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REDEVELOPMENT OF THE HONGOUCHI-TEIBU DAM AS PART OF THE NAGASAKI EMERGENCY FLOOD DAM PROJECT

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1. INTRODUCTION

The Nagasaki Emergency Flood Dam Project, which was planned in response to severe flooding accompanying concentrated torrential rainfall in 1982, is the redevelopment of water supply dams constructed on major rivers in the city during the Meiji Era (1867 to 1912) to provide them with flood control functions, thereby transforming them from water supply dams to multi-purpose dams. The Nishiyama Dam and Hongouchi-kobu Dam have been reconstructed (redevelopment work), the Nakao Dam has been newly constructed, and work on the Hongouchi-teibu Dam is now in progress. The Hongouchi-teibu Dam constructed in 1903 is a civil engineering structure with historical value in the history of modern civil engineering in Japan, and it is being reconstructed according to a design which considers the conservation of the structure and appearance of the dam body. This paper presents an outline of the plan and execution of the Nagasaki Emergency Flood Dam Project and a description of the characteristics of the planning and design of Hongouchi-teibu dam which is now underway.

2. BACKGROUND TO THE PROJECT

2.1. MODERN WATER WORKS IN NAGASAKI CITY

The City of Nagasaki is an ancient trading port which prospered thanks to visits by foreign ships. But cholera and diarrhea were often carried by the foreign ships, and the city's residents suffered from polluted well water. So in 1891, Nagasaki started Japan's third modern water works project, following earlier projects in Yokohama and in Hakodate. To supply its water, a series of water supply dams, namely the Hongouchi-kobu Dam (1891), Hongouchi-teibu Dam (1903), Nishiyama Dam (1904) etc., were constructed in succession upstream on the Nakashima River which flows through the city (Fig. 1). These dams, which were constructed by gathering the essence of the technologies of the time, have continued to function adequately to the present day, supplying precious water to the city's residents.

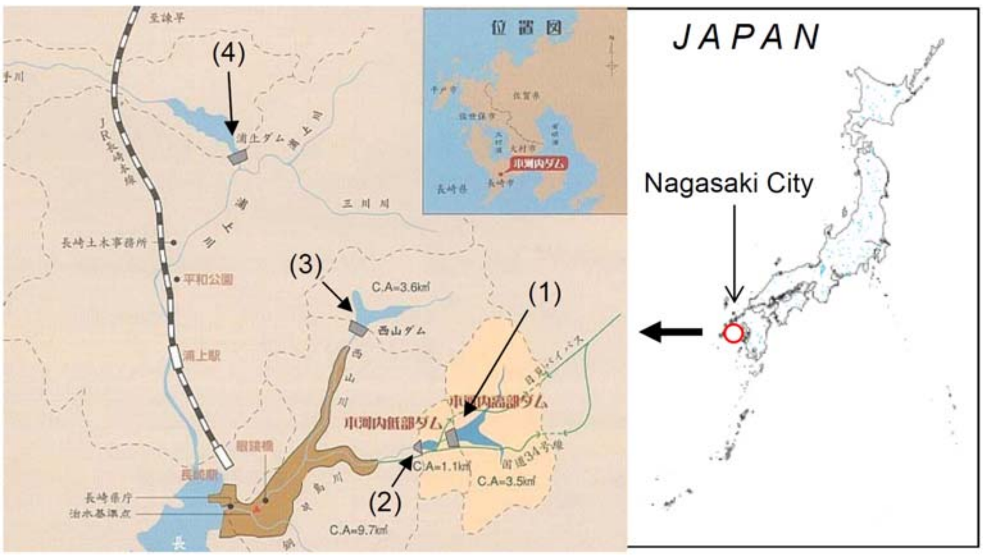

Fig. 1
Location of Dams in Nagasaki City
Localisation des barrages dans la Ville de Nagasaki

(1) Hongouchi-kobu Dam	*(1) Barrage de Hongouchi-Kobu (Partie haute)*
(2) Hongouchi-teibu Dam	*(2) Barrage de Hongouchi-Teibu (Partie basse)*
(3) Nishiyama Dam	*(3) Barrage de Nishiyama*

(4) Urakami Dam *(4) Barrage d'Urakami*

Photo 1
Flood Damage on the Nakashima River
Dégâts provoqués par les crues de la rivière Nakashima

2.2. NAGASAKI FLOOD DISASTER

On July 23, 1982, moist air flowed in from the southern seas along the stationary seasonal rain front, triggering intensive rainfall which dropped more than 300 mm of rain in three hours, mainly in Nagasaki City. The accumulated rainfall from the beginning to the end reached 572 mm. This unprecedented torrential rainfall caused the Nakashima River, Urakami River, and almost all other rivers flowing through the urban district of Nagasaki City (Photo 1) to overflow their banks, triggering scattered landslides and debris flow throughout the region. This torrential rain claimed 257 lives, submerged 25,680 buildings, and caused damage costing 211.9 billion yen, just in Nagasaki City. The Nakashima River and other rivers flowing through the city center are surrounded by urbanized neighborhoods, and in addition, are crossed by a group of stone bridges including the Megane Bridge, which is an important culture property. Therefore, it would be difficult to improve this river through large-scale course expansion. The approach proposed as a result was adding flood control functions to the water supply dams constructed in the Meiji Period.

