# Japanese Dam Technologies Contributing to the World 2018

JAPAN COMMISSION ON LARGE DAMS

It's our honor to introduce

the following expertise

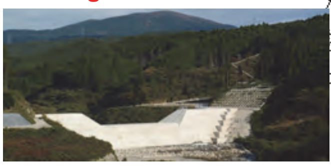
# Japanese Original CSG Technology

# CSG Structures in JAPAN

④ Yokokawa Sediment Check Dam

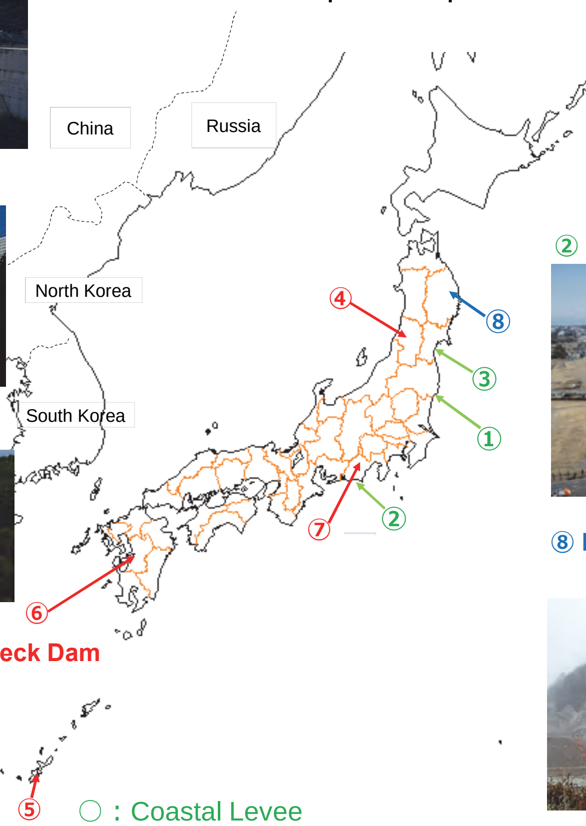
⑤ Taiho Sub Dam

⑥ Kasegawa Sub Dam



⑦ Nagashima Sediment Check Dam

Map of Japan




○ : Coastal Levee
○ : Sediment Check Dam, Sub Dam,etc
○ : Landslide countermeasure

① Natsui Coastal Levee

② Hamamatsu Coastal Levee

⑧ Landslide countermeasure (Isawa dam Reservoir)

## CSG Coastal Levee

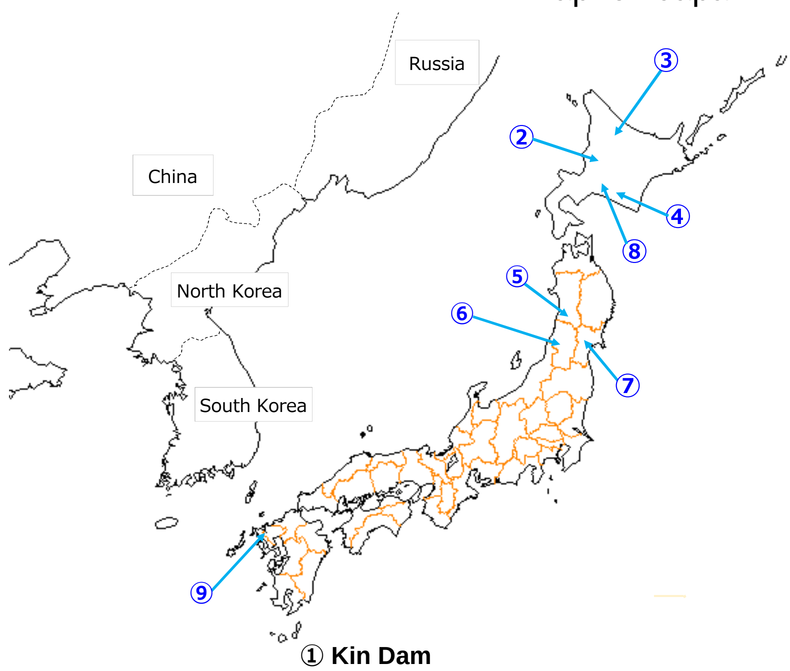
| Status | Name of Structure | Top level (Above sea level) (m) | Length (m) | Volume (CSG) ($m^3$) | Raw Materials | Unit of Cement ($kg/m^3$) |
|---|---|---|---|---|---|---|
| Completed | ①Natsui Coastal Levee | 7.2 | 920.0 | 60,000 (40,000) | Quake concrete wreckage | 80~100 |
| Under Construction | ②Hamamatsu Coastal Levee | 13.0 | 17,500 | 2,000,000 | Terrace deposit | 40~100 |
| | ③Sendai Bay South Coastal Levee | 7.2 | 1,179 | 50,500 | Excavated rock and sand material | 40~100 |

## CSG Small Dam (Sub Dam, Sediment Check Dam, Coffer Dam)

| Status | Name of Structure | Height (m) | Length (m) | Volume (CSG) ($m^3$) | Raw Materials | Unit of Cement ($kg/m^3$) |
|---|---|---|---|---|---|---|
| Completed | ④Yokokawa Dam Upstream cofferdam | 12.4 | 26.0 | 3,200 | Dam excavation material | 60 |
| Completed | ⑤Taiho Sub Dam | 30.0 | 110.5 | 34,000 | Weathered rocks | 60,100 |
| Completed | ⑥Kasegawa Sub Dam | 29.3 | 115.5 | 68,000 | Weathered rocks | 80 |
| Completed | ⑦Nagashima Sediment Check Dam | 33.0 | 127.0 | 23,100 | River bed gravel and sand | 80 |

# Trapezoidal CSG Dams in JAPAN

Map of Japan




**② Tobetsu Dam**

**③ Sanru Dam**

**① Kin Dam**

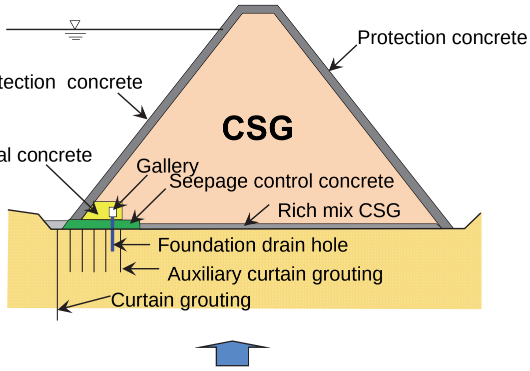
**④ Apporo Dam**

## List of Trapezoidal CSG Dams

| Status | Name of Dam | Height (m) | Length (m) | Dam Body Volume ($m^3$) | Raw Materials | Unit of Cement ($kg/m^3$) |
|---|---|---|---|---|---|---|
| Completed | ① Kin Dam | 39.0 | 461.5 | 300,000 | Weathered rocks | 80～100 |
| | ② Tobetsu Dam | 52.4 | 432.0 | 803,000 | Riverbed sand and gravel | 60～100 |
| | ③ Sanru Dam | 46.0 | 350.0 | 495,000 | Riverbed sand and gravel | 60～100 |
| | ④ Apporo Dam | 47.2 | 516.0 | 480,000 | Weathered rocks | 60～100 |
| Under Construction | ⑤ Naruse Dam | 114.5 | 778.5 | 4,760,000 | Weathered rocks | 60～140 |
| Under Designing | ⑥ Chokai Dam | 81.0 | 365.0 | 1,688,000 | | |
| | ⑦ Tsutsusago Dam | 105.0 | 345.8 | 1,870,000 | | |
| | ⑧ Mikasa-ponbetsu Dam | 53.0 | 160.0 | 480,000 | | |
| | ⑨ Honmyo-gawa Dam | 64.0 | 385.0 | 750,000 | | |

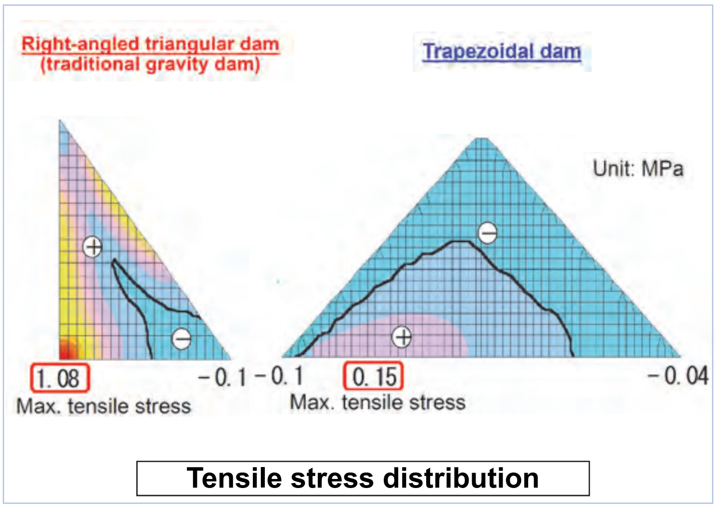
# Japanese Original Technology of Trapezoidal CSG Dam

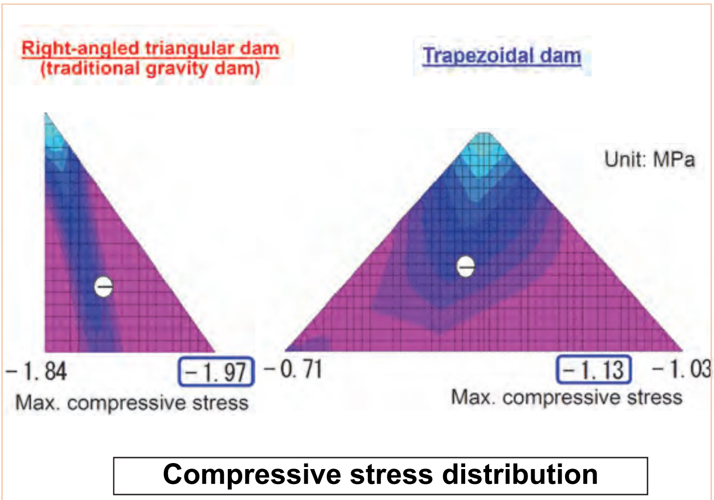
①The trapezoidal CSG dam is a new type of dam which differs from the conventional concrete gravity dams, embankment dams, and hard-fill dams. The dam body is made of cemented sand and gravel (CSG).



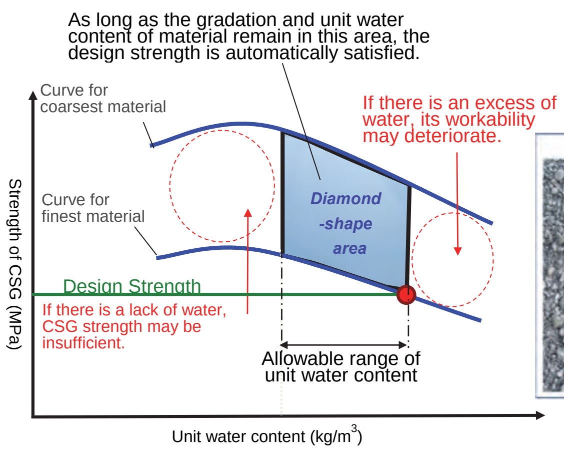

The outlet works, gallery, etc. can be placed inside the CSG dam body.

②The trapezoidal shaped body requires less strength, so the material strength may be low, permitting the use of low-quality materials.



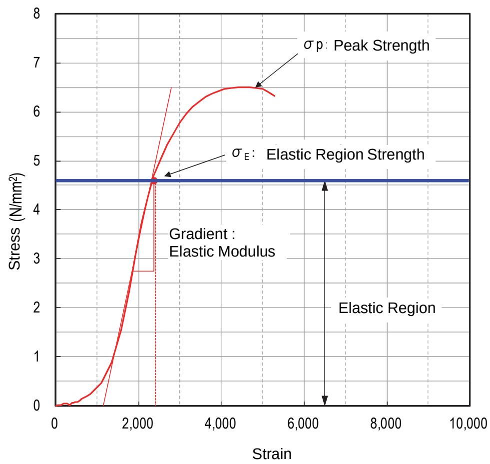

③CSG can be produced easily by mixing cement and water with materials obtained nearby without gradation adjustment and washing.





In consideration of the larger scatter in CSG properties compared to concrete, "Diamond Shape Theory" has been established to design and control CSG strength.

④The trapezoidal CSG dam is designed in range of an elastic body behavior of CSG, (so like a concrete dam).

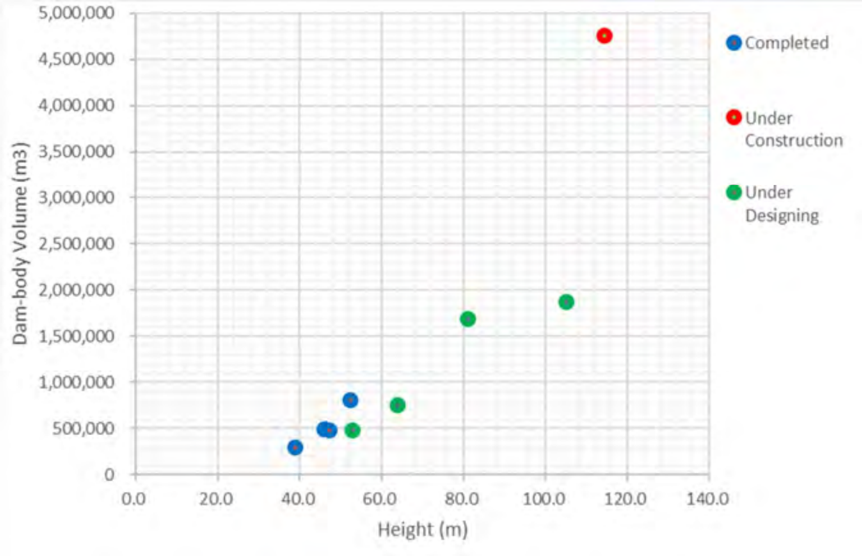


# The Construction Results of Trapezoidal CSG Dams in Japan

Up to present, four trapezoidal CSG dams have been constructed in Japan. Currently, five more trapezoidal CSG dams are under construction or being designed. The highest of the completed trapezoidal CSG dams in Japan is 52m, however, those currently under construction are designed to be over 100m in height.

List of the Trapezoidal CSG Dams

| Status | Name of Dam | Height (m) | Length (m) | Dam Body Volume ($m^3$) |
|---|---|---|---|---|
| Completed | Kin | 39.0 | 461.5 | 300,000 |
| | Tobetsu | 52.4 | 432 | 803,000 |
| | Sanru | 46.0 | 350 | 495,000 |
| | Apporo | 47.2 | 516 | 480,000 |
| Under Construction | Naruse | 114.5 | 778.5 | 4,760,000 |
| Under Designing | Chokai | 81.0 | 365 | 1,688,000 |
| | Tsutsusago | 105.0 | 345.8 | 1,870,000 |
| | Mikasa-ponbetsu | 53.0 | 160 | 480,000 |
| | Honmyo-gawa | 64.0 | 385 | 750,000 |





Tobetsu Dam


Kin Dam


Apporo Dam

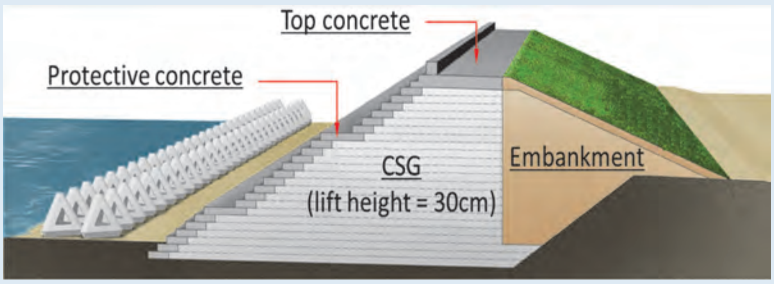

Sanru Dam

# Application of the CSG Technology

The CSG Technology and the CSG construction method have also been to various structures.

**CSG Sediment Check Dam**

**CSG Sub Dam**

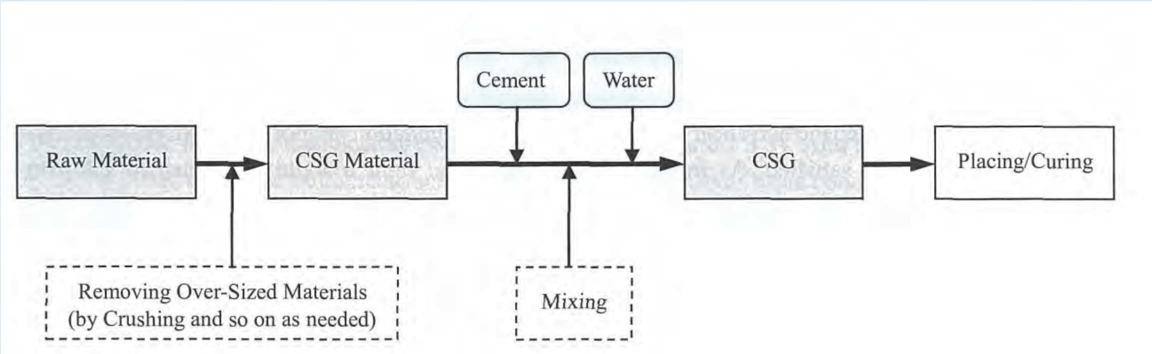


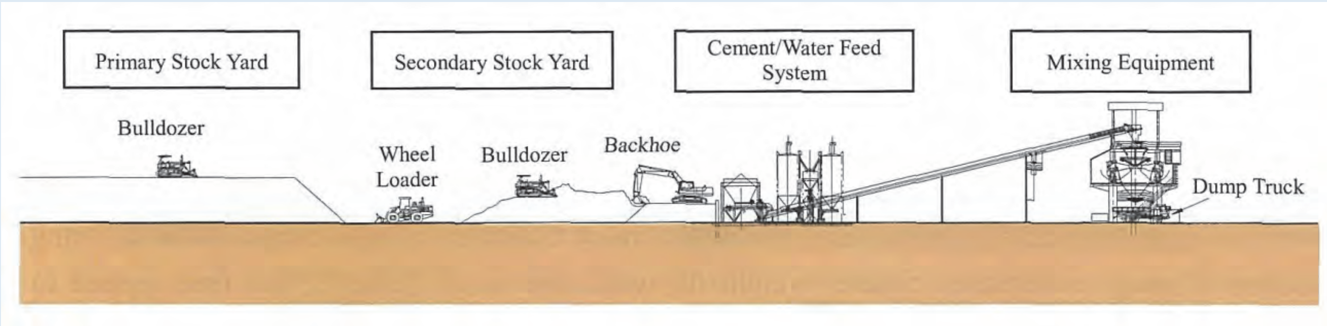

**CSG Coastal Levee**

**Landslide Countermeasure**

# CSG materials

CSG is produced using simple equipment by mixing cement and water with material obtainable nearby without classification, gradation adjustment or washing. When CSG is manufactured, gradation adjustment of CSG material such as sorting, blending, etc. is not carried out, other than removing or crushing oversized pieces, and cleaning. Thus, the equipment required to manufacture CSG is minimal: a simple continuous CSG mixing system.




**CSG Manufacturing Process**

## CSG Material

### Raw material

Gravel which was excavated in the riverbed is used as raw material

## Machinery

### Continuous Mixer

Producing CSG is conducted with a high performance continuous mixer

**CSG Manufacturing Processes for a Trapezoidal CSG Dam**




Stock Yard of Concrete Wreckage（Raw Materials of CSG）


CSG Manufacturing Processes for Small CSG Structures

# The Raw Materials of CSG

CSG consists of is rock-like raw materials such as material excavated to form the foundation, riverbed sand and gravel, terrace deposits, weathered rocks and concrete wreckage all of which can be obtained relatively easily.

CSG requires less strength than concrete, so the CSG raw materials may be lower quality than the rock used as concrete aggregate.

Many kinds of rock-like materials can be used as CSG materials. But we should decide the applicability of the materials proposed, as CSG materials, considering the strength, mixing condition, execution condition and so on. For example, when the material proposed contains high fine particle contents, there is high possibility of low strength and workability.

River Bed Gravel and Sand

Terrace Deposits

Concrete Wreckage

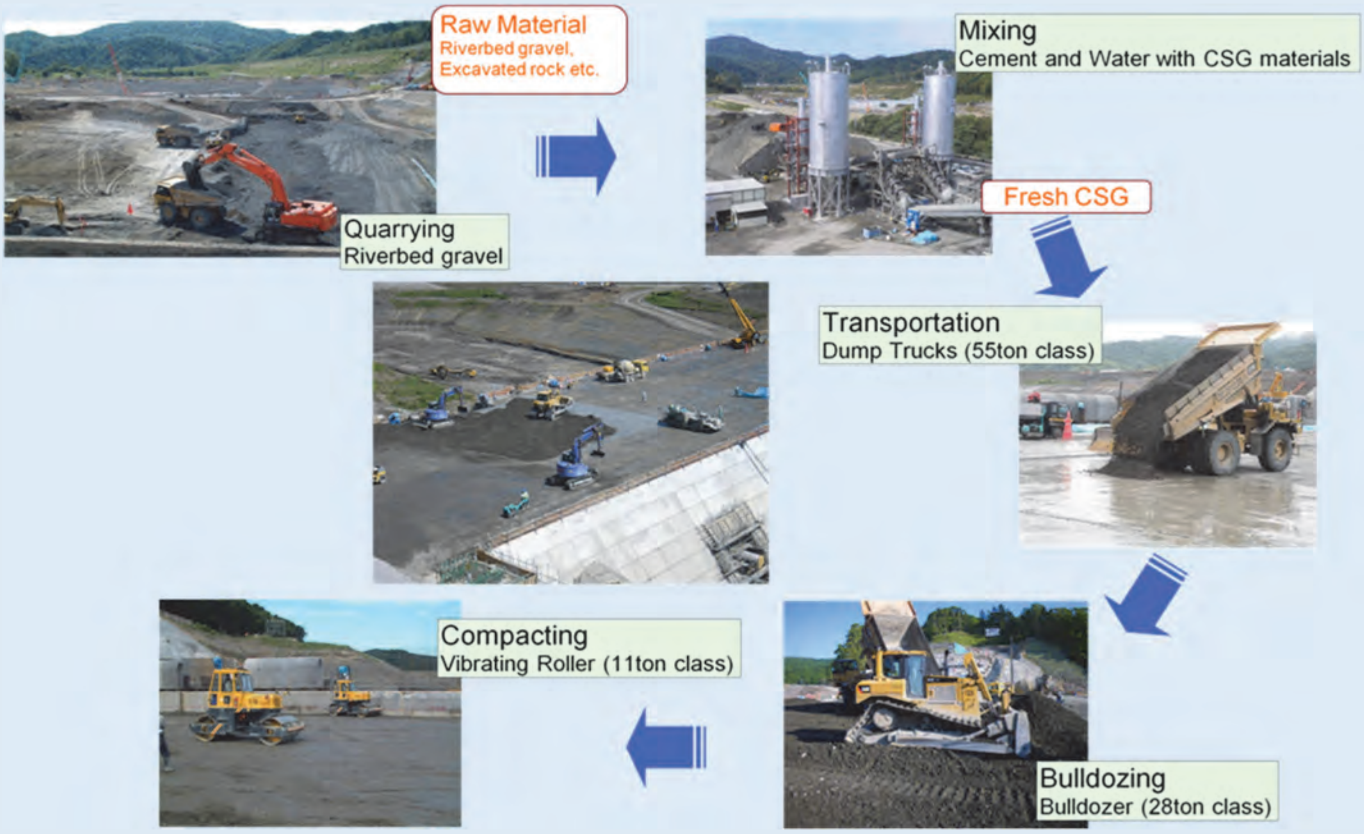
Excavated Rock

The Raw Materials of CSG

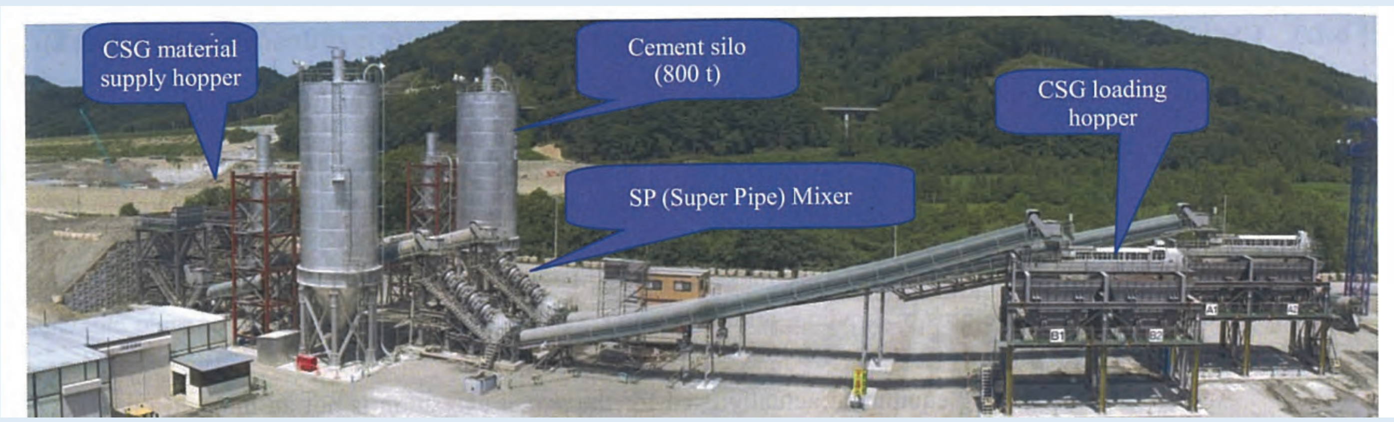
# Construction Flow for a Trapezoidal CSG Dam

The CSG construction method can, like the RCD or RCC method, be executed by the layer placing method using general-purpose machines such as dump trucks, bulldozers, and vibrating rollers. The unit cement content is small and almost no bleeding occurs, so green-cutting is unnecessary.

CSG is made by mixing cement and water with CSG material. A continuous mixing system is used, which is simpler than a normal concrete mixing system.




Construction Flow for a Trapezoidal CSG Dam




CSG Mixing System for a Trapezoidal CSG Dam

# Construction Flow for small CSG structures (Example of CSG coastal levee)

The CSG construction method for small structures can be executed by utilizing widely available small size general-purpose machines.

**Raw Materials:**
Riverbed gravel, terrace deposits, excavated rock, concrete wreckage etc.

Quarrying
Terrace deposits

Concrete wreckage

Crushing
Crawler crushing machine


Mixing
Mobile soil remediation machine

Transportation
Dump Trucks
(10t class Crawler type)

Bulldozing
Bulldozer (7t class)

Compacting
Vibrating Roller
(4t class combined type)

# 1. Feature of The Trapezoidal CSG Dam

## What's the trapezoidal CSG dam ?＊1

The trapezoidal CSG dam is a new type of dam which differs from the conventional concrete gravity dams and embankment dams, and its dam body is trapezoidal in shape and made of cemented sand and gravel **(Fig.-1)**, which is mixture of cement, water and material obtained near the dam construction site. This type of dam has been developed in Japan.

CSG can be produced easily by mixing cement and water with material obtained nearby without gradation adjustment and washing, but it is not as strong as concrete. To overcome this shortcoming, it was combined with a trapezoidal shape, which does not require great strength.

The trapezoidal CSG dam simultaneously leads to "**rationalization of materials**", "**rationalization of design**", and "**rationalization of execution**". And the feature of the trapezoidal CSG dam is shown in **Fig.-1**.

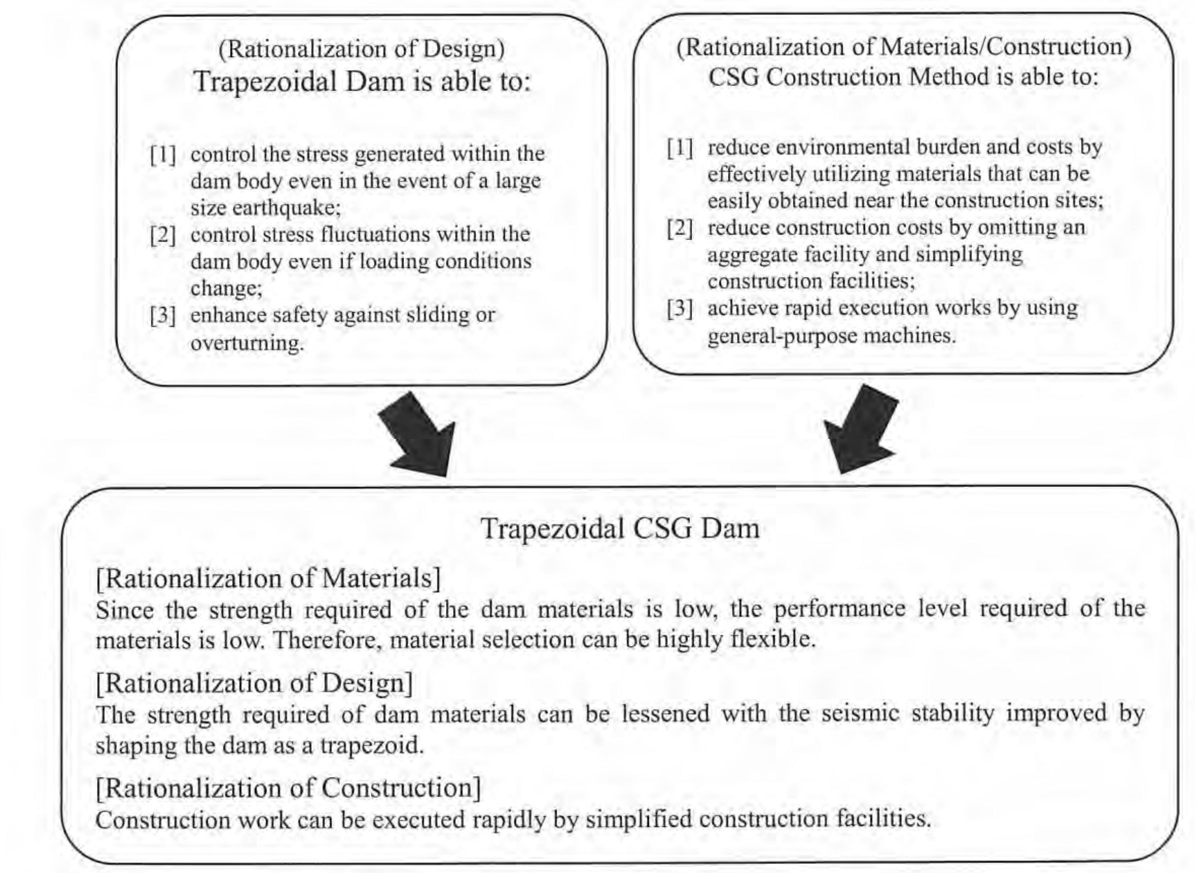



Fig.-1 The Feature of the Trapezoidal CSG Dam

### Standard Cross Section of the trapezoidal CSG dam-body **(Fig.-2)**

The trapezoidal CSG dam is made using CSG **(Photo-1)** for the main part of dam body, and protection concrete is placed on its surface to increase durability. A structural concrete for gallery and a seepage control concrete for securing seepage pass length are placed on the upstream side. CSG on the bottom surface of the dam body is rich-mix CSG selected to ensure durability.

