The Kurobe Dam, highest dam in Japan

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ABSTRACT: The Kurobe Dam is the highest dam in Japan with a height of 186 meters. The large arch-type dam was constructed at the Kurobe Canyon by the KANSAI Electric Power Co., Inc. in 1963. One of characteristics of the dam construction is consideration to natural environment and sightseeing. The construction of the Kurobe Dam brought not only electric power but also tourism resource to Japan. The dam standing in harmony with nature has been one of the most popular tourism spots in Japan, capturing more than one million tourists every year.

1 OUTLINE OF THE KUROBE DAM CONSTRUCTION

The construction of the Kurobe Dam and Kurobegawa No.4 Power Plant was planned by the KANSAI Electric Power Co., Inc. to cope with the sudden increase in power demand due to the rapid economic recovery after the Second World War. The construction project was important for the consistent development of the Kurobe River System. By constructing a large reservoir at the most upstream end of the Kurobe River as a reservoir of the Kurobegawa No.4 Power Plant, the project was planed to enable the existing downstream power plants to be operated during the winter season when there is less rainfall to ensure a stable supply of electricity, and to allow future construction of new power plants and expansion of the existing power plants downstream (KANSAI Electric Power 1966).

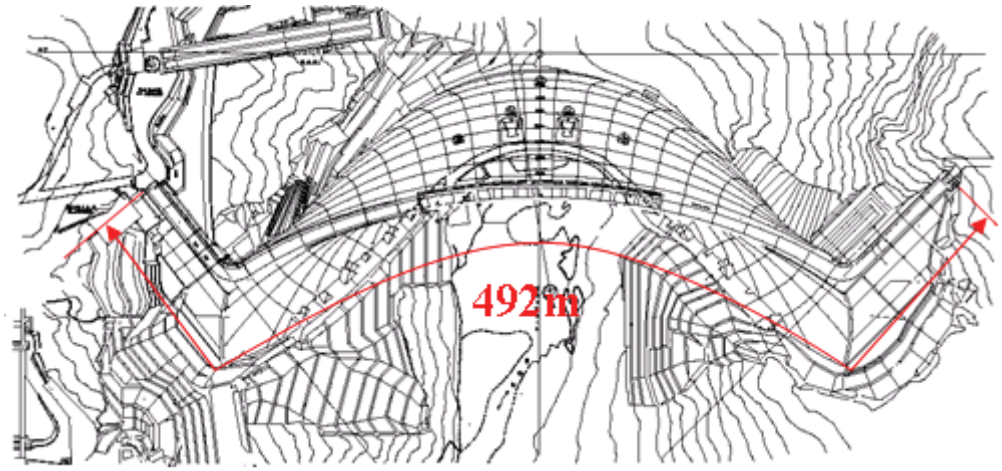

Figure 1. Plan view of the Kurobe Dam

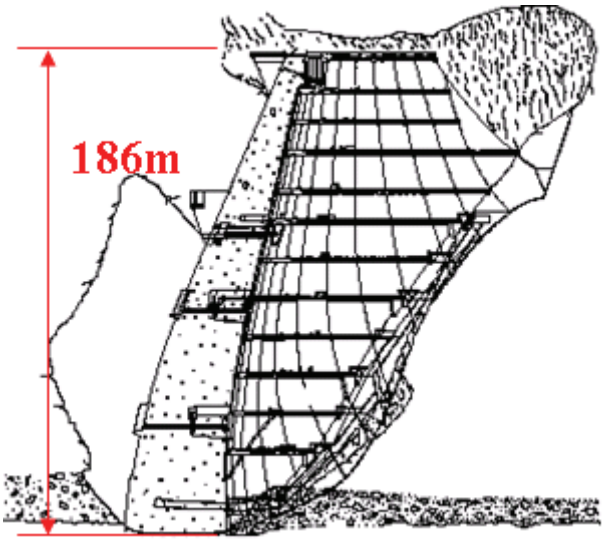

Figure 2. Section view of the Kurobe Dam.

The Kurobe Dam construction site was located in the Chubu Sangaku National Park, which lies among high steep mountains of about 3,000m high. It was a grand project funded by the World Bank to construct the highest arch-type dam in Japan (and the highest in the world at the time) with a height of 186m in a highland of about 1,300m above sea level lying between such steep mountains (Figure 1, 2).