3. OUTLINE OF THE PLAN FOR THE NAGASAKI EMERGENCY FLOOD DAM PROJECT

3.1. ADDING FLOOD CONTROL FUNCTIONS TO WATER SUPPLY DAMS

In response to the 1982 flood, all methods of implementing radical flood control measures on the Nakashima River and Urakami River were studied. As a result, it was decided that in light of the characteristic concentration of population and assets along urban rivers, it would be appropriate to minimize the burden on the rivers by constructing flood control dams upstream and taking measures adapted to river course improvements. In 1983, the Nagasaki Emergency Flood Dam Project commenced, but because of a lack of sites suitable for new dams upstream from the city, the project's goals were set as transforming existing water supply dams to multi-purpose dams by diverting part of their water supply capacity to flood control capacity and constructing a new multi-purpose dam on the Hachiro River where the Hongouchi-kobu dam was raised, as measures to control floods and ensure an alternative water supply source for the region. The existing dams covered by the plan were the Hongouchi-kobu Dam (1891), Hongouchi-teibu Dam (1903), and Nishiyama Dam (1904) on the Nakashima River and the Urakami Dam (1945) on the Urakami River.

Because all of these water supply dams are important sources of water for the people of Nagasaki City, the project had to ensure their past water supply quantities in order to provide these dams with flood control capacity while ensuring water use rights of Nagasaki City. The plan ensured the past maximum daily water intake quantity by implementing this project according to the schedule shown in Fig. 2. In other words, the reconstruction of the Nishiyama Dam and the construction of the new Nakao Dam were executed first, and flood control functions were activated at the Nishiyama Dam after the quantity of water supplied which declined at the Nishiyama Dam was ensured by the Nakao Dam. Next, the water use capacity of the Hongouchi-kobu Dam was increased at the same time as the water supply quantity which was reduced by the Hongouchi-teibu Dam was ensured along with the quantity newly ensured by the Nakao Dam. Later, the Hongouchi-teibu Dam was reconstructed, to ensure the flood control quantity. And regarding the Urakami Dam, a redevelopment plan is now being studied.

3.2. OUTLINES OF THE DAMS

The specifications of the dams are shown in Table 1. The Nishiyama Dam (completed in 2000), Nakao Dam (completed in 2001), and the Hongouchi-kobu Dam (completed in 2006) have already commenced operation, and work is now in progress at the Hongouchi-teibu Dam with its goal set as completion by 2011.

The existing Nishiyama Dam completed in 1904 is a concrete gravity dam with dam height of 31.82 m and dam crest length of 139.39 m. In order to minimize change of the historically valuable existing dam body, a new concrete gravity dam with dam height of 40.0 m was constructed about 60 m downstream from the existing dam body. The dam crest elevations of the new and old dam are identical. And because the existing dam body would be submerged, the existing spillway was lowered at the same time as water passage holes were installed at two locations on the existing dam body to ensure that water passes through the dam.

The existing Hongouchi-kobu Dam is an earth fill dam with dam body height of 16.67 m and dam crest length of 127.27 m completed as Japan's first water supply dam in 1891. In order to minimize change of the historically valuable existing dam body, at the Kobu Dam, a new concrete gravity dam with dam height of 28.2 m was constructed about 50 m upstream from the existing earth dam. In order to ensure reservoir capacity after redevelopment, the dam crest elevation is 4.7 m higher than that of the existing dam.

The existing Hongouchi-Teibu Dam is a concrete gravity dam with dam height of 26.85 m and dam crest length of 116.3 m completed in 1903. It was the second concrete dam completed in Japan following the Nunobiki Dam in Hyogo Prefecture. The following chapter describes the redevelopment design for this dam.

