Improvement and monitoring of Miyanaka Intake Dam fishway structure for harmonization of hydropower and river environment

Tomohiro Omori[a] , Yasuaki Moriyama[b] , Taku Masumoto[a] , Kenichi Yamazaki[a],

[a] Shinanogawa Power Station Improvement Office, East Japan Railway Company,1-7-33 Daimachi, Nagaoka, Niigata 940-0048, Japan

[b] Shinanogawa Power Station Improvement Department, East Japan Railway Company,2-2-2 Yoyogi, Shibuya-ku, Tokyo 151-8578, Japan

Keywords:
Fishway structure
Improvement
New discharage pattern
Monitoring
Run-up environment
Adaptive management

ABSTRACT

There were two problems in the fishway located in the right-bank side of the Miyanaka Intake Dam of the middle reaches of the Shinano River. The 1st problem was due to the continuity of the fishway entrance downstream part was not secured, and the 2nd problem was due to the flow of the pool is unstable. About the 1st of dam problem by, repeating numerical analysis and a local discharge experiment and finding out real almsgiving and the optimal discharge pattern was found. The validity was checked by run-up course check investigation of the salmon. About the 2nd problem, the hydraulic model experiment and the field trial were done, while improving the large-sized fishway to the ice harbor type, the "Seseragi fishway " was newly established by considering biodiversity. By being checked run-up species during the monitoring investigation, after reconstruction than before, improvements of the fishway was confirmed. As part of adaptive management in the fishway structural improvement project it is planned to continue monitoring further.

1. INTRODUCTION

Miyanaka Intake Dam, which is power generation dam, is located at the middle reaches of the Shinano River. The discharge rate to the Shinano River was decreased by the dam, and the river environment has been changed. Therefore, it is required to increase the amount of river discharge and improve the fishway of Miyanaka Intake Dam. The problems of Miyanaka Intake Dam fishway were as follows.

(1) The flow of the fishway and down-stream of the dam was not continuous.

(2) The flow of water was unstable in the fishway.

In order to improve these problems, East Japan Railway Company (hereafter, described as JR-East) set up a committee in 2009. This committee consists of members of academic scientists, experts related to inland waters fishery, and the local and river administrative bodies, etc. Which was conducted various studies to gather.

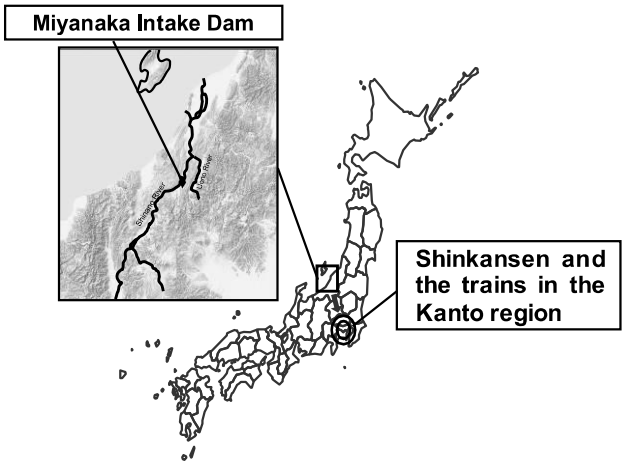

Fig.1. Location of the Miyanaka Intake Dam

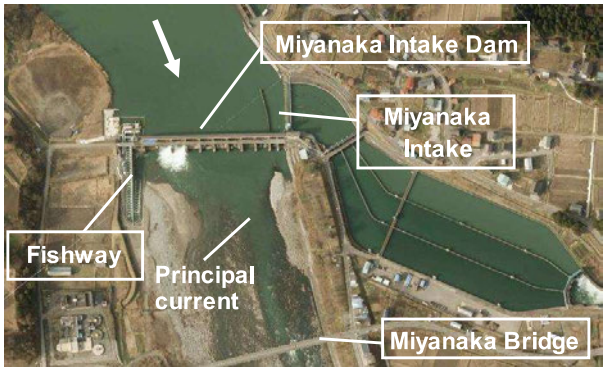

Fig.2. Overview of Miyanaka Intake Dam

In this report, we descried the content and result of the studies carried out to solve these problems.