The construction started in 1956, and the Kurobe Dam was completed in 1963.This construction project attracted a great deal of attention at the time because civil engineers in Japan had no experience with such a grand project, which faced to various difficulties, including constructions in severe nature environment of unexplored mountain range areas and restrictions imposed by the National Park Law. So this big project was called "KUROYON" and became one of symbols of Japan's postwar rehabilitation. The episode of the project was made into a movie after the construction. The movie got a great popularity at the time in Japan.

2 FEATURE OF THE CONSTRUCTION SITE

The Kurobe Dam was constructed on the Kurobe River in Toyama prefecture. Approximately 86km long Kurobe River with its average inclination as steep as 1/40 originates in the Mt. Washiba (E.L. 2,924m) which is one of steep mountains in Northern Japan Alps and flows north into the Sea of Japan.

The site is located in one of Japan's most rainy and snowy regions with an average annual precipitation of about 4,000mm. Abundant rain in the summer months and snow in the winter months provide the Kurobe River with an abundant supply of water throughout. Because of its ideal climate, the Kurobe River has been developed for hydropower generation for many years.

The landscape of the Kurobe River Basin was originally formed by rising due to orogenic movements and erosion by ice, snow, and flowing water. These movements have formed V valleys landscape of the Kurobe Canyon. Because of its fantastic scenery made by nature, the Kurobe Canyon had been regarded as one of the untouched natural beauties in Japan. However, because of its steep topography and harsh climate, going up the Kurobe Canyon was very difficult. So the beauty of the canyon had been hidden from the general public except for some mountaineers and hunters before the Kurobe Dam construction.

Majority of the area surrounding the Kurobe Dam site is designated as Chubu Sangaku National Park for its beauties of mountains and canyon, and as National Forests or wildlife sanctuary because there are wildlife such as a Japanese serow, a specially protected species, ermine, and ptarmigan, the alpine plants. Due to these designations, the dam construction was strictly restricted by various lows, for example, the National Park Low, the National Forest Low, the Low for the Protection of Cultural Properties.

3 THE KUROBE DAM AND POWER GENERATION

The purpose of the Kurobe Dam is hydroelectric power generation. The total reservoir capacity of the Kurobe Dam is approximately 200 million m^3. Water which is 60m height from E.L.1,388m to E.L.1,448m of the reservoir water level is used for power generation.

Water taken from the Kurobe Dam reservoir is carried to about 10km far by the tunnel and falls about 500m to the Kurobegwa No.4 Power Plant. The Kuorbegawa No.4 Power Plant has 4 generators and maximum power generation capacity of 335,000kW (Table 1).

The power plant which takes water from the Kurobe Dam reservoir is only the Kurobegawa No.4 Power plant, but the dam has made contribution to downstream power plants. Before the construction of the dam, downstream power plants could generate only about 70,000kW in winter (dry season) in spite of their total maximum power generation capacity of 230,000kW. However, after completion of the dam, it has saved abundant melted snow water of the Kurobe River and controlled its annual flow quantity to provide downstream power plants the ability generating maximum power in winter. The maximum output of the Kuorbegawa No.4 power plant which had 3 generators was 258,000kW when the dam completed, but the dam created the power generation capacity of approximately 400,000kW including existing downstream power plants.

Other power plants constructed downstream after the completion of the Kurobegawa No.4 Power Plant. Shin-Kuorobegawa No.3 power plant and Shin-Kuorbegawa No.2 Power Plant are connected with the Kurobegawa No.4 Power Plant by tunnels and take water used at the No.4 plant. It is a way to use water of the reservoir effectively.

By such effect of the large reservoir of the Kurobe Dam, presently, the Kurobe River System which has 10 power plants is big power resource region whose total maximum power generation capacity is 892,700kW.

Table 1. the Kurobegawa No.4 Power Plant and the Kurobe Dam specifications.

Item		Specification
Kurobegawa No.4 Power plant	Maximum output	335,000 kW
	Maximum power discharge	72.0 m^3/s
	Maximum effective head	545.5 m
Kurobe Dam	Type	Dome type arch concrete dam
	Crest length	492 m
	Maximum height	186 m
	Volume	1,583,000 m^3
	Design flood discharge	1,260 m^3/s
Reservoir	Catchment area	184.5 km^2
	Impounding area	3.450 km^2
	Maximum reservoir capacity	199,285,000 m^3
	Effective depth	60 m
	Normal water level	EL. 1,448.0 m

4 CONSIDERATION TO NATURAL ENVIRONMENT AND SIGHTSEEING

The Kurobe Dam and Kurobegawa No.4 Power Plant were constructed with considerations about protection of natural environment and sightseeing below the strictly restrictions mentioned above. The following descriptions introduce three typical examples.

