Kyogoku Project

Pumped Storage Hydroelectric Power Plant

Bird's-eye View of Upper reservoir

Technical data of Upper reservoir		
Type of dam	Rockfill dam with asphalt facing	
Specific data of dam	Maximum height	22.6m
	Crest width	13.0m
	Crest length	1,140.9m
	Total volume	1,539,000m³
Name of river	—	
Catchment area	—	
Reservoir area	0.16km²	
Gross storage capacity	4,400,000m³	
Effective storage capacity	4,120,000m³	
Available drawdown	45.0m	
High water level	EL.890.0m	

Technical data of channel and powerhouse	
Intake	I.D. = 11.8-5.0m, L = 51.7m
Penstock	I.D. = 5.0-1.9m From the upper reservoir to the junction: L = 583.0m From the junction to the unit, No.1 unit : L = 71.9m No.2 unit : L = 55.6m No.3 unit : L = 97.3m
Powerhouse	H = 45.8m, W = 24.0m, L = 141.0m
Draft tunnel	I.D. = 3.7m From the unit to the surge chamber, No.1 unit : 108.7m No.2 unit : 100.0m No.3 unit : 108.7m
Surge chamber	H = 108.0m, I.D. = 12.0m, L = 25.0m
Tailrace tunnel	I.D. = 6.4m, L = 2,483.0m
Outlet	H = 6.4-7.0m, W = 6.4-28.6m, L = 75.5m
Turbine unit	Vertical single-stage francis pumped-turbine units
Generator	Synchronous generator-motor
Maximum output capacity	600MW (200MW per unit for 3 units)
Maximum utilizable flow	190.5m³／s
Effective head	369.0m
Operation plan	October, 2014 (No.1 unit, 200MW) December, 2015 (No.2 unit, 200MW) From 2022 onward (No.3 unit, 200MW)

Upper reservoir

Intake

Penstock

Power house

Access tunnel

Quarry

Tailrace tunnel

Bihinai river

Outlet

Concrete plant

Lower reservoir (Kyogoku dam)

Pepenai river

Spillway

Bird's-eye View of Lower reservoir (Kyogoku dam)

Technical data of Lower reservoir (Kyogoku dam)		
Type of dam	Rockfill dam with vertical clay core	
Specific data of dam	Maximum height	54.0m
	Crest width	10.0m
	Crest length	332.5m
	Total volume	1,318,000m³
Name of river	Pepenai river and Bihinai river	
Catchment area	51.3km²	
Reservoir area	0.39km²	
Gross storage capacity	5,546,000m³	
Effective storage capacity	4,120,000m³	
Available drawdown	14.5m	
High water level	EL.486.0m	
Design flood discharge	610m³/s	

Overview of construction site of lower reservoir(Kyogoku dam)

October 2011

Lower reservoir construction(Kyogoku dam) : Pictures log

Site preparation works

Excavation works

Embankment works at riverbed area

After excavation works

Embankment works of core material

Embankment works of rock material

Spillway

Inspection gallery

Embankment works of dam body

Overview of construction site of upper reservoir

October 2011

Upper reservoir construction : Pictures log

Site preparation works

Embankment works of dam body

Inspection gallery

Excavation works (early stages)

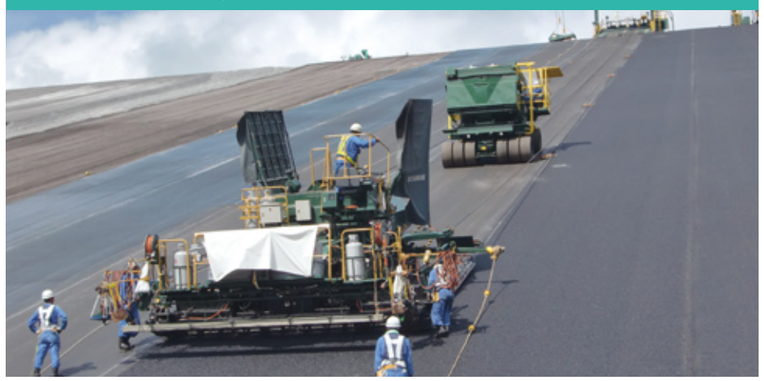
Excavation works (latter stages)

Intake

Aggregate plant

Snow-removal works (after winter)

Asphalt facing work

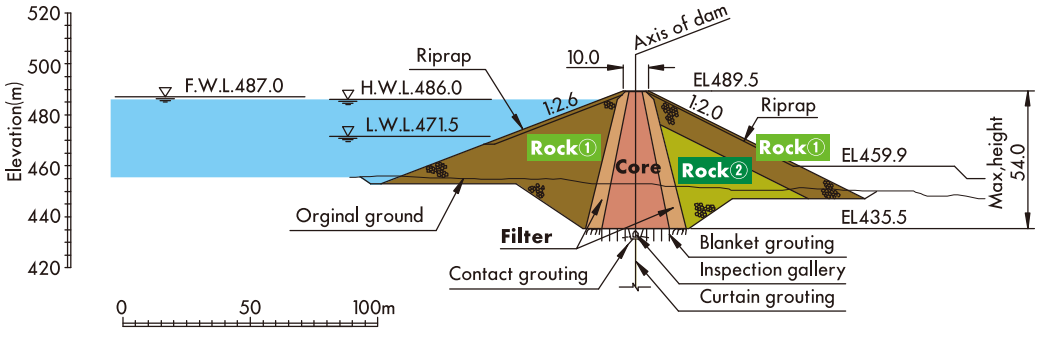


Lower reservoir construction (Kyogoku dam)
Embankment works outline

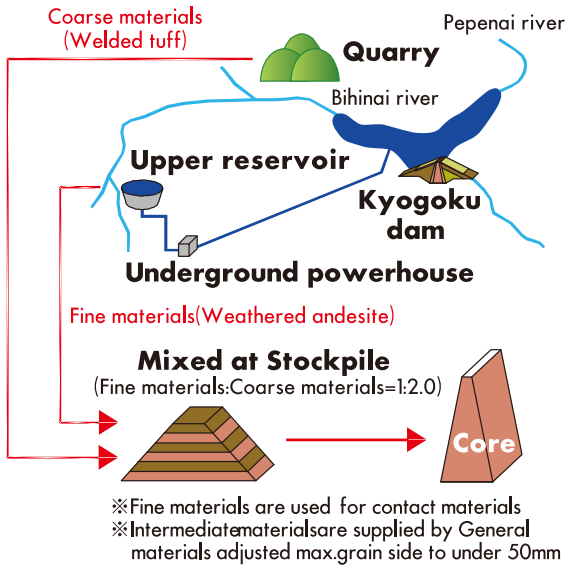
Technical Data

Type of dam	Rockfill dam with vertical clay core
Gross storage capacity	5,546,000m³
Effective storage capacity	4,120,000m³
High water level	EL.486m
Low water level	EL.471.5m
Maximum height	54.0m
Crest length	332.5m
Total volume	1,318,000m³