＊1 This paper is prepared on "**Engineering Manual for Design, Construction, and Quality Control of Trapezoidal CSG Dam 2012"** which Japan Dam Engineering Center published. We forbid the reproduction of figures and photographs in this paper without permission.

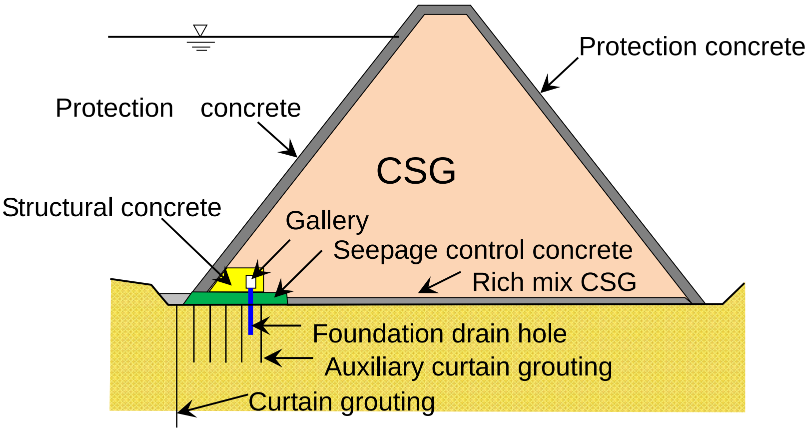



Fig.-2 Standard Cross Section of the trapezoidal CSG dam


Photo-1 CSG Material and CSG

## Advantages of the Trapezoidal CSG dam

1. An required condition for a trapezoidal dam is that the vertical stress generated on the bottom of dam is always on the compressive side, so the dam body and foundation bedrock need not be integrated for the use of cohesion of rock foundation. Because the cohesion of the foundation bedrock needs not be used, it is possible to relax the conditions for the foundation bedrock.
2. In addition to the lower strength required for the dam body material, a trapezoidal CSG dam has fewer requirements for the foundation bedrock, increasing the flexibility for dam site selection.
3. A trapezoidal CSG dam can be built with a simple CSG manufacturing plant, permitting rapid execution by a continuous mixing system.
4. The construction cost depends upon each dam condition, but based on the previous cases, the construction cost of trapezoidal CSG dams is estimated to be 20 to 25% reduction compared to concrete gravity dams.

## The Construction Results of the Trapezoidal CSG Dams in Japan

Two trapezoidal CSG dams were completed in Japan. At present, seven trapezoidal CSG dams are under construction or designing. The maximum height of completed trapezoidal CSG dams in Japan is 52m. However, the design of 100m-high class trapezoidal CSG dams is now designing in Japan **(Table-1, Photo-2, Fig.-3)**.

Table-1 List of the Trapezoidal CSG Dams

| Status | Name of Dam | Height (m) | Length (m) | Dam Body Volume ($m^3$) |
|---|---|---|---|---|
| Completed | ① Kin Dam | 39.0 | 461 | 300,000 |
| | ② Tobetsu Dam | 52.4 | 432 | 803,000 |
| | ③ Sanru Dam | 46.0 | 350 | 495,000 |
| | ④ Apporo Dam | 47.2 | 516 | 480,000 |
| Under Construction | ⑤ Naruse Dam | 114.5 | 778.5 | 4,760,000 |
| Under Designing | ⑥ Chokai Dam | 81.0 | 365 | 1,688,000 |
| | ⑦ Tsutsusago Dam | 105.0 | 345.8 | 1,870,000 |
| | ⑧ Mikasa-ponbetsu Dam | 53.0 | 160 | 480,000 |
| | ⑨ Honmyo-gawa Dam | 64.0 | 385 | 750,000 |

Tobetsu Dam

Kin Dam

Apporo Dam

Sanru Dam

Photo-2 The Trapezoidal CSG Dams

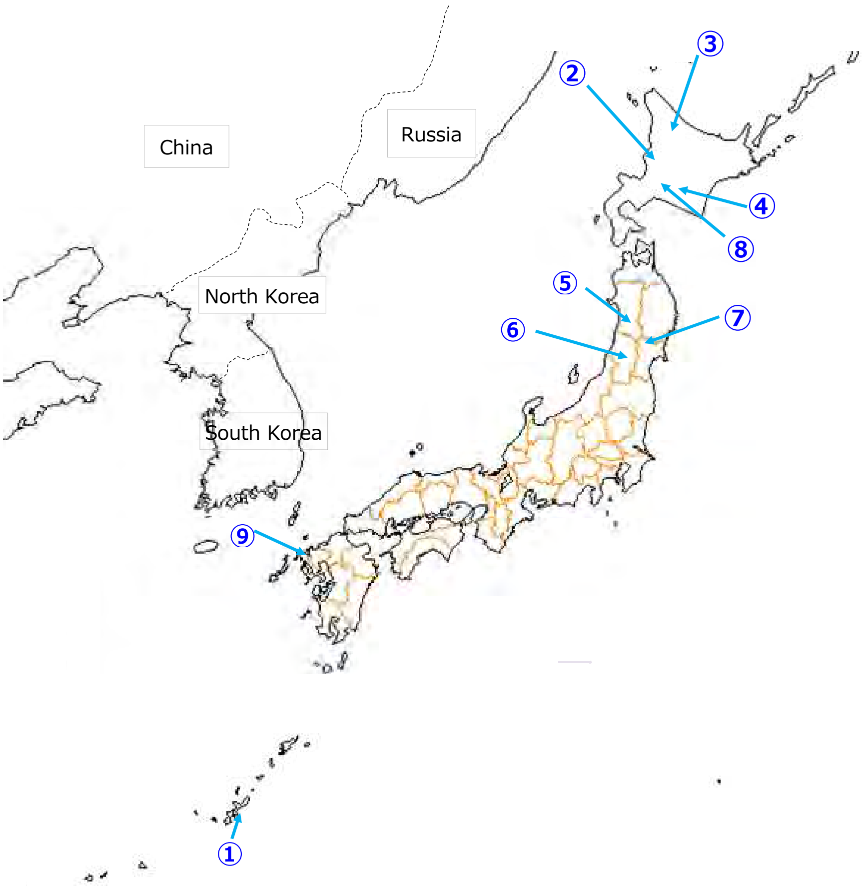



Fig.-3 Map of the Trapezoidal CSG Dams in Japan

# Application of the CSG Technology

The CSG Technology and the CSG construction method were also applied to sediment check dams for reservoir sediment management **(Photo-3)**, sub dams **(Photo-4)**, upstream cofferdams **(Photo-5)**, etc. In addition, considering the advantages of the CSG technology, such as rapid execution and easy supply of materials, we have applied this technology to the coastal levees **(Photo-6,7)**, landslide countermeasures **(Photo-8)**, seepage control works in reservoir, and so on.

Photo-3 CSG Sediment Check Dam
(Nagashima Dam Reservoir)

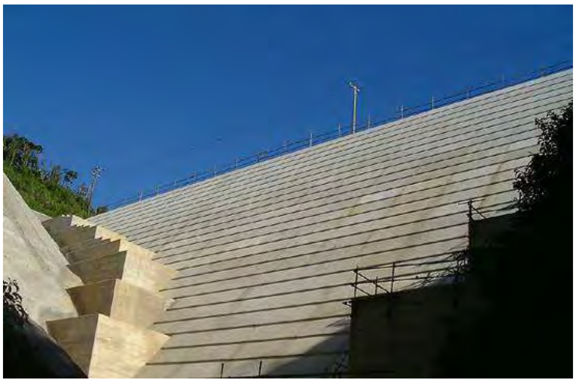


Photo-4 CSG Sub Dam (Taiho Dam)


Photo-5 Upstream Cofferdam (Yokokawa Dam)

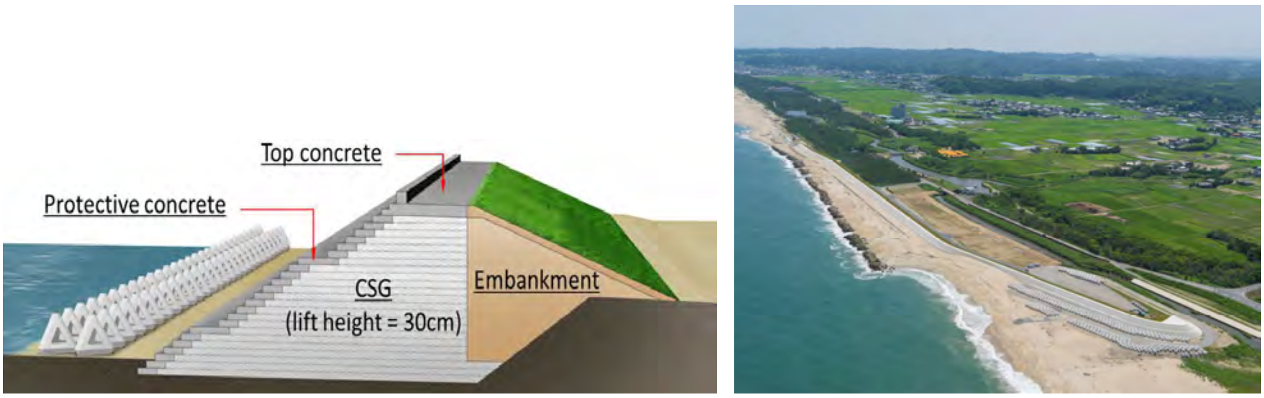



Photo-6 Coastal Levee (Natsui Coastal Levee, Fukushima Pref.)

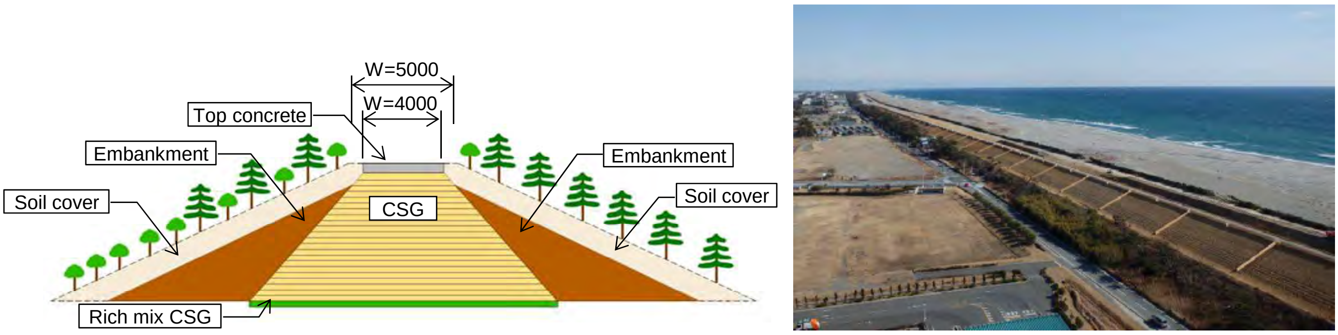



Photo-7 Coastal Levee (Hamamatsu Coastal Levee, Shizuoka Pref.)

Photo-8 Landslide Countermeasure (Isawa Dam Reservoir)

Table-2 List of CSG Coastal Levees and CSG Small Dams

| Status | Name of coastal levee | Top level (Above sea level) (m) | Length (m) | Volume (CSG) ($m^3$) | CSG Raw Materials |
|---|---|---|---|---|---|
| Completed | Natsui Coastal Levee | 7.2 | 920.0 | 60,000 (40,000) | Quake concrete wreckage |
| Under Construction | Hamamatsu Coastal Levee | 13.0 | 17,500 | 2,000,000 | Terrace deposit |
| | Sendai Bay South Coastal Levee | 7.2 | 1,179 | 50,500 | Excavated rock and sand material |

| Status | Nam of Structure | Height (m) | Length (m) | Volume (CSG) ($m^3$) | Raw Materials | Unit of Cement ($kg/m^3$) |
|---|---|---|---|---|---|---|
| Completed | Yokokawa Dam Upstream cofferdam | 12.4 | 26.0 | 3,200 | Dam excavation material | 60 |
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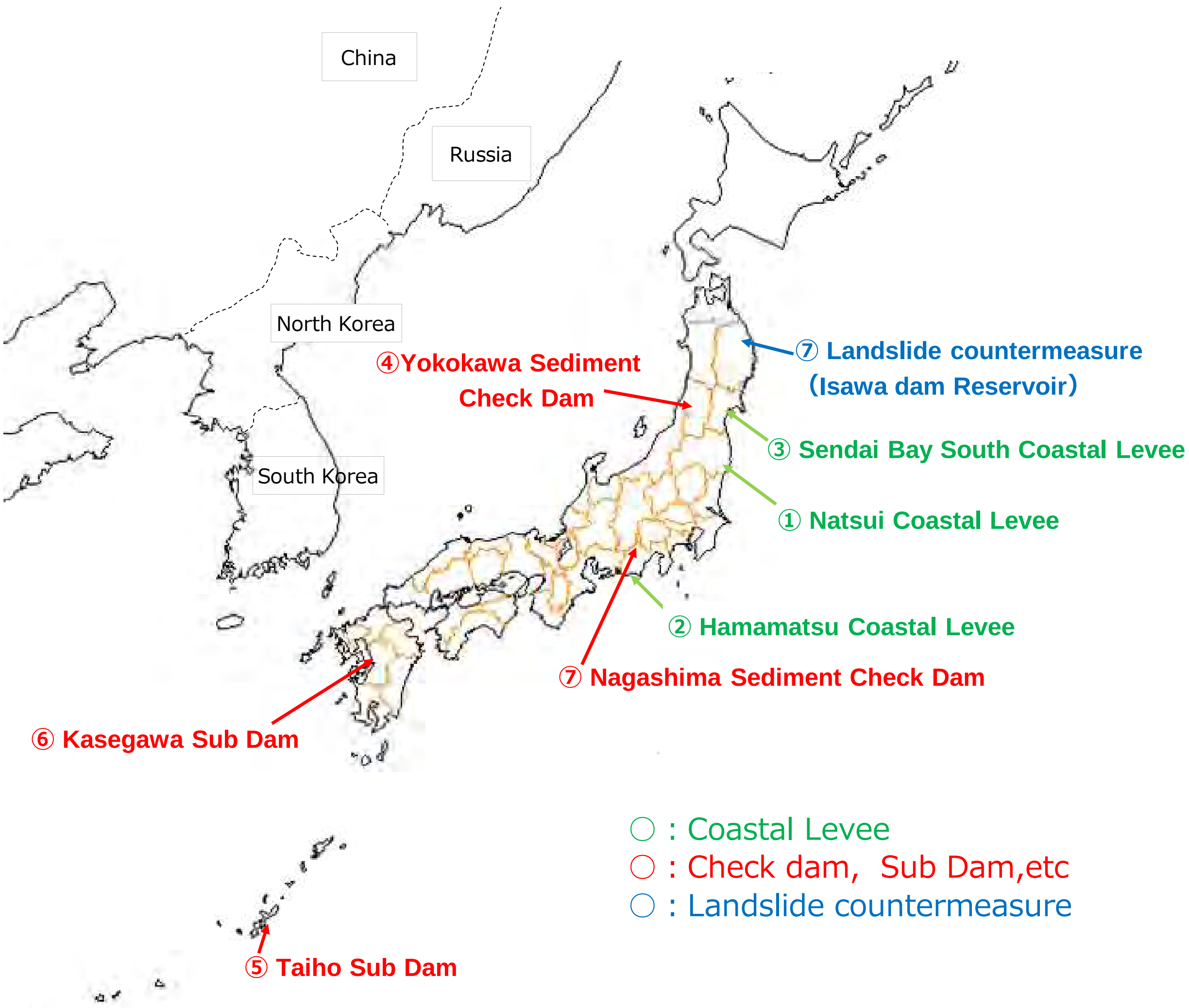



Fig.-4 Map of the CSG Structures in Japan

# 2. Design of The Trapezoidal CSG Dam

## Different points from the Concrete gravity dam and the Hardfill dam

The trapezoidal CSG dam is designed in range of an elastic body behavior of CSG, so like a concrete dam **(Fig.-5)**, the outlet works, gallery, etc. can be placed inside the dam body, and the emergency spillway, etc. placed at the crest.

Besides, in consideration of the larger scatter in CSG properties compared to concrete, "Diamond Shape Theory **(Fig.-6)**" has been established to design and control CSG strength.

The strength of CSG depends on the materials used and cement content. According to previous cases, the CSG strength of riverbed deposit is about 2N/mm$^2$ or higher, and that of weathered rock is about 2N/mm$^2$ or higher. However, these values are not the upper limitation of the CSG strength of these materials.

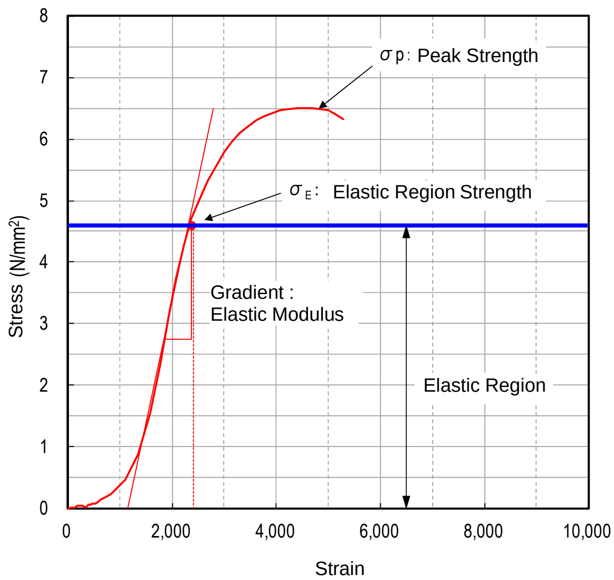



Fig.-5 Definition of the Strength of CSG

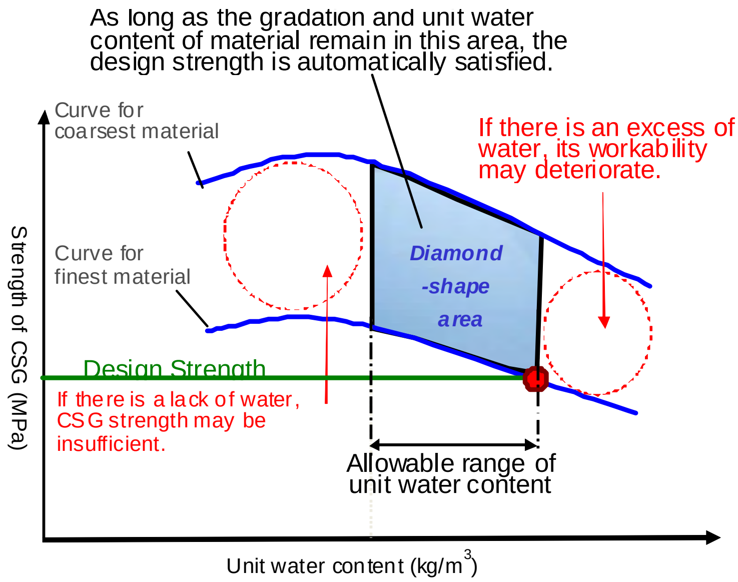



Fig.-6 Diagram of Diamond Shape Theory

## How to decide the Standard cross section of the Trapezoidal CSG dam body.

- A trapezoidal CSG dam is a new type of dam, which is different from conventional concrete dams or embankment dams, and so is designed using an appropriate method for this shape instead of the existing method. The trapezoidal CSG dam is designed using the finite element method (FEM) and dynamic analysis method to consider the earthquake effects. An example of FEM analysis is shown as in Fig.7.
- A trapezoidal CSG dam is designed with upstream and downstream slope gradients set such that both during normal condition and during an earthquake, the vertical stress is compression along the entire base **(Fig.-8)**.
- Upstream surface gradient: Selected based on the strength of the materials obtained, dam height, and foundation bedrock conditions. Based on previous and present cases, it is generally set to be 1:0.8.
- Crest width: Set considering constraints of construction works near crest. Based on previous and present cases, it is generally set to be 8m **(Fig.-9)**.

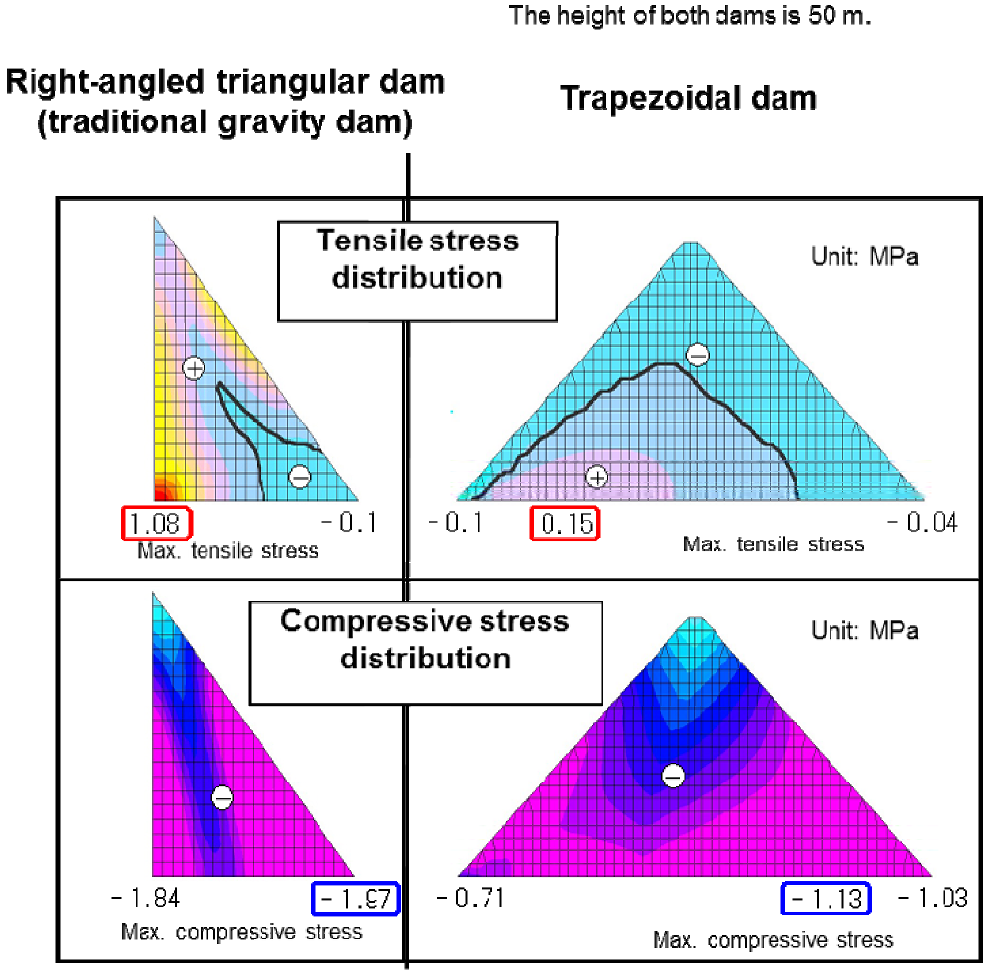



Fig.-7 An example by FEM Analysis
(Distribution of maximum stresses, comparison of the concrete gravity dam and the trapezoidal CSG dam)

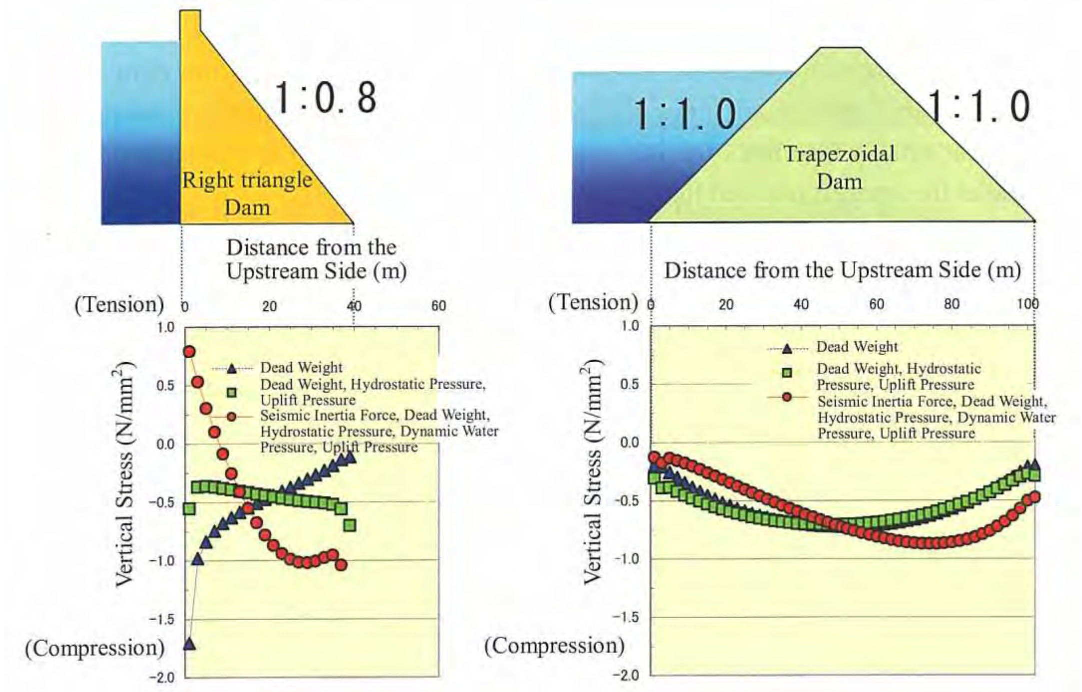



Fig.-8 Distribution of Vertical Stress over Bottom of the Dam body

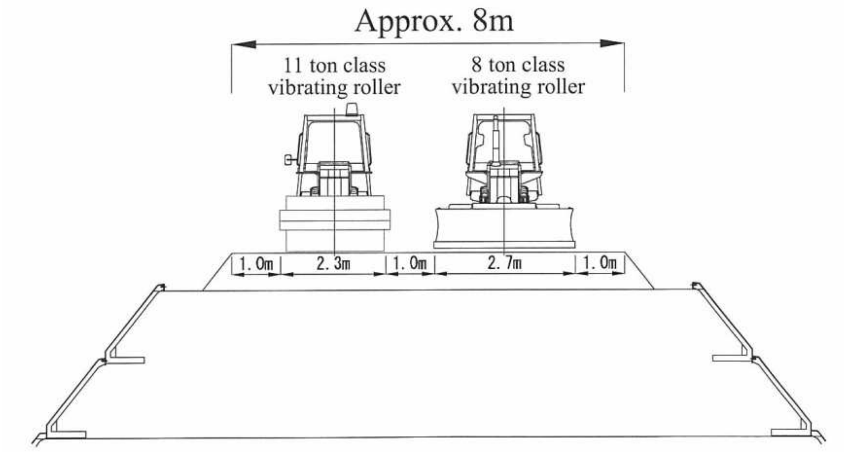


Fig.-9 Necessary Width of Execution of the Trapezoidal CSG Dam Crest

## Zoning of the Trapezoidal CSG Dam-body

The trapezoidal CSG dam is made of CSG for the main part of dam body, and protection concrete is placed on its surface to increase durability. A structural concrete for gallery and a seepage control concrete for securing seepage pass length are placed on the upstream side. The CSG on the bottom surface of the dam body is rich-mix CSG to ensure durability.

Zoning of the Trapezoidal CSG Dam-body is as shown **Fig.-10~13.**

- **Protection concrete**: The permeability of CSG is generally low, but water tightness of trapezoidal CSG dam body depend on protection concrete. Concrete placed on the dam surface to ensure durability. Its thickness is a horizontal thickness of about 1.0～2.0m.
- **Seepage control concrete:** Concrete placed on the upstream side of the dam base to ensure water tightness of the contact rock surface from seepage flow. The length in stream direction are set according to dam height and permeability of rock foundation. The thickness is more than 2 m **(Fig.-15)**.
- **Rich-mix CSG:** Cement with a higher cement content than used generally in the dam body, to accommodate irregularities of the bedrock. Its thickness is basically 1 m, but the thicker layer will be adapted based on topographical conditions.
- **Transversal joints**: Joints are installed in the CSG near the abutments on the left and right banks. In the middle, if the dam crest is long, they are installed about every about 100 m in the dam axis direction **(Fig.-16)**.

