April 9-12
Taipei-Taiwan
2019

3rd International Workshop on
Sediment Bypass Tunnels

Countermeasures against Sedimentation around Kurobe No.2 Power Station at Nekomata area in the Kurobe River, Japan.

Masanori Terada, Yutaka Tanaka, and Keita Kosaka

Abstract

Nekomata area is located in the middle-stream of Kurobe River, Toyama Pref. in Japan, where an extreme large flood occurred in 1995 and caused serious damages on hydropower plants along the Kurobe River, which is owned by the Kansai Electric Power Co., Inc.("KANSAI"). After that, the river bed of the area was raised up about 10m and the amount of power generation of two hydropower plants were decreased. Therefore, countermeasures against the sedimentation including the replacement of tailrace tunnel and the construction of retaining walls in the Nekomata area have been planned and implemented by KANSAI. In this paper, the outline of the countermeasures is reported.

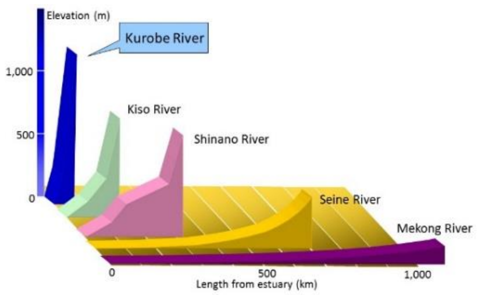
Keywords: Sediment Management, Countermeasure against Sedimentation, Kurobe River

1 Background

1.1 Summary of Kurobe River

Kurobe River has the length of 85km and the total catchment area of 682km^2. The river basin has abundant water resource with heavy snow. The average annual precipitation of the world and Kurobe river basin are about 880mm and 4,000mm respectively.

In addition, the average stream gradient is quite rapid equivalent to about 1/40 compared to other river as shown in Fig.1. Therefore, the Kurobe River is flashy stream and very suitable river for hydro power development. By these reasons, KANSAI has developed and built 12 hydro power stations along this river with total generated energy of about 900MW as shown in Fig.2.



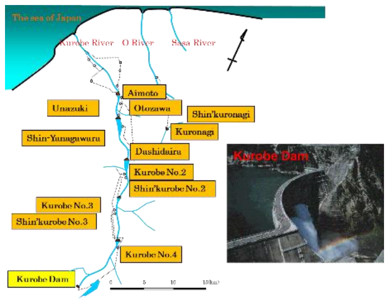


Fig.1 the comparance about stream gradient Fig.2 the locations of power stations

On the other hand, the basin has many erodible area where no plants are seen, occupying 5% of the river basin. As a result, there is a severe problem about sedimentation for development and maintenance of hydro power stations in the Kurobe River.

In 1995, an extreme flood occurred in the Kurobe River. The inflow amount of Dashidaira Dam, located middle stream of the Kurobe river is shown in Fig.3. This flood caused serious damages on hydropower plants along the Kurobe River by debris flow as shown in Fig.4, including sedimentation around outlets, inundation on power stations, malfunctions of facilities and collapse of basement of railway running along the river. This flood was caused by seasonal rain from June to July and the amount of monthly precipitation was 1,354mm, which is quite large amount compared to average yearly precipitation of 4,000mm. There were several damages to generated facilities, , .

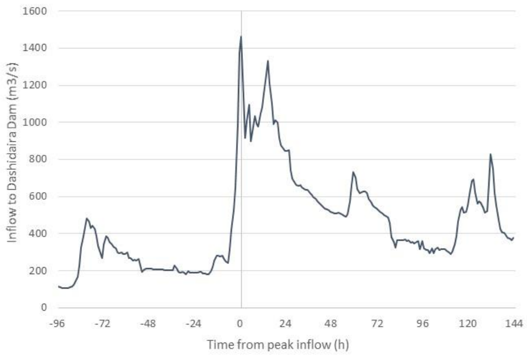


Fig.3 Inflow to Dashidaira Dam in the flood

Fig.4 Debris flow from Nekomatadani

1.2 Nekomata Area

Nekomata area is located at 3km upstream of Dashidaira Dam. In this area, there are two hydro power stations, Kurobe No.2 power station ("Kurobe No.2 P/S") and New Kurobe No.2 power station ("New Kurobe No.2 P/S"). The specifications of these power stations are shown in Table 1. In addition, there is a Nekomata camp where construction and maintenance workers stay. By the way, Dashidaira Dam has sediment flushing facilities and operates combined flushing with Unazuki Dam (downstream of Dashidaira Dam).