Standard Cross-Section



Embankment of Core Materials

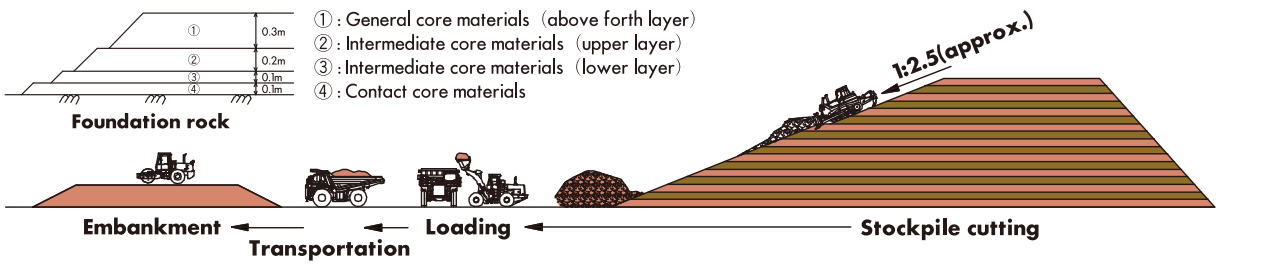


※Fine materials are used for contact materials
※Intermediatematerialsare supplied by General materials adjusted max.grain side to under 50mm

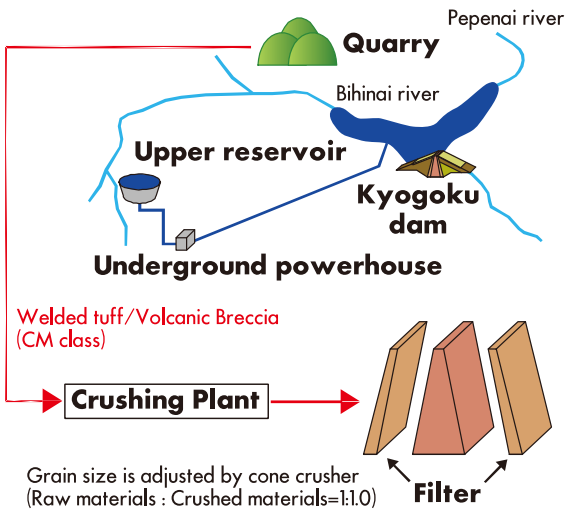
Materials	Max. grain size	Compaction specification	Finishing layer thickness	Construction water content	Field dry density / Degree of compaction	Field permeability coefficient
General core	150mm	Over 8 times compaction using Vibratory roller(11ton class)	0.3m	Wopt+0～4%	≧1.63t/m³ / ≧95%	≦1×10⁻⁷m/s
Intermediate core	50mm	Upper layer : Over 6 times compaction using Vibratory roller(8ton class)	Upper layer:0.2m	Wopt+0～4%	≧90%	≦1×10⁻⁷m/s
		Lower layer : Over 6 times compaction using Vibratory roller(1ton class)	Lower layer:0.1m		———	
Contact core (Contact clay)	50mm	Over 1min/m² compaction using Vibratory compactor or Over 3min/m² compaction using Air tamper	0.1m	Wopt+0～8%	———	≦1×10⁻⁷m/s

※Outline drawing of Embankment specification for rock surface

※Wopt : Optimum water content



Embankment of Filter Materials

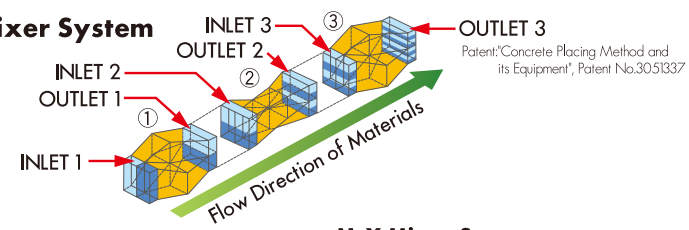


Materials	Max. grain size	Compaction specification	Finishing layer thickness	Field dry density	Field permeability coefficient
Filter	150mm	Over 4 times compaction using Vibratory roller(11ton class)	0.3m	≧1.68t/m³	≧1×10⁻⁶m/s

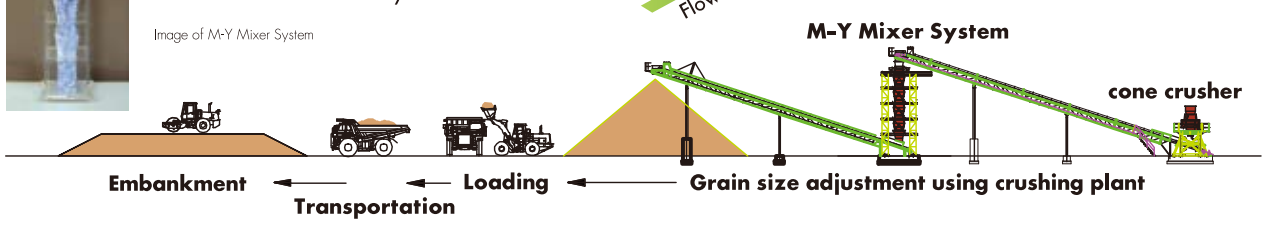
Basic Principle of M-Y Mixer System

M-Y mixer is a continuous mixer consisting of number of units. The mixing of material takes place with the mechanism of kneading and lapping when passing from one to other unit continuously.