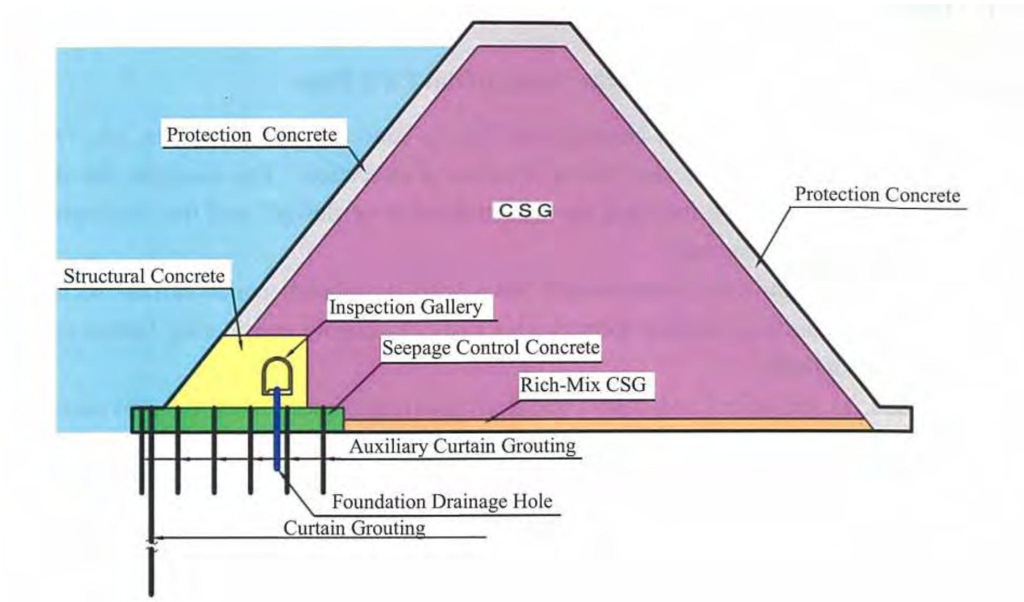


Fig.-10 Standard Cross Section of the Trapezoidal CSG Dam

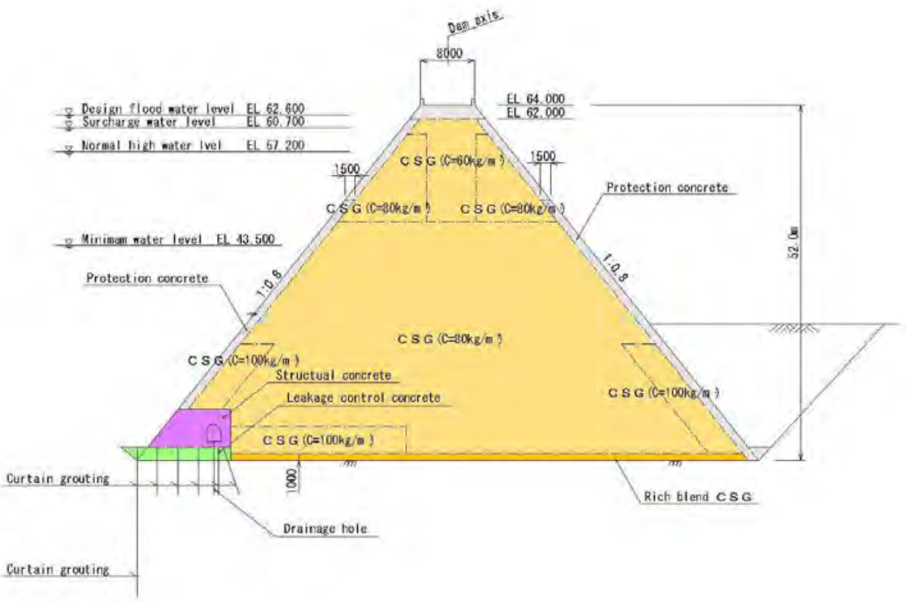



Fig.-11 Standard Cross Section of Tobetsu Dam

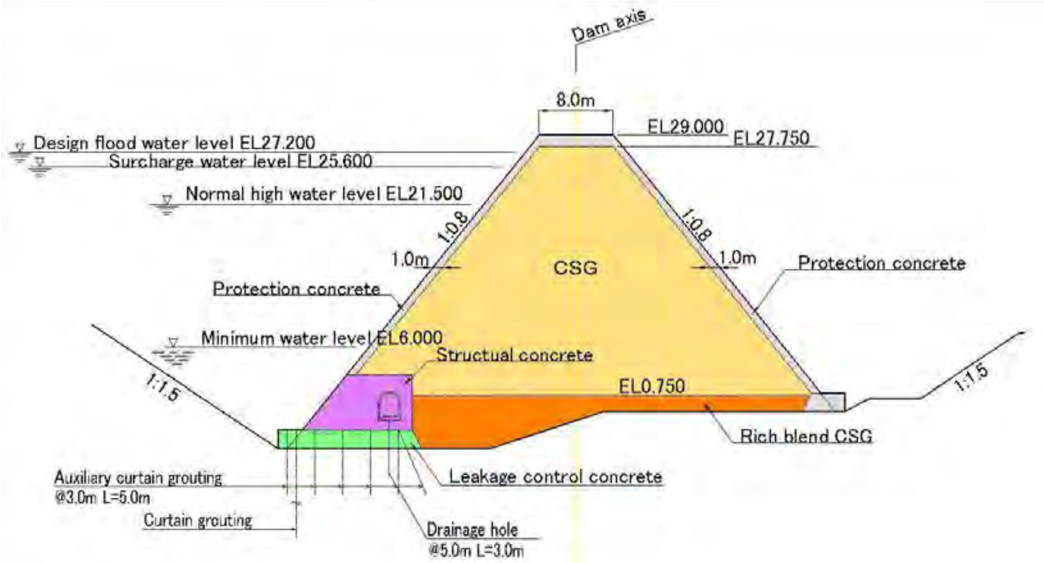



Fig.-12 Standard Cross Section of Kin Dam

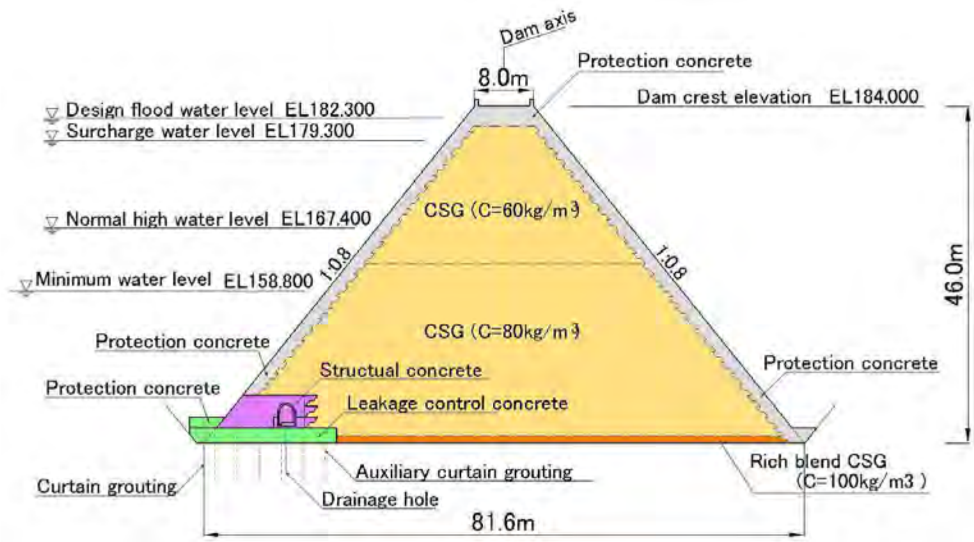



Fig.-13 Standard Cross Section of Sanru Dam

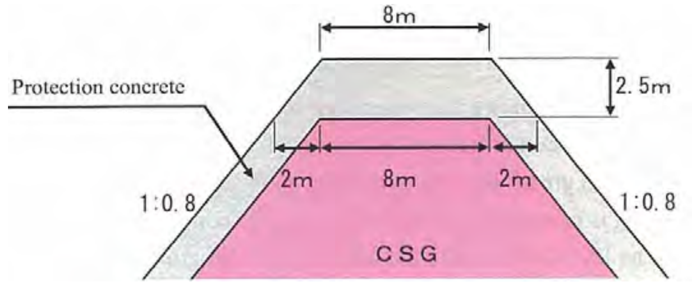



Fig.-14 Width of Protection Concrete

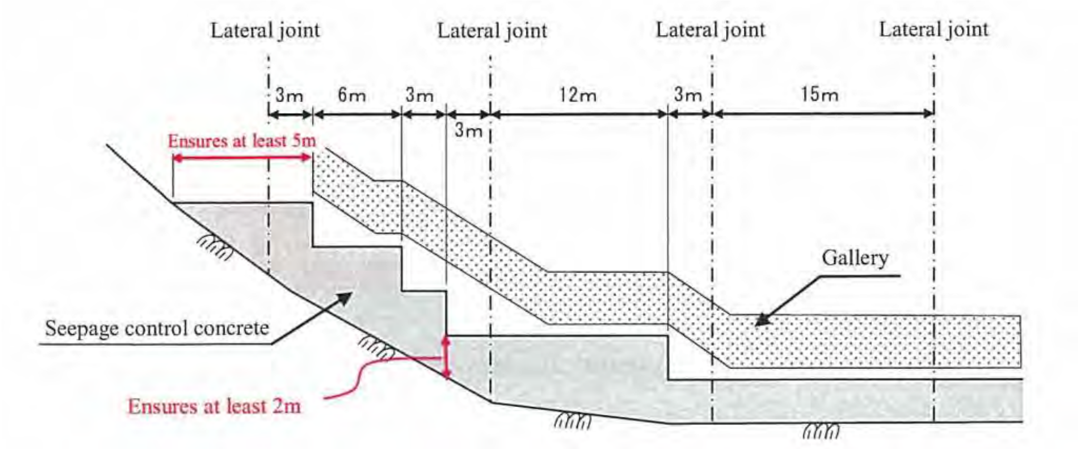



Fig.-15 Layout of Seepage Control Concrete (Dam Axis Direction Section)

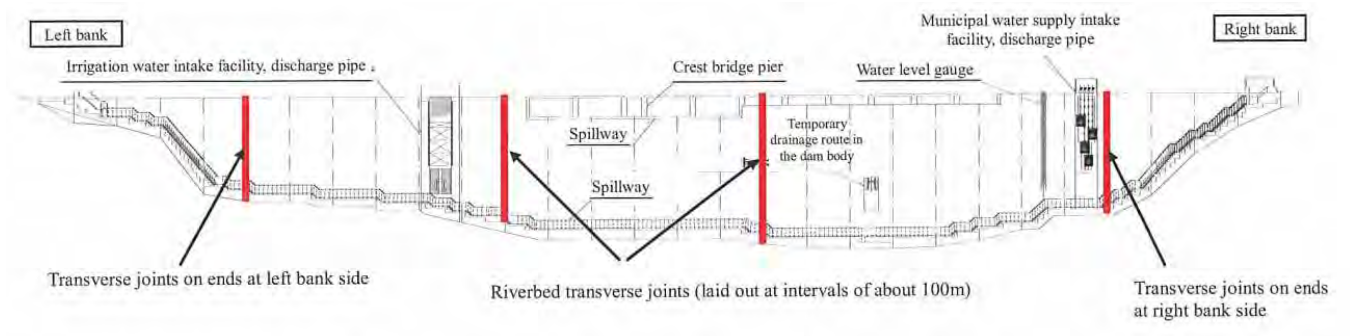
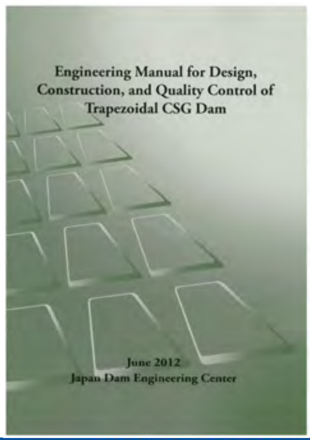



Fig.-16 Example of Locations of Transverse Joints

## How to Detail Design




The trapezoidal CSG dam is a new type of dam, which is different from conventional concrete dams or embankment dams, and so is designed using an appropriate method for this shape instead of the existing method. The trapezoidal CSG dam is designed using the finite element method (FEM) and dynamic analysis method to consider the earthquake effects.

In designing the trapezoidal CSG dams, you should have a detailed knowledge of design concept and procedure. The details are summarized in "**Engineering Manual for Design, Construction, and Quality Control of Trapezoidal CSG Dam 2012"** which Japan Dam Engineering Center published (you can purchase it here), or, please do not hesitate to contact with JCOLD*[2].

JDEC ダム技術センター Japan Dam Engineering Center

*[2] https://search.jcold.or.jp/contacts/new, Tel. +81-3-5614-0968, Fax. +81-3-5614-0969

In the trapezoidal CSG dam design, the physical properties of the CSG (strength, deformability) must be clarified. The design is conducted as follows.

1. First, the usable quantities of materials which can be obtained near the dam site are surveyed, accompanied by investigation and testing of the engineering properties of the material and the hardened CSG which will be made using the material (surface dry density and water absorption of CSG material, strength, elastic modulus and unit weight of CSG).
2. Next, the shape of the trapezoidal CSG dam (upstream/downstream slope gradients) is decided based on the physical properties of the hardened CSG obtained.
3. Analysis is performed based on the physical properties of CSG and the shape decided, to confirm the external stability and internal stability. If there is surplus stability, the gradient is set steeper within a range which ensures that the stress at the dam bottom remains compressive, or the unit cement quantity is lowered. If the stability is insufficient, a study is conducted on either relaxing the gradient or increasing the unit cement content, and the most rational overall shape is finally decided.

For the following reasons, FEM analysis are used (Fig.-17).

1. Both external and internal stabilities can be clarified more directly and rationally than by the conventional design method.
2. The finite element method permits consideration of the deformation properties of the foundation bedrock, allowing rational analysis.
3. Dynamic analysis permits direct and detailed determination of the effect of the shape of the dam body, and along with [2], rationally obtains the stresses inside the dam body, along the dam bottom, etc.

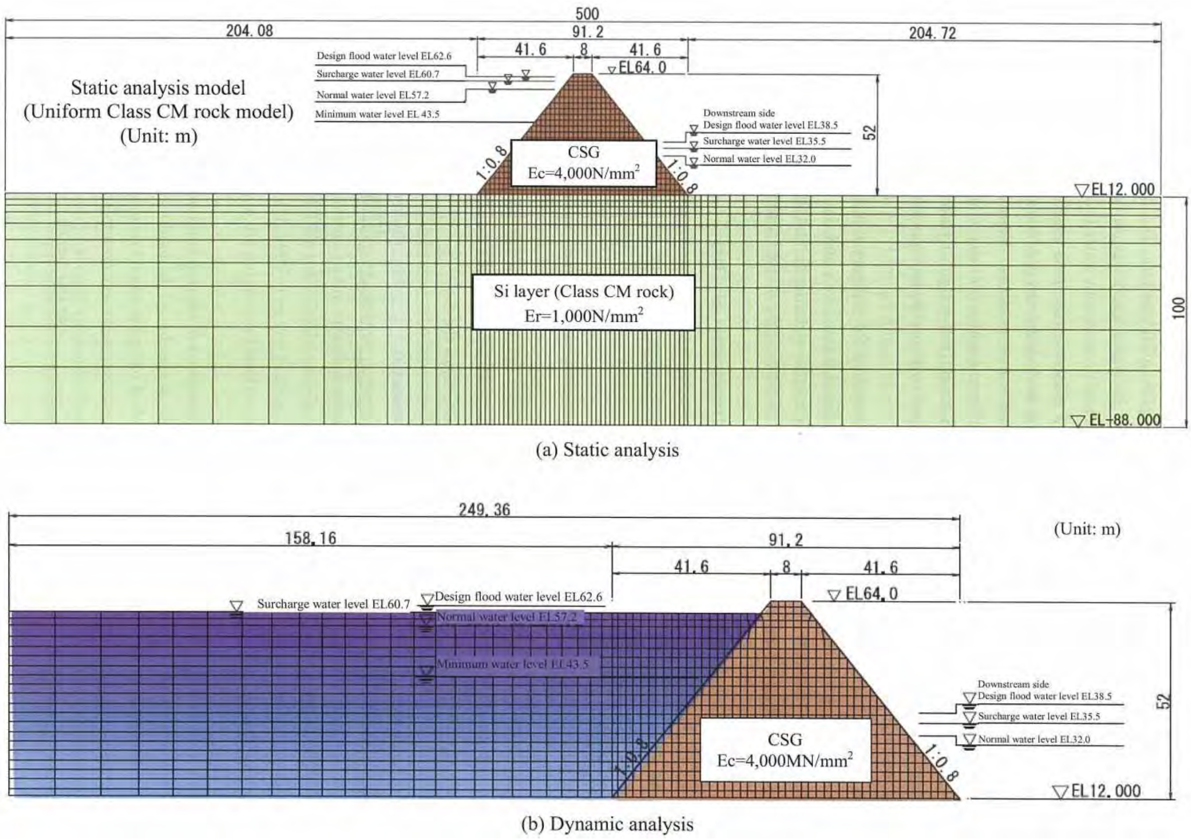



Fig.-17 Example of an FEM Analysis Model

# 3. Feature of The CSG Material

## What is The CSG material ?

CSG is produced using simple equipment by mixing cement and water with material obtainable nearby without classification, gradation adjustment or washing. When CSG is manufactured, gradation adjustment of CSG material such as sorting, blending, etc. is not carried out, other than removing or crushing oversized pieces, and cleaning. Thus, the equipment required to manufacture CSG is minimal: a simple continuous CSG mixing system **(Photo-6~9)**.

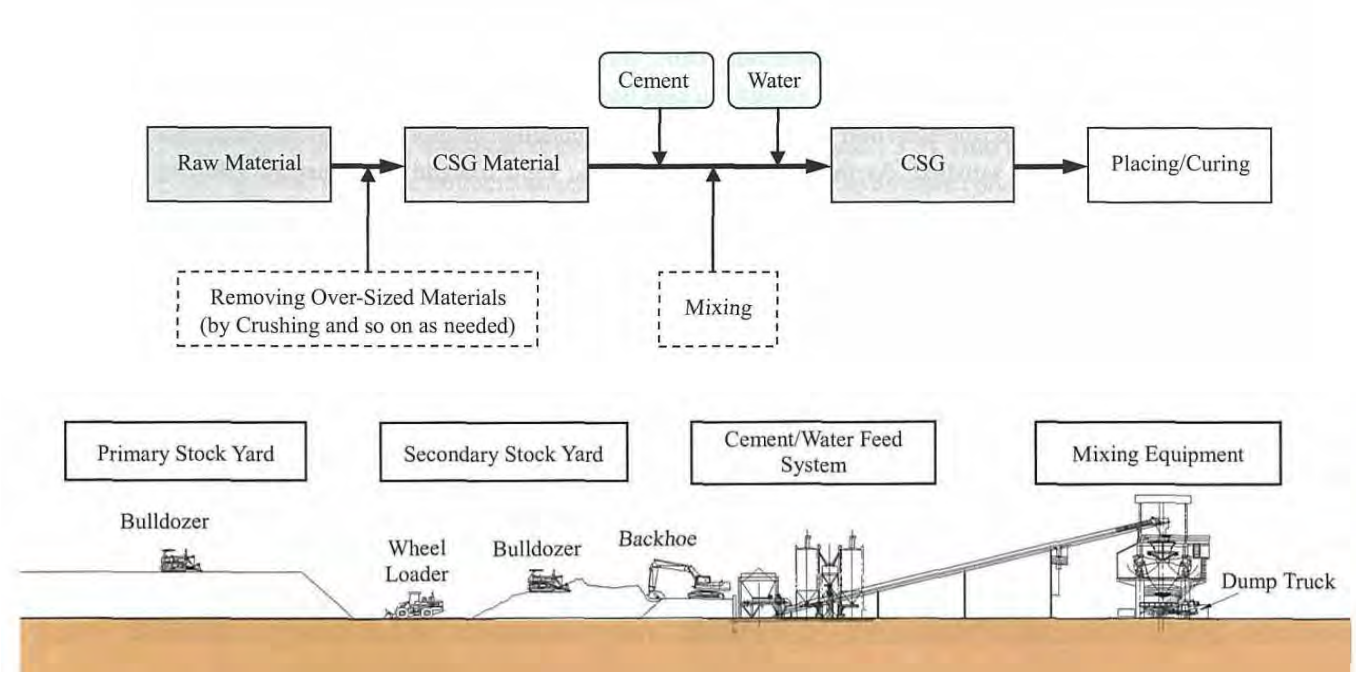



Fig.-18 CSG Manufacturing Process

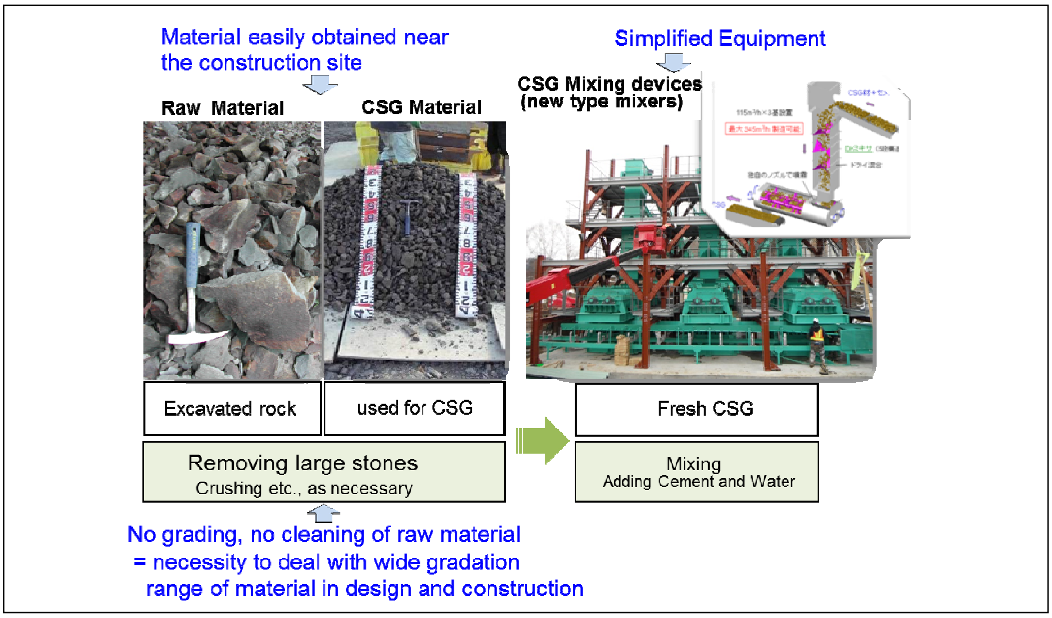



Photo-6 CSG Manufacturing Process of Apporo Dam

**CSG Material**
**Raw material**

**Gravel which was excavated in the riverbed is used as raw material**

**Machinery**
**Continuous Mixer**

**Producing CSG is conducted with a high performance continuous mixer (SP-Mixer)**

Photo-7 CSG Manufacturing Process of Tobestu Dam

**CSG Material**
**Raw material**

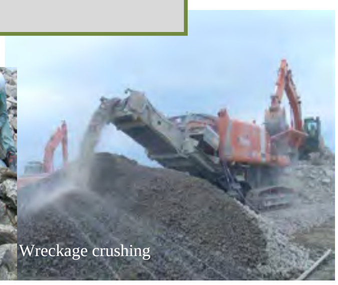
**Gravel which was excavated in the riverbed is used as raw material**

**Machinery**
**Zcross Mixer**

**Producing CSG is conducted with high performance mixer**

Photo-8 CSG Manufacturing Process of Kin Dam

Concrete wreckage




Manufacture of CSG


Photo-9 CSG Manufacturing Process of Small CSG Structure (Coastal Levee)

### Raw Materials of CSG

CSG consists of is rock-like materials such as material excavated to form the foundation, riverbed sand and gravel, terrace deposits, weathered rocks, and quake concrete wreckage; all of which can be obtained relatively easily **(Photo-10)**.

CSG requires less strength than concrete, so the CSG raw materials may be lower quality than the rock used as concrete aggregate.

Many kinds of rock-like materials can be used as CSG materials. However, we should decide the applicability of candidate materials, as CSG materials, considering the strength, mixing condition, execution condition and so on. For example, when the material proposed contains high fine particle contents, there is high possibility of low strength and workability.

(River Bed Gravel and Sand)

(Terrace Deposits)

(Quake concrete Wreckage)

(Excavated Rock)

Photo-10 The Raw Materials of CSG

## Quality control of the CSG material

The quality control for CSG contains three main items:

- Quality control of CSG
- Quality control of raw material
- Quality control of CSG material

Quality control of CSG is performed at the mixing equipment site and at the placing site.

At the mixing equipment site, unit water content and gradation are controlled by simple methods (**Photo-11)**. The frequency of measurement is set to be high at the early stage of execution, and then the data analyses of the results are conducted in order to set an appropriate frequency. And in the mixing equipment, weights of water, cement, CSG materials are controlled. In principle, the material is supplied continuously so weighing should be done in real time.

Next, at the placing site, the roller compaction frequency is controlled as compaction energy control **(Photo-12)**. As an extra precaution, an on-site density test is done to confirm that the control system is operating normally, for example, to check whether the quality of the material has changed, or if the weighing, spreading, and roller compaction, etc. are being done appropriately.

A strength test of specimens is also done in a laboratory **(Photo-13)**, which is for the same purpose as the on-site density test, and the younger age strength, such as a 7-day strength test is usually used to check this as early as possible.

(Grain size distribution)

(Unit water content)

Photo-11 Quality Control Management Tests of the CSG Material
(At the mixing equipment site)

Photo-12 Control of Roller Compaction Energy
(At the placing site)

Photo-13 Strength Test of CSG Specimens
(In Laboratory)

## <u>Quality control Method of the raw material and the CSG material</u>

Quality control of the raw material is done to confirm whether or not the quality of the raw material has changed greatly, and considering the time required to remake the Diamond Shape according to changes of quality, this is done to clarify the quality at least one month before execution.

The items controlled for CSG materials are surface dry density, absorption coefficient, gradation, and surface water content.

Quality control of CSG material is performed in the primary stock yard (quantity scheduled to be used in 3 to 5 days) and in the secondary stock yard (enough for the next day's work).

Sufficient material for the next 3 to 5 days is stocked in the primary stockyard, considering the time required (approx. 3 days) to test the surface dry density and absorption coefficient.

Table- 3 Considering the time required to do the test

| Day | Item |
|---|---|
| 1st day | 24hour water absorption |
| 2nd day | Measuring surface density, 24hour for drying |
| 3rd day | Measuring absolute dryness |

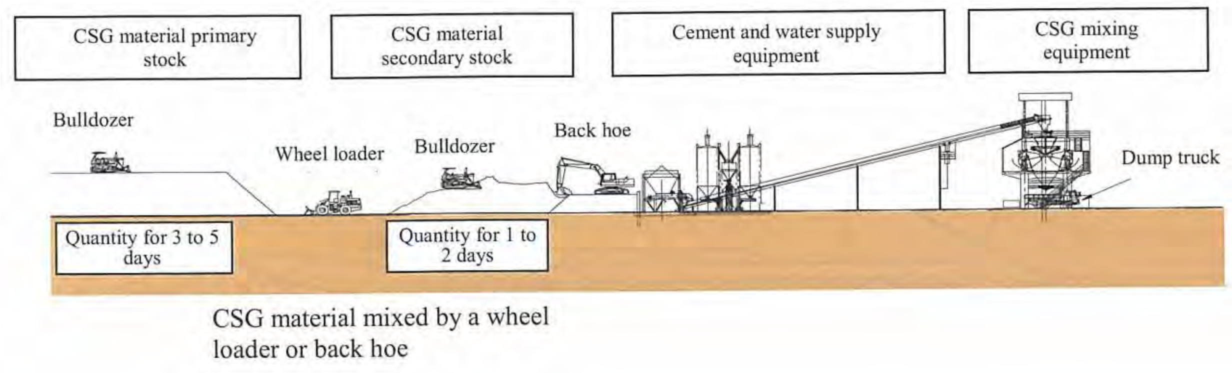



Fig.-19 Flow from Stocking of CSG Material to Production of CSG

Photo-14 Primary Stock of CSG Material

Photo-15 Secondary Stock of CSG Material

# 4. Construction

## Construction Flow for a Trapezoidal CSG Dam

The CSG construction method can, like the RCD method, be executed by the layer placing method using general-purpose machines such as dump trucks, bulldozers, and vibrating rollers. The unit cement content is small and almost no bleeding occurs, so green-cutting is unnecessary.

CSG is made by mixing cement and water with CSG material. A continuous mixing system is used, which is simpler than a normal concrete mixing system.

The unit cement content is small and almost no bleeding occurs, so green-cutting is unnecessary.

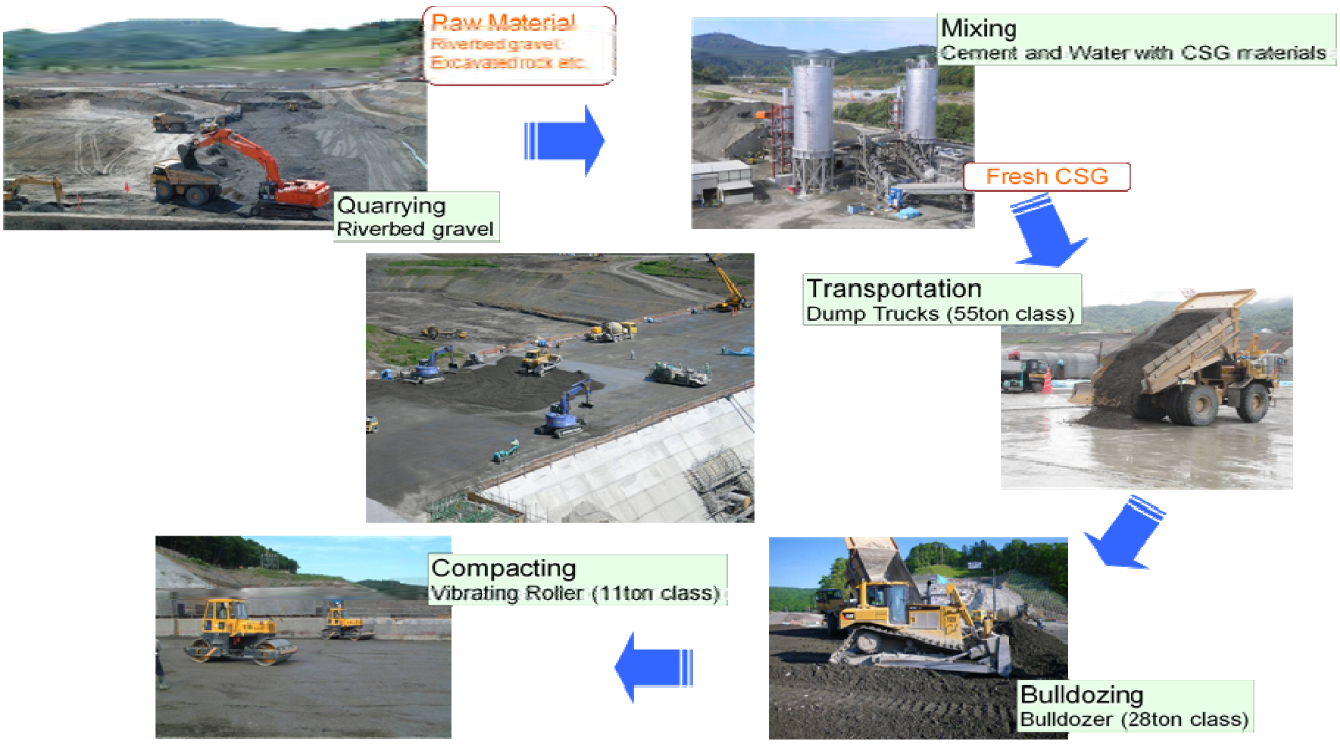



Photo-16 Construction Flow for a Trapezoidal CSG Dam

## Construction Flow for small CSG structures (Example of CSG coastal levee)

The CSG construction method for small structures can be executed by utilizing widely small size general-purpose machines.