Tab. 1: Specification of power stations

	Output [kW]	*Discharge* [m^3/s]	*Head* [m]	*Operation* [-]
Kurobe No.2	72,500	47.20	177.020	1936.10
New Kurobe No.2	74,200	46.00	189.800	1966.9

On upstream of Nekomata area, there are several tributaries (Babadani, Kokurobedani, Kaerazudani, Nekomatadani) which have large scale erodible lands, so these tributaries give Nekomata area huge amount of sediment. On the other hand, several hundred meter downstream flow of Nekomata area is neck section, therefore, sediment is easily deposited around the Nekomata area.

When the flood came in 1995, extreme debris flows were brought from these tributary (especially Nekomatadani) and these debris flows were the cause of terrible damage in Nekomata area. As a result, the flood in 1995 made extreme sedimentation, the river bed was raised up by 10m. Fig.6 shows the history of the river bed elevation around the area.

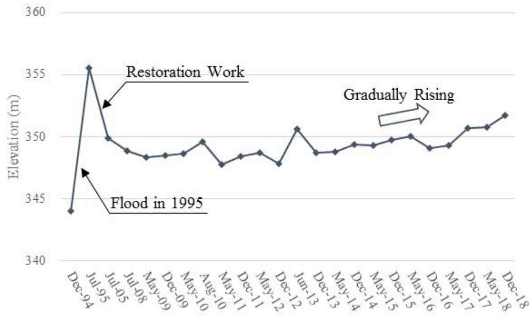


Fig.5 Inflow to Dashidaira Dam in the flood Fig.6 Hydrograf of the flood

2 Countermeasures against Sedimentation due to Flood in 1995

2.1 Restoration work

KANSAI carried out a restoration work for the damage from the flood in 1995. To prevent secondary disaster caused by large flood like in 1995, the sediment was removed and transported to the reservoir of Dashidaira Dam by Toyama Prefecture and KANSAI. A Committee consisting of government, local government and KANSAI decided to carry out urgent sediment flushing from Dashidaira Dam. KANSAI constructed upper outlet of the Kurobe No.2 P/S power station to release the water when the elevation of the river bed was raised by flood. Additionally, KANSAI also constructed walls around the powerhouse to prevent inundation.

2.2 Annual Countermeasures

After the flood in 1995, the sedimentation in Nekomata area has continued, and the elevation of the river bed has also been rising up by annual flood. Therefore, it is the serious problem that the inundation risk of two power stations and Nekomata camp is increasing and the outlets are buried by sedimentation.

As the countermeasures to prevent the elevation of the river bed from rising up, KANSAI transported the sediment (Volume: 60,000m^3) from Nekomata area to Dashidaira Dam reservoir every year. The transported sedimentation is discharged to downstream by flushing operation of Dashidaira Dam. This countermeasure work can be carried out only from September to November, because the countermeasure can't be carried out in winter season from December to April and rainy season from May to August due to heavy snow and heavy rain respectively.

Kurobe No.2 P/S and New Kurobe No.2 P/S were forced to stop or limit generating electricity from high water season from May to August when sedimentation increases. This limitation of power generation continues until the sediment transportation mention above is completed. (Fig.7)