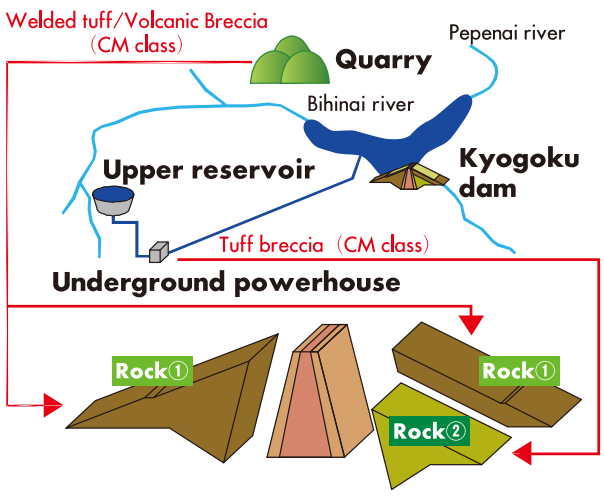
Image of M-Y Mixer System



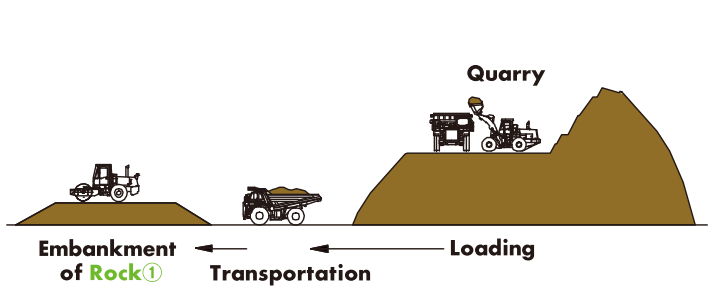
Patent:"Concrete Placing Method and its Equipment", Patent No.3051337

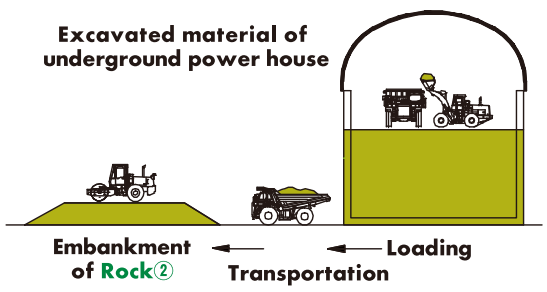


Embankment of Rock Materials



Materials	Max. grain size	Compaction specification	Finishing layer thickness	Field dry density	Field permeability coefficient
Rock①	800mm	Over 4 times compaction using Vibratory roller(18ton class)	1.0m	≧1.74t/m³	≧1×10⁻⁵m/s
Rock②	800mm	Over 4 times compaction using Vibratory roller(18ton class)	1.0m	≧1.91t/m³	≧1×10⁻⁵m/s





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Lower reservoir construction(Kyogoku dam)
ICT-based Construction works system

Improving construction speed

- Without finishing stake
- Effective movement without excessive dependency on the operator's skill

Bulldozer Machine Guidance system

GNSS:Global Navigation Satellite System

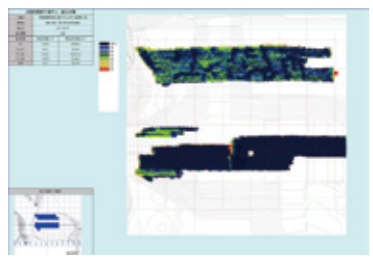
Improving precision in quality control

- Sophisticated control of heavy machinery
- Quality control from "point" to "surface"

Hydraulic shovel Machine Guidance system

Wireless LAN

Automatic document writing system



Integrated DB system by 3D-CAD

- Work instruction data
- Quality control data
- Achieved volume control data
- Automatic creation of control document

Making embankment quality "visible"

- Display of a desired cross section by interlocking the compaction count with 3D-CAD
- Reliable quality traceability

Rolling count control

Enhancing safety of fieldwork

- Reduced work types and workers
- Less frequent access to the heavy machine by exchange of data via the wireless LAN

GNSS surveying

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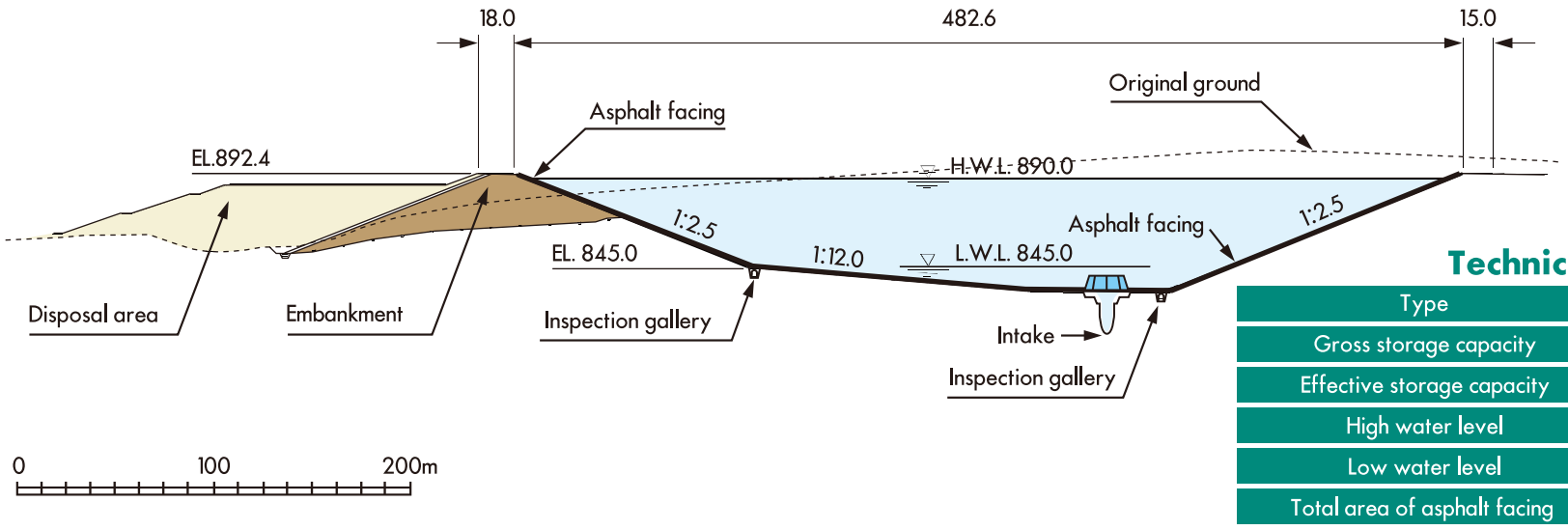
Upper reservoir Construction
Design and Construction of Asphalt Facing