2. OUTLINE OF MIYANAKA INTAKE DAM AND PROBLEM AROUND THE FISHWAY

2.1. OUTLINE OF MIYANAKA INTAKE DAM

The Shinano River, that length is 367 km and catchment area is 11,900km^2, is the longest river in Japan. Miyanaka Intake Dam, which is a power generation dam, is located at 134km from the mouth of the Shinano River. The catchment area of 7,841 km^2 is the greatest in large dams in Japan. Because it is the Sea of Japan River side-specific heavy snowfall, the amount of water flowing in one year boasts about 16 billion m^3 and large amount of runoff in Japan. Hydro power generation was started since 1939, and the dam was succeeded to JR-East in 1987, following division and privatization of Japanese National Railways. The generated electric power was supplied for the operation of the Shinkansen and the trains in the Kanto region. (Fig. 1)

The existing fishway was constructed with the main dam in 1938 next to the navigation lock on the right bank side, and its total head was about 11m. Afterwards, the navigation lock was removed, and fishway had been improved to two lanes for large and small fishes at the reconstruction time of 1988. (Fig. 2)

2.2 PROBLEM AROUND THE FISHWAY

Problems in the fishway of Miyanaka Intake Dam were as follows.

2.2.1. Discontinuity of the flow between the fishway and the downstream.

Problems concerning the continuity of the flow were as follows.

Since fishway of a Miyanaka Intake Dam was installed in the right-bank side,it was difficult for fish because to run-up principal current which was formed at the left-bank side was reached at the entrance of fishway. The circulating flow had generated in the vicinity of the fishway entrance by that gate discharge. (Fig. 3)

2.2.2 Unstable flow in the fishway

Problems concerning the continuity of the flow were as follows.

Due to the shape of the pool was oblong, notch and orifice were alternately prepared. The flow of the pool was complex. Transverse wave was generated according to flow rate. (Fig. 4)

3. APPROACH TO IMPROVEMENT OF RIVER ENVIRONMENT FROM THE VIEW POINT OF THE OPERATION

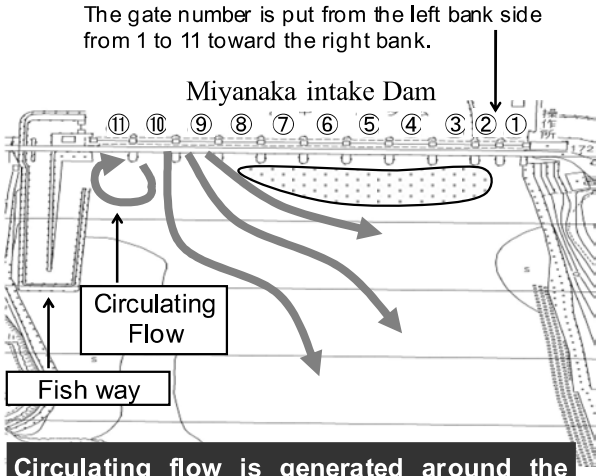

Fig.3. Discontinuity of Miyanaka Intake Dam downstream

Fig.4. Unstable flow in the fishway

TECHNIQUE

3.1. IMPROVED CONSIDERATION BY THE CHANGE OF THE GATE DISCHARGE PATTERN

3.1.1 Examination technique

To secure the continuity of the flow between the fishway and the downstream, and also for the easement of fishes for their migration, examinations were performed about some patterns of discharge from the crest gate located 11 on a dam.

The study was achieved by combining a numerical hydraulic analysis with in situ discharge experiment. The system analysis model has improved by checking the situation of actual flow and the validity of the result was proved by telemetry investigation using a salmon.

3.1.2 Method of numerical analysis

There are two types of the numerical analyses. One is an ordinary analysis to recognize the improvement of the upstream environment, and the other is an analysis at the flood to search for the possibility of formation of the principal current on the right bank side.