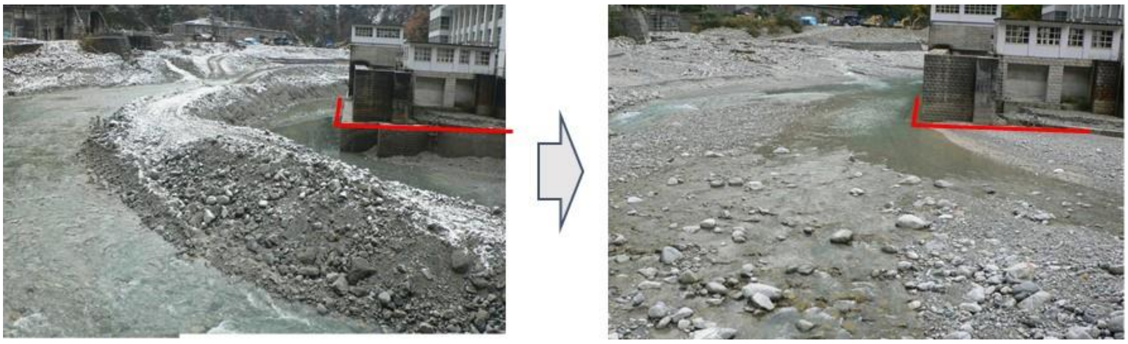


Fig.7 Comparison between before and after annual flood

From these background, further countermeasures are required to increase power generation and to reduce the generation outage risk by the sedimentation around the outlet, and inundation risk.

3 Further Countermeasures against Sedimentation

For above reason, KANSAI decided to carry out the further countermeasures against sedimentation as bellow.

1. Replacement of tailrace tunnel

2. Additional Construction of retaining wall (Kurobe No.2 P/S)

3. Construction of retaining wall (Nekomata Camp)

The outline of countermeasures against sedimentation in Nekomata area shows in Fig.8.

These constructions had two issues.

Firstly, Kurobe Gorge Railway ("Kurotetsu") must be used to access to Nekomata area. Kurobe river is located in precipitous mountains. This railway is the only measure to approach to the siteand to carry materials of construction and tunnel muck There is no train operation in snow season, from December to next April. The construction can't be carried out in winter.

Secondly, this construction shall be carried out while Kurobe No.2 P/S and New Kurobe No.2 P/S are under operation. Therefore there are various limitations in this construction, without adverse impact to these P/S generation.

The outline of the construction plan of the coutermeasure against sedimentation in Nekomata area is as below.

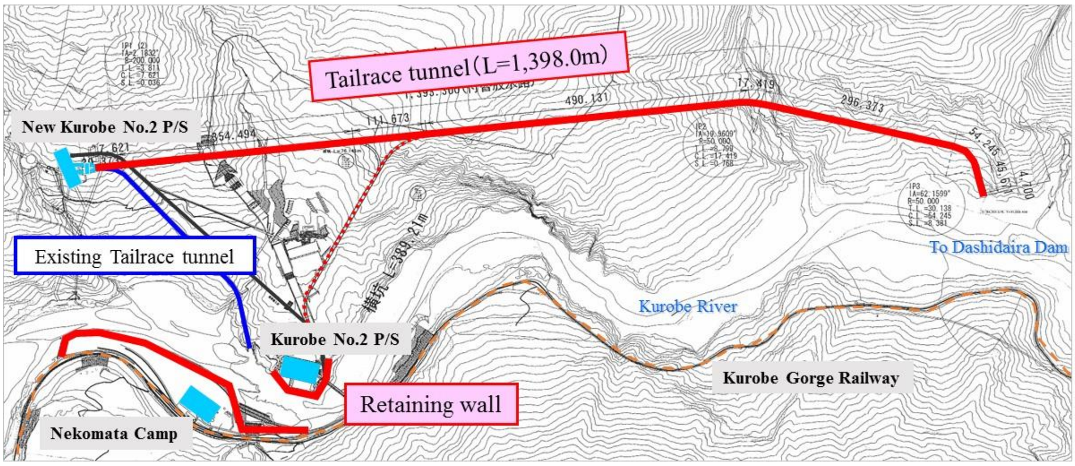


Fig.8 The outline of countermeasure

3.1 Replacement of tailrace tunnel

After river bed raised 10m due to the heavy flood in 1995, generation outage is increased due to the sedimentation around the outlet of New Kurobe No.2 P/S as mentioned above. Therefore it was decided to replace the tailrace tunnel.