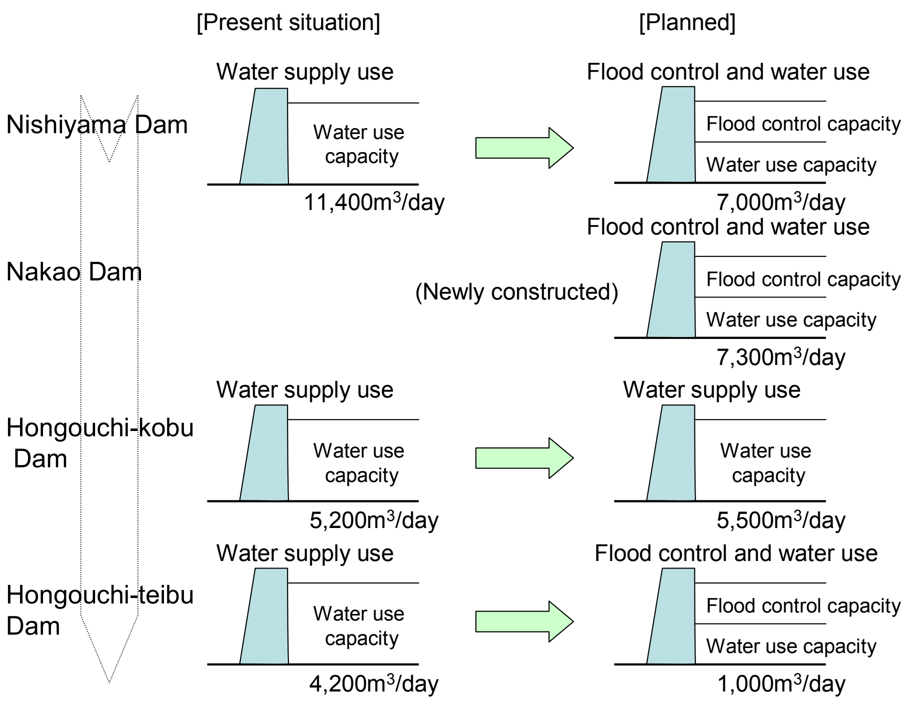

Fig. 2
Capacity Allotment Diagram
Diagramme de distribution de la capacité

Table 1
Dam Specifications
Caractéristiques techniques du barrage

NAME OF DAM	ITEM	Pre-redevelopment	Post-redevelopment
Nishiyama	TYPE	PG	PG
	H (m)	31.82	40.00
	L (m)	139.39	216.00
	V (1,000m^3)	*Unknown*	85
	Flood control capacity(1000m^3)	0	710
	Water use capacity(1000m^3)	1 469	760
	Sedimentation capacity(1000m^3)	0	110
	Year completed	1904	2000
Nakao	TYPE	—	PG
	H (m)	—	40.00
	L (m)	—	201.00
	V (1,000m^3)	—	84.7
	Flood control capacity(1000m^3)	—	460
	Water use capacity(1000m^3)	—	1 010
	Sedimentation capacity(1000m^3)	—	110
	Year completed	—	2001
Hongouchi-kobu	TYPE	TE	PG
	H (m)	16.67	28.20
	L (m)	127.27	158.00
	V (1,000m^3)	*Unknown*	47
	Flood control capacity(1000m^3)	0	0
	Water use capacity(1000m^3)	359	386
	Sedimentation capacity(1000m^3)	0	110
	Year completed	1891	2006
Hongouchi-teibu	TYPE	PG	PG
	H (m)	26.85	27.80
	L (m)	116.30	118.80
	V (1,000m^3)	Approx.22	Approx.32*
	Flood control capacity(1000m^3)	0	534
	Water use capacity(1000m^3)	608	43
	Sedimentation capacity(1000m^3)	0	30
	Year completed	1903	*Under const.*

* Including existing volume

4. RECONSTRUCTION DESIGN OF THE HONGOUCHI-TEIBU DAM

4.1. CHARACTERISTICS OF THE EXISTING DAM

The Hongouchi-teibu Dam is also an historically valuable dam which the Japan Society of Civil Engineers has designated as a modern civil-engineering legacy (Photo 2, Photo 3). Documents concerning the design and execution of this dam were almost entirely destroyed by bombing during World War II, so only a few remain. Boring has revealed that the dam body was covered with wedge-shaped blocks on its upstream side and concrete blocks on its downstream side, and that its interior was constructed with rubble concrete. No foundation grouting was executed. The maintenance bridge executed on the spillway is valuable as Japan's first reinforced concrete structure (Photo 4). A porous water intake system protruded in semi-cylindrical shape at the center of the upstream side of the dam body, and a bottom sluiceway passing through the dam body from its base was installed to introduce water through a pipeline. Through the process of this work, it was clarified that the intake use steel pipes and valves used were made in U.K. (Photo 5).

4.2. BASIC GUIDELINES TO RECONSTRUCTION

The major features of the reconstruction of the Hongouchi-teibu Dam were increasing the thickness of the existing dam body and constructing a new spillway. Considering the importance of its value in the history of modern civil engineering of Japan, the basic guidelines to the design preserve the historical appearance of the existing dam body to the greatest possible degree.

The existing dam body has upstream slope gradient of 1:0.08 and downstream slope gradient of 1:0.62, and comparing this with present dam structural standards reveals that the safety factor for stability of the dam body is insufficient. So as methods of ensuring the safety factor, ① thickening the upstream side, ② thickening the downstream side, ③ retrofitting using anchor work, and ④ constructing a new dam separated from the existing dam body were studied, and in light of the basic guidelines, executability, and economic factors, the method chosen was thickening the upstream side. Fig. 3 shows the standard section for the thickening of the new dam body on the existing dam body.

Photo 2
Hongouchi-kobu and -teibu Dam
Barrages de Hongouchi-Kobu (Partie haute) et de Hongouchi-Teibu (Partie basse)

Photo 3
Upstrewm and Downstrewm Surface of the Hongouchi-teibu Dam
Surfaces en amont et en aval du Barrage de Hongouchi-Teibu (Partie basse)

Photo 4
Maintenance Bridge of the Spillway (Japan’s first RC bridge, 1903)
Pont dédié à l’entretien de l’évacuateur de crues
(Premier pont RC construit au Japon en 1903)

Photo 5
Water Intake Pipe (Made in U.K., 1901)
Canalisation d’entrée/admission d’eau (Fabriquée au Royaume-Uni en 1901)