## Manufacturing Facilities of CSG

When CSG is manufactured, gradation adjustment of CSG material such as sorting, blending, etc. is not done, other than removing or crushing oversized particles, and washing is also not done, so the equipment required to manufacture CSG is very simple: simple continuous CSG mixing systems are used **(Photo-17,18)**.

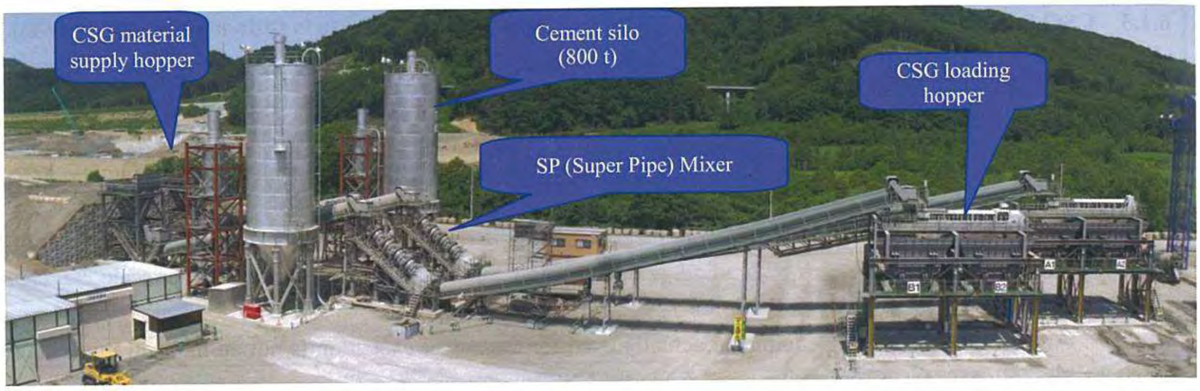



Photo-17 CSG Production Equipment (Tobetsu Dam)

Zcross Mixer (Kin Dam)

Mobile Soil Remediation Machine (For Small structure; Natsui Coastal Levee)

Photo-18 CSG Mixing Systems

## Construction Facilities

For rapid execution, there are almost no restrictions on equipment for material production and mixing of CSG. Therefore, the manufacturing equipment for CSG material and CSG can be selected flexibly to suit the execution speed.

Next, the placing work of the trapezoidal CSG dam consists of:

1) CSG placing work,

2) Protection concrete placing work, and

3) Formwork installation work, but performing these works at the same location greatly reduces efficiency. Therefore, these placing works are done at different times to avoid interference and ensure smooth construction of the dam body.

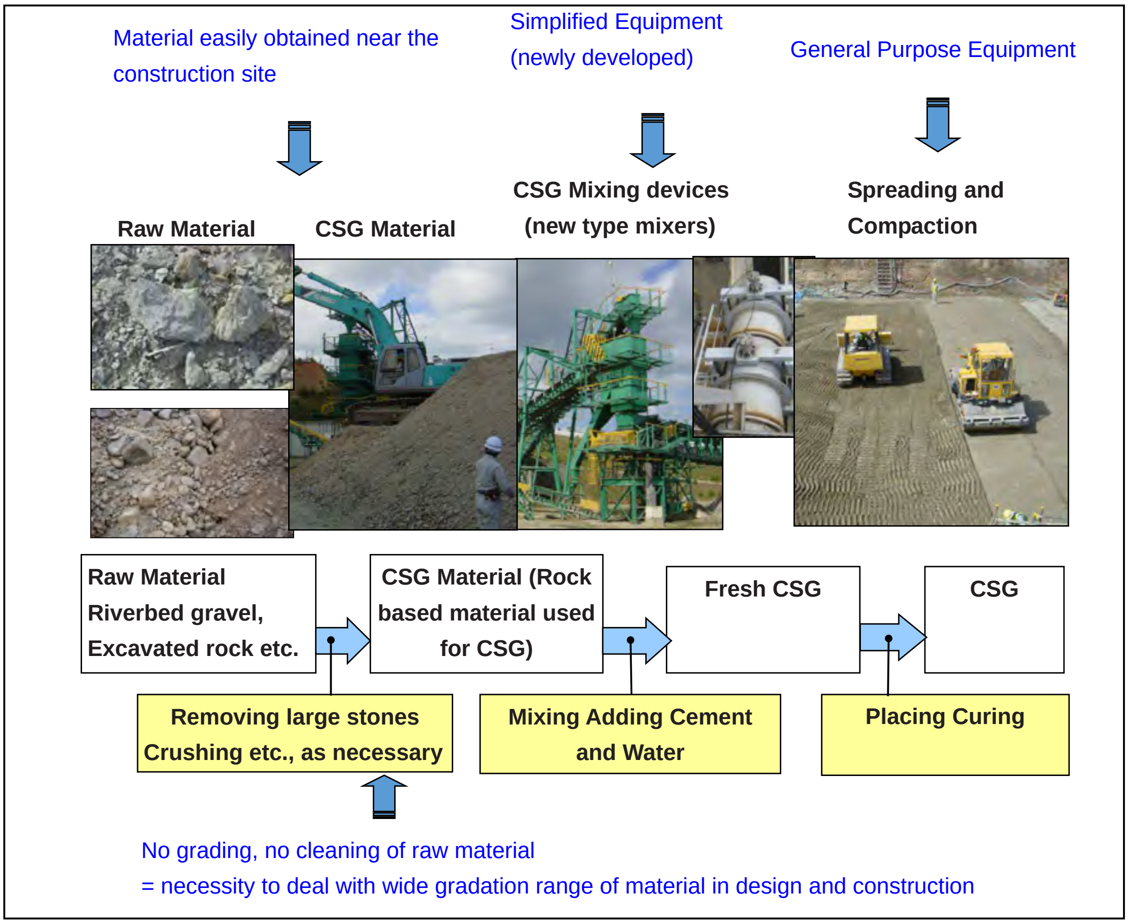



Fig.-20 Manufacturing Flow of CSG

Photo-17 CSG Placing Work

Photo-18 Protection Concrete Placing Work

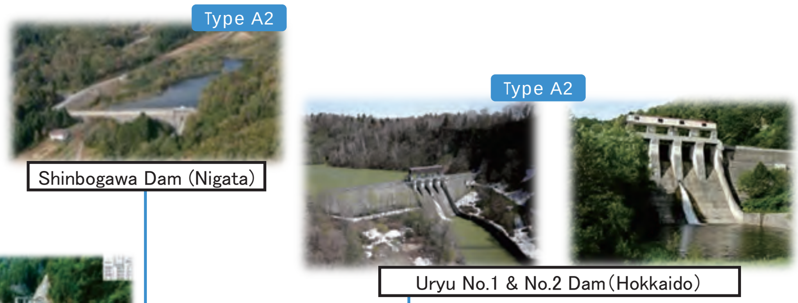
## References

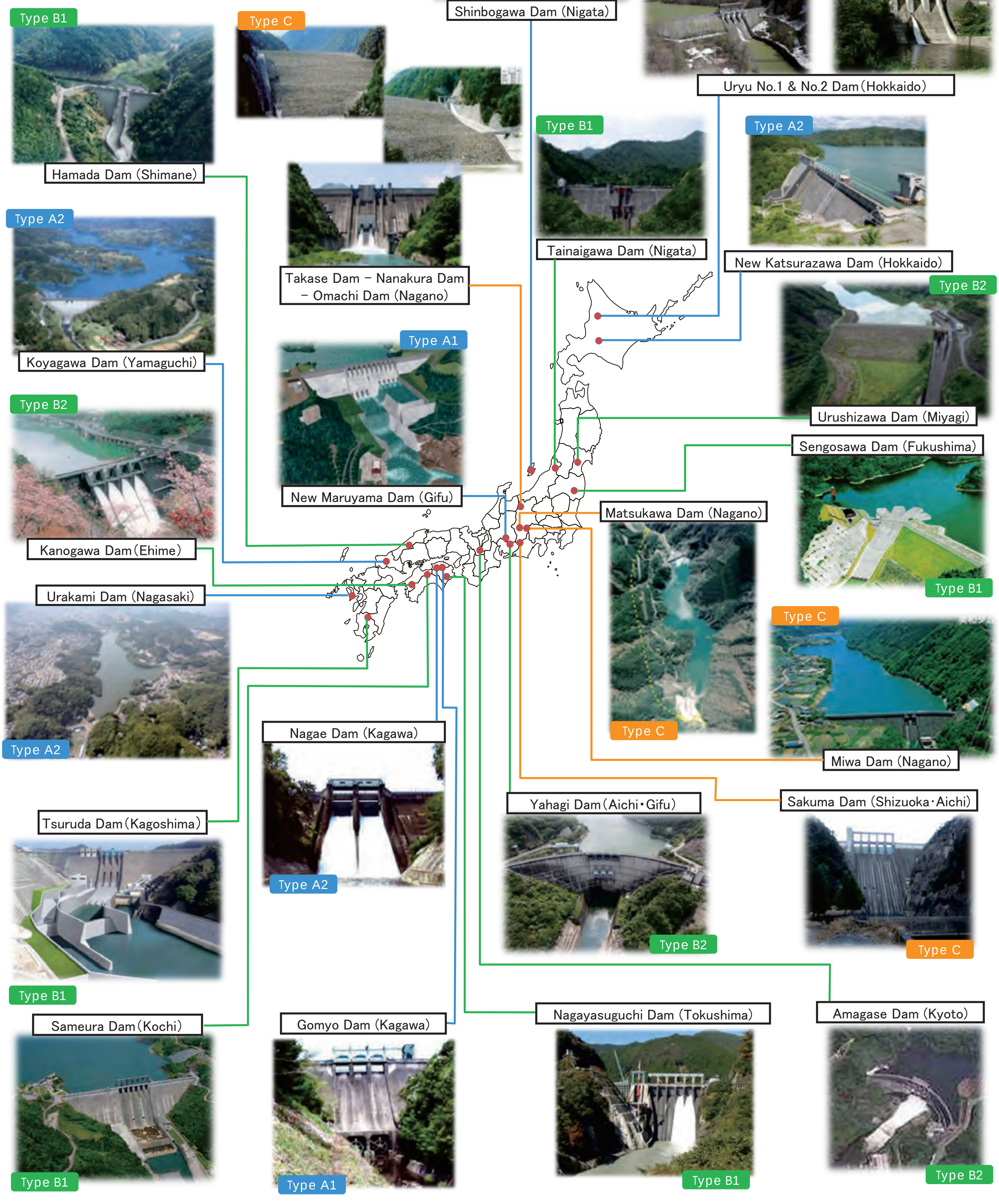

- Engineering Manual for Construction and Quality Control of Trapezoidal CSG Dam 2007, Japan Dam Engineering Center
- Engineering Manual for Design, Construction, and Quality Control of Trapezoidal CSG Dam 2012, Japan Dam Engineering Center

# Upgrading Dams with Japanese Advanced Technologies under Operation

# Upgrading of operating dams
## (Major projects)

Type A1 : Increasing capacities by constructing new dam body
Type A2 : by raising dam bodies
Type B1 : Additional outlets by drilling technologies
Type B2 : by tunnel technologies
Type C : Sediments management facilities

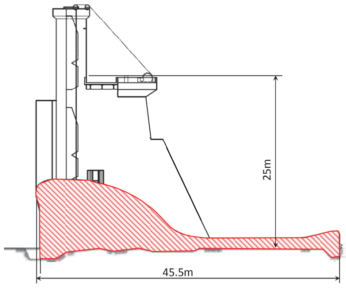


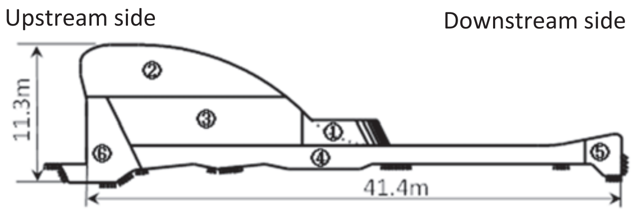
# Controlled blasting technique with an electronic detonator

In the conventional blasting technique with a DS (decisecond-level) electric detonator, the gas created by the previous blast escapes through the construction joints before the next blast occurs, which makes this technique not suitable for concrete demolition. Therefore, by adopting the MS (millisecond-level) electric detonator, the next blast is successfully detonated before the gas escapes.

However, there were concerns about a blast vibration at private residence area exceeding the limit value set by management standard. Our solution was to deploy an electronic detonator (product name eDev II) and set one-hole one-step blasting with a time difference of 15 milliseconds, which enabled demolition blast to generate moderate vibration that was significantly lower than the standard limit value.




Part to Be Demolished by Blasting




Procedure of Demolition by Blasting

Drilling

Charging explosives

Blasting completion

【Characteristic】

- Time setting in arbitrary milliseconds for each detonator is possible on the spot.
- Time setting can be set in 1 ms increments within range from 0 to 20,000 ms.
- The precision of the set time is ± 0.1%.
- Includes safety devices to protect integrated circuits in the detonator from high voltage such as static electricity or induced current due to lightning strike.
- Includes a capacitor that stores the energy necessary for communication with the explosive device as well as for ignition.
- Each explosive device can detonate up to 500 electronic detonators.

This technique is effective in cases such as blast vibrations need to be suppressed, especially when other properties are in close proximity, or in when construction time is too limited to deploy conventional blasting technique.

【Regarding Environment, Surroundings, etc.】

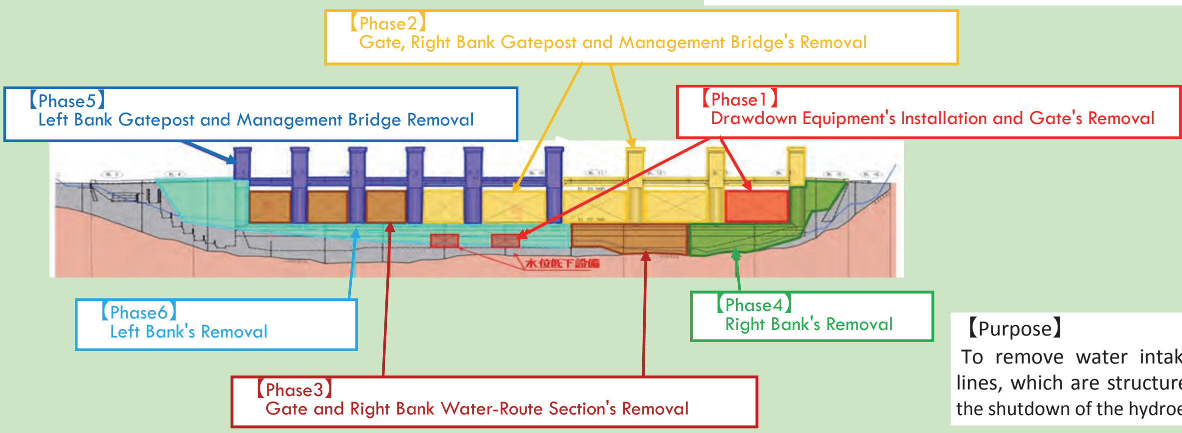
(Plan) Vibration level: not to exceed management standard value of 75 dB
(Actual) Vibration level: actual value of 61 dB (average)

【Future Prospects】

- Among controlled blasting methods for demolition, this technique is the most superior at present.
- In the introduced case, we set 15 ms as the time difference, however, we are still working on finding the optimal setting.

## Work Description

【Dam】 Arase
【Type】 Concrete gravity dam
【Dimensions】 Height 25 m Length 210.8 m Volume 47, 167 m³
【Purpose】 Power generation




【Purpose】
To remove water intake facilities and drainage lines, which are structures inside the river, due to the shutdown of the hydroelectric power station.

# LIBRA-S Method: Temporary piers oblique tie installation method

【Purpose】 To streamline the submerged brace installation work for temporary platforms.

【Background of selection of the method】

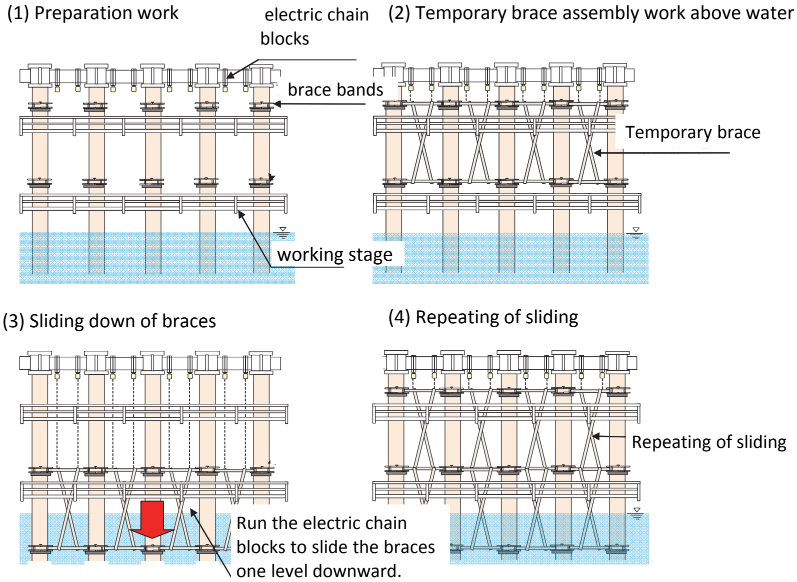
The brace installation work had been carried out using divers. However, the small range of visibility of the dam interior significantly harmed the work efficiency. The high turbidity of water after floods suspended the work for several days. Due to these, this work method to streamline the underwater operations was developed.

【Construction conditions】 Construction depth: 0 - 30m

【Outline of work method】

In constructing the substructure (brace) of a temporary platform, unit substructure members are assembled above water and slid downward and installed, thereby considerably reducing the diving operation.

- Most of the braces are assembled on stages installed above water, which reduces submerged operations, leading to an increase in the construction efficiency and safety.
- Once the work is completed, only bolts are loosened under water then the substructure members are collected in succession and demolished above water. This also results in higher safety and efficiency.



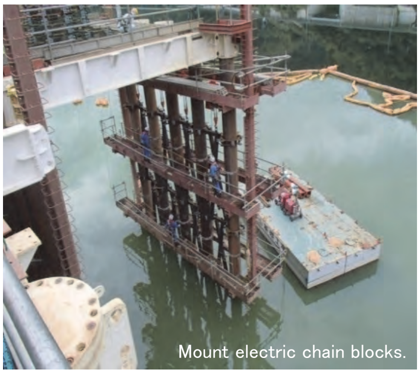

(1) Preparation work
Install a hanging working stage above water.
Mount electric chain blocks onto the upper structure girder.
Tie brace bands onto steel pipe piles to couple braces and steel pipe piles.

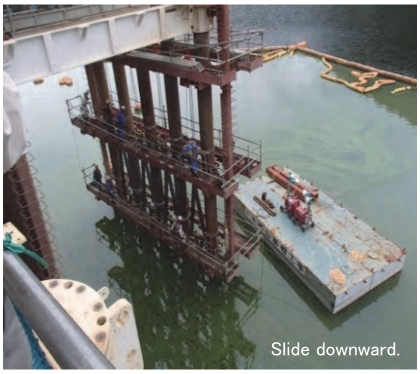
(2) Temporary brace assembly work above water
Install horizontal and diagonal members.
Hook the chain on a hanging jig on the upper horizontal members.

(3) Sliding down of braces
Run the electric chain blocks to slide the braces one level downward.

(4) Repeating of sliding
Repeat the above steps from tying brace bands in (1) to the rest.


Assemble members.

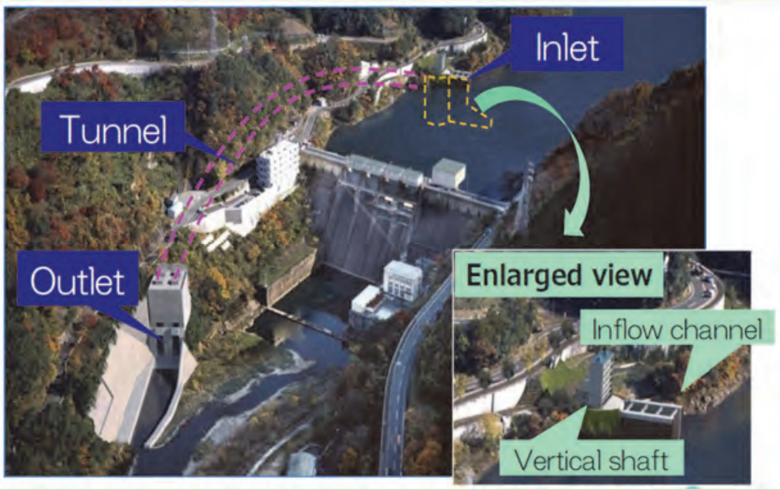

Mount electric chain blocks.


Slide downward.

## Summary of the project

【Dam】Kanogawa dam
【Type】Gravity concrete dam
【Specifications of the dam】
Height：61m、Crest length：167.9m、Volume：161,000m$^3$
【Purpose】
Flood control、hydropower

【Purpose of work】
A tunnel spillway will be constructed on the right bank of the dam in order to increase the flood regulation capacity of the existing Kano River Dam 1.4-fold.
Tunnel spillway:
Standard finished inner diameter: 11.5m; maximum cross section of excavation: 320m$^2$




Source: Ministry of Land, Infrastructure, Transport and Tourism, Shikoku Regional Development Bureau pamphlet

# Full Rotation and Full Casing Method

【Purpose】To bore holes for installing steel pipe sheet piles in the bedrock under water.

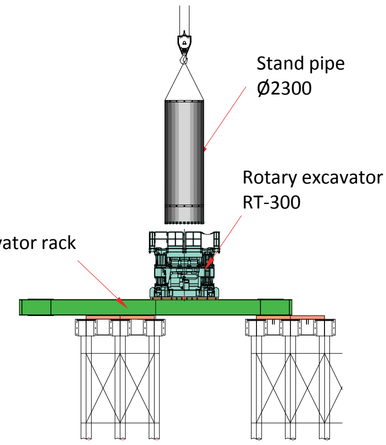
【Background of selection of the work method】

・Relatively economical for the excavation of 2m-dia. and max. 30m-deep holes in submerged bedrock.

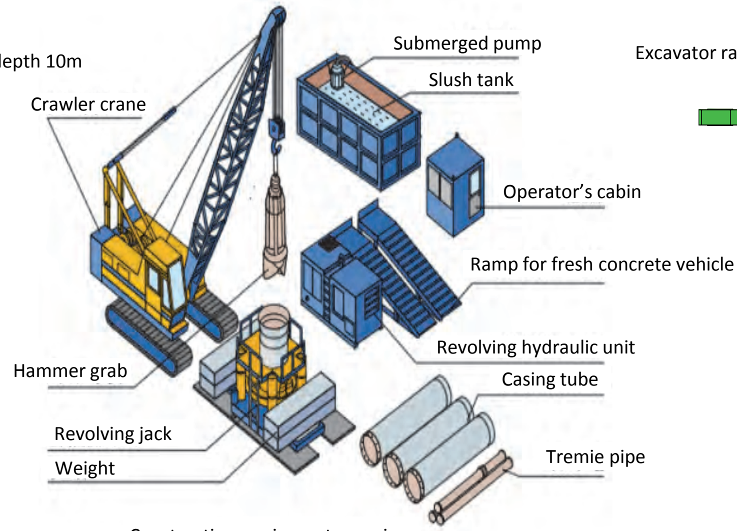
・Has an operational record.

・Applicable to a wide range of bedrocks.

Construction site view with rotary excavator RT-300




Excavation scale:
Width 10m x length 45m x maximum depth 30m
Excavation volume: 4,900m$^3$
Excavation shape:
Width 11m x length 11m x average depth 10m



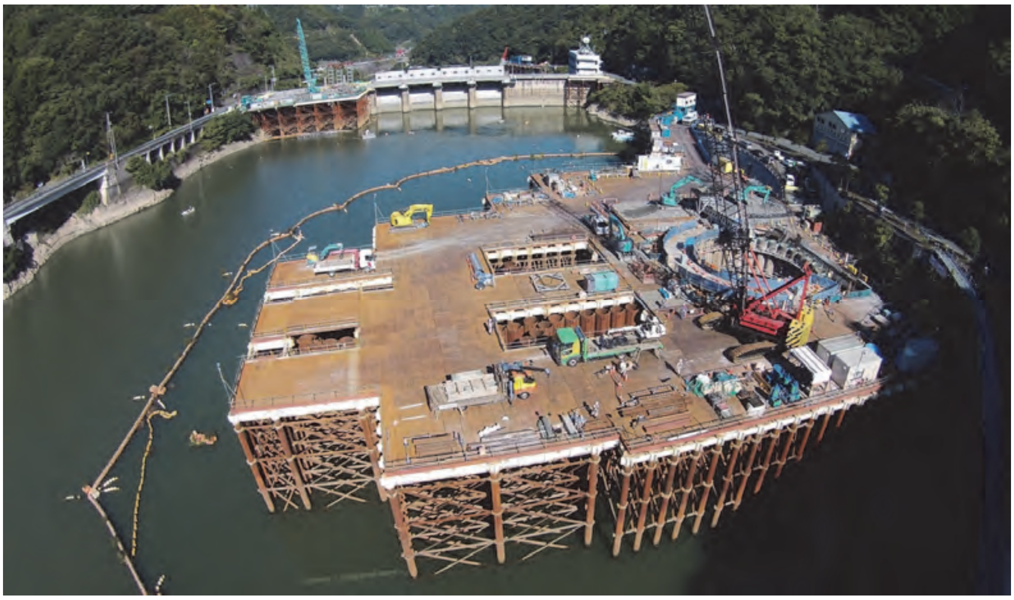

Construction equipment overview

【Characteristics】

・This method can apply to a wide range of soils and also allows for greater construction depth and excavation diameter than other methods. (Excavation depth: about 50m; excavation diameter: 3,000mm)

・The method supports most soil conditions.

・Clayey soil deposits on the outer periphery of the casing could increase a friction resistance, possibly hampering or preventing the revolving of the casing.



## Summary of the project

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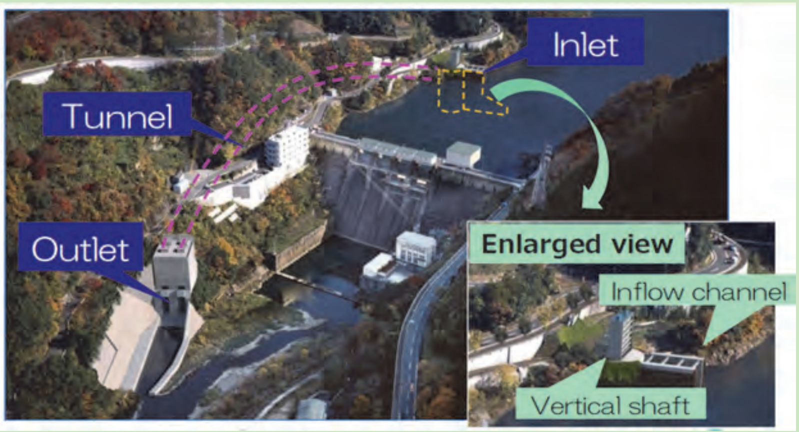
Tunnel spillway:
Standard finished inner diameter: 11.5m; maximum cross section of excavation: 320m$^2$




Source: Ministry of Land, Infrastructure, Transport and Tourism, Shikoku Regional Development Bureau pamphlet

# Underwater wire saw method

【Purpose】 A part of underwater concrete structure was cut and removed by the wire saw, which was then placed above water level.

【Selection process of method】

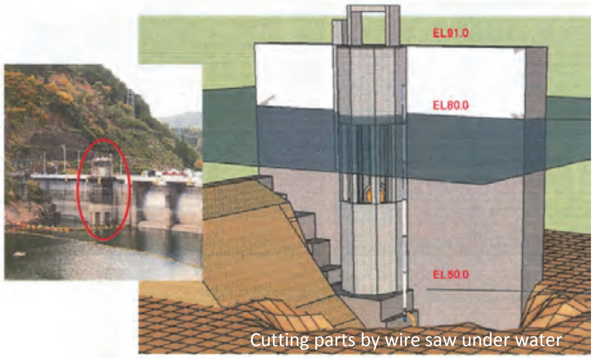
Because of the lack of visibility in the reservoir (only 0～1m), the original method, that the main body was set underwater was changed to the alternative method that the main body was set on the barge above water level and extend wire into water , since it will be difficult to cope with incase of cutting the wire, and it has less ability of cutting, etc.

(Adopted wire saw：K-WAC-04、32.2Kw)

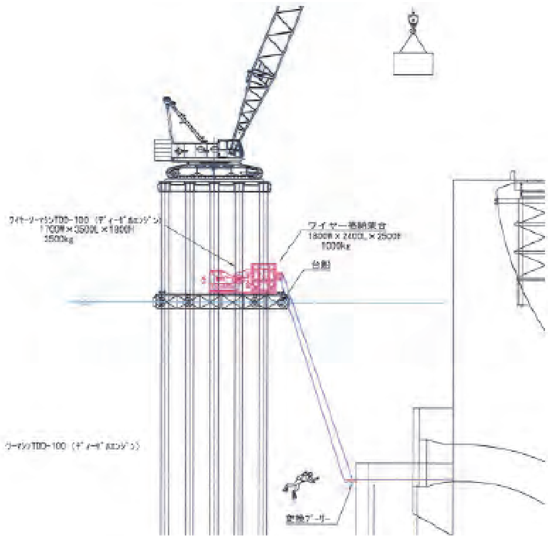
【Conditions】 Water depth：0～30m、Concrete strength：Approximately 30N/mm$^2$

【Features】

・Under water concrete structure was cut by wire saw and was placed above water level.
・It is possible to execute when that the reservoir has the lack of visibility and it is difficult to work underwater.
・Maintenance work is easy because the wire saw itself is placed above water level.
・It is not necessary for the wire saw to replace every place to cut off.
・Great depth result in the increasing the risk of cutting wire because the length of the wire saw is long.
・Since the method use crane, restraint time will be longer.

