Planning of sediment bypass tunnel for hydropower dams

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Abstract

In Japan sedimentation in hydropower reservoir is one of the most important problems for sustainable power generation. Many J-POWER Electric Company's dams and reservoirs were installed in post war reconstruction period, then for decades reservoirs have stored much sedimentation inside up to sedimentation ratio 10% because of high degree of sediment production and river flow regime. We have been trying to excavate sedimentation out of reservoirs to avoid loss of reservoir capacity, aggradation of upstream riverbed and obstacle for intake and outlet functions. It is time to change sedimentation management of hydropower reservoir, because of the reasons bellow. There is too much sediment to remove, resulting too much cost for excavation, and no disposal site near reservoir, on the other hand, sediment flow is strongly requested in dam downstream river and coastal area. It is not effective to excavate and dispose sediment just considering hydropower generation, appropriate sedimentation management is needed both for power generation and river basin sustainability. Sediment bypassing is one of the most effective methods instead of excavation. In Japan 4 sediment bypasses have been installed. Sediment bypass does also have some difficulties in installation and operation. We study the feasibility of bypass installation on 2 J-POWER reservoirs and in this paper we show the site condition of sedimentation, expected effects, difficulties of bypass and our challenges to them.

Keywords: hydropower, sustainable power generation, sediment bypass

1 Introduction

Because of active sediment production and much rainfall, dams in Japan have incurred sedimentation problem in these days. As countermeasure against reservoir sedimentation, installation of sedimentation capacity, monitoring sedimentation and local excavation have been selected as ordinary ways for many years. In 1997 River Law in Japan changed, sedimentation control had drastically changed from keeping sediment in mountains for disaster prevention to flowing sediment down the river for environment of river basin. For sustainable power generation, sedimentation management is not only for keeping reservoir capacity and riverbed control, but also for environment of river basin. Regarding these situation, reservoir sedimentation management has been discussed (Okumura and Sumi 2013).

Hydropower has been changing the role of energy supply, from base energy source to peak energy source. In these days, it has been more important to sustain power generation of existing hydropower plant as a role of regulating power supply using its convenience of easy start and stop generation. Hydropower has more advantageous points, such as producing no greenhouse gas in operation, renewable and domestic. The climate change and extensive disaster make hydropower more important. Therefore, existing hydropower plant has to be maintained for sustainable power generation.

2 Outline of planed hydropower dams

J-POWER has started to plan of sediment bypass tunnel for 2 hydropower dams as shown in Table 1. The sedimentation countermeasure in F dam has started in 1970's, and it has been excavated for amount of 200,000 m^3/year. On the other hand, in T dam excavation has been started in 1990's for amount of 50,000 m^3/year at present.

Table 1: Specifications for F dam and T dam

		F dam	T dam
Area		Kinki	Tohoku
Catchment area (km^2)		801	1978.8
Design flood (m^3/s)		9,600	5,100
Power plant	Max. output (MW)	58	92
	Max discharge (m^3/s)	75	300
	Starting operation	1962	1961
Dam	Type	Arch	Gravity
	Height (m)	76	46
	Crest length (m)	210.6	264
Reservoir	Gross storage (10^3m^3)	43,000	27,000
	Effective storage (10^3m^3)	11,000	10,300
	Available depth (m)	5.0	5.0

3 Plan and design of sediment bypass system

3.1 F dam

Present accumulated sedimentation volume in 2016 is 13.3 MCM with annual average sediment accumulation of 247,000 m^3/year. The storage loss is 34% of the total capacity of 43.0 MCM.

In F dam, there is a major tributary that flows into main stream, and supplies a large amount of sediment. Therefore, inlet of bypass tunnel will be located at the tributary for better plan (F-1) as show in Figure 1.