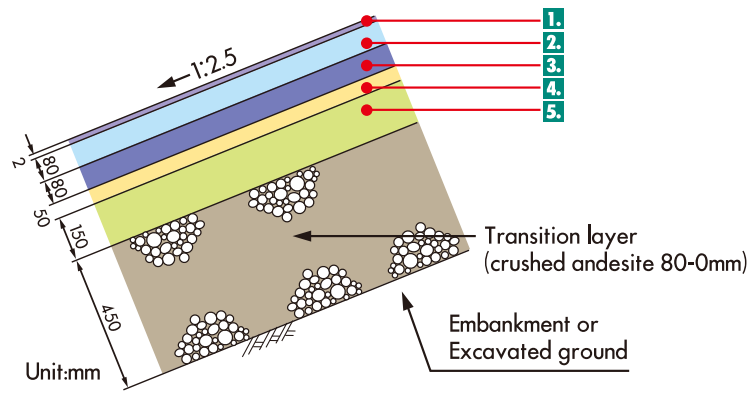
Standard Cross-Section

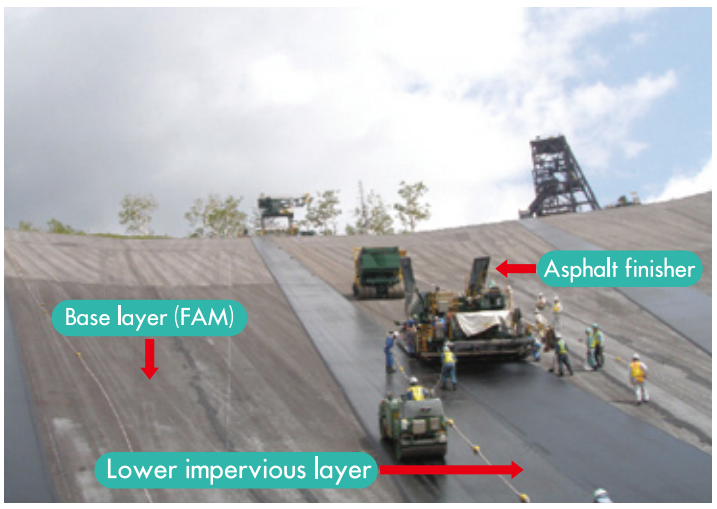


Technical Data

Type	Rockfill dam with asphalt facing
Gross storage capacity	4,400,000m³
Effective storage capacity	4,120,000m³
High water level	EL. 890m
Low water level	EL. 845m
Total area of asphalt facing	178,000m²
Maximum height of embankment	22.6m

Configuration of Asphalt Facing





1. Protective layer (asphalt mastic)
- Protects against damages caused by air, water and ultraviolet.
- Protects against erosion caused by snowslide.

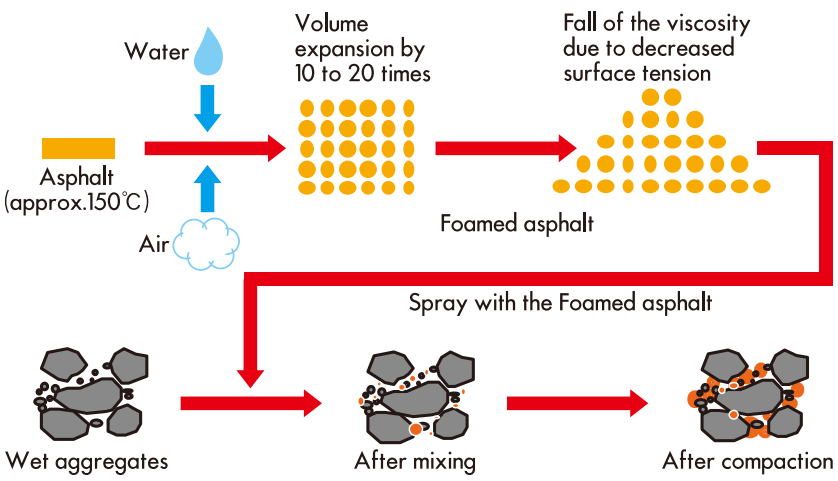
2. Upper impervious layer (dense graded asphalt mixture)
- Seals the storage water directly.

3. Intermediate drainage layer (open graded asphalt mixture)
- Monitors any leakage from the upper impervious layer.
- Leads leakage to the inspection gallery and the drainage tunnel.

4. Lower impervious layer (dense graded asphalt mixture)
- Seals any leakage from the upper impervious layer.
- Leads leakage to the inspection gallery and the drainage tunnel.
- Seals the underground water.

5. Base layer (foamed asphalt mixture (FAM))
- Protects the transition from avalanches and sliding or melting ice during winter and early spring.
- Maintains the thickness of the lower impervious layer.
- Secures the mechanical continuity of the embankment and asphalt facing materials.