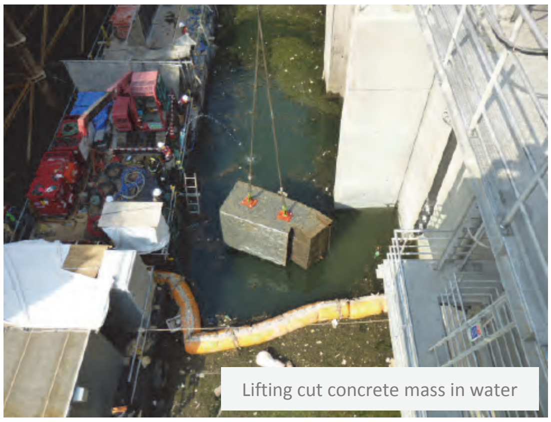


Cutting parts by wire saw under water



Cutting of the concrete structure undrewater by wire saw


Cutting of the concrete structure


Lifting cut concrete mass in water

【Procedure of the work】

( i ) Set the wire saw body (cutting machine) on the barge and cut the concrete in the underwater block into blocks of 20 t or less.

( ii ) Cut the concrete block by lifting it with a crawler crane (120 t) placed on the temporary gantry.

( iii ) Dispose of the removed concrete lumps in large trucks after handling them to a predetermined location.

## Summary of the project

【Dam】 Kanogawa dam
【Type】 Gravity concrete dam
【Specifications of the dam】
Height：61m、Crest length：167.9m、Volume：161,000m$^3$
【Purpose】
Flood control、hydropower

【Purpose of the project】

A tunnel flood discharge is newly constructed on the right bank of the dam, with the aim of setting the flood control capacity of the existing Kanogawa dam 1.4 times.

A tunnel flood discharge:

Standard inside diameter 11.5m, Maximum excavate section 320m$^2$

In the Kano River dam remodeling project, new low water discharge facility "and "selective water intake facility" are constructed for the purpose of preventing cold water discharge and prolongation of turbid water discharge and suppressing eutrophication of reservoir.

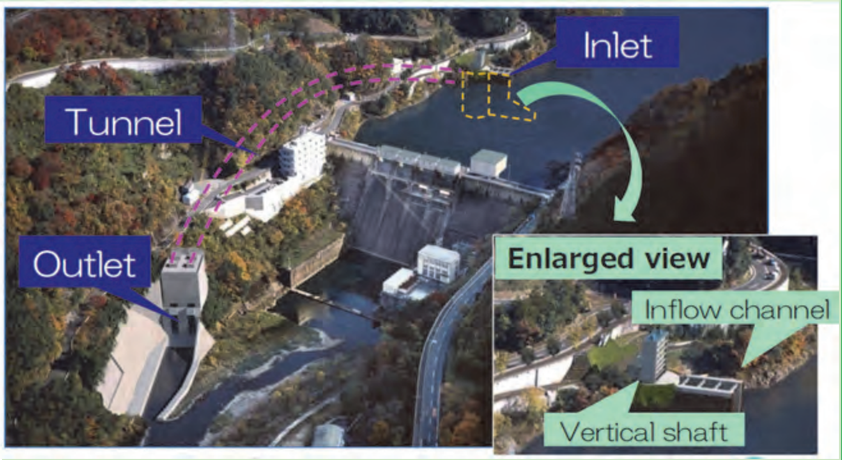
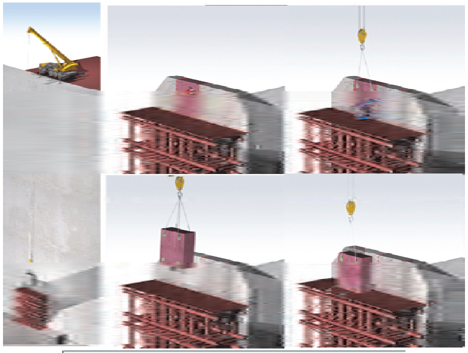



Image of the project

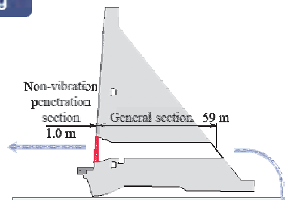
"Reprinted from the pamphlet of Yamasakizaka Dam Construction Office, Shikoku Regional Development Bureau, Ministry of Land, Infrastructure and Transport"

# Drilling the existing dam body using road header

Dam-body Drilling



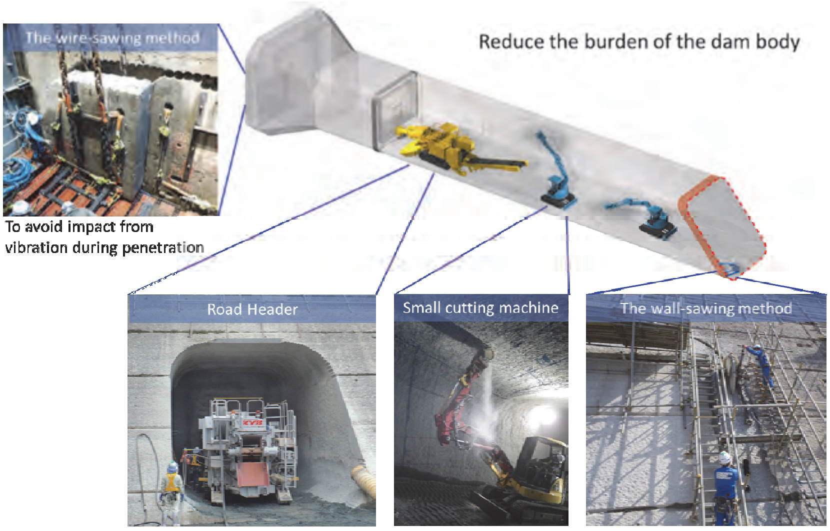
Overview of the non-vibration penetration technique




Longitudinal profile of the drilled dam-body

Drilling the dam-body

In the existing dam, a total five holes were drilled: three for the expansion of discharge pipes and two to move the power generation intake pipes.
To drill five locations in the same dam-body is the largest scale in Japan, as a dam upgrading work.
The drilling depth per hole is approx. 60 m, which contains a section of 1 m of upstream non-vibration penetration section (hole size: vertical 6 m, horizontal 6 m).
To drill the general section, a 200 to 240 kW class road header was used.
The vibration value on the dam-body was mesured to confirm if there are any effects on the dam-body.
This picture shows the drilling work performed by a road header.
As it was reported from similar construction that vibration would be the strongest at the time of penetration, the non-vibration penetration technique was adopted to avoid impact from vibration during penetration.




The wire-sawing method: To avoid impact from vibration during penetration

Road Header: Main drilling, reduction of vibration at the time of drilling

Small cutting machine: Finish drilling, improvement of drilling accuracy

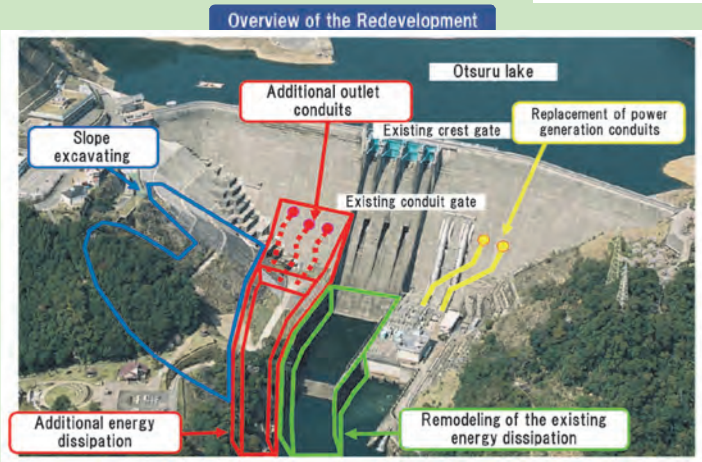
The wall-sawing method: To avoid impact from vibration at the time of drilling start

## Summary of the project

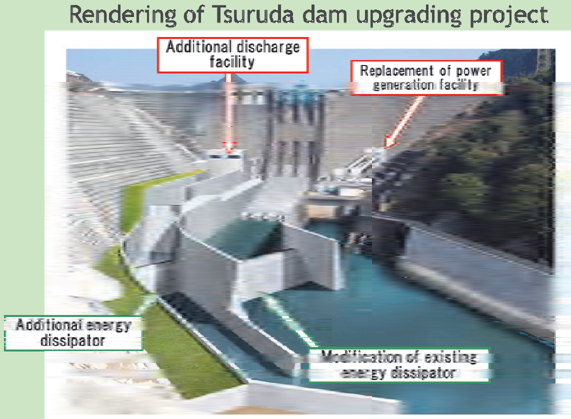
【Dam Specifications】
Type：Concrete gravity dam
Height：117.5m
Length：450.0m
Volume：1,119,000m$^3$
purpose：flood control and power generation

The concept of the project is to increase flood capacity and discharge facilities.
The increase in flood storage will increase to a total capacity of between 75 million m$^3$ and 98 million m$^3$ by transferring the power generation capacity during flood season of 2.5 million m$^3$ and dead water storage of 20.5 million m$^3$, for a total of 23 million m$^3$, to flood storage.The discharge facility was expanded to enhance discharge capacity by adding three conduit gates on the right dam-body (EL 115.6) at a location lower than the current discharge facility (EL 130.0) in accordance with the decline of the lowest water level.

Overview of the Redevelopment

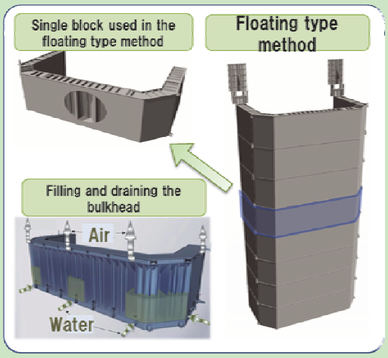



Rendering of Tsuruda dam upgrading project

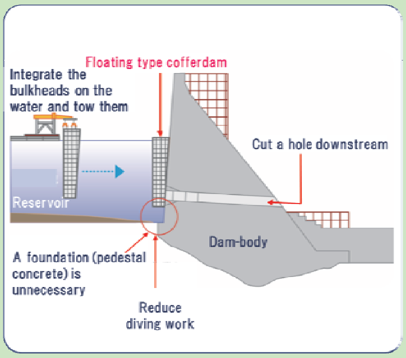


# Floating type temporary cofferdam method

## Overview of New Technologies



Bulkhead structure of floating type method




The cofferdam construction requires long diving hours at a very deep water depth, large temporary equipment, and a long construction timeframe.

For the floating type temporary cofferdam method, steel plates (skin plates) are attached to both the inside and outside of the bulkhead to make an airtight structure, and this becomes the buoyancy chamber to make the bulkhead float.
It is important to maintain the balance between buoyancy forces and dead weight by filling and draining the bulkheads blocks in the proper order.
And this new method was used for the first time in the Tsuruda Dam upgrading.

## Efficiencies of the technologies

| | |
|---|---|
| Increasing safety | Reduce diving works in deep water |
| Shorter construction | Unnecessary to prepare large-scale temporary equipment |
| Cost reduction | Unnecessary to prepare large-scale temporary equipment |
| Increasing quality | Improving water tightness (The bulkhead blocks can be assembled out of the water) |
| Decreasing the environmental burden | Unnecessary to prepare under water equipment |

## Construction Method


Transport bulkheads on the water


Integrade the bulkheads on the water


Tow the cofferdam


Draining the bulkhead blocks


Draining water from the cofferdam


Completion

For actual construction, bulkhead blocks made at local factories will be assembled on the reservoir to standardize them and they will be towed to the installation position by a ship, and subsequently pulled by a winch and secured.
And then, water is drained from the cofferdam.

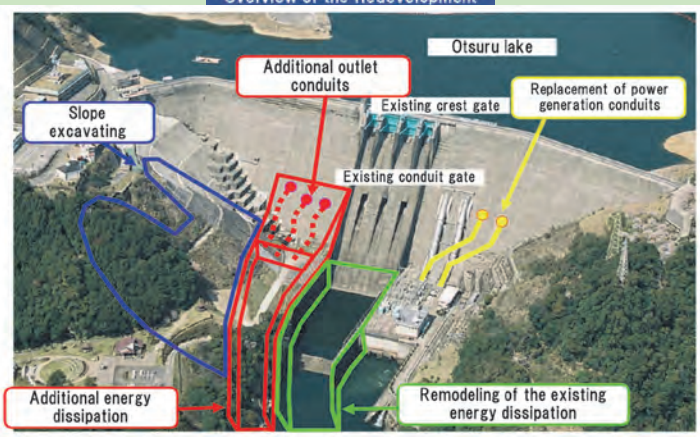
Efficiencies of this method :
This is dependent on scale of the cofferdam and construction depth, as large temporary facilities, such as pedestal concrete and support framework, are unnecessary and diving work can be greatly reduced, costs and processes can be reduced, and safety can be improved, leading to an increase in construction efficiency.
Moreover, when drilling holes in the same dam, it is necessary with conventional methods to dissemble and then reassemble the bulkheads, but with this method there is no need to disassemble the bulkheads; flood the cofferdam and detach the bulkheads from the dam-body and tow it as is to the next construction site where it can be installed.

## Summary of the project

【Dam Specifications】
Type：Concrete gravity dam
Height：117.5m
Length：450.0m
Volume：1,119,000m³
purpose：flood control and power generation

The concept of the project is to increase flood capacity and discharge facilities.
The increase in flood storage will increase to a total capacity of between 75 million m³ and 98 million m³ by transferring the power generation capacity during flood season of 2.5 million m³ and dead water storage of 20.5 million m³, for a total of 23 million m³, to flood storage.The discharge facility was expanded to enhance discharge capacity by adding three conduit gates on the right dam-body (EL 115.6) at a location lower than the current discharge facility (EL 130.0) in accordance with the decline of the lowest water level.

### Overview of the Redevelopment

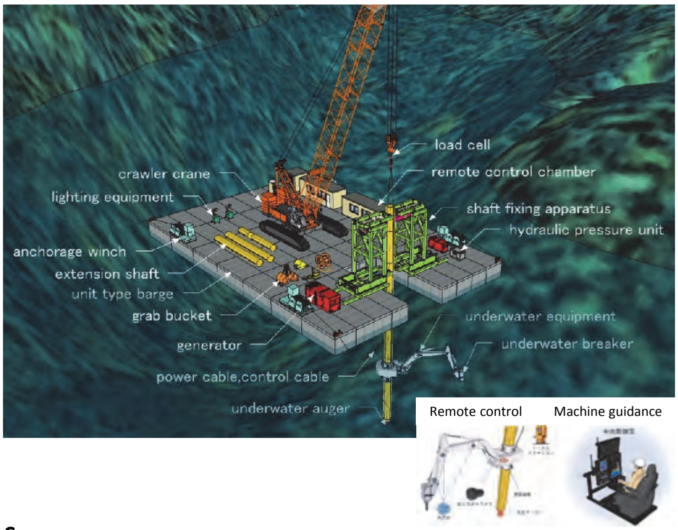



### Progress status of construction


Aerial photograph taken at the end of March 2015

# Underwater Work Method by Shaft-Style Equipment

## Remote Controlled Multifunctional Underwater Equipment
## Underwater Operation Using an Equipment with Apprratures




### Summary

This equipment enables a series of underwater operations such as rock crushing, excavation, debris, disposal, precise sounding, photography, etc. in a safe and reliable condition through remote controlling. These are carried out by using various apparatus on a machine attached to a shaft which is lowered from a barge. The machine moves up and down along the shaft.

The equipment has been developed to conduct various underwater works without divers. It is especially advantageous for works in deep, steep and limited visibility areas such as dam reservoirs. Significant improvements of safety and operational efficiency are observed through remote controlled visualization technology and computerized technology.

### Specific Features

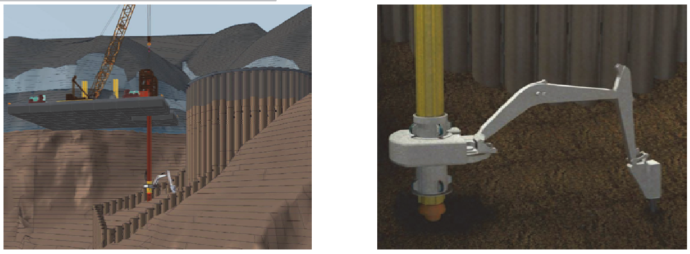
a. Enables deep underwater ( -50m) works without divers
b. Applicable for all types of reservoirs
c. Applicable for very steep areas via an equipped casing auger
d. Applicable for deep and dark reservoir bases via equipped ultrasonic camera
e. Enables precise execution via equipped sounders

### Various Apparatuses

①Erection of Shaft

②Instllation of Equipment, Launch

③Rock crushing, Debris collecting



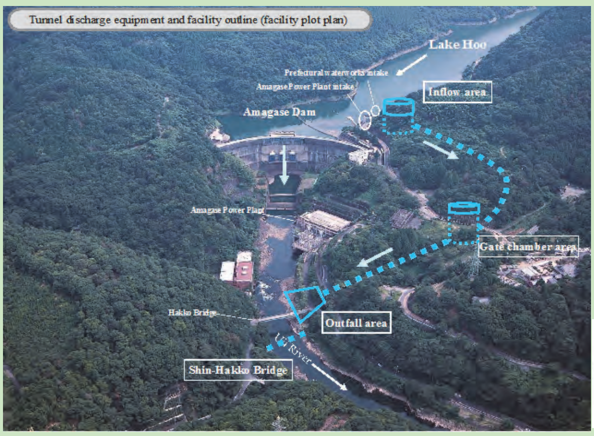
④Dredging

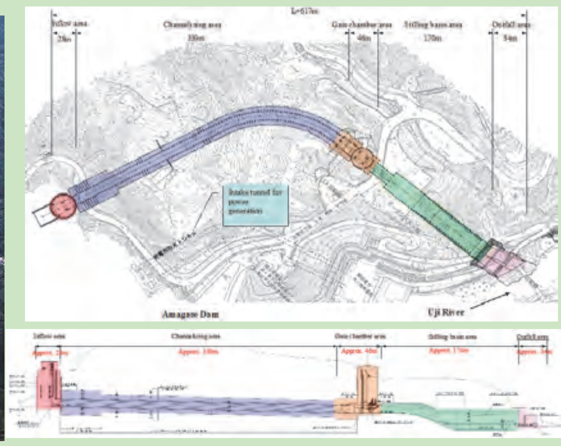
## Summary of the project

This method was adopted for the construction of the inflow and vestibule area of the tunnel discharge facility in the **Amagase Dam Redevelopment Project**.

### Amagase Dam Specifications

Model: Arched concrete dam
Dam height: 73.0m
Crest length: 254.0m
Dam volume: 122,000m$^3$
Total reservoir capacity: 26,280,000m$^3$
Effective reservoir capacity: 20,000,000m$^3$
Purpose : Flood control, Waterworks, Power generation



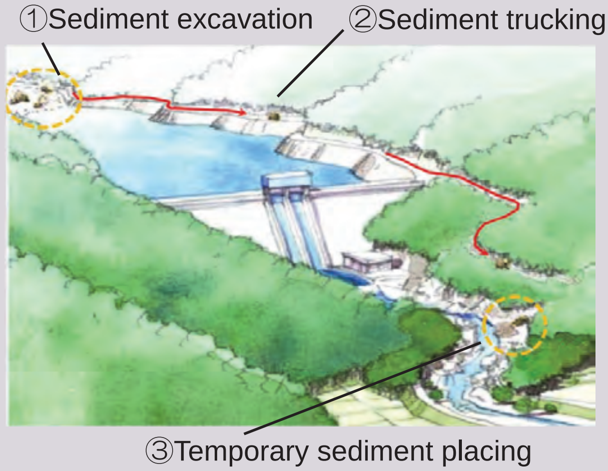



# Japanese Advanced Technologies for Sediment Management

# Replenishing to the river by artificially removing sediment and temporary placing this to the downstream
## – Countermeasures for sedimentation –

## ■ Outline

- ○ Temporary sediment placing is a method of artificially removing sediment of reservoir and check dam, trucking and temporary placing them to the downstream riverbed and flushing down by natural or artificial flood.
- ○ This method can be implemented without using special facilities and is adopted by many dams in Japan for sediment management measures and environmental improvement.
- ○ The amount of replenishing to the river is around 1 to 10 thousand m$^3$ per year, which is 1 to 10% of the annual average sedimentation.




## ■ Case on Countermeasures for sedimentation at Nagayasuguchi dam

- ○ Nagayasuguchi dam is a multipurpose dam completed in 1956 in the Nakagawa River.
- ○ The progression of sedimentation of the dam is remarkable. The sediment volume as of 2016 was 16,078 thousand m$^3$ and those sedimentation for approximately 30% of total water storage capacity.
- ○ As a countermeasure for sedimentation, 1,372 thousand m$^3$ sediments from 2007 to 2016 have been temporary placed downstream.
- ○ In the downstream river, various environments are created, including rapids, pools and dry riverbed due to sediment replenishing to the river by temporary placing to the downstream.


Nagayasuguchi Dam


● The placed sediments are flushed by natural flood



**Flood of 5,384 m$^3$/s**

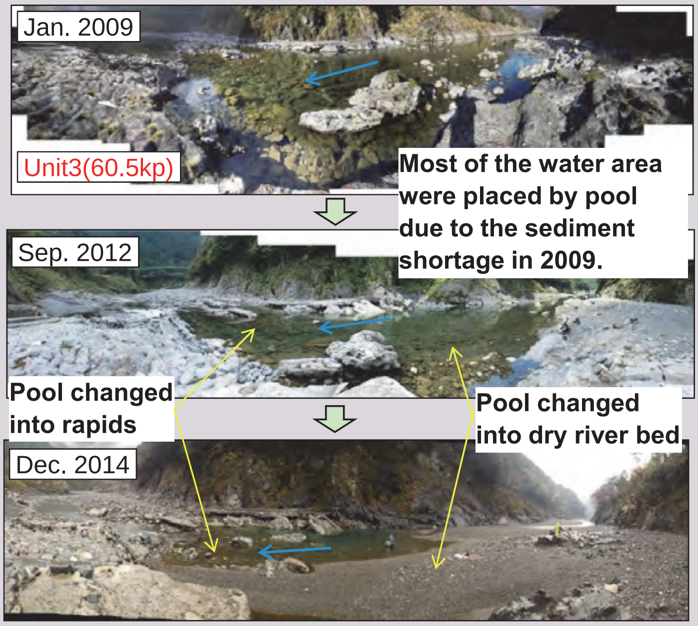
**Flood of 5,384 m$^3$/s**



**85,000m$^3$ sediments out of 85,000m$^3$ were flushed out.**

**88,000m$^3$ sediments out of 185,000m$^3$ were flushed out.**

● The change of riverbed



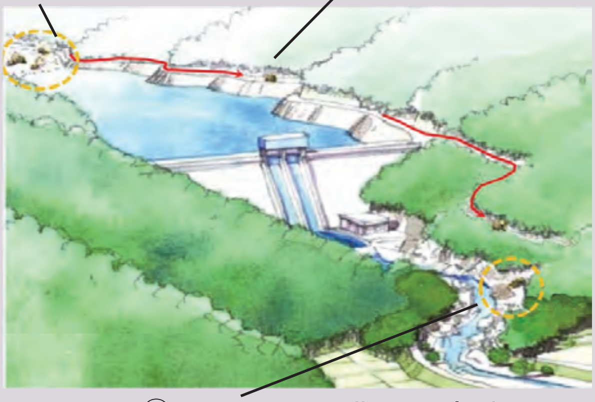

(Data provided by Nakagawa River Office. Ministry of Land, Infrastructure, Transport and Tourism Shikoku Regional Development Bureau)

## ■ Performance: We have temporary placed 1,372 thousand m$^3$ of sediments to downstream rivers in 10 years.

# Replenishing to the river by artificially removing sediment and temporary placing this to the downstream
– Improvement of the river environment –

## Outline

- ○ Temporary sediment placing is a method of artificially removing sediment of reservoir and check dam, trucking and temporary placing them to the downstream riverbed and flushing down by natural or artificial flood.
- ○ This method can be implemented without using special facilities and is adopted by many dams in Japan for sediment management measures and environmental improvement.
- ○ The amount of replenishing to the river is around 1 to 10 thousand $m^3$ per year, which is 1 to 10% of the annual average sedimentation.

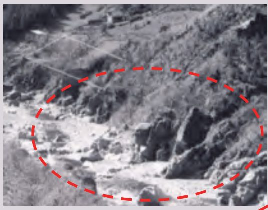



## Case on improvement of the river environment at Shimokubo dam

- ○ Shimokubo dam is a multipurpose dam completed in 1968 in the Kanna River, a tributary of the Tone River.
- ○ Sediment supply to the downstream river was blocked by the construction of the dam. As a result, river bed degradation, bed materials coarse grain progressed and the boulders of Sanbaseki-kyo, the scenic spot, were covered with moss.
- ○ Since 2003 we have replenished sediments to downstream rivers by temporary replacing them to the downstream of dam.
- ○ On the downstream river, sandbar shaping and cleansing effects (recovery of river landscape) have been confirmed by sediment replenishment to downstream.


Shimokubo Dam


**Replenished sediments by temporary placing them**

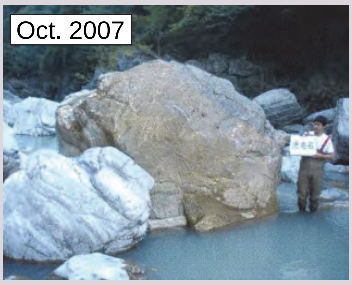

Before dam constructed (1960's)


After 44 years constructed of dam (current)

**Sand and gravel washed away from the river bed**

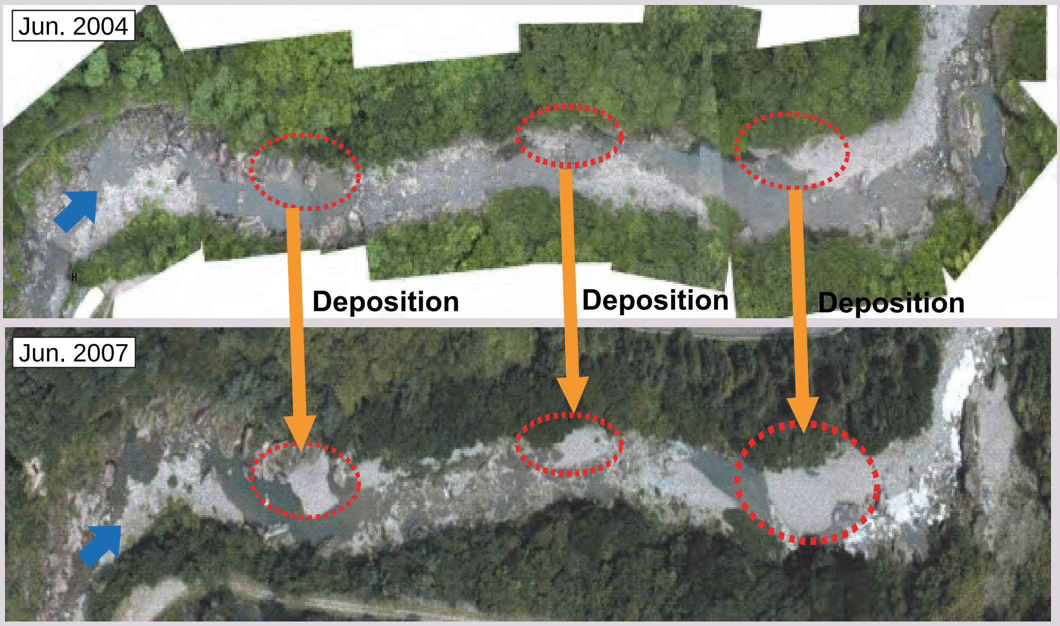
● Cleansing effects (recovery of river landscape)

Before the supplying



After the supplying

● Sandbar shaping




**Performance: We have replenished about 20 thousand $m^3$ of sediments to downstream rivers in 4 years and improved the river environment.**

# Countermeasure for sedimentation using sediment sluicing

- Total sediment management in the Mimikawa river basin -

## Outline

### Through coordinated sediment management of dams

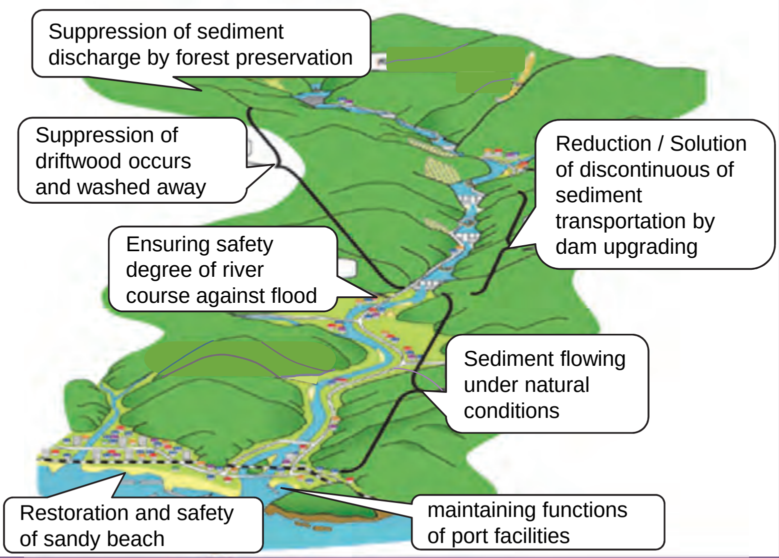
○ (Mountain zone) Suppression of discharge of sediment and driftwood by forest preservation, erosion control works and sabo works.

○ (Dam area) Recover the continuity of sediment transportation by dam upgrading and appropriate operation management.

○ (River course zone) Realize safety and biodiversity through appropriate river management.

○ (River mouth and shore zone) Conservation of sustainable estuaries and coasts through appropriate management of consistent sediment in the water system.

The vision of coordinated sediment management in a basin



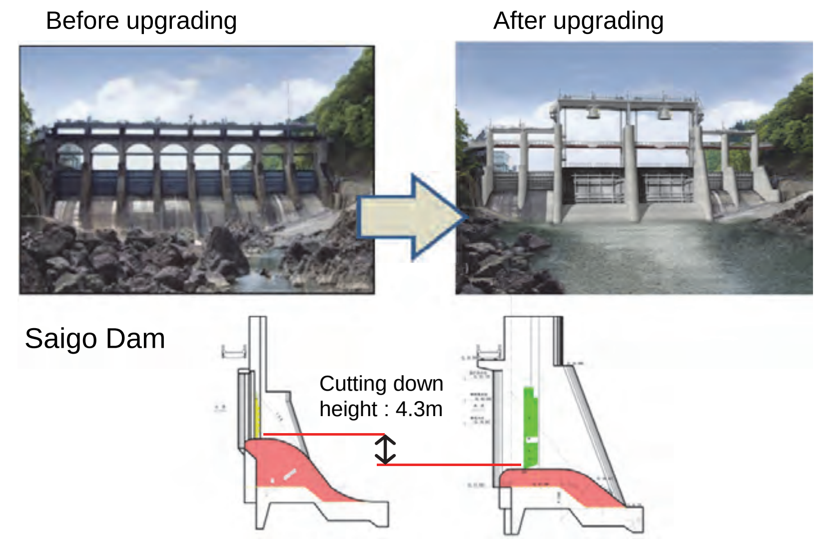

## Contents

### Scheme of dam upgrading

Implementation of dam upgrading to partial cutting down of existing dam within a range where there is no structural problem.

