



Sediment Transport Monitoring with Impact Plates during Koshiibu Sediment Bypass Tunnel Operations in 2016 – 2018

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1 Introduction

One topical issue on the maintenance and design of sediment bypass tunnels (SBTs) is the reduction of their invert abrasion. In the 2nd International Workshop on SBT held in Kyoto, the topics which should be investigated for addressing the abrasion problem was summarized in three: (1) how bedload is transported in SBTs, (2) how bedload give an impact on inverts, and (3) What kind of countermeasures are effective.

In order to investigate topics (2) and (3) above, we have used a surrogate bedload monitoring system named an impact plate (IP) at Koshiibu SBT. Koshiibu SBT is one the largest SBTs in the world completed in 2016, which measures 4,000 m, 7.9 m, 5.5 m, and 2 % of length, width, height, and inclination, respectively. Since the first operation in 2016, the SBT was already operated eight times and IP also monitored each event successfully. In this study, findings based on the observations is reported.

2 Impact plate

The impact plate (IP, manufactured by Hydrotech Co., Ltd., Japan, Fig. 1), consists of a microphone mounted underneath a steel plate (49.2 cm × 35.8 cm × 1.5 cm), records acoustic energy caused by bedload impact on the plate. Five impact plates are employed on the outlet invert of Koshiibu SBT (Fig. 2). During SBT operations, IPs record raw signal data with a 50 kHz of sampling rate and a summary value called number of impulses (I_{ps}). I_{ps} counts the number of spikes in signals being over a certain threshold voltage. High amplification factors (Amp) correspond to the high sensitivity thus the sediment with wider range of grain sizes can be detected, and vice versa. The detailed information about the IP and is mentioned in Koshiba et al. 2018.

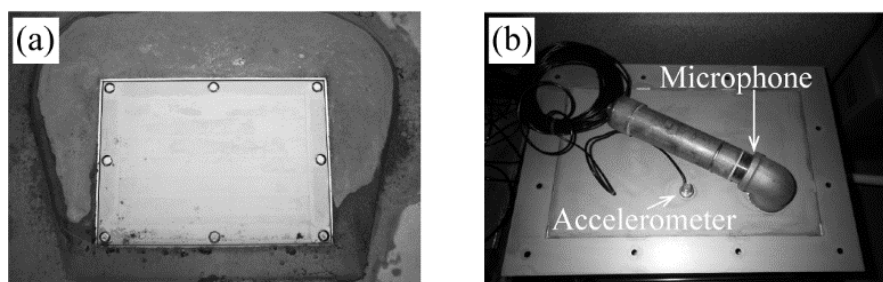


Figure 1 (a) An IP installed on the Koshiibu SBT outlet invert, (b) back side of the IP with a microphone.



Figure 2 Koshiibu SBT outlet with five IPs for bedload monitoring

3 Sediment transport monitoring for test operations

3.1 Koshiibu SBT test operations during 2016 – 2018

Koshiibu SBT was operated eight times during 2016 – 2019 for its test operation. Fig. 3 shows inflow discharges to Koshiibu reservoir during this three years and the bypassed discharges. Although operations at first were done for relatively small and short-time floods, the late operations recorded high bypass discharges along with the inflow hydrograph. In particular, the last two operations were successful because floods were bypassed from the rising limbs including their flood peaks. It is reported that, owing to the last two operations, 150,000 m³ of sediment were bypassed in total.

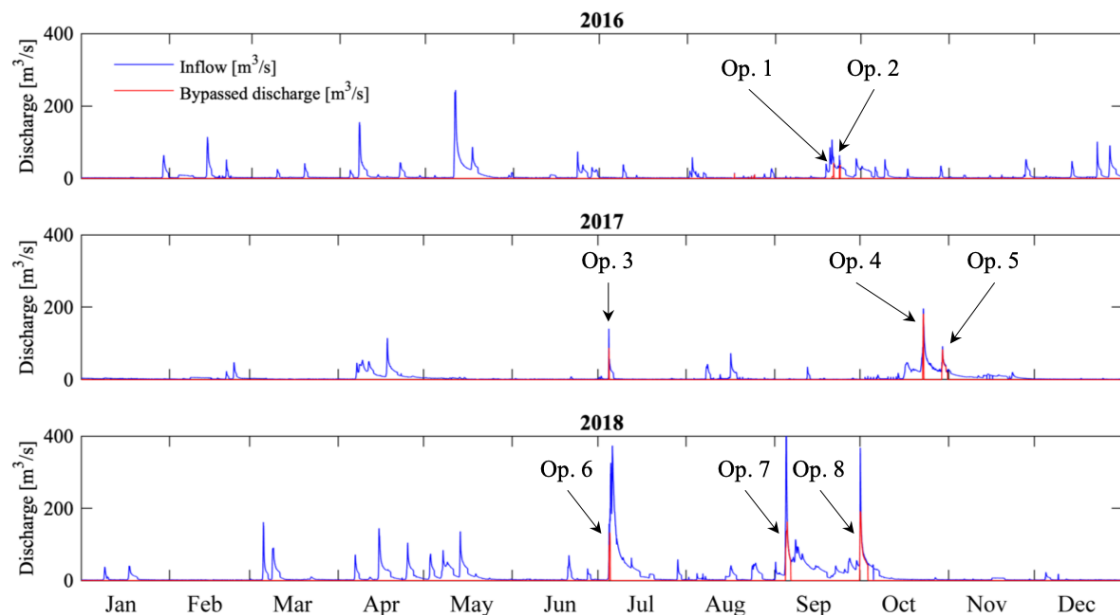


Figure 3 Inflow discharges into Koshiibu reservoir and bypassed discharges during 2016 – 2018. Op. 1 – 8 indicate each bypass operation.

