Acoustic sediment surrogate measurements for high sediment flux: case study at Koshibu sediment bypass tunnel

**Takahiro Koshiba**, Kyoto University, Kyoto, Japan, koshiba.takahiro.47v@st.kyoto-u.ac.jp
**Tetsuya Sumi**, Professor, Kyoto University, Kyoto, sumi.tetsuya.2s@kyoto-u.ac.jp

**Introduction**

Surrogate bedload measurement is a promising technique for continuous sediment monitoring (Rickenmann 2017). Actually, more than 300 sites in Japan have employed a steel-pipe type acoustic sediment monitoring device called Japanese Pipe Microphone (JPM). One severe problem for the JPM, however, is pipe deformation due to the high sediment flux that causes the alternation of their acoustic signal properties. Therefore, recently, more and more sites employ an acoustic monitoring system which uses a rigid steel plate instead of a steel pipe.

In this paper, a case study at Koshibu sediment bypass tunnel in Japan is introduced where five plate-type acoustic bedload monitoring systems are installed. The sediment bypass tunnel (SBT) is a facility to mitigate reservoir sedimentation by routing sediment-laden floods to the downstream reaches during flood events (Kondolf et al. 2014).

**Bedload monitoring with impact plates at Koshibu SBT**

**Koshibu sediment bypass tunnel**

The Koshibu dam is located at the Koshibu river catchment in Nagano prefecture, Japan, and is operated by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT). Due to a severe sedimentation problem, MLIT constructed the SBT in 2016. The length of the SBT is 3,982 m with a cross section of circular shape and a plane invert with a slope of 2 %. The width and height are 5.5 m and 7.9 m, respectively. Most of the tunnel is straight but the last 600 m from the outlet is curved on the orographic right direction (Radius = 1000 m).

In the SBT, sediment monitoring is desirable to know the transported sediment information, i.e. grain sizes and transport rates, for unveiling the bypass efficiency and required SBT maintenance works. Because the design discharge at the Koshibu SBT is extreme, with a flow rate of 370 m$^3$/s yielding velocities in excess of 20 m/s, the impact plate system was chosen for this site.

**Impact Plates**

The impact plate (IP, manufactured by Hydrotech Co., Ltd., Japan, Figure 1), consists of a microphone and an accelerometer mounted underneath a steel plate (49.2 cm × 35.8 cm × 1.5 cm), records acoustic and oscillation impact caused by bedload transport on the plate. Five impact plates are embedded on the outlet invert of the Koshibu SBT (Figure 2). Additionally, two JPMs were also placed at the site to confirm the rigidness of the IPs. During the SBT operations, IPs record raw signal data with a 50 kHz of sampling rate and a summary value...
called the number of impulses ($I_{ps}$). After a raw signal is amplified with ten levels of amplification factors (Amp.) from 2 to 1024 times with 2 times of the interval, the number of spikes in each amplified signal being over a certain threshold voltage, which is sufficiently higher than signals produced by water noise, are counted as $I_{ps}$. High amplification factors correspond to the high sensitivity thus the sediment with wider range of grain sizes can be detected, and vice versa (Koshiba et al. 2018).

Figure 1. (a) An IP installed in the Koshibu SBT invert, (b) the back side of the IP with a microphone and an accelerometer.

Figure 2. Koshibu SBT outlet part with five IPs for bedload monitoring

Case study: Typhoon in 4th July, 2017

Bedload observation during an SBT operation in 4th July, 2017 is picked up. The hydrograph, bypassed discharge and water level at the SBT inlet gate are shown in Figure 3. SBT was operated from around 21:00 to midnight. In the first half of the operation, the bypassed discharge shows a step-wise increase with following the SBT gate opening, while the latter half of that is in a state of free flow to efficiently bypass sediment.

Figure 3. SBT operation and the water level at the gate during a flood event in 4th July, 2017
The timeseries results of bedload observation by the IPs are demonstrated in Figure 4. Figure 4a depicts the $I_{ps}$ with Amp. = 1024 for each plate, and (b) is $I_{ps}$ by five levels of Amplification factors recorded by the plate No. 3 (Figure 2) and the bypassed water discharge. The observation demonstrates that:

1. although the JPMs were completely broken during the first operation of Koshibu SBT, IPs are still working after several SBT operations, thus the IP has the much higher rigidness than JPM.
2. more bedload transported on the plate 1 side which locates tunnel curve inner side. 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).
3. the result (Figure 4b) depicts the incipient and the termination of sediment flow at the SBT outlet. The time series variation of bedload flow magnitude is also clear.
4. the increase of $I_{ps}$ with Amp. = 256 at 22:30 to 23:00 is larger than that of Amp. = 1024 (Figure 4b). It implicates that the ratio of sediment with the relatively larger grain sizes increased during the period. Monitoring with several Amps gives rough estimation of grain size distribution shift.

![Figure 4. Time series results of bedload observation by IPs. (a) $I_{ps}$ (Amp. = 1024) by five IPs, and (b) Bypassed discharge and the $I_{ps}$ in five Amps by Plate No. 3.](image)

**References**