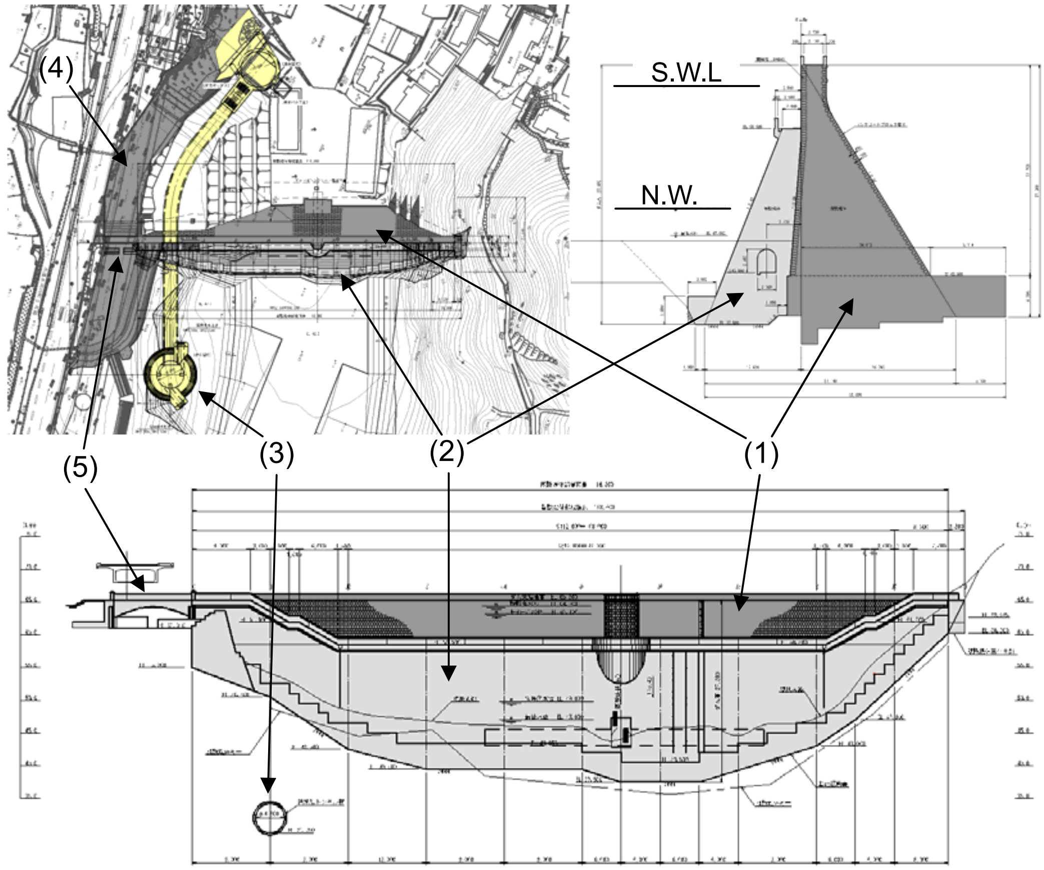

Fig. 3
Orthographic View of the Dam Body
Vue orthogonale du corps du barrage

(1) Existing dam body
(2) New dam body
(3) New spillway
(4) Existing spillway
(5) Maintenance bridge of the spillway

(1) Corps du barrage existant
(2) Nouveau corps du barrage
(3) Nouvel évacuateur de crues
(4) Evacuateur de crues existant
(5) Pont dédié à l'entretien de l'évacuateur de crues

Regarding the spillway required to ensure its flood control function, methods considered were ① installing a spillway by partially destroying the dam body and ② constructing the spillway separate from the dam body by the tunnel method. The latter, the tunnel method, was selected in light of the basic guidelines which prioritize preservation of its appearance. But in the region around the dam site, during the past one-hundred years, urbanization has advanced, so redirecting water to the left bank or the right bank would have a serious impact on homes etc., and also considering economic factors, a vertical shaft tunnel type spillway passing under the dam body, was adopted for the first time in Japan. The location was on the left bank side from the center of the dam (Fig. 4).

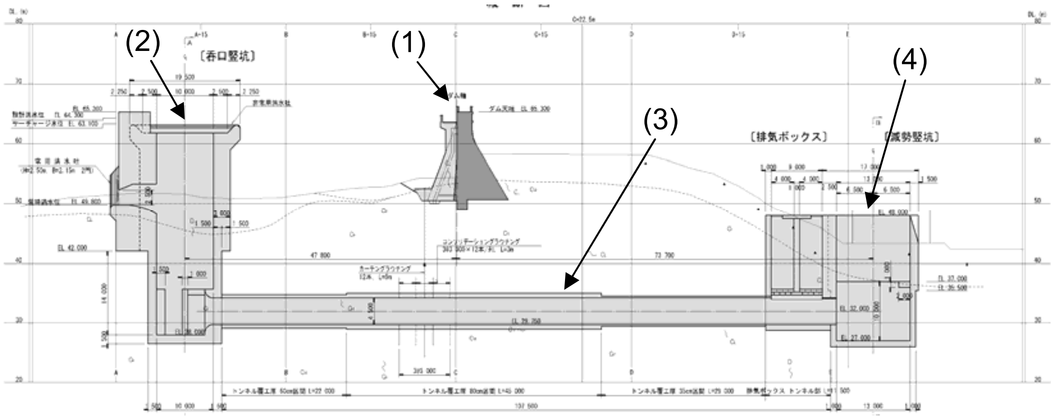

Fig. 4
Longitudinal Section of Spillway
Coupe longitudibale de l'évacuateur de crues

(1) Existing dam body	*(1) Corps du barrage existant*
(2) Open vertical shaft	*(2) Puits vertical ouvert*
(3) Tunnel	*(3) Tunnel*
(4) Energy dissipation vertical shaft	*(4) Puits vertical pour la dissipation de l'énergie*

And as shown by Photo 2, in the area where urbanization had advanced around the dam site, private homes are concentrated close to the dam, so during the work, it has been necessary to pay close attention to noise, vibration, and dust, and at the same time, to execute the work under a restriction limiting the time execution is permitted to the period ending at 5:00 p.m.