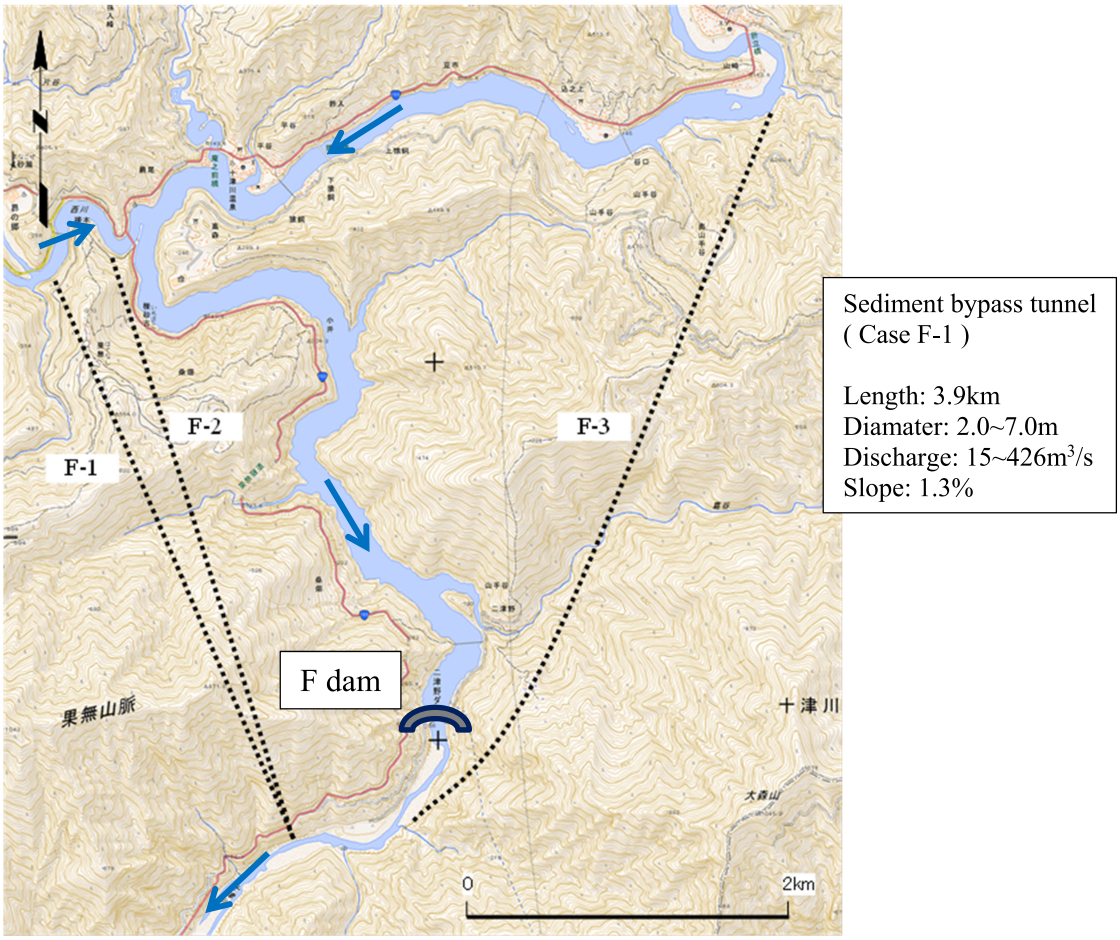

Figure 1: Three options of sediment bypass tunnels for F dam

If we select F-1 sediment bypass option with the design discharge of 95 m^3/s (diameter = 4 m), total sediment of 106,000 m^3/year including coarse sediment of 80,000 m^3/year can be diverted as show in Figure 2. And if the design discharges of sediment bypass increase, the sediment bypass volume will increase, too.

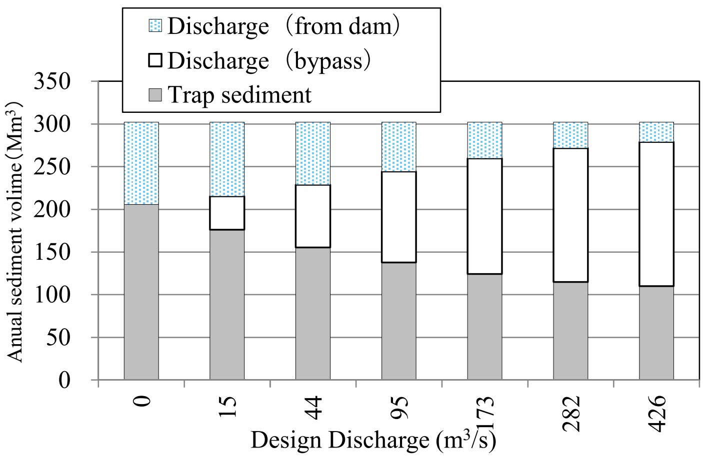

Figure 2: The relation between annual sediment volume and design discharge of sediment bypass tunnel

Figure 3 shows the relation between 50 years necessary cost and design discharge of sediment bypass tunnel. Necessary cost includes construction of the tunnel, maintenance of the tunnel, power generation loss by the operation and excavation of sedimentation which will be accumulated from upstream to reservoir by no passing tunnel.

And Figure 3 shows Design discharge 95 m^3/s is the lowest economical plan. If Design discharge will be larger or smaller than 95 m^3/s, it is not economically best choice.