The analysis in ordinary circumstances was done by the non-steady flow analysis that used two dimensional plane model with a general coordinate system. To predict the change in location and shape of the principal current, an analytical model at the flood combined the riverbed evolution analysis with two dimensional plane non-steady flow model made in the analysis in ordinary circumstances. The analytical model set up the range of 750m downward from Miyanaka Intake Dam.

The result of the analysis was evaluated whether the place of below flow velocity of 1.0m/s was formed at the boundary part of a strong flow continuously.

3.1.3 Method of in situ discharge experiment

Items of investigation in the in situ discharge experiment were direction of the flow, flow velocity, range of occurrence of dead water and circulating flow and range of generation of bubble. The range of the bubble was assumed to be one of the judging materials when the route of upstream was considered, because there is an opinion in committee that the upstream fishes should avoid the place where flow velocity is large and the bubble is generated.

The float was turned on, and the behavior of the flow was understood by watching the video. The range of the investigation was a section of about 200m from Miyanaka Intake Dam down to Miyanaka Bridge.

It became an experiment under the condition that the amount of discharge could not be set arbitrarily. Therefore, the experiment was flexibly conducted so that the opportunity which can be observed the actual phenomenon of this site might not be spoiled.

3.1.4 Results of study of discharge pattern

Consideration of new discharge pattern

To ensure the continuity of the fishway and dam downstream portion, the discharge pattern were investigated from three steps by the discharge pattern between 50-100 m^3/s.

The 1st step means a discharge method from the gates No.9 and No.10 of the right bank side, the 2nd step means an effect of improving the flow around the fishway entrance by discharge from the gate No.11 of the edge of the right bank, and the 3rd step means a method of discharge from the gates from No.6 to No.11.(Fig. 5)

The following result was referred.

- The pattern that makes the discharge of the gates No.9 and No.10 the same is reasonable.
- It is unsuitable to enlarge the discharge from the gate No.11 too much.

- As for an appropriate discharge method of the gate No.11, it should be controlled under the amount of discharge rather than the pattern, and suitable range is around 12-15m^3/s.

By the above results, the new discharge pattern by which the principal current which followed the fishway was found out from analysis with in situ discharge experiment.

3.2 Monitoring study

3.2.1 Method for investigating migratory behavior of fishes

In order to measure the effects of the new discharge pattern, the easiness for fishes to reach fishway was investigated as an index.

Captured fish with a transmitter were released from the downstream side of the dam. The difference between the upstream routes and arrival rate of two discharge patterns were investigated.(Fig.6)

Case 1: Discharge pattern in the present operation system

Case 2: Discharge pattern in the new operation system

Two experiments were carried out under the same condition except the discharge pattern. Discharge amount in each day of the investigation day was 160~180m^3/s about the present operation system, and was 110~160m^3/s in a new discharge pattern.

For each case, 5 chum salmons (Oncorhynchus keta) were used as a capture fish for investigation.

The salmons were collected from a cage trap set in the middle of fishway. The salmons with a transmitter were sustained in a cage for one day in order to confirm that fishes do not vomit the transmitter.

These fishes were released into the river at a left bank side about 1km downstream from the dam. The gate operation for discharge pattern was set on the morning of the day before the salmons, which was released after acclimatized to the downstream river.

Directions of the salmon were pursued by the two or more observers holding receivers disposed along the riverside. The locations of salmon were recorded at 5 minutes interval by seeking a cross of directions. The supplement measurements were done partly near the vicinity of the gates and the fishway where precise positions were required.