4.3. THICKENING THE DAM BODY

In order to comply with the construction standards for dams, it is necessary to firmly integrate the new dam body constructed to thicken the upstream side with the existing dam body. So the stress distribution on the boundary surface between the old and new dam bodies was calculated and compared with the adhesion strength of the concrete with the upstream side of the dam body obtained by testing.

The stress distribution on the boundary surface of the old and new dam bodies are produced by the external load acting on the dam body and by the thermal stress caused by pouring the new concrete. The dam body stress produced by external load and the thermal stress according to the concrete pouring lift schedule were separately analyzed to calculate the stress of the boundary surface. The results revealed that the required adhesion strength is produced near the rock adhesion surface, and that its maximum value is 0.55

N/mm^2.

The upstream side of the existing dam body is, as shown in Photo 3, covered with wedge-shaped stones, and the plan calls for a new dam body to be poured while leaving these in place. Wedge-shaped blocks are, as shown in Photo 6, about 30 cm on each side and with an extra 60 cm. The adhesive strength of the concrete poured on this surface was confirmed by performing direct tensile testing using a specimen made by applying concrete with the same blend as the newly constructed dam body on the wedge shaped stone obtained in cores taken from the existing dam body (Fig. 5). The results obtained adhesion strength of 0.32 N/mm^2 or more as shown in Table 2, so predicting a safety factor of 4, the adhesion strength was evaluated as 0.08 N/mm^2 or more.

Judging from the above, the stress analysis results and adhesion strength test results are compared and joint bars installed for reinforcement purpose within the range where the adhesion strength is inadequate.

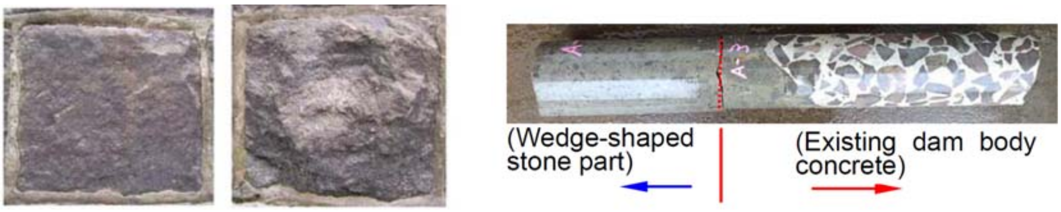

Photo 6
Surface of Wedge-shaped Block from Upstream Side of Existing Dam Body and Core Taken from Dam Body
Surface du bloc cunéiforme provenant du côté amont du corps du barrage et partie centrale noyau prélevée sur le corps du barrage

Table 2
Adhesion Strength Test Result
Résultats de l'essai concernant la force d'adhésion

	Case 1				Case 2			
	Compressive strength (N/mm^2)	Direct tensile strength(N/mm^2)			Compressive strength (N/mm^2)	Direct tensile strength(N/mm^2)		
		Concrete	Part A	Part B		Concrete	Part A	Part B
①	29.0	1.34	0.753	0.318	35.2	1.21	0.741	0.368
②	28.5	1.05	1.030	0.379	35.6	1.24	1.060	0.320
③	27.6	1.10	0.917	0.489	35.1	1.31	0.611	0.365
Ave.	28.4	1.16	0.900	0.395	35.3	1.25	0.804	0.351

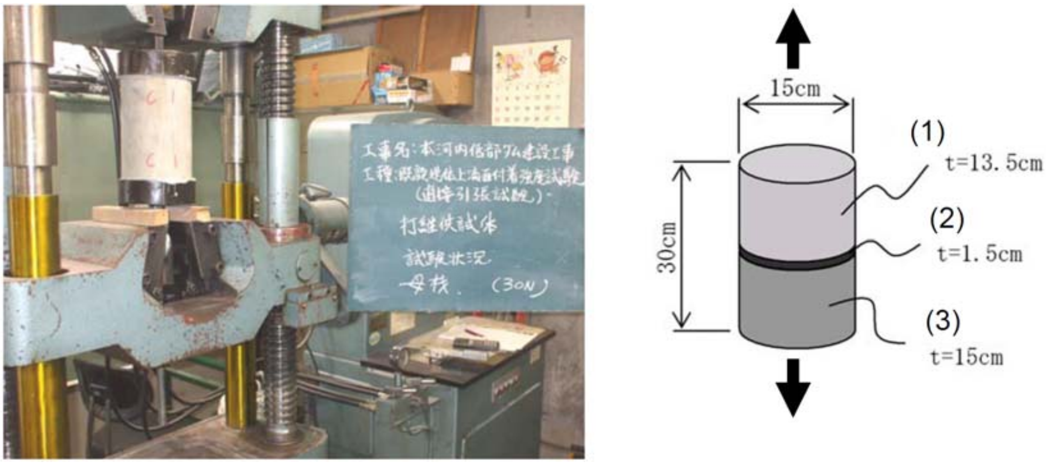

Fig. 5
Adhesion Strength Test (Direct Tensile Test)
Essai d'adhérence (Essai de traction directe)

(1) Newly poured concrete
(2) Mortar
(3) Existing dam body

(1) Nouveau béton coulé
(2) Mortier
(3) Corps du barrage existant

4.4. VERTICAL SHAFT TYPE TUNNEL SPILLWAY

The vertical shaft type tunnel spillway on the dam consists of an approximately 50 m open vertical shaft upstream from the existing dam, a tunnel, and an energy dissipation vertical shaft. The discharge capacity of the service spillway is Q = 108 m^3/s at the surcharge level and it is Q = 235 m^3/s at the design flood stage.

