Sediment control and logs capturing in sand pocket with combination of sabo dam with large conduit and iron bars

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Abstract. In the Otoishi River, a tributary on right side of the Akatani River in the Chikugo River basin, a large amount of sediment and woody debris were deposited on riverbed due to the sediment disaster caused by the heavy rainfall in northern part of Kyushu Region on 5th to 6th July in 2017. As one of countermeasures to control the outflow of sediment and woody debris to the Akatani River, a sand pocket is planned with the sabo dam with large conduit parts and the log broom works. In this study, hydraulic model test and flume test were carried out to obtain knowledges for design of the sand pocket. Iron bars are installed vertically at the upstream front of the large conduit parts for capturing sediment and logs, and those intervals are desirable to be set in consideration of sediment diameter and sediment movement without the dam. Besides, it is necessary to consider capturing function and flow characteristics such as shockwave when the log broom works is planned in setting of layout and dimensions.

1 Introduction

In the Otoishi River, a large amount of sediment and woody debris were deposited on riverbed due to the sediment disaster caused by the heavy rainfall in northern part of Kyushu Region on 5th to 6th July in 2017. The Otoishi River is a tributary on right side of the Akatani River in the Chikugo River basin, and it has 5.99km² in basin area and 4.0km in length and 1/4 to 1/30 in bed slope. Accumulated rainfall depth for 24hours reached to 638mm at Tsurukouchi rain-gauge station of Ministry of Land, Japan where is next to the Otoishi River basin. As one of countermeasures to control the outflow of sediment and woody debris to the Akatani River, a sand pocket is planned in the Otoishi River basin, and it includes the sabo dam with large conduit and the log broom works. Some researches were carried out on sediment control function using sabo dam with large conduits in the past [1].

In this study, it aimed to obtain knowledges for contributing to detail design of the sand pocket. A flume test was used to set the adequate vertical interval of the iron bar installed at the large conduits. In addition, a hydraulic model test was carried out to confirm the effect of planar shape of river channel and the iron bars on capturing of sediment and logs. Besides, the test was conducted to evaluate the longitudinal layout of log broom works in apron and transverse intervals of bars.

2 Experimental models

Two kinds of models in straight flume and hydraulic model were used. Model scale was 1/50, and some

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parameters were set to satisfy Froude similarity. Straight flume was used to set the vertical interval of the iron bars installed at upstream front of the large conduit parts. Length and width of the flume were 20.0 m and 0.6m, respectively. Figure 2 shows the plane view of the hydraulic model with 8.0m long and 4.0m wide in model values. Bed was fixed bed. Water, sediment, logs were supplied from the upstream end of the model. Water and sediment discharge were gauged by bucket at the downstream end, and water level was automatically measured by servo-type gauge at the downstream end.

3 Experimental conditions

Experiments focused on 2 contents shown in Table 1. Table 2 shows the experimental conditions in prototype value. Figure 3 shows the grain size distribution curve in composition of riverbed and slope failure area.

This study focuses on bed load, and grain size diameter less than 2.0mm in prototype value was excepted from the curve. The representative values of grain size diameter are as follows: $d_{50} = 366.5 \text{mm}, d_{60} = 30.1 \text{mm}$. Herein, the symbols of $d_{50}$ and $d_{60}$ show the value of 95% and 60% of sediment diameter for the percentage passing by mass. The dimensions of logs were set based on field survey and the previous study [2]. The value of 95% and 50% of the distribution curve for log length are shown as $L_{50}$ and $L_{50}$, and those values were set to 8.3m and 5.9m, respectively. Those values show 1/3 times of length of fresh woods because woods are broken in process of outflow [3]. The representative value of log diameter was set to 0.261m as 50% of frequency distribution of the diameter. The ratio of supplying number of logs for $L_{50}$ and $L_{50}$ was set as 1:1. Logs except for roots and crown were modeled by plastic stick. The specific weight of logs was referred to the previous study [3], and it was set less than 1.0 because the tree species on site is mostly conifers.

Flume test aimed to set the effective intervals of the iron bars for confirming the capturing and runoff function of the open parts of the dam for sediment and logs capturing. Therefore, the peak flow discharge was set to 100m$^3$/s in clear water, that overflow does not occur from the spillway, and the recession-type hydrograph was set in the flume test. In hydraulic model, the hydrograph reproduced the flood in July 2017 was applied shown in Figure 4.

![Fig. 3. Grain size distribution curve in composition of riverbed and slope failure area.](image)

![Fig. 4. Hydrograph, sediment discharge rate and temporal changes of supplying number of logs in hydraulic model test.](image)

4 Setting of vertical intervals of iron bars

Area ratio of open part against large conduit part is defined as $\Sigma A_n / A_t$, in which $\Sigma A_n$: Total area of open part, $A_t$: Area of large conduit part (Figure 5). Four patterns of the area ratios were set based on grain size diameter.