3.2 SBT operation on 22nd October, 2017 for a Typhoon (Op. 4)

On 22nd October 2017, Koshiibu SBT was opened for approx. 10 hours for bypassing flood caused by a Typhoon (Op. 4 in Fig. 3). Fig. 4 shows the hydrological data, information about the SBT operation, and the reservoir water level. At first, the bypass discharge was increased in step-wise for avoiding sudden rise of downstream water level. Since the time at 22:10, the flow state was kept free flow until 5:00 to efficiently bypass sediment. As a final step, the gates were closed step-wisely again before inflow discharge adequately decrease in order for sediment not to be deposited inside the tunnel.

The timeseries results of bedload observation using IPs are displayed in Fig. 5. Fig. 5a depicts the I_{ps} with $Amp = 1024$ for each plate, and Fig. 5b is I_{ps} with five levels of Amp recorded by the plate No. 3 (see Fig. 2) and the bypassed water discharge. The results demonstrate that:

1. the higher rate of bedload transported on the plate 1, which locates tunnel curve inner side, than plate 5. It might be caused by a secondary current (Prandtl's first kind secondary current) and this phenomenon is in line with tunnel invert damage measured in other SBTs (e.g., Nakajima et al. 2017, Mueller-Hagmann et al. 2018).
2. the result (Fig. 5b) depicts the incipient and the termination of sediment flow at the SBT outlet. The time series variation of bedload flow magnitude is also clear.
3. bedload transport abruptly increased when the flow state changed to free-state. Also, I_{ps} with $Amp = 4$ recorded the highest value in the beginning of the operation, at the same time the discharge is still low. It explains that the coarse sediment was transported in the rising limb of the bypass discharge hydrograph.
4. the increase of I_{ps} with $Amp = 256$ at 22:30 to 23:00 is larger than that of $Amp = 1024$ (Fig. 5b). It implicates that the ratio of sediment with the relatively larger grain sizes increased during the period. Monitoring with several Amp gives a rough estimation of grain size distribution shift.

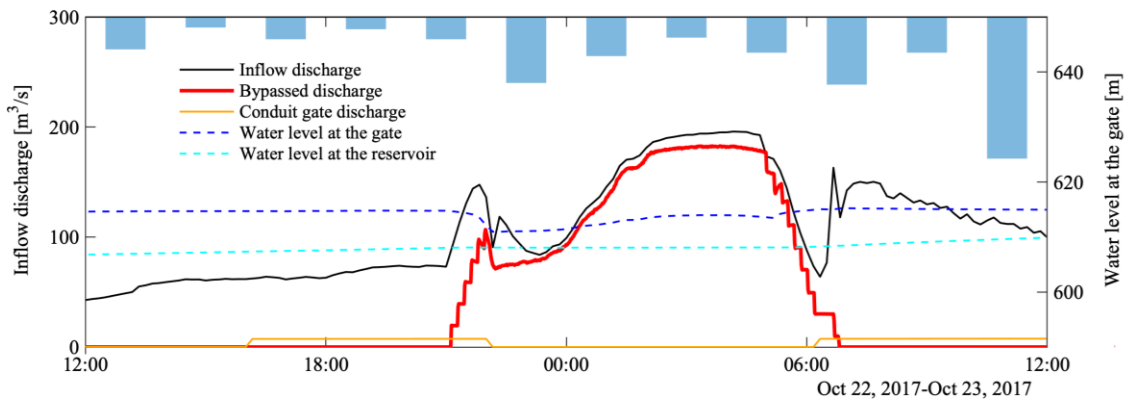


Figure 4 Hydrological data, information about the SBT operation, and the reservoir water level

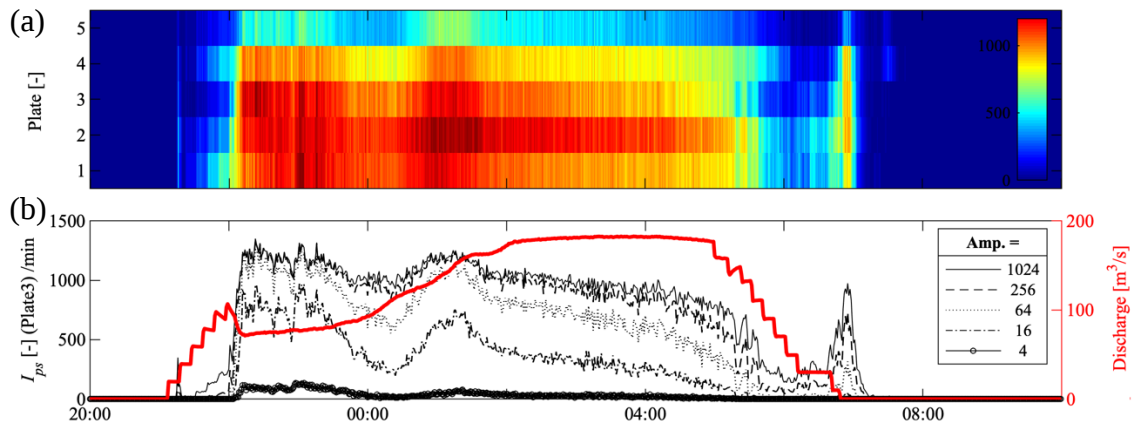


Figure 5 Monitoring results using IPs, (a) I_{ps} with Amp = 1024 for each plate, (b) I_{ps} with five levels of Amp recorded by the plate No. 3 (see Fig. 2)

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