The open vertical shaft, a cylindrical stand-alone tower type with internal diameter, φ = 10 m, is equipped with an emergency spillway at the topmost circular overflow part and two service spillway orifices with bed elevation at the full reservoir level of 49.8 m. The depth of the open vertical shaft is H = 36.6 m. The tunnel, a circular horizontal tunnel with length L = 96 m and internal diameter, φ = 4.5 m, passes under the existing dam body from the base of the open vertical shaft and is connected with the energy dissipation work on the downstream side of the dam. The energy dissipation vertical shaft, a vertical shaft with internal diameter, φ = 13 m, and depth, H = 22.0 m, is a type which performs underwater energy dissipation and discharges into the river course.

This spillway is the first of its kind in Japan, so hydraulic model testing was done to study its design. The problem clarified by hydraulic model testing of the design proposal with a single orifice (Fig. 6) is that large quantity of air is entrained, air bubbles entrained in the tunnel gather, forming an air pocket, and in the energy dissipation shaft, this spouts upward, worsening the flow regime (Fig. 7).

To resolve this problem, it was redesigned with two orifices so that flowing water falls along the inside wall of the vertical shaft. This revised proposal effectively reduced air-entraining and spouting in the energy dissipation work, but it caused another problem: water flowing into the inflow vertical shaft triggers a strong revolving flow at the bottom of the vertical shaft, also impacting the tunnel part. As a result of a study of installing an overhang at the top of the tunnel inlet, installing soldiers on the base of the vertical shaft, or taking both measures to inhibit this rotation, it was decided that it would be effective to install soldiers (Fig. 8).

And installing an emission vertical shaft before the energy dissipation vertical shaft in order to inhibit the spurting of an air mass in the energy dissipation vertical shaft was studied. As a result of the testing, the spurting of the air mass in the energy dissipation vertical shaft was eliminated, but, water surface vibration, noise etc. caused by spurting into the air exhaust box was observed. It was confirmed that it is possible to resolve this problem by installing porous panels and soldiers between the tunnel and the exhaust vertical shaft, allowing the air mass to disperse (Fig. 9).

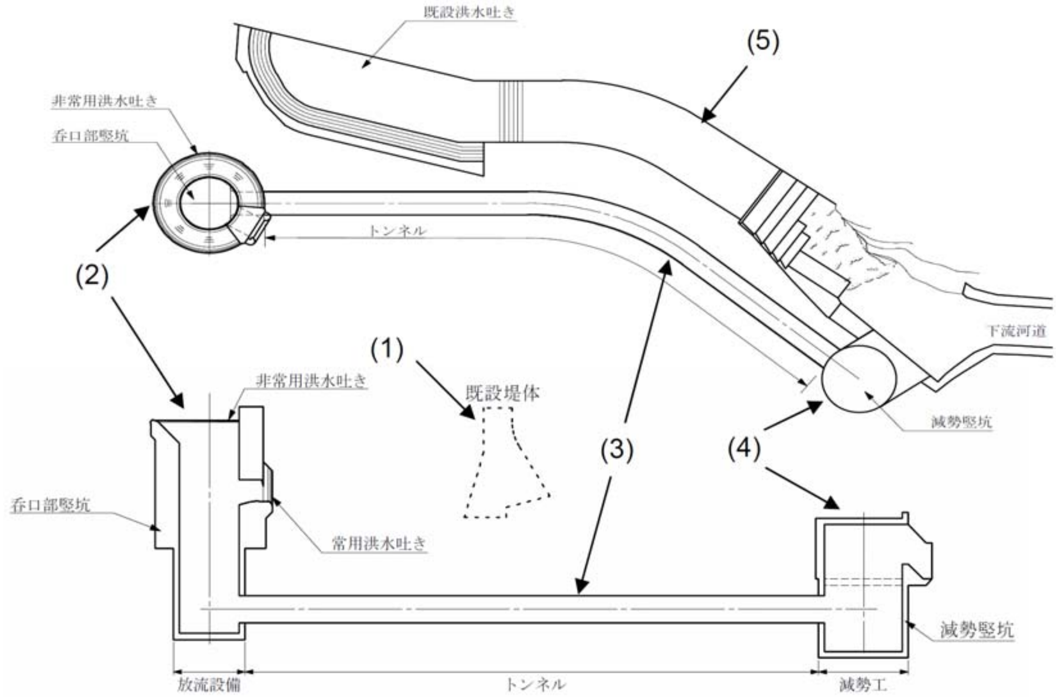

Fig. 6
Proposed Spillway Design
Conception de l'évacuateur de crues proposée

(1) Existing dam body
(2) Open vertical shaft
(3) Tunnel
(4) Energy dissipation vertical shaft
(5) Existing Spillway

(1) Corps du barrage existant
(2) Puits vertical ouvert
(3) Tunnel
(4) Puits vertical pour la dissipation de l'énergie
(5) Evacuateur de crues existant