FAM:Manufacturing process and pavement works



Levelling by a bulldozer

Compaction by a self-climbing vibration roller

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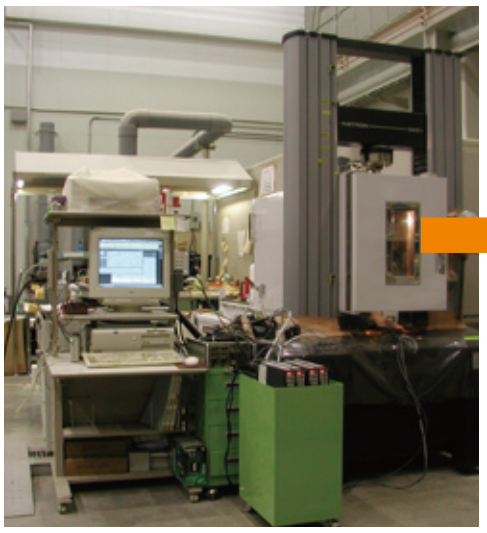
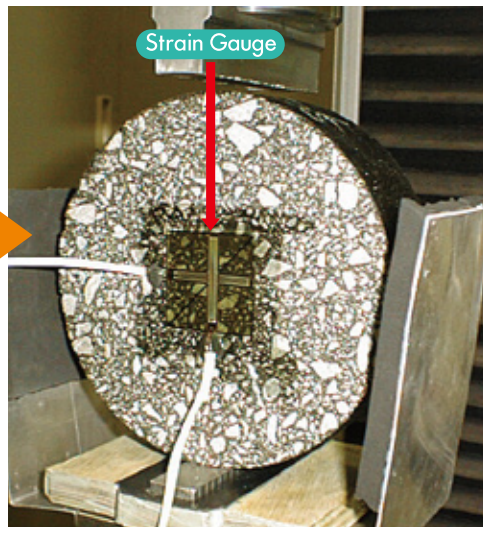
Upper reservoir Construction
Design and Construction of Asphalt Facing

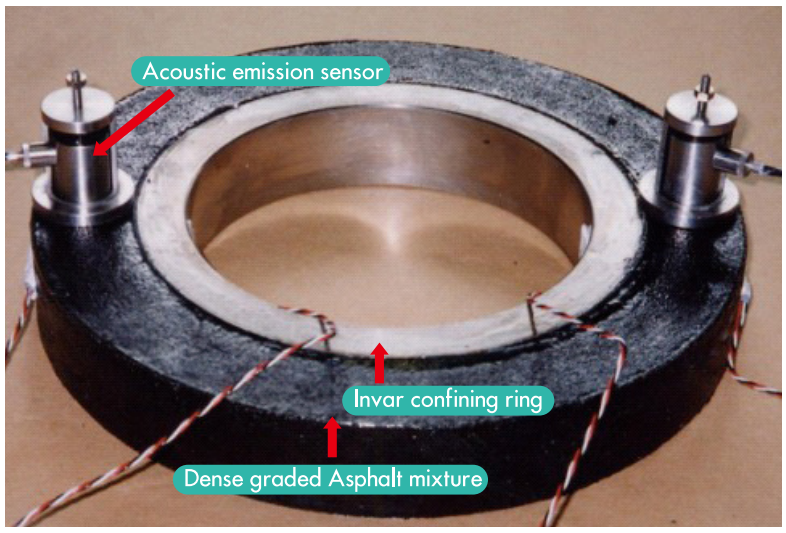
The Rational Design and Construction System of Asphalt Facing

Two laboratory tests were conducted to fulfill the design requirement.

Design Features







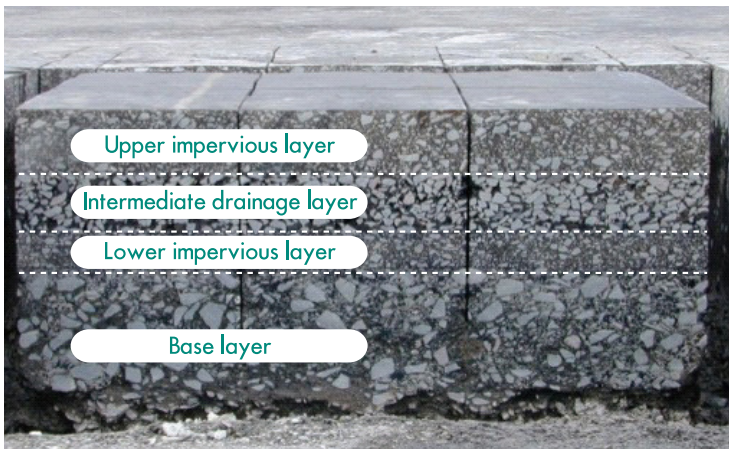
SHRP indirect tensile test

Not only tensile strength and strain but also creep compliances, modulus number, and Poisson's ratio of asphalt mixtures were measured accurately and simultaneously using indirect tensile test (SHRP ITT).

Low temperature cracking test

A creative test detecting micro cracks was designed to evaluate the resistance to low temperature cracking.

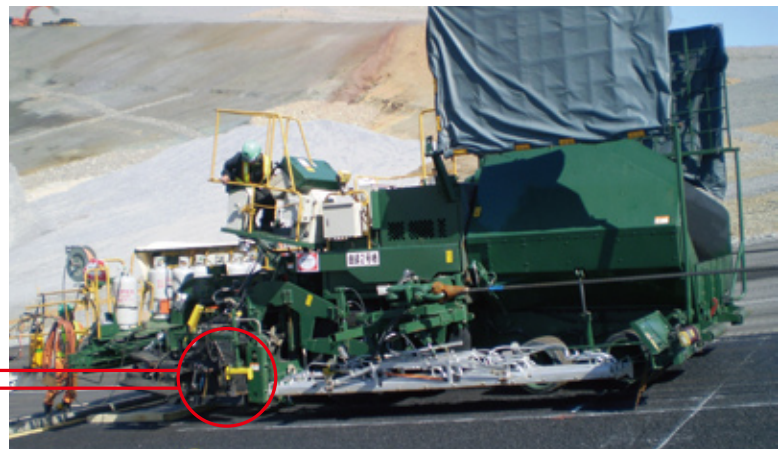
Full Scale Field Trials

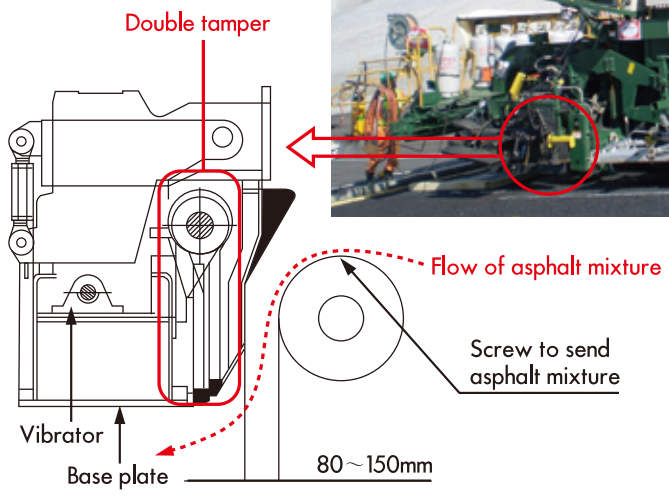


Cross section of the slope paved by field trial

Due to the cold, heavy snow conditions at the project site, a unique composition was applied to the asphalt facing of the upper reservoir.