On the other hand, the Necessary Cost in case of only excavation with no construction of bypass tunnel is higher than cost of design discharge 95 m^3/s, therefore construction of bypass tunnel is economic plan. After that, planning of bypass tunnel will be progressed in detailed design.

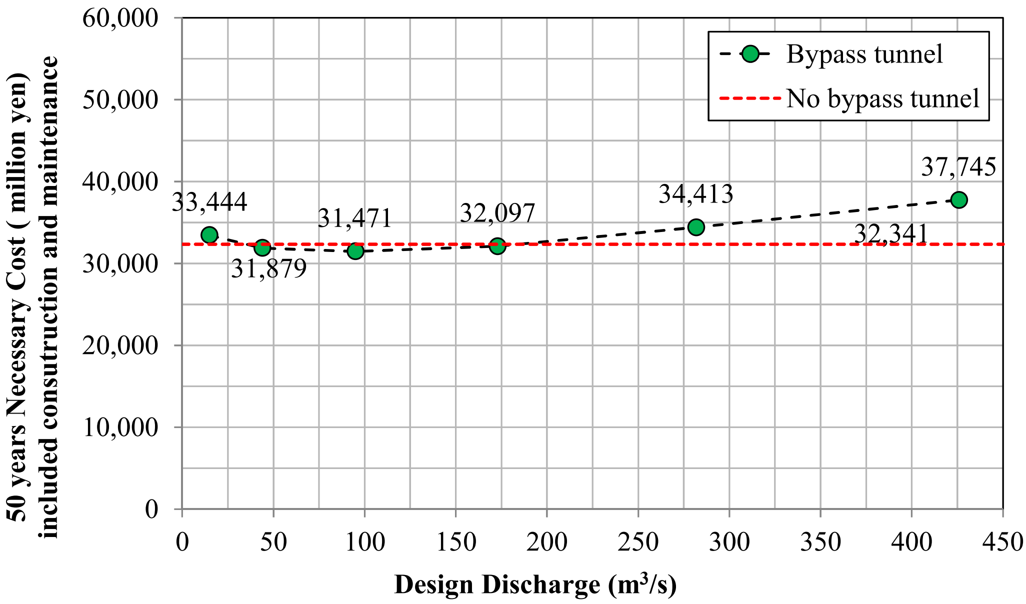

Figure 3: The relation between Necessary cost and Design discharge of sediment bypass tunnel

3.2 T dam

Present accumulated sedimentation volume in 2016 is 8.9 MCM where annual average accumulated sediment is 162,000 m^3/year and storage loss is 33% of the total capacity of 27.0 MCM.

In T dam, there is only the main meandering stream, which supplies a large amount of sediment. Then, inlet of bypass tunnel will be located at meandering for plan (T-1 and T-2) as show in Figure 4.

There are mainly sand and silt around inlet of T-1 case, but there is mainly silt around inlet of T-2.

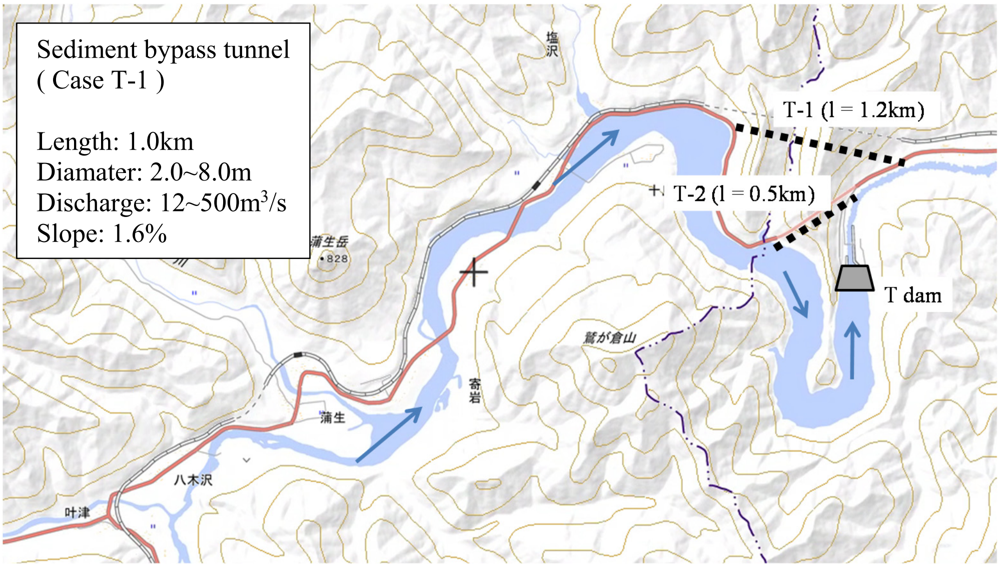

Figure 4: Two options of sediment bypass tunnels for T dam

If we select T-1 sediment bypass option with the design discharge of 300 m^3/s, total sediment of 212,000 m^3/year can be diverted as show in Figure 5. And if the design discharges of sediment bypass increase, the sediment bypass volume will increase, too.