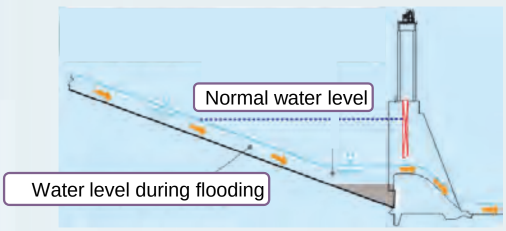
Cutting down height :

Saigo Dam = 4.3m , Yamasubaru Dam = 9.3m




### Sediment sluicing operation

○ Drawing down the water level of the reservoir beforehand at the time of large-scale flooding, and making flow conform to the ordinary river condition and sediment inflow into the reservoir.



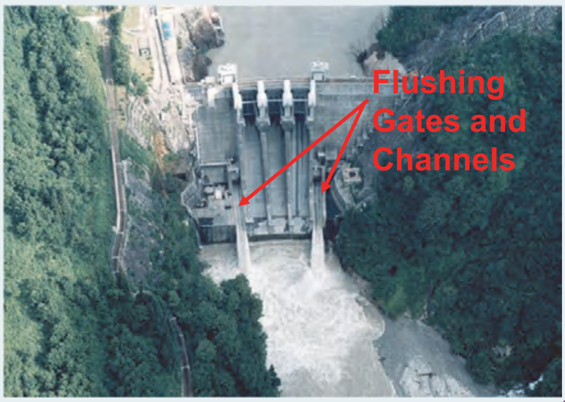

○ On the Mimikawa, River sluicing operation conducts at downstream 3 dams.


Saigo Dam (Sept. 9. 2017)

# Sediment Flushing at Dashidaira Dam

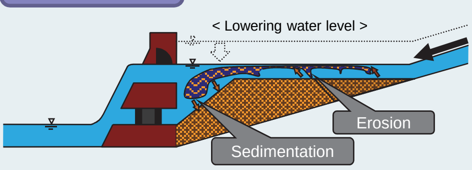
## Outline

- ○ The Kurobe River is known in Japan to produce numerous sediment due to its poor geology and heavy rainfall.
- ○ Dashidaira Dam, located 28 km upstream from the river mouth of the Kurobe River, was constructed in 1985 as the first dam equipped with full-scaled sediment flushing gates in Japan.
- ○ The flushing gate operation is optimized by lowering the water level and reaching the free-flow river condition during floods.
- ○ An environmental assessment committee has been in operation involving academic experts, which has functions of authorizing the scheme of flushing operation and evaluating the environmental impacts of flushing based on sampled data.




## Procedure for Sediment Flushing Operation

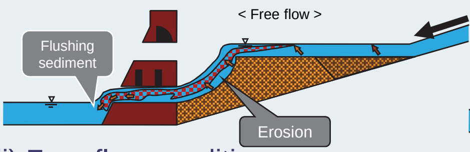
After peak of floods




### i) Lowering water level

After confirmation of the peak of the inflow, the flushing gates start opening, and then sediment upstream of the reservoir only starts to move.

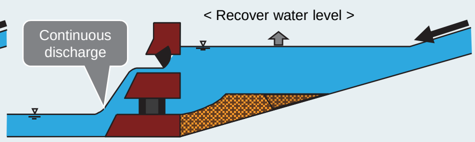
Decline stage of floods




### ii) Free-flow condition

Once free-flow river condition appears during the decline stage of floods, more sediment moves by the large tractive force of the flow and is discharged downstream through the flushing gates.

After floods

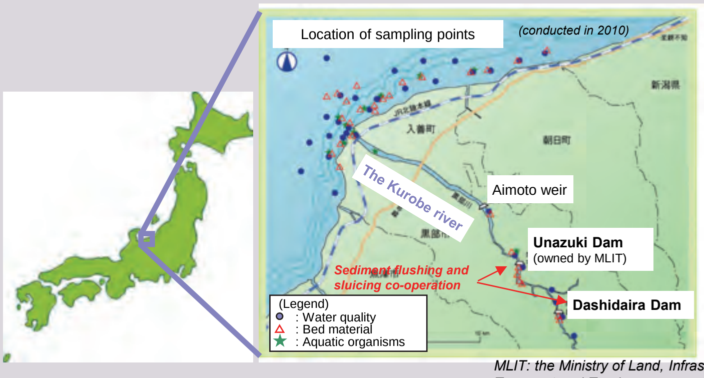



### iii) Recovering water level

When the inflow decreases to certain level – before dilution effect of water dramatically drops, the flushing gates start closing.

## Environmental Sampling

- ○ Numerous sampling surveys have been carried out, covering the downstream part of the Kurobe River as well as the coastal areas of the Japan Sea expanding from the river mouth of the Kurobe River.
- ○ Sampling is periodic, providing three statuses: before, during and after flushing operation, to monitor the environmental impacts of flushing.

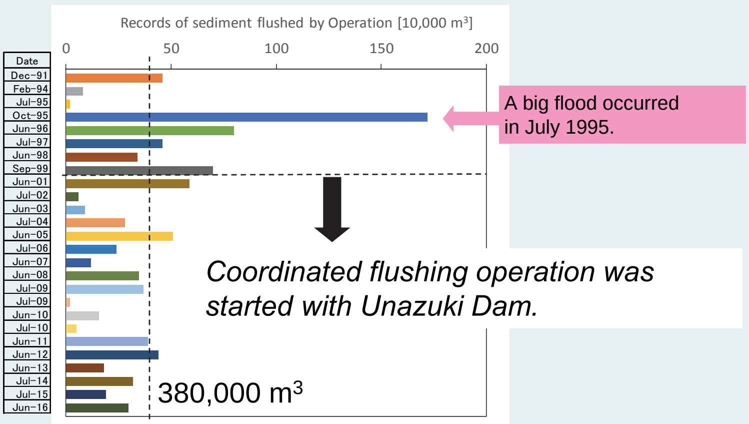



*MLIT: the Ministry of Land, Infrastructure, Transport and Tourism*

## Historical Records in Effects of Sediment Flushing Operation

- ○ Coordinated flushing and sluicing operation has been carried out since 2001 with Unazuki Dam, owned by MLIT, located 7 km downstream from Dashidaira Dam.
- ○ Annual flushing volume of sediment is 380 $\times 10^3$ $m^3$ on average.

*MLIT: the Ministry of Land, Infrastructure, Transport and Tourism*

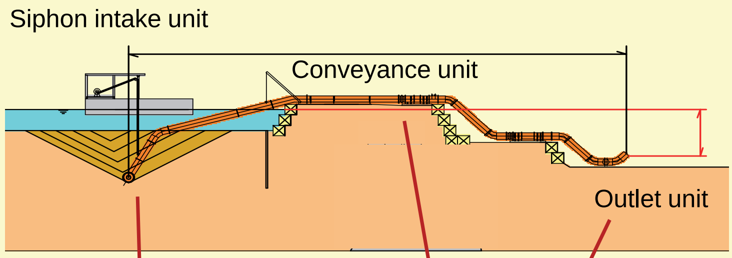


# Hydro-suction sediment dredging

## Outline

The mobile siphon dredging system which consists of three parts: a siphon intake unit, a conveyance unit and an outlet unit.
The siphon dredging system which uses the difference in the reservoir water level and the sediment transport destination outlet level to excavate/dredge and convey sediments.
The Siphon Barge forming the siphon intake unit is able to move reservoir area and dredging sediments.

Conceptual drawing of siphon dredging




## System features

〇Transferable
A Siphon Barge equipped with a suction unit is freely transferable on the reservoir.

〇Simple structure
Since there is no impeller unlike the pump, the sucked dust can pass through the inside of the pipe as it is.

〇Powerless
Using the siphon principle so, there is no need mechanical power.

〇Cost reduction
Low energy consumption and running cost.

Siphon intake unit - Siphon Barge

Conveyance unit - Sediment discharge pipeline & pressure regulator

Outlet unit - View of Sediment dredging

Dredged & transported sediment from reservoir

【WONOGIRI DAM】

View of dredging site

【Upstream】

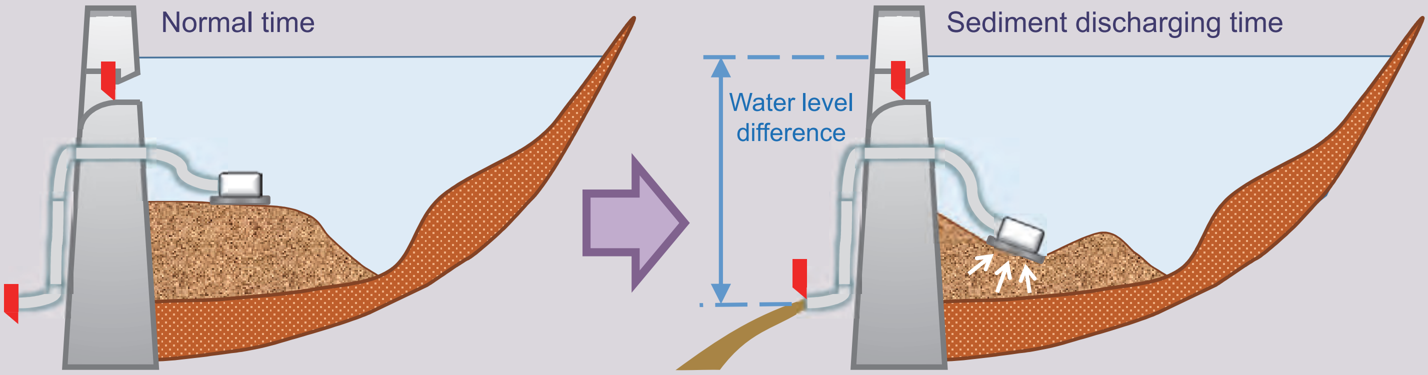

View of siphon dredging facility

## Performance: Dredging volume = 77 $m^3$/hour, The sediment concentration = 2 %, Sediment discharge pipe = φ 600 mm

# Model experiment of hydro-suction sediment dredging

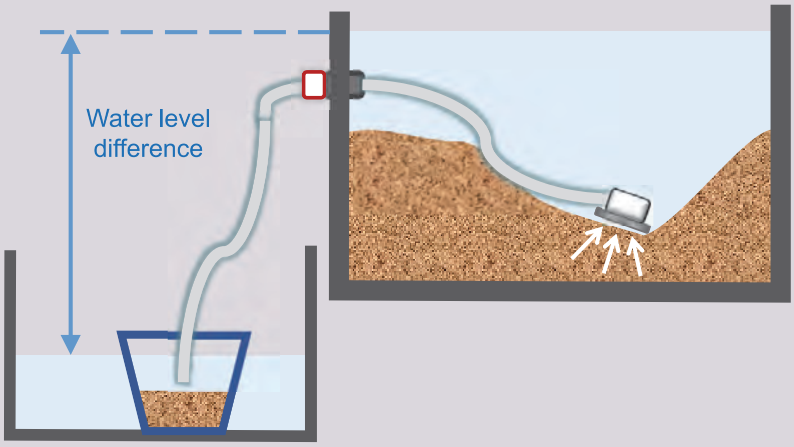
## Outline of Hydro-suction sediment dredging

- ○ The method of sucking and removing sediments is using the difference water level between reservoir and the downstream water levels.
- ○ Since it does not require mechanical power, the initial cost and running cost can be reduced.

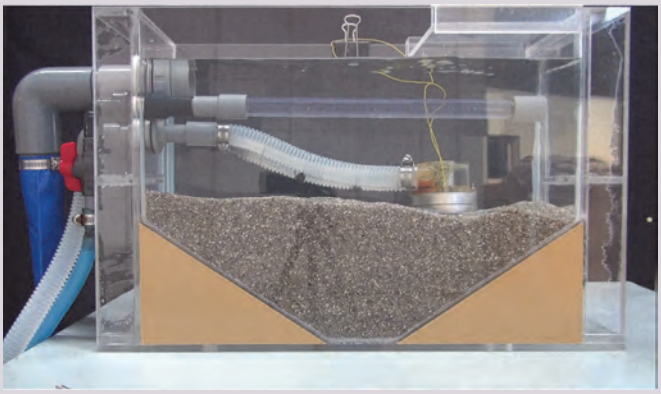



## Outline of model experiment

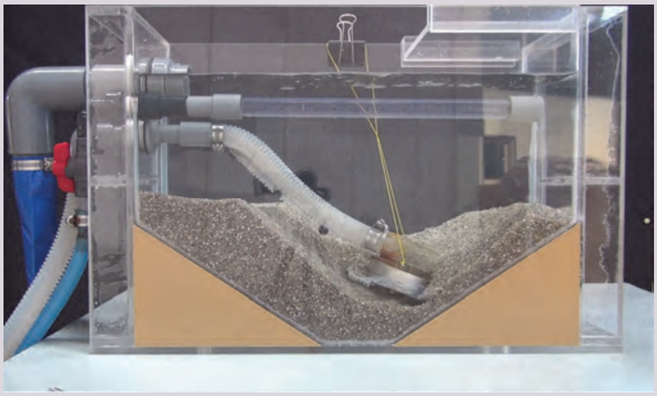
○Reproduce the water level difference at the model, generate water flow inside the pipe, and suck sediments from the suction holes at the bottom of the pipe by using negative pressure.




## View of model experiment

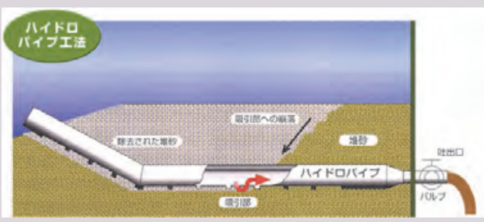


Before suction



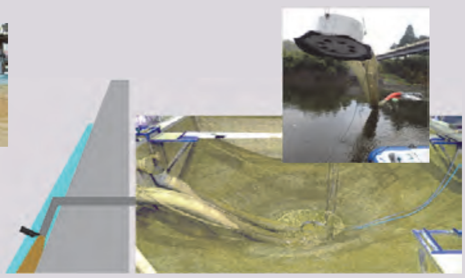
During suction

## Cases of Hydro-suction sediment dredging




The fixed type

The mobile type



The surface installation type

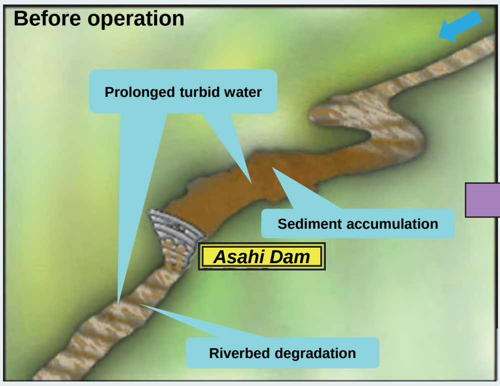
# Sediment Bypass at Asahi Dam

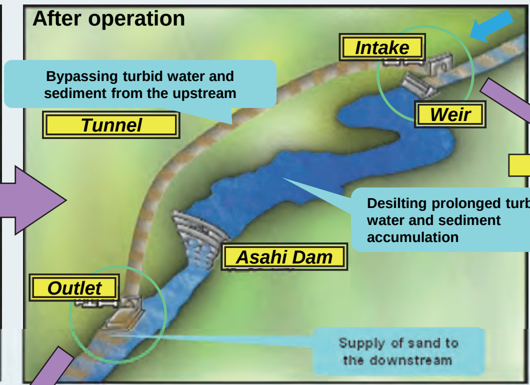
## Outline

○ Asahi Dam had suffered prolonged turbid water, caused by collapsed sediment brought by large typhoons, since its start in 1978, and KANSAI ELECTRIC POWER adopted the bypassing method as a drastic measure against the problem of prolonged turbid water in the reservoir.

○ This method takes full advantage of the characteristics of Asahi Dam that there is no function of storing water because it is a lower dam of the associated pumped-storage power station. Turbid water coming from upstream is diverted before the reservoir to downstream through the bypass tunnel, which can also contribute to controlling reservoir sedimentation conveying bed load as well as suspended load.

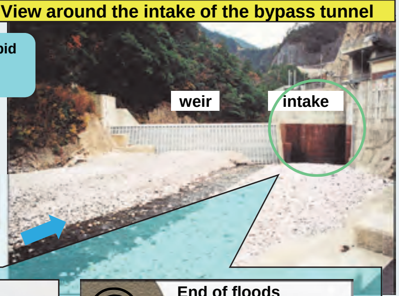
## Procedure for Sediment Bypass Operation



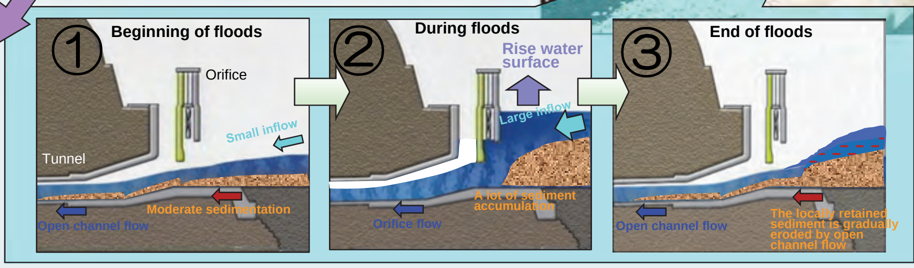

Intake

View around the intake of the bypass tunnel




Outlet

(Patent:No.3347104)【Patentee: Kansai Electric power Co., Inc. and NEWJEC Inc.】




A well-designed combination of structures of a weir and an orifice is the key to this bypassing method. At beginning of floods, there occurs moderate sedimentation in front of the orifice, followed by sediment accumulation as the water level rises in front of the weir during floods. As a flood eases off and the water level goes down, the locally retained sediment is gradually eroded by open channel flow and conveyed to the tunnel, where erosion helps prevent the tunnel from being clogged with sediment.

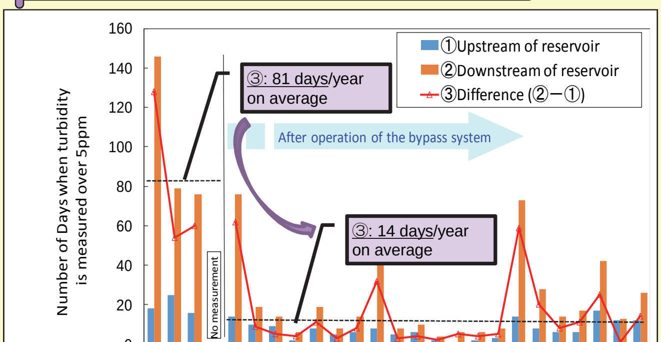
## Historical Records in Effects of Sediment Bypass Operation

Introduction of the sediment bypass system has improved the reservoir environments as follows:

○ The annual number of days of occurrence of prolonged turbid water - over 5 ppm - has decreased from 81 days to 14 days on average, and

○ The annual sedimentation rate has decreased from 78 x $10^3$ $m^3$ to 17 x $10^3$ $m^3$ on average.

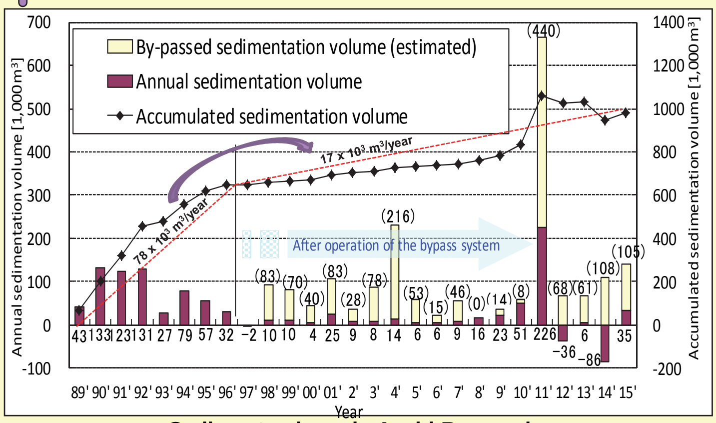
### Days of occurrence of Prolonged Turbid water




| | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ①Upstream of reservoir | 18 | 25 | 16 | | 14 | 10 | 9 | 2 | 8 | 5 | 6 | 8 | 5 | 6 | 2 | 1 | 2 | 3 | 14 | 8 | 6 | 6 | 17 | 12 | 12 |
| ②Downstream of reservoir | 146 | 79 | 76 | | 76 | 19 | 14 | 6 | 19 | 8 | 14 | 40 | 8 | 10 | 4 | 6 | 6 | 8 | 73 | 28 | 14 | 17 | 42 | 13 | 26 |
| ③Difference (②−①) | 128 | 54 | 60 | | 62 | 9 | 5 | 4 | 11 | 3 | 8 | 32 | 3 | 4 | 2 | 5 | 4 | 5 | 59 | 20 | 8 | 11 | 25 | 1 | 14 |

Data: over 5 ppm

### Annual Rate on Reservoir Sedimentation




Sediment volume in Asahi Reservoir

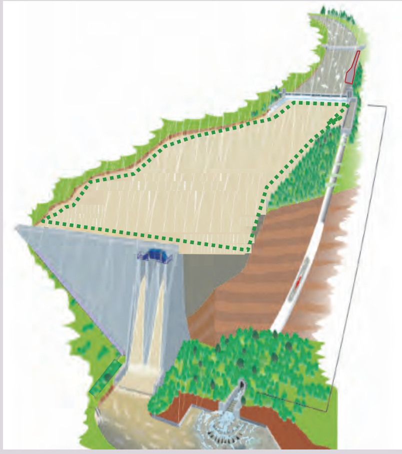
# **Sediment Bypass** - Bypassing of clay and silt -

## Outline

○ Sediment bypassing is a method to divert all or part of flood water containing sediment at the diversion weir constructed upstream of a reservoir, and route this via the bypass tunnel to the downstream reaches.

○ This method is adopted for 4 dams in Japan for the purpose of permanent sedimentation countermeasure for dams with large sedimentation and relatively plentiful discharge.

○ The target sediment materials can correspond according to the characteristics of the dam, such as in the case of only wash road or all grain size.



## Case on Miwa Dam

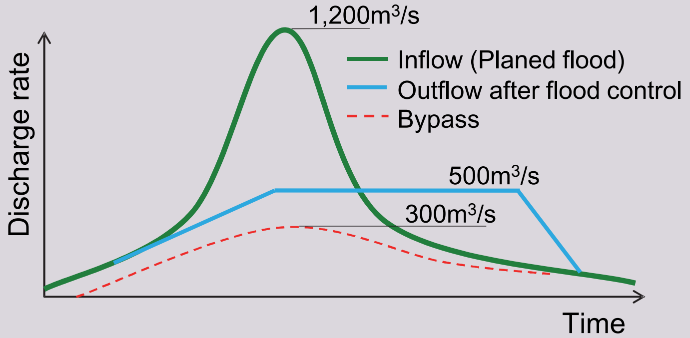
○ Miwa dam is a multipurpose dam complete in 1959 in the Tenryu river basin Mibu River.

○ Because of the reservoir sedimentation is quickly, we started sediment bypass operation in 2005, and it is showing its effect.

○ At the Miwa Dam, among the incoming sediment material, only the wash road are flowed from the upstream of the reservoir by sediment bypass tunnel to the downstream of the dam and coarse grain material is trapped by the check dam and the diversion weir.

○ On the downstream river, monitoring is carried out to ascertain the effect and impact of sediment bypassing.

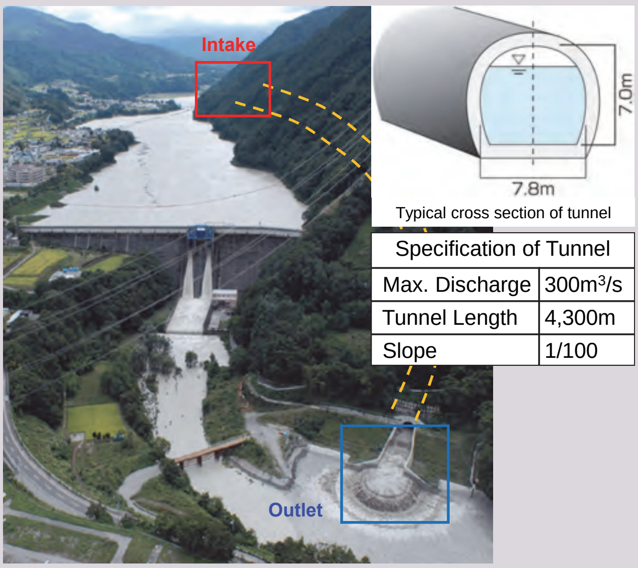
● Operation rule of Miwa Dam sediment bypassing




● Operational performance

| Flood name | Maximum flow rate | | Bypass discharge time | Wash load amount | |
|---|---|---|---|---|---|
| | Inflow | Bypass | | Inflow | Bypass |
| July 2006 | 366 $m^3/s$ | 242 $m^3/s$ | 47 hours | 326,000 $m^3$ | 150,000 $m^3$ |
| July 2007 | 166 $m^3/s$ | 136 $m^3/s$ | 35 hours | 37,000 $m^3$ | 14,000 $m^3$ |
| Sept. 2007 | 568 $m^3/s$ | 264 $m^3/s$ | 48 hours | 462,000 $m^3$ | 155,000 $m^3$ |
| July 2010 | 229 $m^3/s$ | 199 $m^3/s$ | 146 hours | 131,000 $m^3$ | 80,000 $m^3$ |
| Sept. 2011 | 218 $m^3/s$ | 178 $m^3/s$ | 87 hours | 99,000 $m^3$ | 60,000 $m^3$ |

● Miwa Dam and Sediment bypass tunnel




Typical cross section of tunnel

| Specification of Tunnel | |
|---|---|
| Max. Discharge | 300$m^3/s$ |
| Tunnel Length | 4,300m |
| Slope | 1/100 |

Sediment check dam

Mibu weir (Diversion weir)

| | |
|---|---|
| Dam type | Concrete gravity |
| Dam Height | 20.5m |
| Crest Length | 244.5m |

Intercept coarse sand and gravel (sedimentation) and make it easy to excavate out after flooding.

Bypass outlet

It is overflowing to draw a semicircle radially from the energy dissipater and it is being energy dissipated.

■ Performance: Along with the operation of the sediment bypass, increase in sedimentation volume could be suppressed in general.

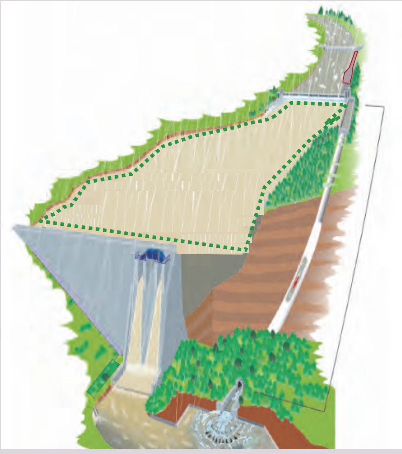
# Sediment Bypass - Bypassing of clay, silt, fine sand -

## ■ Outline

○ Sediment bypassing is a method to divert all or part of flood water containing sediment at the diversion weir constructed upstream of a reservoir, and route this via the bypass tunnel to the downstream reaches.

○ This method is adopted for 4 dams in Japan for the purpose of permanent sedimentation countermeasure for dams with large sedimentation and relatively plentiful discharge.

○ The target sediment materials can correspond according to the characteristics of the dam, such as in the case of only wash road or all grain size.



## ■ Case on Matsukawa Dam

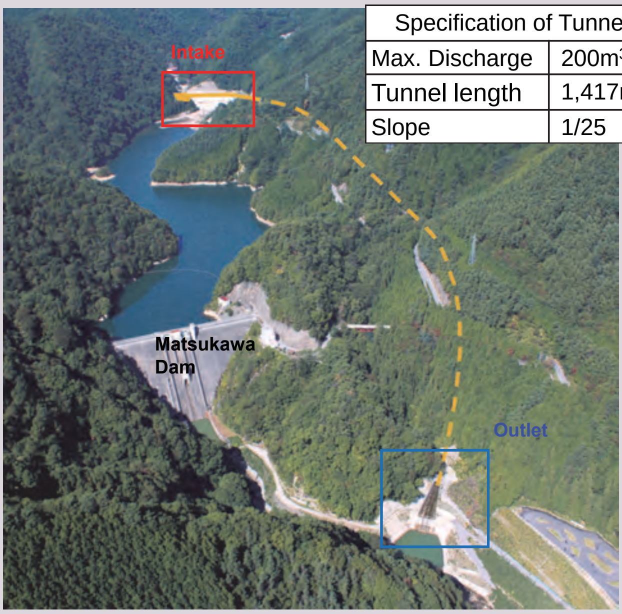
○ Matsukawa dam is a multipurpose dam completed in1974 in the Tenryu river basin Matsukawa River.

○ Because the upper stream of Matsukawa Dam is steep in the topography and fragile in the geology, due to repeated floods including Typhoon No.10 in 1983, design sediment storage of dam flowed into the reservoir and accumulated.

○ Among the incoming sediment material, fine sediment are flowed from the upstream of the reservoir by sediment bypass tunnel to the downstream of the dam with running water and reducing sediment inflow into the reservoir.

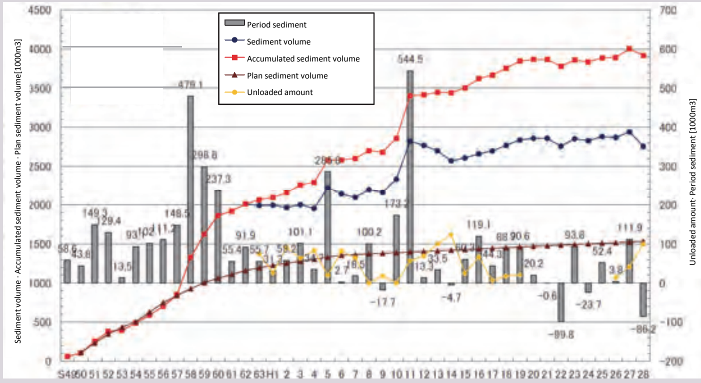
○ From 2016, experiment operation of the sediment bypass was started.

