 1.5 km upstream from the dam site. In addition, cumulative displacement of 1 cm was discovered in the borehole inclinometers used to measure the ground interior. As there is a national road in the area and safety was a top priority, the reservoir level was temporarily lowered and a thorough inspection was conducted. The inspection found that these problems were the result of the movement of a landslide block that had not been discovered prior to first filling, and that a countermeasure was needed. Accordingly, counterweight filling (approximately 500,000 m3) was conducted as the countermeasure. When the countermeasure had been completed and safety had been confirmed, the reservoir level was once again increased beginning on August 18, 2006, and subsequently, the reservoir level was raised steadily. On May 1.2007, however, cracking was again discovered in two locations in the slope on the left bank of the reservoir approximately 1.0 km upstream from the dam site. As in the previous case, there was a national road in the area and safety was a top priority, so the reservoir level was maintained at the current level, and beginning on May 10 the level was decreased with the objective of stabilizing the slope. However, a slope collapse occurred at this location early in the morning on May 13 (approximately 50,000 m3). Approximately 30 m from the national road, and the road was not affected. However, to prevent enlargement of the collapsed area and prevent any impact on the road, anchor works (approximately 680 anchors) were provided, as these could be put in place immediately. When the countermeasures had been completed and the stability of the collapsed slope had been confirmed, the reservoir level was once again raised beginning on August 30, 2007. Subsequently, there was no major deformation in the slope, and on March 30, 2008 the reservoir level reached the surcharge level, and beginning on April 1 the lowering of the reservoir level was initiated at a rate of 1 m or less per day.

The following is an overview of the course of first filling.

Progress of first filling

2005	
October 1	First filling begins
November 2	Cracks in four locations on west bank of reservoir slope; cumulative displacement of 1 cm in ground (approximate elevation 503 m)
November 9	Reservoir level decreases (no more than 30 cm / day)
2006	
January 6	Reservoir level reaches near lowest intake level (approximate elevation 485 m)
January 18	Counterweight fill work begins
Mid-August	Counterweight fill work is completed
August 18	Filling is resumed ((approximate elevation 485 m)
2007	
May 1	Cracks in two locations on left bank of reservoir slope; reservoir level is maintained (elevation close to 549 m)
May 13	Slope collapse (approximately 50,000 m3)
May 19	Reservoir level is maintained
May 21	Anchor work begins
Late August	Anchor work is completed
August 30	Filling is resumed (approximate elevation 546 m)
2008	
March 30	Surcharge level reached
April 1	Reservoir level lowering test begins (max 1 m per day)

CONCLUSION

Dams are one of the types of civil engineering structures for which safety is most important, as in the event of an accident the impact on society would be enormous. In the case of ordinary civil engineering structures, the anticipated behavior of the structure can be confirmed at the construction stage, and by the time the structure is completed, its attributes that include stability will have been thoroughly checked. In contrast, dams are only subjected to maximum load when they have been completed and are filled with water. Moreover, the type and direction of load differs from that applied during the construction process. Therefore, only at the stage of first filling can they be examined and the design and construction checked. In this sense, dams are very different from ordinary civil engineering structures.

Takizawa Dam once again teaches us the importance of first filling implemented as a check at the final stage of dam construction, as well as the fact that engineers involved in dam construction must always work to ensure safety above all else. Dam construction is being promoted in places around the world. The experience of Takizawa Dam should underscore the importance of conducting observations and inspection patrols during the first filling process.

SUMMARY

This paper, based on the case of Takizawa Dam for which first filling begun in October, 2005, reports on the first filling plan, the safety control methods designed prior to the first filling to ensure the safety of the dam, and the safety control methods implemented when cracking accidents occurred twice on the bank of the reservoir during the first filling process.

With quite a few landslide areas on the slopes around the reservoir, rankings were made according to the size and configuration of slip surfaces and their effect on the slopes requiring maintenance. Countermeasures have been taken in advance on the slopes that would have a large impact on filling procedures. As for the slopes where no countermeasures are going to be taken in order to reduce costs, the safety of the reservoir slopes will be checked by conducting a first filling. Since the body shape and condition of the reservoir slopes of each dam are different, it is necessary to create a first filling plan from the standpoint of each dam’s characteristics when considering safety control during a first filling.

Verifying the safety of the dam and the surrounding slopes of the reservoir is the most important factor in conducting a first filling, and by verifying safety, it is judged that the dam can be operated at its maximum capacity and put into

service. In this report, we introduce the case of Takizawa Dam, explain the importance of first filling process, and set down some reference points for dams which will be put into service in the future.

RÉSUMÉ

S'appuyant sur l'exemple du barrage de Takizawa pour lequel des tests de remplissage ont débuté en octobre 2005, cette étude rend compte à la fois du programme des tests de remplissage préalablement conçu pour s'assurer de la sécurité du barrage, des méthodes de contrôle du remplissage ainsi que des procédés de vérification de sécurité appliqués lors des deux déformations de pente qui se sont produites pendant les tests de remplissage.

En raison de la présence de plusieurs zones de glissements de terrain sur les versants situés autour du barrage, on a effectué des classements d'importance selon l'aspect et l'envergure des glissements de terrain ainsi que selon leurs effets sur les pentes nécessitant de l'entretien. Les contre-mesures nécessaires ont été prises au préalable sur les pentes qui auraient particulièrement affectées les procédures de remplissage. La sécurité des pentes du barrage qui n'ont pas fait l'objet d'un contrôle préalable par souci d'économies sera vérifiée à l'aide d'un test de remplissage. Etant donné les différences de structure et d'état des pentes inhérentes à chaque barrage, il est nécessaire d'élaborer un programme de tests de remplissage prenant en compte les spécificités de chaque barrage quand on envisage de vérifier la sécurité par des tests de remplissage.

Il est primordial de vérifier la sécurité du barrage et celle de ses versants lors des tests de remplissage. De ces deux vérifications dépendent la possibilité d'exploitation maximale des capacités du barrage et la réussite du transfert de gestion. Cette étude présente le cas spécifique du barrage de Takizawa et expose l'importance des tests de remplissage, tout en établissant des points de référence pour les transferts de gestion des barrages dans le futur.