Machine to pave





Asphalt Finisher with double tamper

Adopting double asphalt tamper was attained to compact the thick layer adequately.

Construction Works

Paving the Lower impervious layer by an asphalt finisher.

Compaction by a vibration roller

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Upper reservoir Construction
ICT-based Construction works system

Adoption and outline of the system

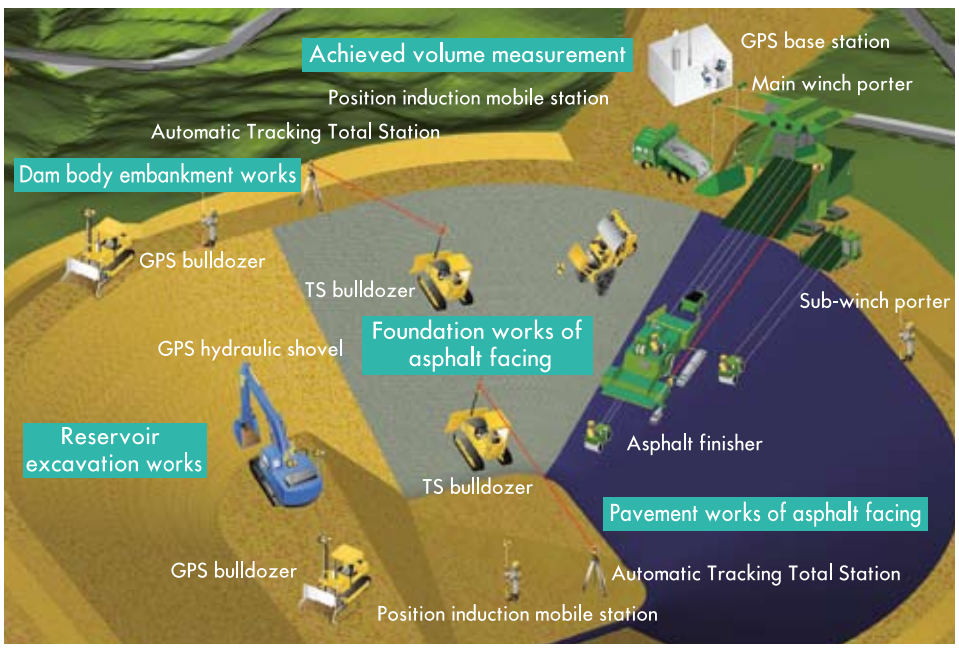
The upper reservoir is located in one of the areas of heaviest snowfall in Hokkaido. The annual construction period is practically restricted by snowfall to five months from June through October. Further, 64% of the inner surface of the reservoir is curved in complicated forms. This system was introduced for such a large-scale and urgent construction works under such severe conditions. The earthworks of this project were completed in a seven-year period from 2003 through 2009 (in 35 months in terms of actual working months).
This system is composed of five systems, and the entire system is built on the basis of 3D-design data created by a design support system.

Survey and design	A	Information-based design works support system (3D-DAMCAD)
Surveying	B	3D-position induction system (3D-Navi)
		3D-work system RTK-GPS
Construction works	C	3D-MC bulldozer system using GPS Bulldozer and TS Bulldozer
	D	3D-MG hydraulic shovel system using GPS hydraulic shovel
	E	Compaction management system
Work management	B	3D-position induction system (3D-Navi)
OUTPUT	A	Information-based design works support system

Earthworks volume for upper regulating reservoir

Dam body excavation	6,581,000m³
Dam body embankment	1,539,000m³
Sloping area	165,000m²

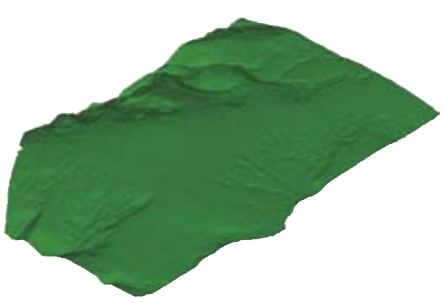
GPS:Global Positioning System TS:Total Station (Surveying instrument)

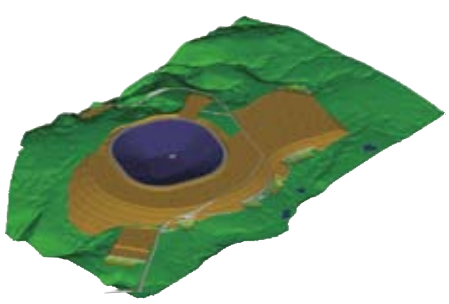


ICT-based construction works system configuration and image of construction works

Planning and construction works assisted by an information-based design works support system (3D-DAMCAD)

A


CG by 3D-DAMCAD (before construction)


CG by 3D-DAMCAD (after construction)


Completion of excavation and embankment (complete view, as of 2009)

ICT-based Field works

B **3D-position induction system(3D-Navi)**

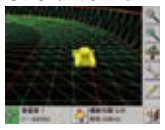


RTK mobile station set

C **3D-MC bulldozer system**

Dam body embankment


GPS antenna


Dedicated display screen

D **3D-MG hydraulic shovel system**

Reservoir excavation

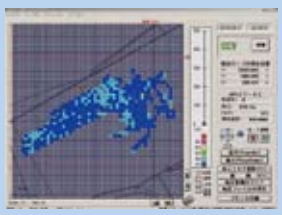

GPS antenna
(two sets mounted)