● Matsukawa dam & sediment bypass tunnel

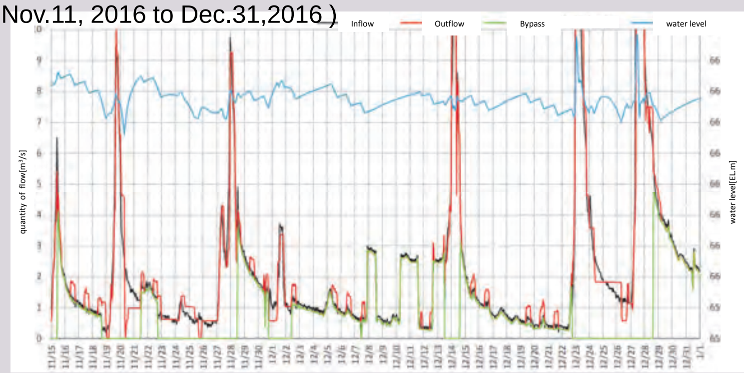



| Specification of Tunnel | |
|---|---|
| Max. Discharge | 200m$^3$/s |
| Tunnel length | 1,417m |
| Slope | 1/25 |

● Change over the years of reservoir sedimentation situation




● Overview of experiment operation of the sediment bypass (From Nov.11, 2016 to Dec.31,2016 )

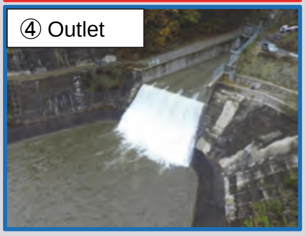



● Sediment bypass facility


① Trap weir


② Diversion weir


③ Bypassing canal


④ Outlet

■ Performance: Along with the experiment operation of the sediment bypass, an increase in sedimentation volume can be suppressed.

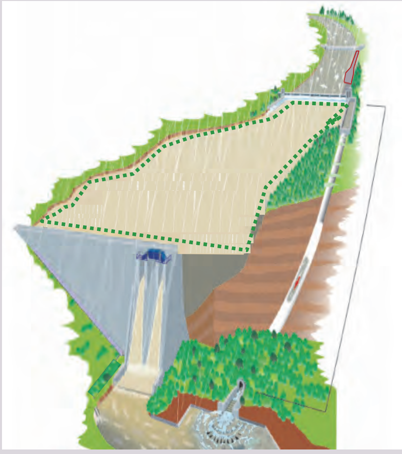
# Sediment Bypass - Bypassing from clay to gravel -

## Outline

○ Sediment bypassing is a method to divert all or part of flood water containing sediment at the diversion weir constructed upstream of a reservoir, and route this via the bypass tunnel to the downstream reaches.

○ This method is adopted for 4 dams in Japan for the purpose of permanent sedimentation countermeasure for dams with large sedimentation and relatively plentiful discharge.

○ The target sediment materials can correspond according to the characteristics of the dam, such as in the case of only wash road or all grain size.



## Case on Koshibu Dam

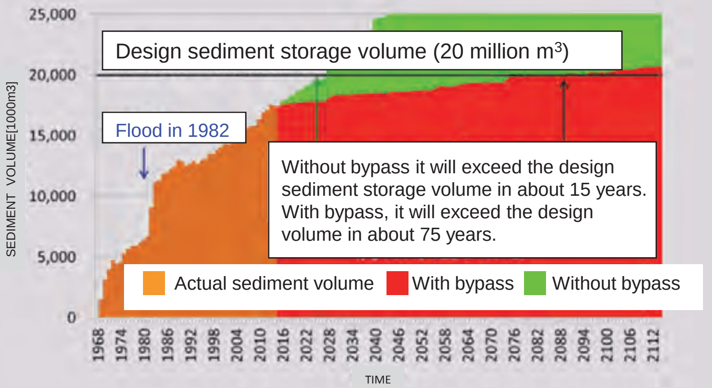
○ Koshibu dam is a multipurpose dam completed in June 1969.

○ As of 2015, the sedimentation rate of the reservoir is 89%, and if in such a situation sedimentation proceeds, it is predicted that the sedimentation rate will be 100% after another 15 years.

○ By operating sediment bypass, it is possible to extend the life of the reservoir by about 60 years.

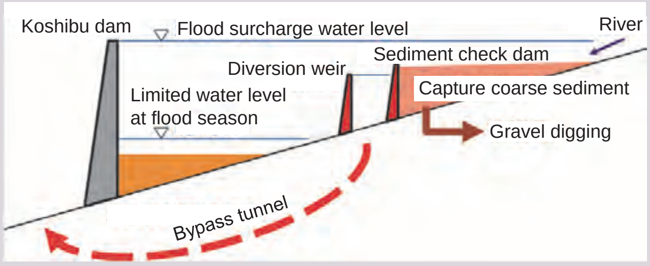
○ The incoming sediment material without large stone are flowed from the upstream of the reservoir by sediment bypass tunnel to the downstream of the dam with running water and reducing sediment inflow into the reservoir.

### ● Effect of Koshibu dam sediment bypassing

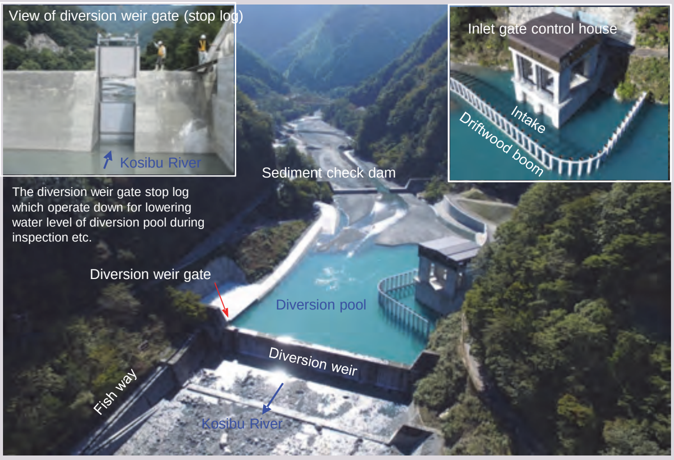



(Estimated based on actual results of 2014 years since completion of dam)

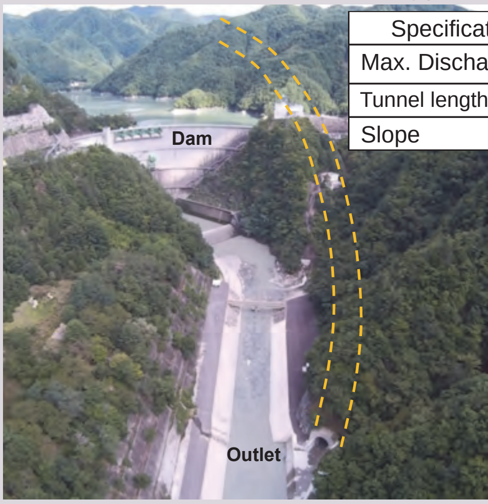
### ● Conceptual diagram of sediment bypassing facility




### ● Sediment bypass inlet area and diversion weir

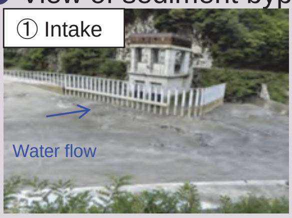


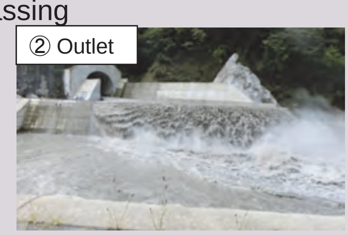

### ● Koshibu dam and sediment bypass tunnel outlet




| Specification of Tunnel | |
|---|---|
| Max. Discharge | 370m³/s |
| Tunnel length | 3,999m |
| Slope | 1/50 |

### ● View of sediment bypassing




■ Performance: Three bypass discharges were carried out in 2016, bypassing almost the same amount of sediments as the incoming from the upstream to suppress the inflow of sediment into the reservoir.

# Appendix

We have Original Advanced Technologies

# Improvement of Sediment Transportation in Dam

## 1. Reservoir Sediment Restoration for Fish Habitat in Downstream of Hiranabe Dam

### 1.1 Background

J-POWER has three dams for hydropower plants in Nahari river basin having 61 kilometers of the length and 311 square kilometers of river catchment area as shown in Figure 1. Due to its steep gradient;1/250, the Nahari river is suitable site for hydropower and hydropower development was commenced in 1960s. However, transportation of riverbed material was terminated by the dams; consequently, degradation and granulation of river bed (armor coating) had been caused in the downstream of dams. Although the Nahari was famous for fishery of Sweet fish (Ayu), it was damaged seriously.

Against this situation, J-POWER, fishermen, residents and an expert of Ayu jointly started river improve activities from 2004.

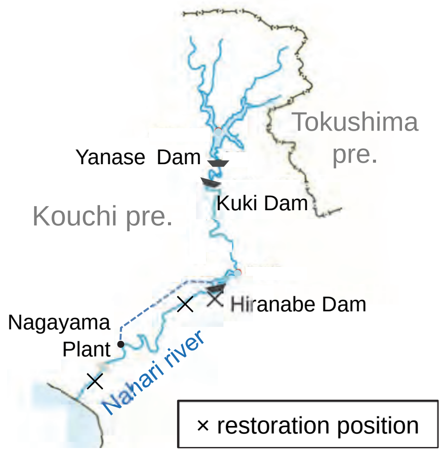



Figure 1 Dams in Nahari river

### 1.2 Contents of Improve Activities

The main activities executed are as illustrated in Table 1. Considering length to be improved; that is from dam to river mouth and early appearance of activities effect, measures has been taken at three positions in the downstream of Hiranabe dam, which is located in the most downstream site in the three dams.

Table 1 River Improve Activities

| Position | Start Year | Contents |
|---|---|---|
| Mouth of River | 2005 | To make Ayu spawn bed, sediment having appropriate grain size is supplied on the riverbed covered by hard and large sized grain, before November in every year. November is Ayu spawn season. |
| Intermediate Point from Dam to Mouth | 2006 | Sediment taken from the reservoir is supplied to the riverbed, which was done in 2006 and 2010. |
| Downstream of Dam | 2017 | Sediment taken from the reservoir is supplied to immediate downstream of Dam. Equipment was installed in 2016, shown in Figure 2. Larger amount of sediment will be supplied in 2018. |

### 1.3 Result

It is observed that the assumed number of Ayu has been gradually increasing since 2004 as shown in Figure 3, which is investigated in May every year before fishing season. Accordingly, it is judged that the taken measures have positive effect to restoration of habitat in downstream river of dams.

### 1.4 For the Future

It is planed that sediment supply to immediate downstream of Hiranabe dam and monitoring of Ayu number are continuously conducted and enhanced. if necessary, in order to Improve all section of river from dam to mouth.


Figure 2 Equipment of Sediment Restoration

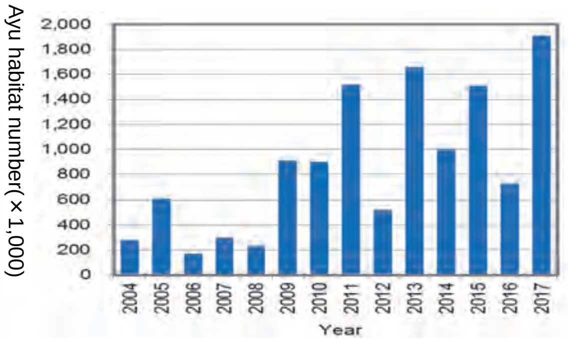



Figure 3 Secular Change of Ayu Habitat Number

## 2. Draw-Down Operation in Setoishi Dam

### 2.1 Background

J-POWER has Setoishi dam for hydropower plant, as shown in Figure4 in Kuma river having 115 kilometers of the length and 1,880 square kilometers of river catchment area. The Kuma flows into Yatsushiro sea, having problems such as water quality deterioration and much mud on the bottom. One of the reasons for the problems is sediment termination by dam, then improvement of sediment control in dam is needed.

Setoishi reservoir has flooding risk around itself because of aggradation of riverbed by reservoir sedimentation, and it is planned that in flooding draw-down operation to control sedimentation will be conducted. Downstream of Setoishi dam, there was Arase dam in possession of Kumamoto prefecture, which had been under removal work between 2012 and 2018. In 2017 water channel appeared in dam removal site, then we started draw-down operation in Setoishi dam by way of experiment.

Figure 4 Setoishi Dam, Hydropower Plant and Reservoir

### 2.2 Draw-Down Operation

To make inflow sediment run out of reservoir through spillway gate, draw-down operation in flooding has to be conducted to get bigger tractive force in all area of reservoir than usual operation.

During draw-down operation, power generation has to be kept stopped. It is the most important for effective use of renewable hydropower to make an effective operation rules. We made the operation rules as shown in Table 2, using our own rainfall prediction system.

Table 2 Setoishi Draw-Down Operation Rules

| Items | Contents |
|---|---|
| Period | From June to September (avoiding going upstream and spawning season of Ayu) |
| Draw-Down Water Level | Low Water Level - 4.0m. Draw-Down rate is under 0.5m/hr. |
| Entry Criteria | When dam inflow volume is predicted over 2,000$m^3$/s on our own rainfall prediction system. |
| Exit Criteria | When dam inflow volume is under 1,000$m^3$/s on record. |
| Interruption standard | When Dissolved Oxygen of is under 5mg/liter on record. |
| Ground | Rules are grounded on result of numerical analysis considering balance between inflow sediment and output sediment. |

### 2.3 Result

Experiment operation in 2016 and 2017 told us that our operation rules were available. Because we did not have large rainfall during two years, effect in sediment control of draw-down operation was not clear.

### 2.4 For the Future

Full-scale operation will be started in 2018 and it is expected that environmental improvement in Yatsushiro sea and Kuma river will appear. Also operation rules will be checked and revised by estimation of effect of draw-down operation. (End)


| J-POWER | |
|---|---|
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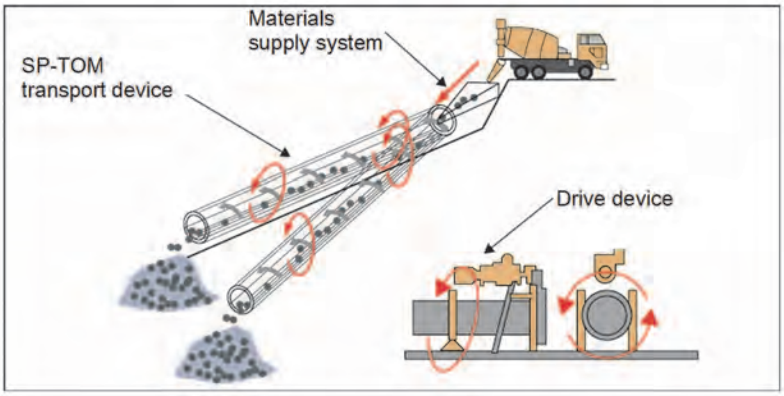
# New Construction Technologies

## SP-TOM (Special Pipe Transportation Method)

This method can transport large quantities of concrete, soil and stone stably and continuously, by rotating a steel-pipe which several hard rubber blades are installed in a spiral pattern inside. The pipeline is installed on the slope.




## SP mixer (Special Pipe mixer)

This mixer was developed to mix CSG materials. This method is to mix materials passing through the interior by rotating a mixing tube equipped with blades inside the mixer.

The mixing tube is installed to incline. The self-weight of the CSG materials cause them to flow through the mixer. This mixer has two mixing effects inside its mixing tube; forced agitation by drive power and falling.

Patent:
Incorporated Administrative Agency Japan Water Agency; KAJIMA CORPORATION; OBAYASHI CORPORATION; TOBISHIMA COPORATION; Kumagai Gumi Co., Ltd.; The Zenitaka Corporation; Osakasaiseki Engineering Corporation

KAJIMA CORPORATION

| | | |
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| Phone: | +81-3-5544-0664 | |
| URL: | https://www.kajima.co.jp/english/welcome.html | |

# Floating Type Temporary Cofferdam Method

Innovative Dam Redevelopment – A New Coffering System for Underwater Work–

## Feature of technology

With the floating type temporary cofferdam method, steel plates (skin plates) are attached to both the inside and outside of the bulkhead, the temporary cofferdam barrier that is integrated into the base is floated, and is supported by installing an anti-buoyancy brace on the top barrier of the dam body. The construction assembles barrier blocks made at the site on the reservoir surface, tows them to the installation position, pulls them by winch and secures them. The floating type temporary cofferdam method--assembling and installing while adjusting the ballast by filling and draining water from a reservoir--is the first of its kind in the world.

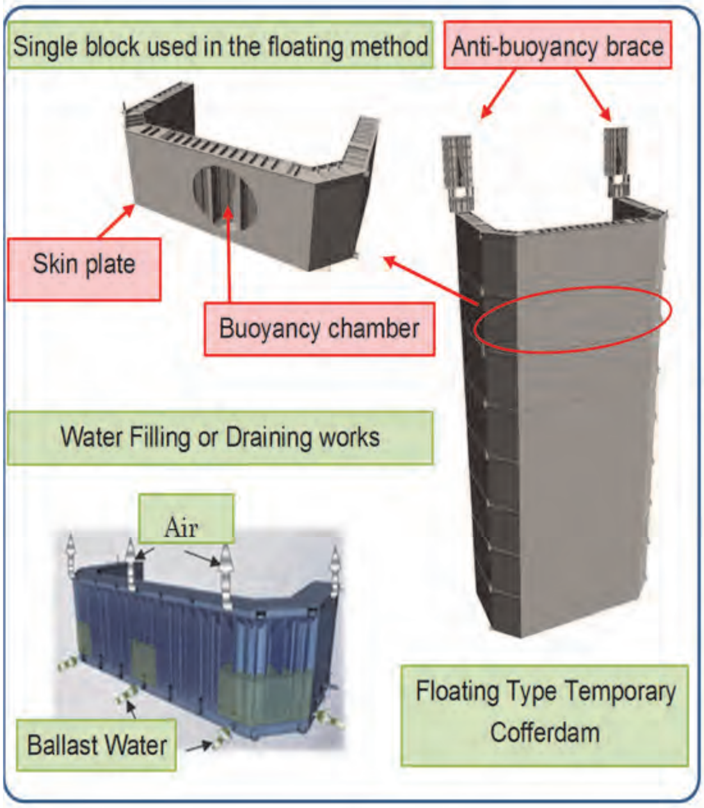


Figure of Structure

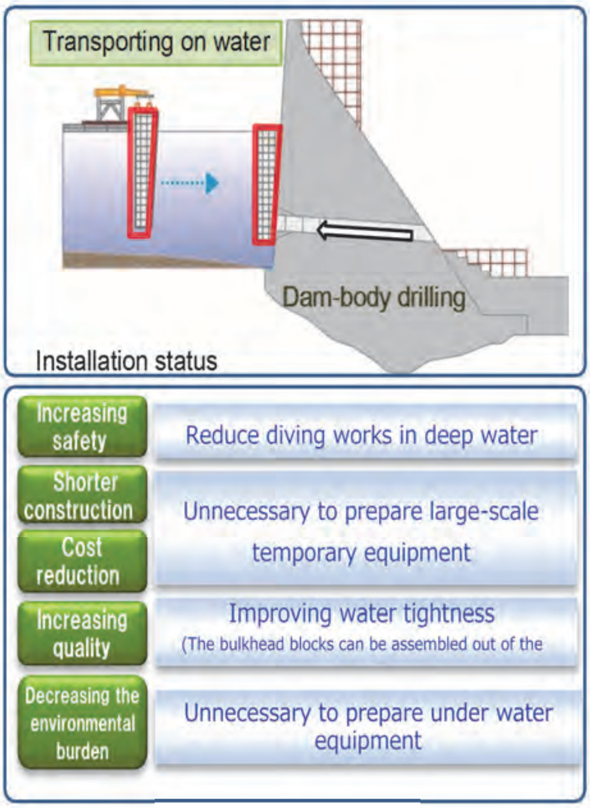


Figure of Structure

Technology developers:
Kajima Corporation; Hitachi Zosen Corporation
Joint developers:
Ministry of Land, Infrastructure, Transport and Tourism Kyushu Regional Bureau; Japan Dam Engineering Center

KAJIMA CORPORATION

| | |
|---|---|
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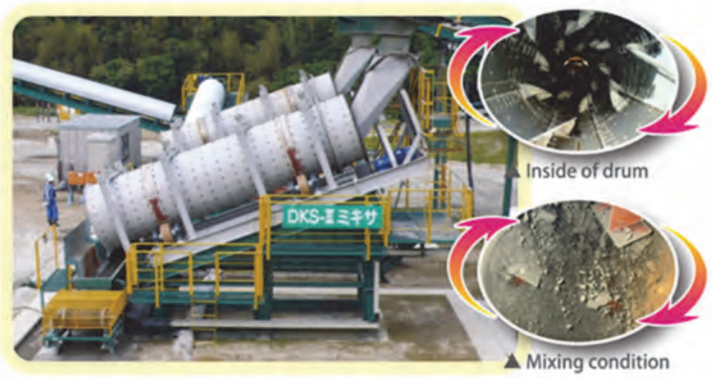
| URL: | https://www.kajima.co.jp/english/welcome.html |

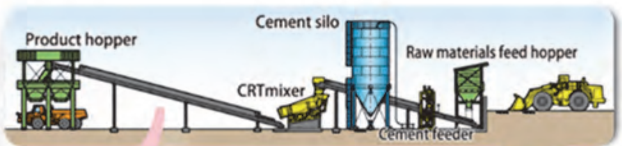
## CRT(The Continuous Rotary Tube)Mixer System

The Continuous Rotary Tube (CRT) Mixer System provides using the Cemented Sand and Gravel (CSG) Method. By attaching agitating blades inside the steel drum and maintaining specified rotation speeds and angles, the mixer is capable of producing mixtures of consistent and stable quality.




**Features of Mixer**

1. Continuous rotary mixer
2. Stable supply of high-quality CSG
3. High production capacity (200m3/hour)
4. Automation of CRT Mixer System
5. An energy saving machine & Low cost




**Mixing Plant Description**

| | |
|---|---|
| Name of Plant System | DKS- II Mixing Plant |
| Name of Mixing Element | CRT Mixer |
| Type of Mixing Element | Forced Type in the shape of Pipe |
| Dimension | φ1,500mm・L6,000mm |
| Productivity | 200m$^3$/hour |
| Rotational Speed | 5~20 rpm |
| Capacity of Motor | 30kW 200V |

**Nishimatsu Construction Co., Ltd.**

| | |
|---|---|
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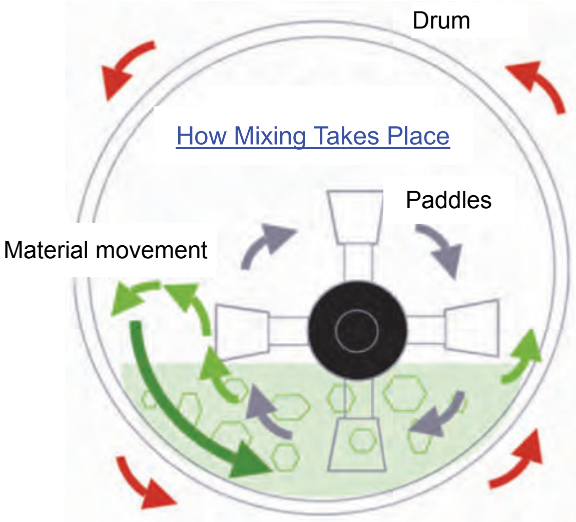
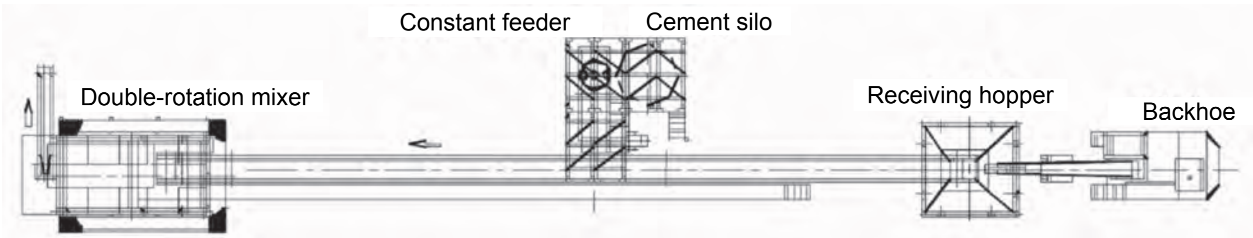
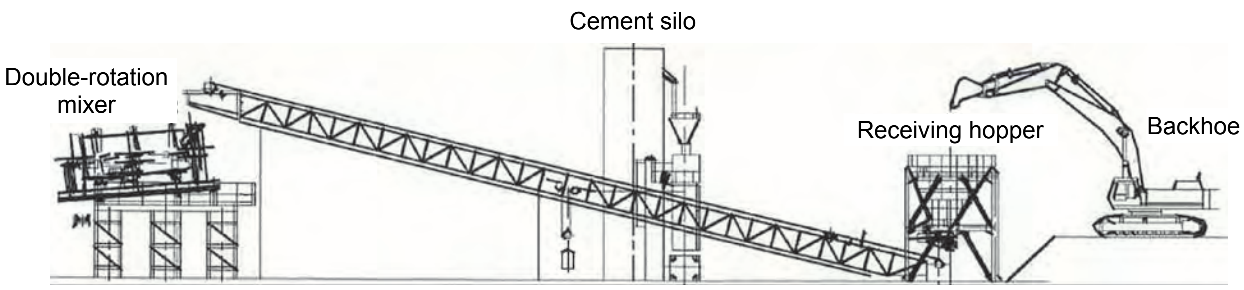
## Newly Developed High-performance CSG Mixer: Double Rotation Continuous Mixer

The newly developed double-rotation mixer combining the characteristics of a tilting mixer and a forced circulating mixer produces high-quality CSG (Cemented Sand and Gravel) mixes at a rate exceeding 200 $m^3/h$

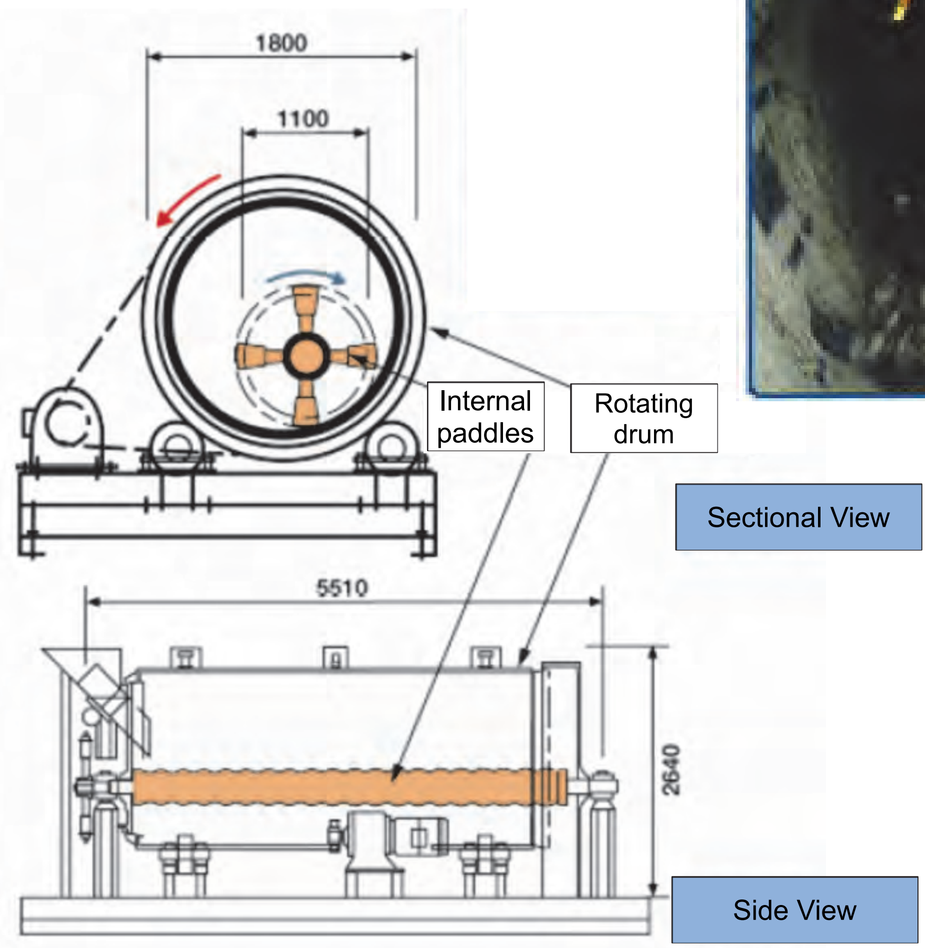

Example of Concrete Plant Layout



## Mixer Specifications

| | | |
|---|---|---|
| Rotating Drum Specifications | | |
| Drum inside diameter and height | | φ1800×4200L |
| Rotation speed and direction | | 10 rpm (clockwise looking in the direction of movement) |
| Motive power | | 37kw×220V |
| Drive system | | Chain drive |
| Support system | | Roller (φ400 × 145L) × 4 |
| | | Thrust roller (φ250 × 90L) × 2 |
| Inner Paddle Specifications | | |
| Mixer outside diameter, pitch and number of paddle shafts | | φ1100 × P1000 (two shafts) |
| Rotation speed and direction | | 38 rpm (counterclockwise looking in the direction of movement) |
| Motive power | | 45kw×220V |
| Drive system | | Chain coupling drive, chain drive |
| Support system | | Bearing |
| | | Plummer block (φ135) |
| Paddle inserts | Size | 30t-220-220 |
| | Quantity | 36 pcs. |




Mixing



| SHIMZ CORPORATION | |
|---|---|
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| Phone: | +81-3-3561-3883 |
| URL: | https://www.shimz.co.jp/en/ |

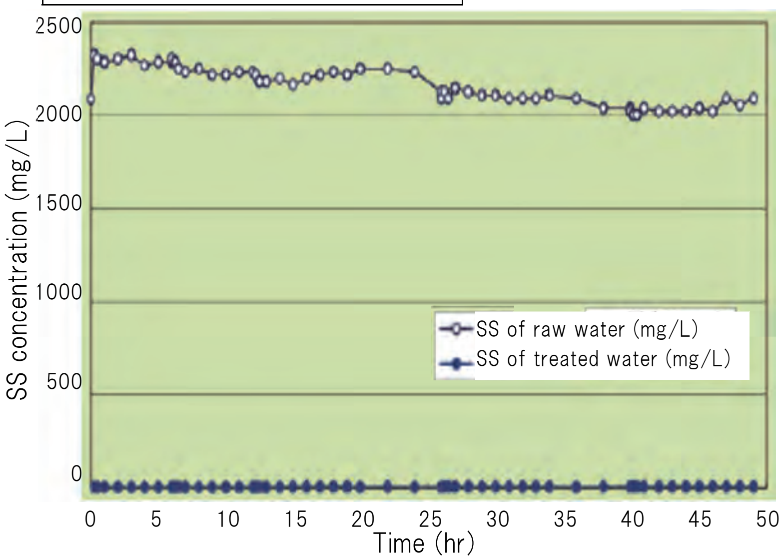
## New Water Filtration System (Advanced Membrane Filtration Process)


In construction projects such as tunnel and dam construction and site preparation, proper treatment of turbid water generated from construction work is important in order to protect the environment. There has also been growing demand for higher water treatment performance than required by the current standards of the local governments.
Conventional turbid-water treatment processes relied mainly on coagulation and sedimentation. Shimizu's newly developed filtration system effectively removes suspended solids by use of a membrane filtration process to achieve higher water quality in an environmentally considerate manner and provide solutions to current and emerging problems.