Figure 3. Power line exits of the Kurobegawa No.4 Power Plant.

4.1 *The fully underground power plant*

Almost all facilities (penstock, power plant, substation, switching station, etc.) of the Kurobegawa No.4 Power Plant were constructed underground to avoid changing natural environment on the ground by felling trees and excavating mountains. As a result, the facility we can see above the ground around the power plant is nothing except for power line exits (Figure 3). Total length of the cavern and tunnel for the underground facilities was about 10 km, which required total excavation volume of approximately 500,000m^3 and total concrete volume of approximately 160,000m^3.

There was no case in the world at the time, to construct not only a power plant but also a substation and a switching station underground. The large-scale fully underground power plant is a feature of the Kurobegawa No.4 Power Plant.

There were other two big merits to construct the power plant underground. The first other merit was that facilities were able to be constructed and maintained without influence of severe climate of winter season. The second other merit was that facilities were designed and constructed safely and economically without influence of the steep landscape above the ground.

4.2 *Using material hauling road for sightseeing*

Before the construction of the Kurobe Dam, there was no access route except for mountain trails. Therefore, to enable to construct the dam within given short period of time, there was a necessity to construct an appropriate material hauling road which could transport considerable amount of construction materials and large equipment to the dam site.

As a material hauling road, a 25.2km route was constructed. The route connected the dam site and Ohmachi City in Nagano prefecture, including a 5.4km tunnel section (the Kanden Tunnel) that was to run through Mt. Akazawa (E.L. 2,678m) and Mt. Narusawa (E.L. 2,641m) from the right bank of the dam. In the excavation of the Kanden Tunnel, a large-scale fracture zone which was very difficult to break through prevented advancing. The popular movie mentioned above tells the story of the excavation of the Kanden Tunnel, which is one of the hardest works in the Kurobe Dam construction.

Figure 4. Trolley buses bring tourists to the Kurobe Dam.

One of the conditions imposed by the Ministry of Health and Welfare at the time to construct the power plant was that the material hauling road was to be available for public use after completion of the project. The road including the Kanden Tunnel is now being used as a part of touring route. Tourists can pass through the Kanden Tunnel by trolley buses which don't exhaust (Figure 4).

The route connecting the left bank of the dam and Toyama Prefecture passing through the peaks of the Tateyama of about 3,000m high was also developed and upgraded for sightseeing by a tourism company. This route was the mountain trail and also used as a material hauling route in the early stages of the dam construction. Now, tourists can pass through this route by trolley buses, ropeways, cable cars, etc.

The construction of the Kurobe Dam provided the new tourism route connecting Nagano prefecture and Toyama prefecture via the dam and a mountain range, and this route named the Tateyama-Kurobe Alpine Route was opened in 1971 (IEA Implementing Agreement 2006).

4.3 *Discharge for sightseeing*

As another condition imposed by the Ministry of Health and Welfare at the time to construct the dam, the Kurobe Dam discharges water for sightseeing at daytime between June and October. The quantity of the discharge is decided according to the season and the time of the day. The maximum quantity of discharge is $15m^3/s$. The discharge is called "discharge for sightseeing". The purpose of the discharge is to maintain quantity of the river flow at scenic spots downstream of the dam and to keep their beautiful natural scenery.

Howell-Bunger valves which can discharge the water as mist form are adopted for the discharge valves, because the mist form discharge decreases the vibration of the bedrock immediately downstream of the dam. This type of valves is also appropriate to the discharge for sightseeing because of its easiness to control quantity of the discharge.

The discharge for sightseeing is originally purposed to keep the scenery downstream, but now the discharge itself is one of the major facts for sightseeing. It is one of the best view spots in the Kurobe Dam tourism that the discharge water mist of $15m^3/s$ quantity is falling magnificently from the arch dam of 186m high with drawing the rainbow (Figure 5).

Figure 5. Discharge for sightseeing from the Kurobe Dam.