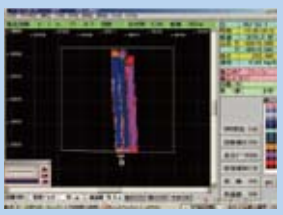

Dedicated display screen

E **Compaction management system**


Compaction of dam body embankment


Compaction of base layer


Dam body embankment


Base layer

Dedicated display screen

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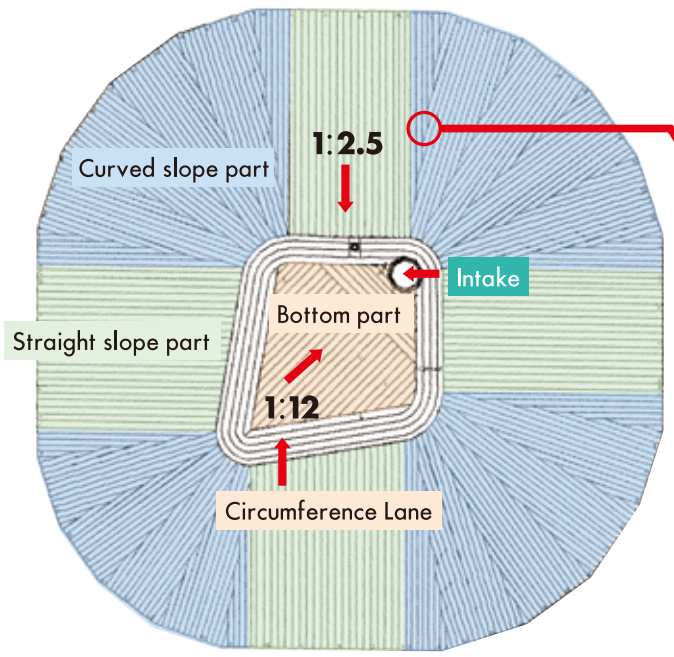
Upper reservoir Construction
Construction of asphalt facing

Overview of asphalt facing

The asphalt facing is a five-layer paved structure. The work area has a sloping section of 627,000 square meters having an inclination of 1 to 2.5, and the bottom section of 84,000 square meters having an inclination of 1 to 12. The overall work area is 711,000 square meters.
The construction will be completed in four years from 2010 through 2013 (20 actual working months).
Various types of flexible measures have been taken at the work site to ensure that the required impervious control performances of the reservoir with a completed curved shape (a bowl-shaped valley) will be constructed in a short period of time.



Complete view of triangular part

Volume of construction work

Layer name	Area (m²)	
	Sloping section	Bottom section
1. Protective layer	156,000	19,400
2. Upper impervious layer	156,800	21,000
3. Intermediate drainage layer	155,800	2 1,500
4. Lower impervious layer	157,400	20,500
5. Base layer	156,900	2 1,200

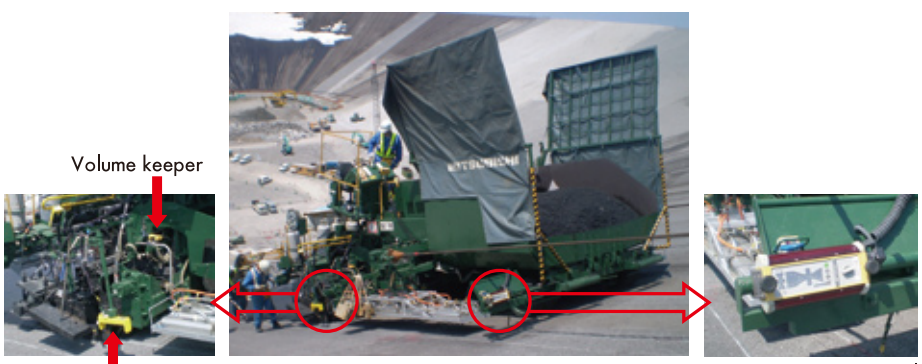
- Lane width
  Straight part 5.0m
  Curved part 4.0m
- Number of lanes per layer
  390 lanes
- Longest slope length
  163.0m

Features of paving machinery

- Large-sized, high-speed machine
- Screed adjustment capable of conforming to slope and curved structure
- Adoption of automatic control system
  Automatic steering system ⇨ straight traveling capacity
  Automatic control of volume and height of mixtures ⇨ horizontal surface
- Accurate formation of joint portions
  Joint heater and joint compactor ⇨ continuous heating and compaction

Paving machinery that meets the requirements of curves and high speed

Asphalt finisher for slope (double tamper type)

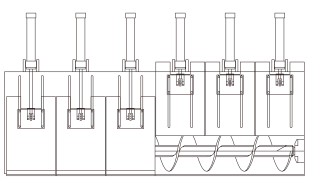


Construction of triangular part

Gate type supply system

At the curved slope parts, construction lanes' width varied and changed into triangular forms as shown in the overview. Therefore, the Asphalt Finisher equipped with gate type supply system has been designed to assure the following pavement work advantages:

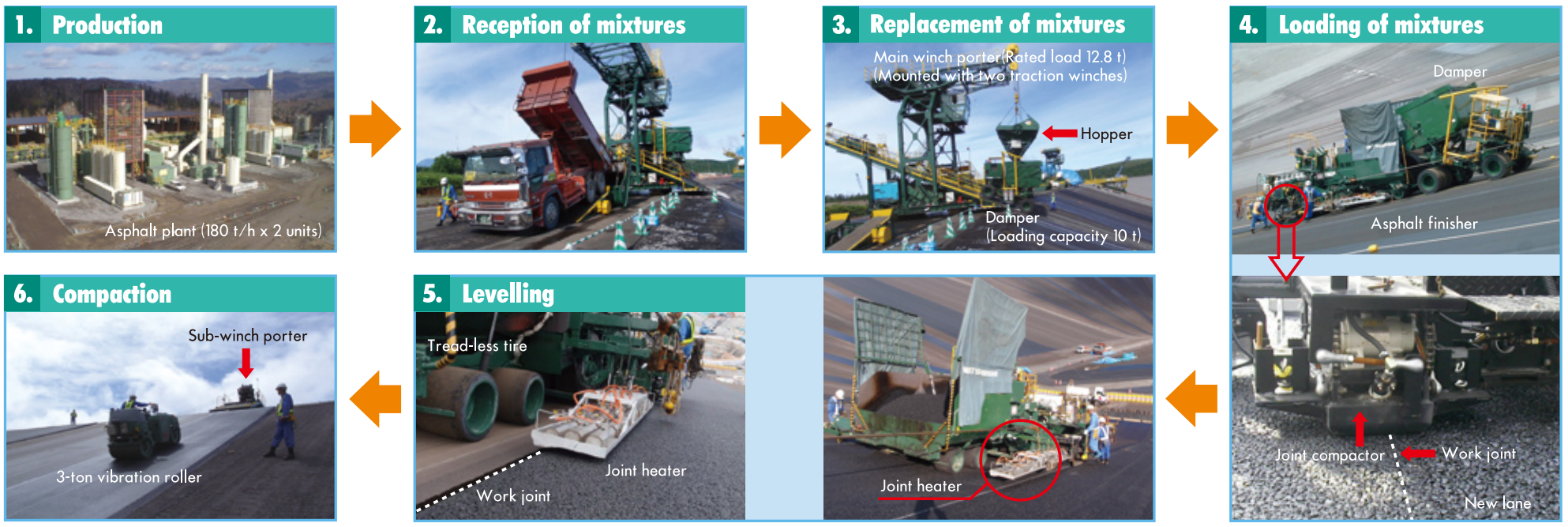
■Enhanced quality ■Increased speed ■Greater safety