The length of new tailrace tunnel is about 1.4km from New Kurobe No.2 P/S to reservoir of Dashidaira dam where there is no impact from sedimentation and flood (Fig.9). New Austrian Tunneling Method (NATM) was adopted for the construction of the tunnel and a lining was constructed for the purpose of reducing water resistance.

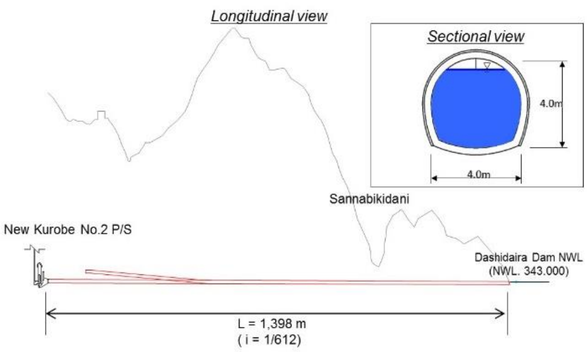


Fig.9 Longitudinal and sectional view

Fig.10 The outlet of tailrace tunnel

Characteristics in construction are as below.

, Sannabikidani, one of the main tributary in Kurobe River is located on the route of replacement tailrace. Under the Sannabikidani, large amount of spring water was predicted because the overburden was most shallow. Therefore an examination of TSP (Tunnel Seismic Prediction) method for prediction to ahead of the tunnel face was carried out around Sannabikidani. Actually in construction, most of the host rock was solid and the amount of spring water was 5 litter per minute.

Control blasting was needed near New Kurobe No.2 P/S to avoid adverse impact to the P/S generation. Coefficient based on measurement of the vibration was calculated by blasting at existing facilities, and using the coefficient, the velocity at the nearest facility from the blasting point was estimated. While checking that the estimated velocity within 4kine at civil engineering equipment and within 0.5kine at electrical equipment, tailrace tunnel was excavated.

The work was completed in December 2013.As a result, the generated energy increased by 48.9% as shown in Fig.11.The power generation was saved due to the sedimentation around outlet from 2005 to 2008. During the construction, the generated energy was almost kept except in 2013 when the energ generation is reduced due to the commissioning work. The energy generation has increased since 2014 when the new tailrace tunnel was completed.

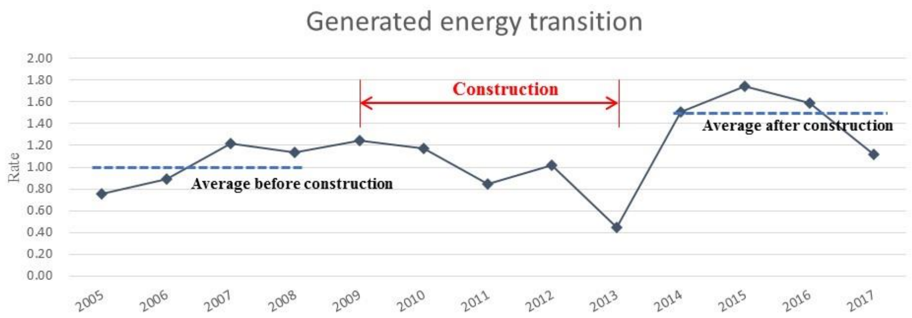


Fig.11 Generated energy transition rate to average before construction

3.2 Additional construction of retaining wall (Kurobe No.2 P/S)

After the flooding in 1995, the river bed remained high and the inundation risk of the Kurobe No.2 P/S was still high. Therefore, the additional retaining wall around the Kurobe No.2 P/S was constructed.

The design water level at design flood and riverbed elevation of these walls were calculated by 1D flow and sediment transport model, because the amount of deposit by sedimentation in Nekomata area has been increasing and the elevation of the river bed was raised up during flooding. The design flood is the hydro curve in 1995.

The wall mainly consists of gravity type retaining wall. The height is 3.67~14.2m and the total length is about 120m.

Next, the feature points for the construction was explained.

It was needed to construct the wall during the Kurobe No.2 P/S is under operation. When the hydraulic turbine generator of the power station was tripped, the water vigorously splashed to right bank by high pressure. Therefore, when the wall in front of the power station was constructed, the operation of the Kurobe No.2 P/S shall be stopped for the safety of the construction workers.