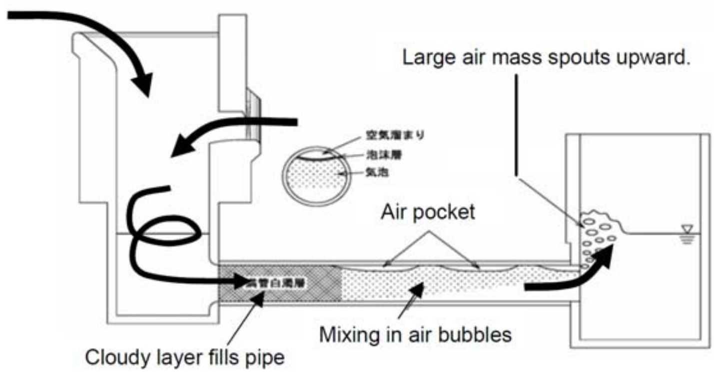

Fig. 7
Formation of Whirlpool and Air Pocket
Formation detourbillons d'eau et de poches d'air

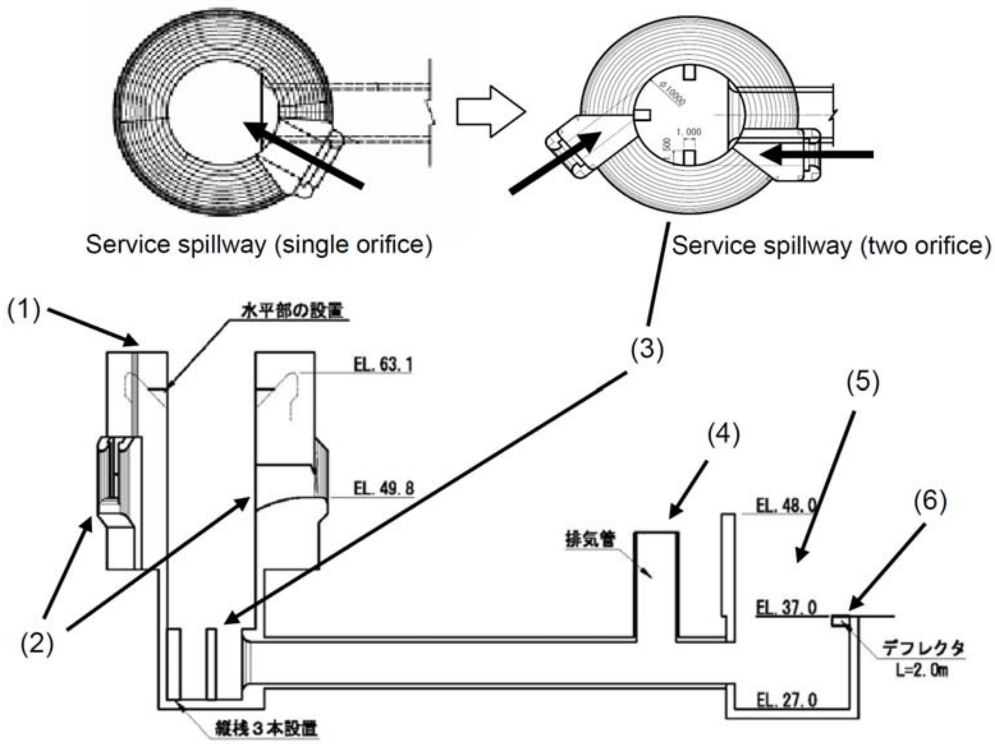

Fig. 8
Spillway Improvements
Améliorations de l'évacuateur de crues

(1) Emergency spillway | *(1) Evacuateur d'urgence*
(2) Service spillway | *(2) Evacuateur de service*
(3) Soldiers (three) | *(3) Blocs posés debout (3)*
(4) Exhaust pipe | *(4) Canalisation d'évacuation d'air*
(5) Energy dissipation vertical shaft | *(5) Puits vertical de dissipation d'énergie*
(6) Deflector | *(6) Déflecteur*