Sketch of gate type supply system


Gate type supply system

Man-handled compaction works

Work flow



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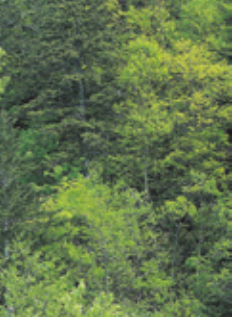

Environmental protection measures

Introduction

The Hokkaido Electric Power Co., Inc. has determined the four following basic policies. This is intended to implement the construction work of Kyogoku Power Plant in harmony with the surrounding environment by avoiding and minimizing the possible impact on the surrounding environment and protecting the natural environment in the work area.
The environmental protection measures include an afforestation program which will protect rare species such as Black Woodpecker (*Dryocopus martius martius*, Endangered species (Japan Red Data Book)) and Ezo Salamander (*Hynobius retardatus*,Species requiring special attention (Japan Red Data Book)) including the Raptores situated in a higher position in the ecosystem, as well as rare plants such as Ezomantema (*Silene foliosa*,Endangered species (Japan Red Data Book)) and Ezonoreijinsou (*Aconitum gigas*, Precious plants (in Hokkaido)) and vegetation in the wetland. The measures against muddy water generated by land modification and landscape protection measures are also included in the environmental protection measures. Further efforts are taken to implement the construction work by monitoring and verifying the effects of these environmental protection measures.

Basic policies for environmental protection

- All-out efforts for raising workers' awareness of environmental protection
- Observance of laws and regulations
- Setting of targets and monitoring
- Release of information

Overall education for environmental protection

To ensure that all members engaged in the construction work will pay due attention to the natural environment and will make efforts for preservation of rare species, the "Environmental protection handbook" has been worked out and has been handed down to each of the members engaged in the construction work. This is intended to raise workers' awareness of environmental protection.

Environmental protection handbook

Environmental monitoring

In addition to environmental protection measures, environmental monitoring is implemented on a continuous basis to check the noise, vibration, water quality, animals, plants, ecosystem and landscape, in an effort to verify the impact on the environment and the effect of the environmental protection measures.
These survey results are reported to the Ecosystem Committee consisting of academics and experts every year. Further, the related information is released to the public whenever possible.

Protection of Raptores and Black Woodpecker as rare species

To preserve rare Raptores and Black Woodpecker as protected species considered being on the verge of extinction, further efforts have been made to protect the trees used for feeding and nest building, wherever possible, in the planning phase of working out a layout plan of the structures. Further, during the construction work, the material and equipment are carried during the daytime, in principle. Illumination during the night is restricted to the work area alone. Noise and vibration of the heavy machinery are minimized.
For deforestation, efforts are made not to cut down trees during the nest-building period.


Black Woodpecker


Oriental Honey Buzzard
(Pernis apivorus orientalis,Quasi-endangered species (Japan Red Data Book))

Protection of rare plants

The basic point is to minimize the impact on the environment for growth of rare plants. Measures are taken to ensure that the rare plants found in the modified area will be transplanted to an area more suitable for growth where plants will not be affected by modification in the surrounding area.

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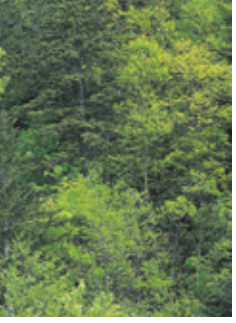

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Wetland protection measures

In the area surrounding the upper reservoir of the Kyogoku Power Plant, there is an expanse of Kyogoku Wetland that was formed 13,000 years ago, and this is the oldest mountainous wetland in Hokkaido. The Kyogoku Wetland is composed of typical snow bed vegetation, and is an academically precious wetland because the largest Iwaicho (*Fauria crista galli*) plant community in Hokkaido is located in this region.
In the assessment survey, the position of the upper reservoir was changed twice in the planning phase in an effort to avoid impact of the construction work on the wetland.
During the construction, monitoring is implemented to keep track of the current status of the vegetation of the wetland, underground water level and water content in the soil. The construction work is carried out by checking the impact on the wetland.

Iwaicho forming a plant community

Full view of Kyogoku wetland

Snow bed vegetation: peculiar plant community mainly consisting of perennial plants, where these plants come into flower and bear fruit with the melting of snow caused by the snowdrift produced in the depression on the mountain top or edge line.

Protection of Ezo Salamander

For example, when a spawn or individual has been identified in the construction area, it is brought to a nearby habitat not affected by modification. The catch basins installed in the construction area are provided with "Haiagaru" (provisional name denoting a simple slope that permits small animals to escape) so that small animals falling in these basins can escape under their own power.
The habitat is a puddle into which clean water flows and is kept at a temperature (10 through 20 degrees Celsius) suitable for growth and propagation. It is located close to the mountainous area where there are land habitats.

Ezo Salamander
(Hynobius retardatus,
Species requiring special attention
(Japan Red Data Book))

"Haiagaru" (slope: 1 to 0.8, width: 0.2m)

Afforestation

The bare ground resulting from construction work is subjected to speedy afforestation to ensure earlier stabilization of the slope and preservation of landscape and to provide measures against muddy water. In the phase of afforestation, consideration is given to the ecosystem and biodiversity. Seeds are collected from the native plants found in the construction area and its surroundings, and are germinated and grown into seedlings, which are then planted (by a biological mixed planting method).

Afforestation slope

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