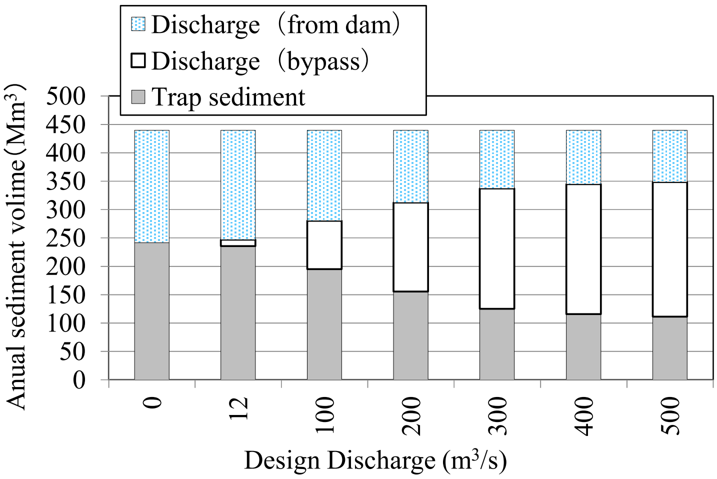

Figure 5: The relation between annual sediment volume and Design discharge of sediment bypass tunnel

Figure 6 shows the relation between 50 years necessary cost and design discharge of sediment bypass tunnel at T dam.

Design discharge 300 m^3/s is the lowest economic plan as shown Figure 6. If Design discharge will be larger or smaller than 300 m^3/s, it is not economically best choice.

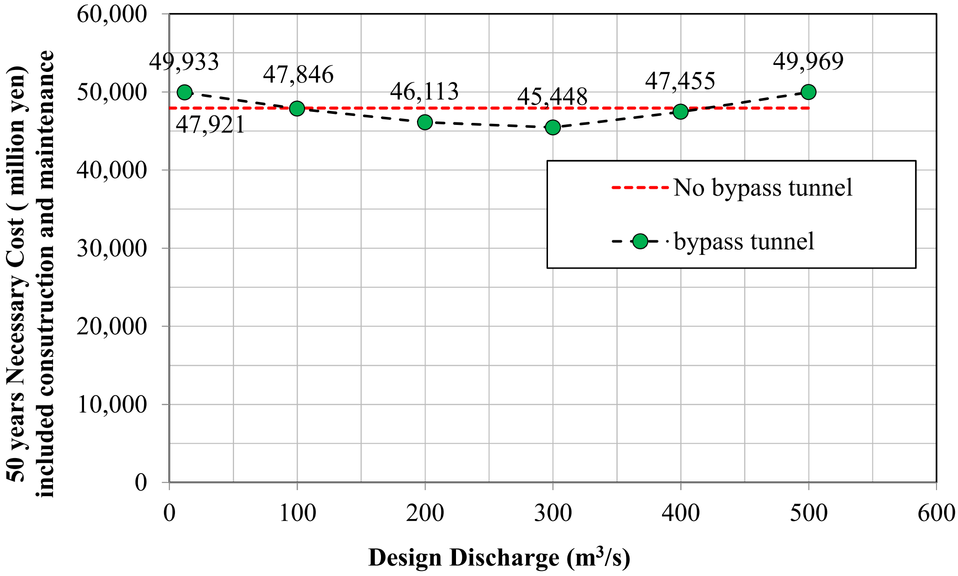

Figure 6: The relation between necessary cost and design discharge of sediment bypass tunnel

4 Conclusions

Thus, we can find optimum design discharges in two dam with respect to sediment removal rate which is defined by bypassing sediment volume via necessary construction and maintenance cost with power generation loss by the operation and excavation of sedimentation left.

In this paper, the evaluation period is tentatively 50 years, but if the evaluation period would be shorter, optimum design discharge will be changed.

After these analyses, we should select appropriate tunnel size based on bypassing sediment volume, bypassing efficiency, tunnel construction cost and the evaluation period.

References

Okumura, H. and Sumi, T. (2013). Influence of sedimentation progress in storage reservoirs on hydropower plant operation. *Journal of JSCE B1,* Vol.69, No.4, I_979-I_984. (In Japanese)

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