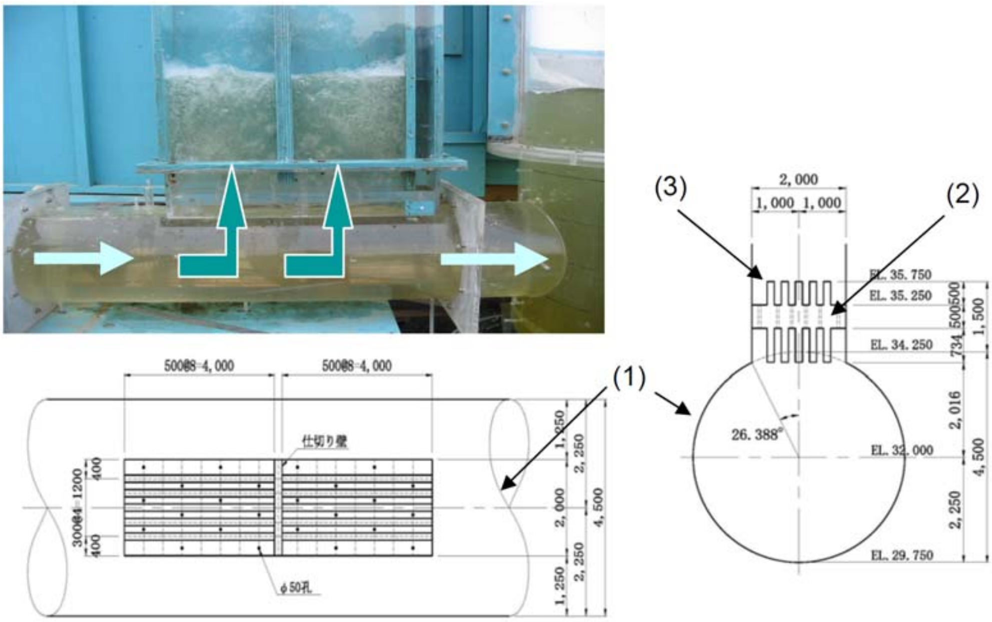

Fig. 9
Air Exhaust System
Système d'évacuation d'air

(1) Tunnel
(2) porous panel
(3) Soldier

(1) Tunnel
(2) Panneau poreux
(3) Bloc posé debout

5. CONCLUSIONS

The Nagasaki Emergency Flood Dam Project is a redevelopment project which will effectively use a group of existing dams in response to the current demand for a response to severe flood disasters. Dam construction projects are facing difficulties more severe than in the past as a result of a shortage of suitable sites for dams and growing concern with the conservation of the environment, and in the future, it will be increasingly important to plan ways to effectively use existing facilities as was done in this project.

When a project to add new functions to a precious civil engineering legacy more than 100 years old and hand it on to future generations is undertaken with, as the basic guideline of this project, minimizing any change in its appearance and structure, the reconstructed dam should sustain its history and condition to function forever. The plate shown in Photo 7 is installed at the outlet of the bottom sluiceway of the downstream slope of the existing Hongouchi-Teibu Dam. This is said to mean, "We pray for an endless source of pure water.", but even now, storing and controlling water remains essential for human life.

At the Hongouchi-teibu Dam, this work is now in progress with its target completion year set as 2011, and we are looking forward to its early completion.

Photo 7
Plate on Downstream Surface of the Dam Body
Plaque apposée sur la surface en aval du corps du barrage

ABSTRACT

The Nagasaki Emergency Flood Dam Project was undertaken in response to severe flooding accompanying concentrated torrential rainfall in 1982 in order to redevelop water supply dams constructed on major rivers in the city during the Meiji Era (1867 to 1912) to provide them with flood control functions, thereby transforming them from water supply dams to multi-purpose dams. The characteristics of the project are that is being implemented combining reconstruction and new construction so that the existing water supply dam group can be used effectively without impacting the supply of water to public water systems, and that the reconstruction of the historically valuable civil engineering structures which have stood for more than 100 years has been designed accounting for the conservation of their original structures and external appearances. Reconstruction of the Nishiyama Dam and Hongouchi-kobu Dam (redevelopment work) and the construction of the new Nakao Dam have been completed, and work on the Hongouchi-teibu Dam is now underway. At the Hongouchi-teibu Dam where work is now being executed, the dam body will be thickened and a new spillway constructed, but the dam body thickening will be performed on the reservoir side to conserve the structure and appearance of the dam body, while to provide the spillway, the vertical shaft type tunnel spillway which does not require notches in the existing dam body has been adopted for the first time. Hydraulic model tests were performed repeatedly to design the vertical shaft type tunnel spillway, establishing this technology.

Le projet du barrage d’urgence pour prévenir les dégâts causés par les crues de Nagasaki a été entrepris en réaction aux graves inondations qui ont suivi les pluies torrentielles qui se sont concentrées dans le secteur en question en 1982 afin de redévelopper les barrages d’approvisionnement en eau construits sur les principales rivières traversant la ville durant l’ère Meiji (1867-1912) en vue de leur fournir des fonctions de contrôle des crues, transformant ainsi leur rôle initial de barrages d’approvisionnement en eau en barrages polyvalents à usages multiples. Les caractéristiques de ce projet sont les suivantes : la réalisation du projet en combinant des travaux de reconstruction et de construction de nouvelles installations de telle façon que l’ensemble des barrages d’approvisionnement en eau existants puissent être utilisés efficacement sans affecter les systèmes d’alimentation en eau de ville ; et le fait que la reconstruction les structures de génie civil ayant une valeur historique et qui ont perdurées pendant plus d’un siècle a été conçue en tenant compte de de la préservation des structures d’origine et de leur aspect extérieur. La reconstruction (travaux de redéveloppement) du Barrage de Nishiyama et du Barrage de Hongouchi-Kobu (Hongouchi-Partie haute) et la construction du nouveau Barrage de Nakao ont été menées à bien et les travaux concernant le barrage de Hongouchi-Teibu (Hongouchi-Partie basse) sont en cours d’exécution. Au barrage de Hongouchi-Teibu où les travaux sont en cours d’exécution, le corps du barrage sera épaissi et un nouvel évacuateur de crues construit. Toutefois, l’épaississement du corps du barrage sera réalisé du côté du réservoir afin de préserver la structure et l’aspect extérieur du corps du barrage, et en vue d’installer un évacuateur de crues, on a adopté pour la première fois un tunnel évacuateur de crues en forme de puits qui ne nécessite pas de faire des entailles dans le corps du barrage existant. On a procédé de manière répétée à des essais de modélisation hydraulique afin de procéder à la conception du tunnel évacuateur de crues en forme de puits et d’établir les bases de cette technologie.