![Fig. 5. Schematics and definition for area ratio of large conduit parts and intervals of iron bars.](image)
Figure 6 shows the relationship between the ratio $\sum A_n / A_t$ and runoff rate of sediment and logs. The result gives that the effective area ratio for capturing function differs in sediment and logs. The values of effective area ratio for sediment and logs are 0.6 and 0.663, respectively. In this study, area ratio of 0.663 (interval of bottom clearance: 1,000 mm, other intervals: 500 mm) is applied, and the ratio is effective setting for both of sediment and logs capturing.

![Graph showing the relationship between area ratio of open part and runoff rate of sediment and logs.](image)

**Fig. 6.** Relationship between area ratio of open part and runoff rate of sediment and logs.

Figure 7 shows the flow patterns around the sabo dam in decreasing stage of hydrograph. Logs are trapped by the iron bars installed at upstream front of the large conduit parts. However, sediment runs out from the bottom of the clearance in decreasing stage of the hydrograph because the clearance is not blockaded completely. Even if the iron bars are installed at the large conduit parts, the function of sediment runoff in decreasing stage of flood is not prevented if the vertical intervals of the iron bars are set adequately.

![Diagram showing flow patterns around the sabo dam.](image)

**Fig. 7.** Flow patterns around the sabo dam in decreasing stage of hydrograph.

Log broom works trap the logs gradually and water level in the apron increases. Logs stay in the apron, and flow angle of logs are easily change to right-angle against the flow direction. Then, logs are easy to be captured by the works, and the works is finally blockaded. Water level in apron increases due to the blockade, and the effect of the high velocity and shockwave on the works becomes small because submerged hydraulic jump is formed.

Figure 8 shows logs trapping in differences of interval of the iron bars. Capturing ratio of logs is defined as trapping number of logs by the works against supplying number of logs at upstream end. The intervals are set to 2.5m and 5.0m, and the value of 5.0m is approximately 0.5 times of log length $L_{95}$. The test gives that the interval of 2.5m is more effective for the capturing of the logs than that of 5.0m.

Sediment passes through the intervals because the interval is set larger than sediment diameter of $d_{95}$, and sediment easily become depositing in the apron if the works is blockaded by logs.

![Diagram showing capturing function of logs in difference of transverse interval of iron bars.](image)

**Fig. 8.** Capturing function of logs in difference of transverse interval of iron bars.

### 5.2 Flow patterns

Figure 9 and Figure 10 shows the flow patterns of sand pocket at few hours intervals. Figure 11 shows the flow pattern of the apron.

In 3 hours, the main flow is formed along left side bank of the sand pocket because the flow angle from upstream area tends to be left in the plane view. The flow angle depends on the direction of channel works and low flow channel in the plane view. The flow collides to the upstream front of the main dam, and it flows in clockwise in the sand pocket. Besides, overflow from the spillway is not occurred, and logs are trapped by the iron bars installed at the large conduit parts.

![Diagram showing flow pattern in sand pocket in 3 hours.](image)

**Fig. 9.** Flow pattern in sand pocket in 3 hours.

Peak discharge is shown in 4 hours. Most of sediment deposits in left side of the sand pocket because the main flow is formed along the left side bank. Though the logs overflow from the spillway of the dam due to
changes of sediment discharge. Sediment discharge is reduced by about 90% at peak stage of discharge.

6 Conclusions

The results support the following conclusions. 

(1) The dimensions of intervals of the iron bars installed at upstream front of the large conduit parts were examined by the flume tests. The effective area ratio of the large conduit parts differed between the function of capturing sediment and that of logs (Sediment: Effective area ratio is 0.604, log: Effective area ratio is 0.663). The dimensions were set effective for both of sediment and logs capturing shown as follows: Effective area ratio is 0.663, bottom interval of clearance is 1,000mm, other intervals are 500mm.

(2) The functions of the iron bars are as follows: Cut off sediment discharge, preventing from rapid sediment runoff from large conduit parts in decreasing stage, trapping sediment and logs. Interval of bottom part should be set to thickness of sediment moving layer so that sediment runs out from bottom of clearance in decreasing stage of flood. Other intervals are desirable to set less than log diameter or maximum grain diameter for trapping sediment and logs.

(3) The iron bars trap logs if the overflow from the spillway is not occurred. The log broom works installed in the apron trap the logs that overflow from the spillway or are running out from the large conduit parts.

(4) Flow in clockwise is formed along the left side bank in the sand pocket until 5 hours, and sediment also deposits along the main flow. Main flow gradually shifts from left side to right side bank due to the deposition of sediment, and flow in counter-clockwise is formed in final stage of hydrograph. Those depend on the planar layout of the channel works and transverse shape of the sand pocket. It induces the flow in clockwise or counter-clockwise by collision of flow to the main dam, and sediment deposits with channel shifting.

Present experimental data helps facility design of sand pocket for sediment control such as sediment capturing and sediment runoff.

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References