In the original design, retaining wall are to be constructed on the sound rock foundation as shown in ***Fig.12***. Deep foundation excavation were to be carried out behind the cofferdam. However it was found that the amount of spring water through the cofferdam was larger than the planned one so that many pumps were required in the original design. Therefore, the design was revised as shown in (b) of Fig.12 to reduce the amount of pumps. In the new design, the retaining wall have to be constructed on the soil. Therefore, the soil stabilization is required to ensure the bearing capacity for the retaining wall.

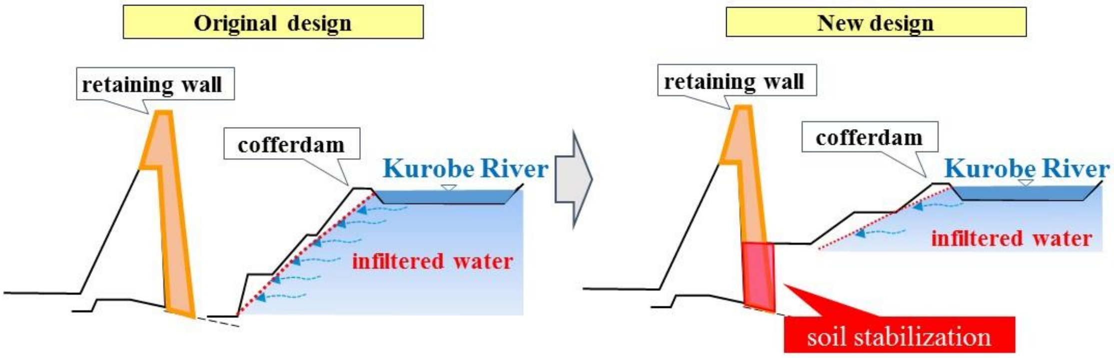


Fig.12 Comparison between original and new design

This construction was started in October 2014, and ended in November 2017. Although total construction period is 38 months, substantial construction period was 23 months because construction work in winter is not possible due to the heavy snow and limitation of the access, and thus the period in winter is not effective.

3.3 Construction of retaining wall (Nekomata Camp)

Additionally, retaining walls were constructed around the station of Kurobe Gorge Railway and Nekomata camp, where workers stay during maintenance works of the New Kurobe No.2 P/S and the Kurobe No.2 P/S. The wall mainly consists of gravity type retaining wall and gabions. The height is 3.67~14.2m and the total length is about 120m. The construction started in September 2016 and end in December 2017 in the original plan.. Some parts of Nekomata yard were scoured and collapsed by the flood in 2017(max discharge: 1,074m^3/s 10 year probable flood), and therefore, construction schedule was delayed and the construction is still underway. The flood continued in several days on

Kurobe river basin caused by seasonal rain early in summer which was developed by moisture wind from Typhoon. As a result, this flood gave terrible damages, inundation at the Nekomata camp, scouring and collapse of Nekomata yard, and sedimentation around the Kurobe No.2 P/S.

Fig.13 Damage by the flood in 2017

This damage became a trigger for the further consideration about the total sediment management method in Nekomata area. For example, a committee consisting of the authorities of sedimentation, numerical analysis and river engineering were organized to consider the optimum shape of river section to reduce the sedimentaiton.

4 Conclusion and Future works

In this paper, various countermeasures for sedimentation in Nekomata area were introduced including restration work from flood in 1995, replacement of tailrace tunnel and the construction of the retaining walls (Kurobe No.2 P/S and Nekomata Camp).

Due to several limitations, including transportation by railway and limited construction term by heavy snow, these countermeasures are quite challenging. We have to address to make solution for sedimentation for the effective and efficient hydropower plants operation as precious renewable energy.

We are going to restart to construct retaining wall (Nekomata Camp) in May, 2019. We make effort to complete the construction safely.

Authors (Text style: Authors Address)

Masanori Terada (corresponding Author)
Yutaka Tanaka
Keita Kosaka
Kansai Electric Power Co., Inc.(“KANSAI”), Japan
Email: terada.masanori@a4.kepco.co.jp