Figure 6. Tourists enjoying on the Kurobe Dam.

5 CONCLUSION

The construction of the Kurobe Dam brought big tourism resource to Japan by the effects of considerations to natural environment and sightseeing. Typical facts of these considerations are

the construction of the fully underground power plant, the utilization of the material hauling road for sightseeing, and the discharge from the dam for sightseeing.

The Tateyama-Kurobe Alpine Route which is partly using the material hauling road for the dam construction is one of famous tour spots in Japan today, and capturing more than one million tourists every year (Figure 6). In particular, the scenery of the Kurobe Dam which is the highest dam in Japan and the reservoir with emerald water in harmony with surrounding mountains is regarded as the highlight of this route. Around the dam area, there are various facilities, including a pleasure boat, lakeside walks, resting places and observation decks viewing the dam (Figure 7, Figure 8). The Kuorobe Dam is a typical tour spot in the Toyama prefecture, and it is thought that the dam provides the large ripple effect for the local economy.

The construction of the Kurobe Dam is a good case which succeeded to protect natural environment and to contribute to sightseeing with accomplishing its original purpose of supplying electricity. Recently, at the Kurobe Dam site, the KANSAI Electric Power Co., Inc. has also done the enrichment of facilities for sightseeing and the ecological acts. For example, the construction of a new observation deck, preparation of barrier-free facilities, the tree planting on damaged area due to the construction work, and the effective utilization of the driftwood resources of the dam. In the future, it is expected that the Kurobe Dam will attract many people not only as a facility of hydropower but also as a facility which will coexist with natural environment and around region (Figure 9).

Figure 7. Pleasure boat on the reservoir of the Kurobe Dam.

Figure 8. Tourists viewing the dam discharging from the observation deck.

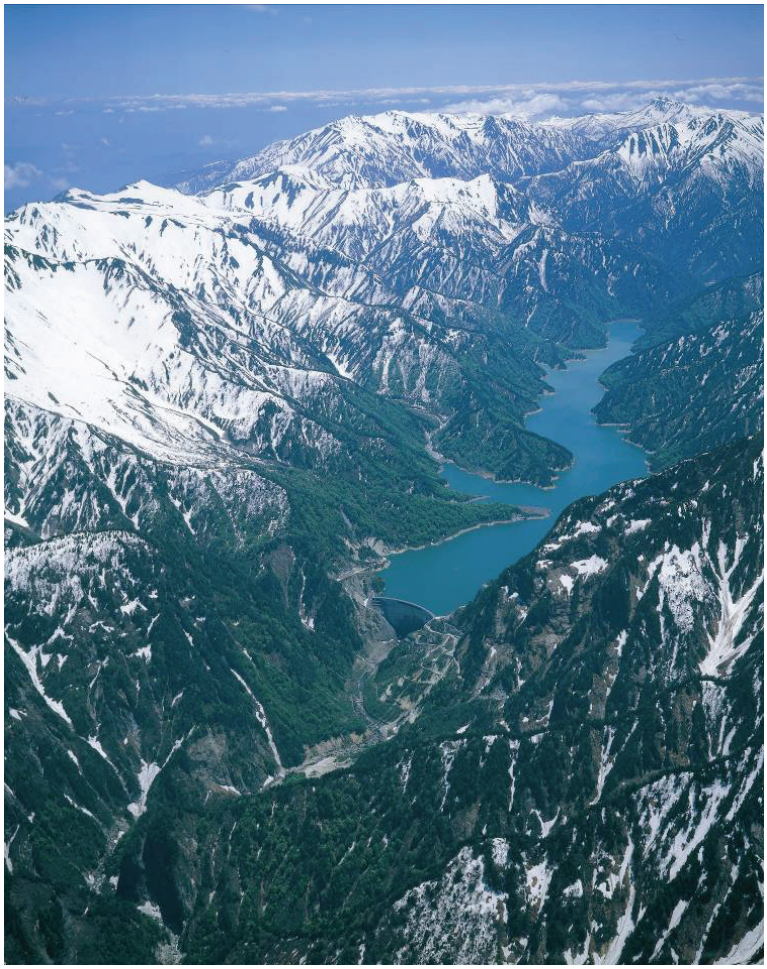

Figure 9. Scenery of the Kurobe Dam standing in harmony with nature.

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