### Features

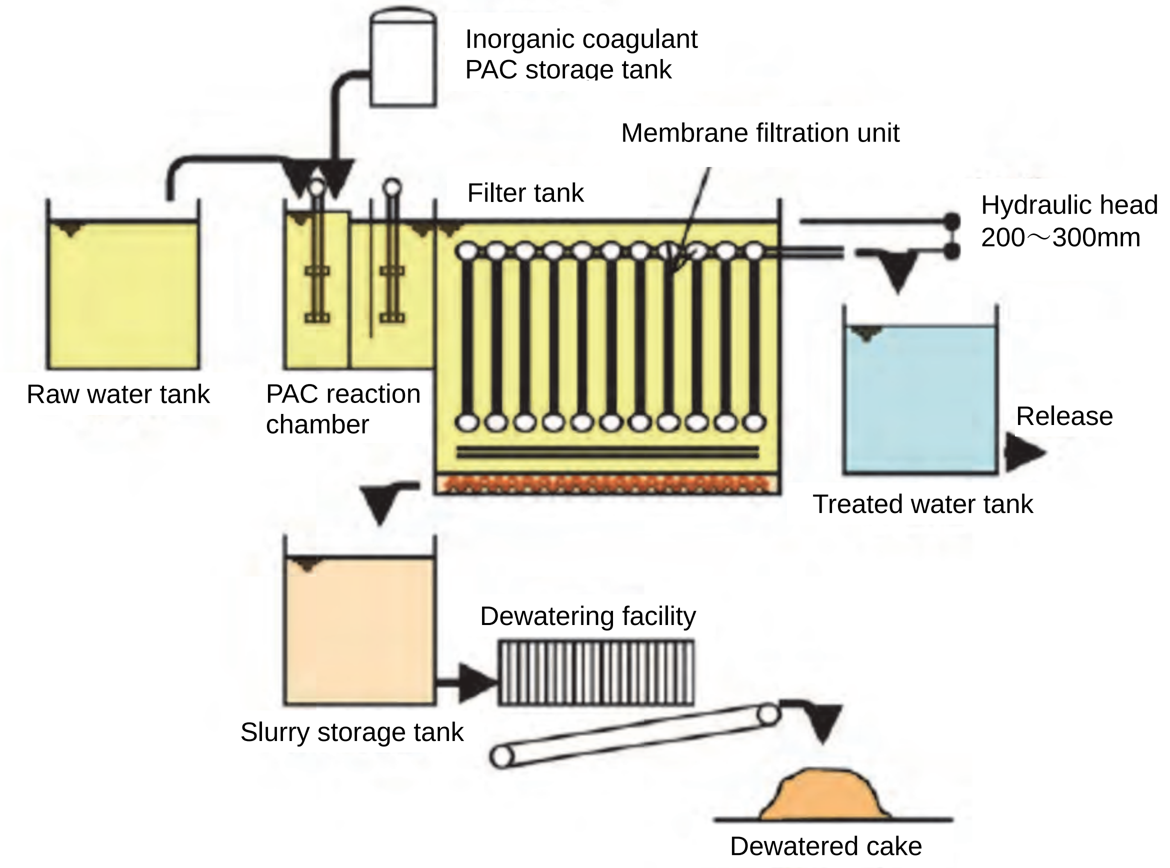
- The filtration process reduces the SS concentration of turbid water to 5 mg/L.
- High turbidity (SS1000–3000 mg/L) water can be treated directly.
- The process is environmentally friendly because it does not use any organic polymer coagulant.
- The system footprint is compact because sand filtration is not used.
- The water treatment system is environmentally considerate because it requires only a small amount of electricity.

### Turbid Water Treatment Test Data

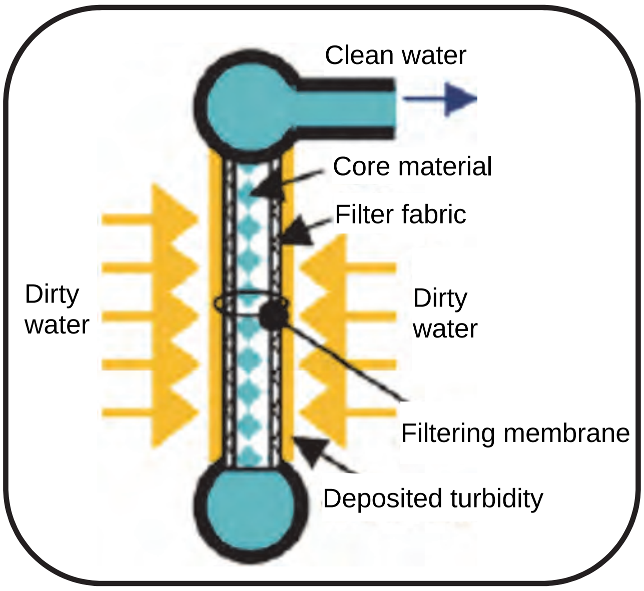



Raw water and treated water

System Flow




How Membrane Filtration Works




Membrane Filtration Capacity

Let A (m2) represent the area of the membrane surface. Then, membrane filtration capacity V (m3/day) can be calculated as follows:

V = A × 2 m3/day



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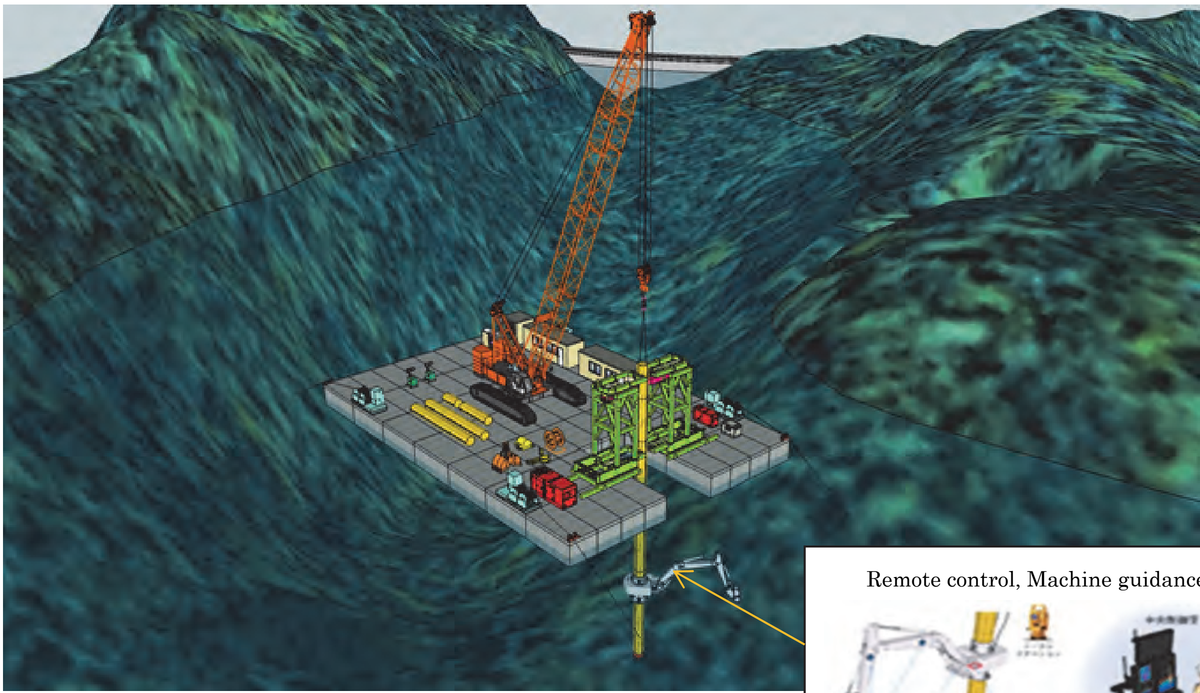
## Remote Controlled Multifunctional Underwater Equipment

## Underwater Operation Using an Equipment with Apparatus (T-iROBO UW)



Remote control, Machine guidance


## Summary

This equipment enables a series of underwater operations such as rock crushing, excavation, debris disposal, precise sounding, photography, etc.in a safe and reliable condition through remote controlling. These are carried out by various apparatuses on a machine attached to a shaft which is lowered from a barge. The machine moves up and down along the shaft.

The equipment has been developed to conduct various underwater works without divers. It is especially advantageous for works in deep, steep and limited visibility areas such as dam reservoirs. Significant improvements of safety and operational efficiency are observed through remote controlled visualization technology and computerized technology.


## Specific Features

a. Enables deep underwater works without divers
b. Applicable for all types of reservoirs
c. Applicable for very steep areas via an equipped casing auger
d. Enables a series of works to be carried out by various apparatuses
e. Equipped with I.T, machine guidance
f. Applicable for deep and dark reservoir bases via equipped ultrasonic camera
g. Enables precise execution via equipped sounders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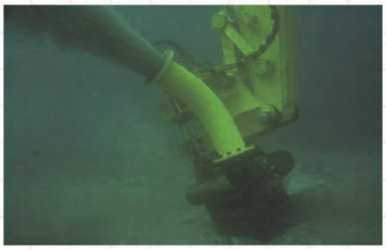
## Various Apparatuses

Applicable for a series of works via various apparatuses attached to a machine

Rock crushing with a breaker

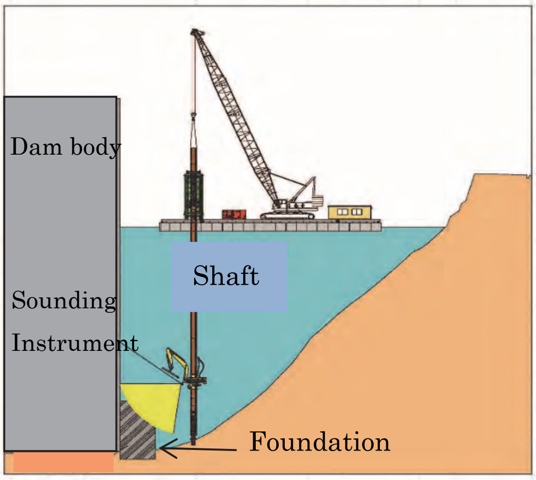


Sand pump suctioning

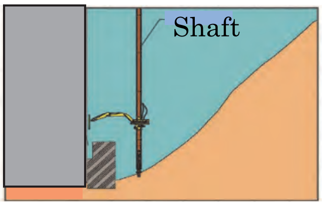
Cleaning by an ejector

Examples of applicable works

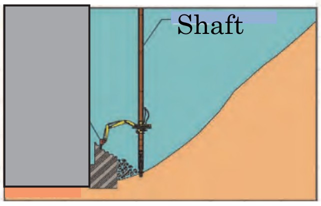
Precise sounding



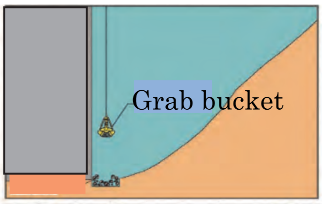

Edge cutting



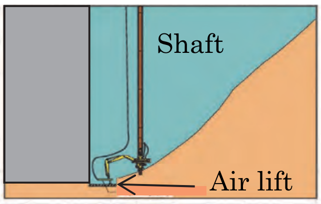

Crushing concrete




Grab dredging




Surface treatment




Other applications

a. Drilling by an air drifter

b. Surface cleaning by a rotary brush

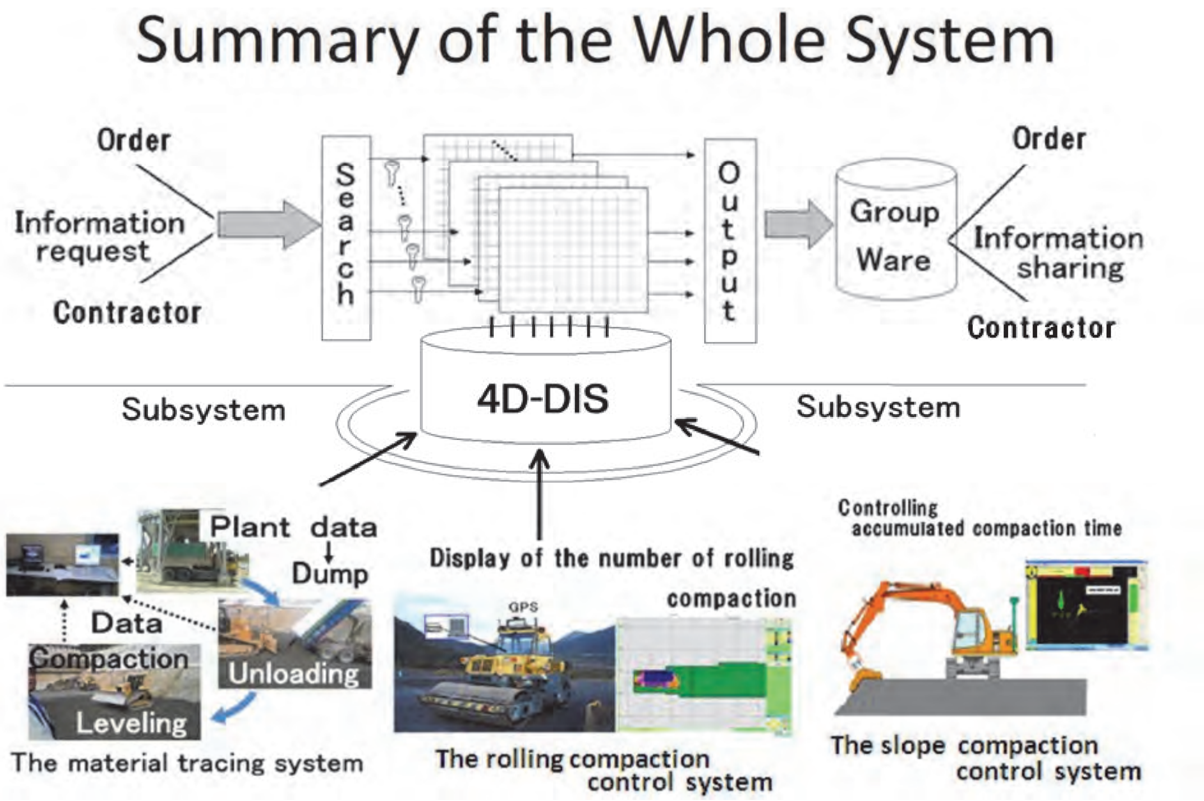
c. Rock & concrete cutting by wire-saw

d. Steel beam & pipe and reinforced concrete cutting by nibbler

# The Development and Management of the ICT System for Dam Construction

## Summary of the Whole System

This system centers on the 4 Dimensions-Dam Information Service and consists of individual subsystems such as the rolling compaction control system, material tracing system and the slope compaction control system. These subsystems enable improvements in efficiency and assurance of the quality of construction.

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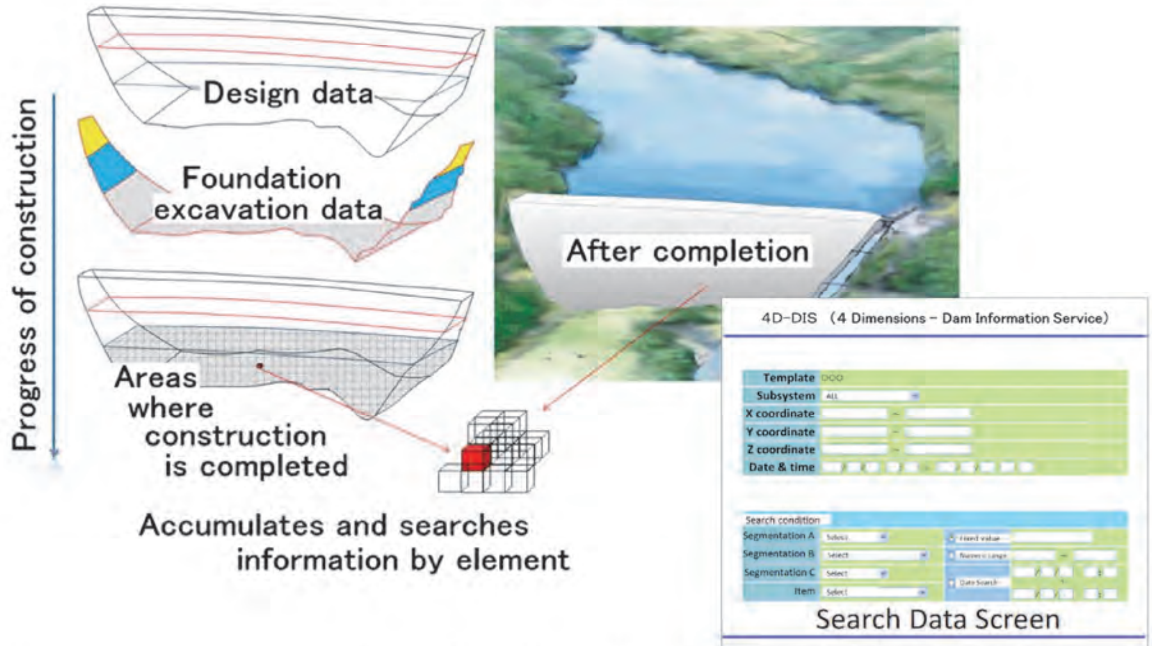
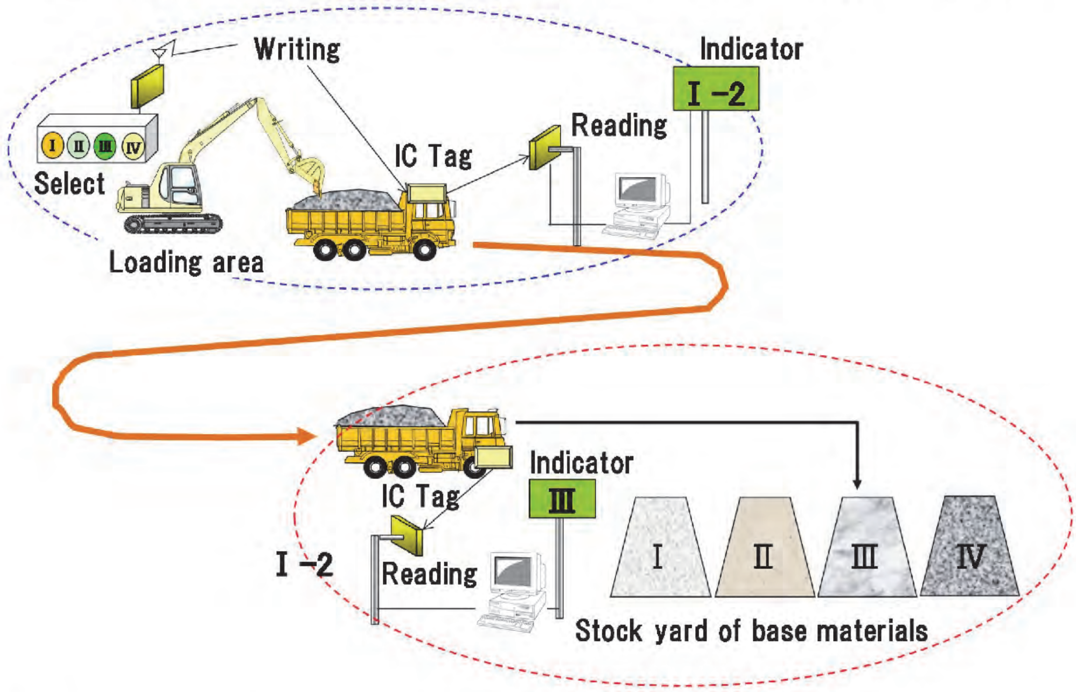
# Data Concept




For the 4D-DIS core, we have adopted the Relational Database Management System. The characteristics of the core exist in that it manages accumulated data four-dimensionally with use of a coordinate and time .

# Image of Base Material Management

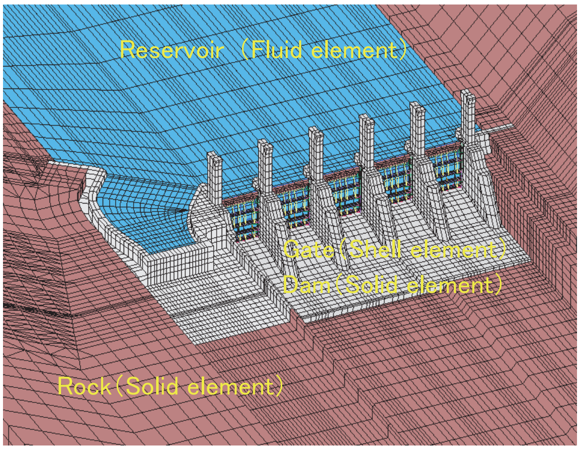



By utilizing Integrated Circuit tags in the management of extraction, transportation and temporary placement of base materials, the system prevents human errors, assures classification in temporary placement and grasps quantities .

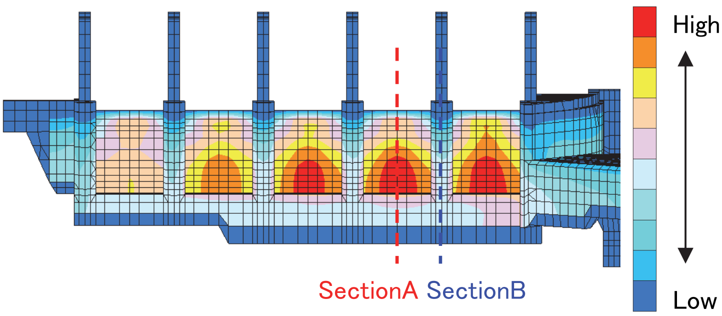
# Hydrodynamic Pressure on the Gate

The hydrodynamic pressure acting on the Gate is larger than which acting on the Dam body (Westergaard's formula)

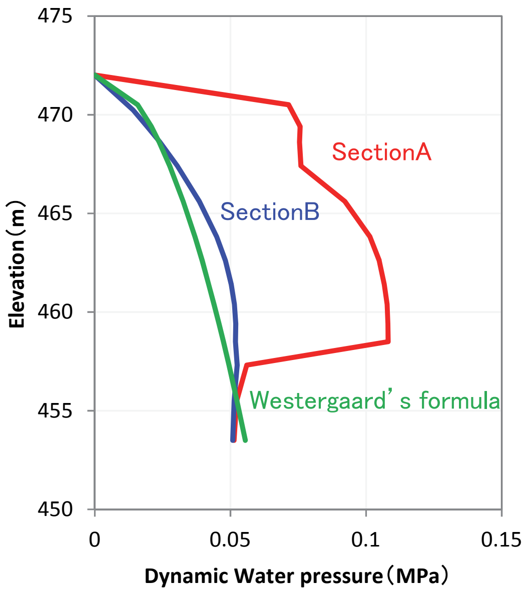
## ①Entire System Analysis Model (Dam-Gate-Rock-Reservoir)




Analytical model: Dam-Gate-Rock-Reservoir Model
Analysis approach: 3-Dimensional Linear Dynamic Analysis
Number of nodes and elements: About 250,000

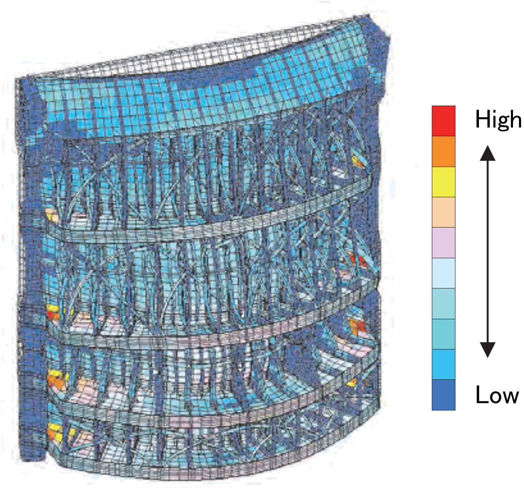



Distribution of hydrodynamic pressure




## ②Gate Analysis Model

Analytical model: Gate Model
Analysis approach: 3-Dimensional Linear Dynamic Analysis
Number of nodes and elements: About 20,000



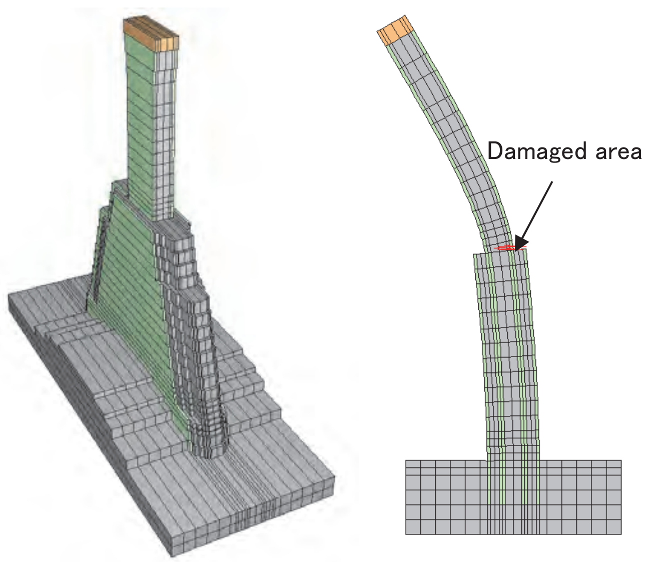

Distribution of stress and displacement

- The hydrodynamic pressure acting on the Gate is derived from the entire system analysis model.
- High reliable value of the stress on the Gate is calculated by Detail Gate Analysis Model.

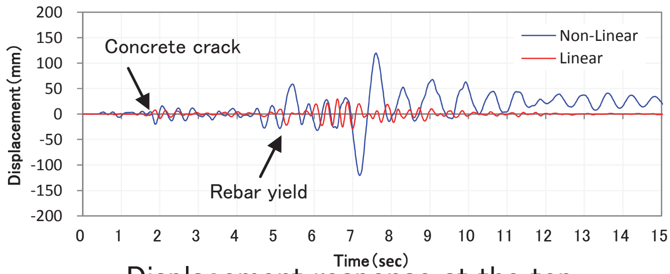
# The Non-linear Analysis of Pier

## Plastic deformation is visualized

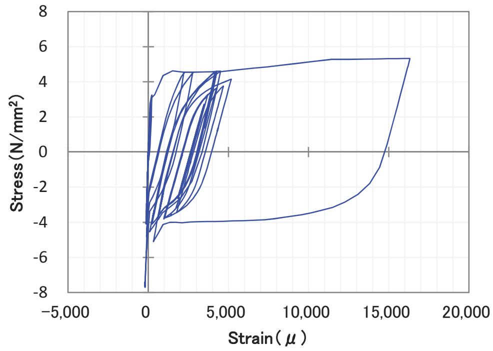
## ①Before aseismic reinforcing work




■ : Reinforced concrete element
■ : Concrete element

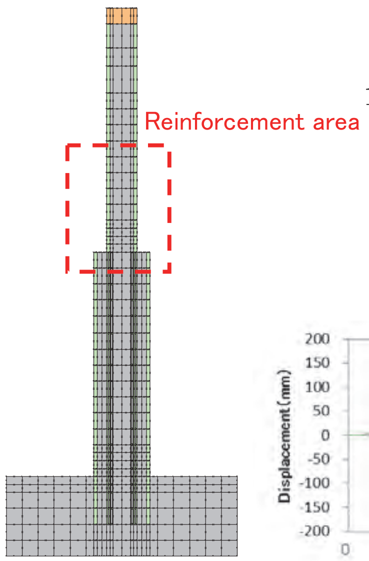


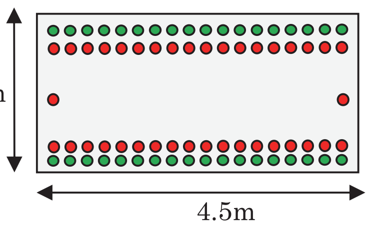

Displacement response at the top



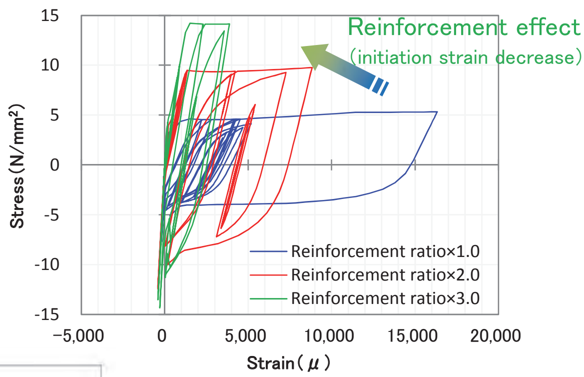

Stress-Strain relation

## ②After aseismic reinforcing work

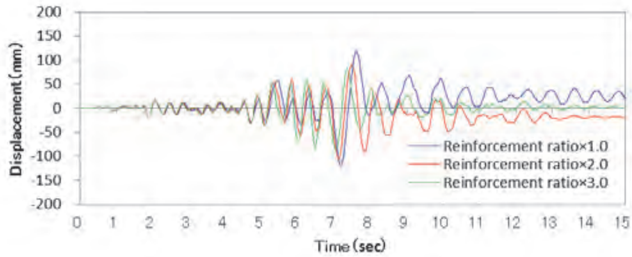



● Existing rebar
● Added rebar




Stress-Strain relation




Displacement response at the top

- Physical behavior of the pier concrete after cracking is derived and visualize
- Structural residual deformation on the pier after the earthquake is derived and visualize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