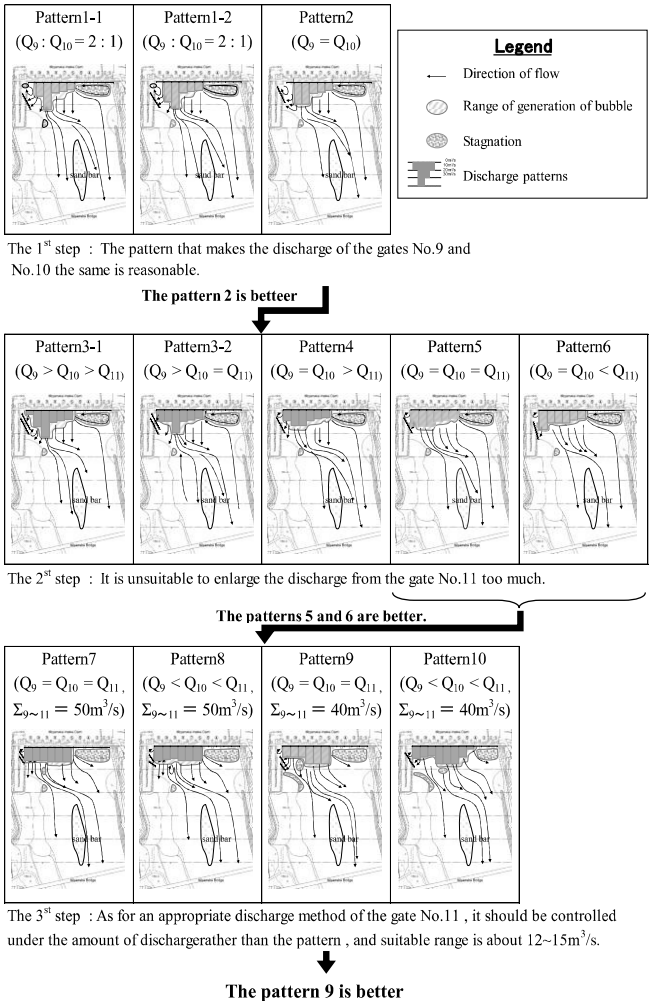

Fig.5. Three stages of the study on the discharge pattern

Left: Equipment of transmitter
Right: Transmitter

Fig.6. Mounting by transmitter

3.2.2 Migratory behavior survey results of fish

Case1: 40% of individual which passed through the right bank side downstream in front of a No.8 gate, and arrived at the fishway pool was observed.(Table 1)
Case2: 80% of investigation fish which passed through the No.8 gate front and

Table 1 The arrival rate of migrating salmons near the fishway

	Case 1						Case 2					
	Numbers					Ratio (%)	Numbers					Ratio (%)
	ID1	ID2	ID3	ID4	ID5		ID6	ID7	ID8	ID9	ID10	
individuals arriving in front of the dam	○	○	○	—	○	80	○	○	○	○	○	100
individuals passing through the front of the gate No.8	○	—	—	—	○	40	○	○	○	○	○	100
individuals arriving the entrance and entering the fishway	○	—	—	—	○	40	○	○	—	○	○	80
individuals arriving the turning pool	○	—	—	—	○	40	○	○	—	○	○	80

※○ : Fish have been run-up
— : Fish that have not been run-up

arrived at the fishway was observed.(Table1)

4. STUDY OF FISH PASSAGE FACILITIES FOR IMPROVEMENT OF THE RIVER ENVIRONMENT

4.1 Aim and method of fishway design

In addition to solution of the problem at the fishway, examinations of the fishway, and its disposition were performed to consider the facility for ascending of various species of fishes.

In order to improve the unstable flow in the fishway, it designed to combine the hydraulic model experiment and the field trial, and improved the employment method of the fishway.

4.2 Placement and format of fishway

To achieve migrating environments of various species of fishes including the bottom fishes and fishes with small swimming ability, a small size fishway with natural rough stones was set up newly. In addition to two lanes of the existing pool and weir type fishways. In this paper, the additional new one will be called a brooklet fishway (“Seseragi fishway” in Japanese).

The brooklet fishway was designed by 25cm in width like the meander in the existing channel of the fishway for smaller fishes, and its slope is 1/20.

In order to decrease the complex flow in the pool that originated in the oblong plane shape of the pool with the alternate arrangement of notch and orifice, measures were necessary to the fishway for larger fishes. Therefore, the width of the fishway was reduced from 10m to 8m, improving to the Ice Harbor type fishway.

About the fishway for smaller fishes, the current shape was transferred since desirable flow was experienced on the existing fishway, and the grade of upstream migration was excellent in the investigation. (Fig.7 , Table 2)

The effect of improvement to the Ice Harbor type was confirmed by the experiment of extract hydraulic model, and the followings were elicited.

- Necessary depth of the overflow section should be secured.
- Space that is appropriate for the orientation and upstream is formed to the downstream of the overflow section.
- Dead water region that should be a rest

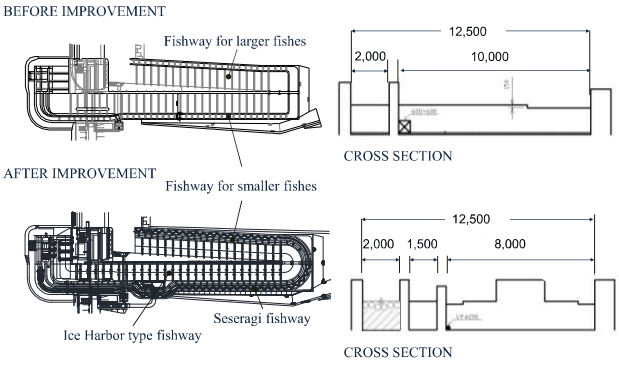

Fig.7. Outline of the improvement plan of the fishway structure

Table 2 Flow rate of the fishway

Fishway for larger fishes	Fishway for smaller fishes	Seseragi fishway
1.637m^3/s	0.133m^3/s	0.022m^3/s

space is realized to the downstream of the non-overflow section

In order to confirm the flow when the

non-overflow section was set up in the downstream part of the turning pool, the experiment of controlling the transverse wave was accomplished. However, this experiment was not effective. The following measures are planned to control the generation of the transverse wave.

- The Ice Harbor type that reduces the fluctuation of water surface is adopted.
- The turning pool is established like the semicircular shape.

It will be observed after the improvement is accomplished, because it is difficult to predict whether these measures will be effective or not.

4.3 Results of Monitoring survey

In order to understand the run-up situation after a fishway structural improvement, the trap was temporarily installed to the fishway upstream border, monitoring investigation by capturing total was conducted before and after the improvement, and was performed a comparison of fish species.

Since Amur goby(*Rhinogobius kurodai*) that the design target species in order to fishway renovation is being run-up select “Seseragi fishway”, it was possible to confirm the validity of the “Seseragi fishway”.

In the fishway of the Miyanaka Intake Dam after an improvement, since 14 species of run-up fish before an improvement were captured, the integrity of ascension environment was able to be confirmed.Moreover, since ascension of 19 to 24 species of fishes, such as "Ukekuchi-ugui(*Tribolodon nakamurai*)", "Masu salmon(*Oncorhynchus masou*)", "Amur goby(*Rhinogobius kurodai*)", and "Charr(*Salvelinus leucomaenis pluvius*)", was newly captured, the creativity of ascension environment was also able to be checked. (Table 3)

Table 3 The Harvey results of the fishway

【Before reconstruction】		【After reconstruction】								
2010 fiscal year		2012 fiscal year			2013 fiscal year			2014 fiscal year		
Fishway for larger fishes	Fishway for smaller fishes	Fishway for larger fishes	Fishway for smaller fishes	Seseragi fishway	Fishway for larger fishes	Fishway for smaller fishes	Seseragi fishway	Fishway for larger fishes	Fishway for smaller fishes	Seseragi fishway
10types	12types	14types	14types	9types	17types	13types	10types	14types	11types	7types
14types		22types			24types			19types		

5. CONCLUSION

We performed the various methods to solve the problems in the Miyanaka Intake Dam.

- Effective discharge pattern was found by combining numerical analysis and local discharge experiments.
-We were investigated the actual behavior of fishes by application of salmon with telemetry moreover it was observed this combination secured the ideal discharge pattern as well.
-Improvement of fishway facilities has been verified by repeating the observation of an actual flow as a validation measure.

The monitoring program is designed to confirm the additional causalities at least one more year as a part of the adaptive management of this project.

6. ACKNOWLEGEMENTS

We would like to special thanks to Dr.Yoshiharu Honma of Niigata University Professor Emenitus, Dr.Takashi Asaeda of Saitama University, and Dr.Lu Minjiao of Nagaoka University of Technology for their guidance.