Experimental study on sediment trap capacity of ring net barrier with varying basal openings

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Abstract. Ring net barrier is originally developed as a protection from rockfalls, but some countries have proven that this type is also effective in trapping debris flow sediment. In Indonesia, ring net barrier as sediment control is applied by Sabo Research and Development Center in Lumajang, East Java on a slope of 3.48° and is placed 0.8 m above the river bed surface. To identify the optimal position of the basal opening, a hydraulic flume test is performed with a scale of 1:60, 0.6 cm of diameter of ring, and a variety of discharge (11 liters/sec, 8 liters/sec, and 1.8 liters/sec). These numbers are based on the scaling with 10% sediment concentration and a flow time of 144 seconds. The basal opening position is varied from the same elevation as river bed, placed as deep as 1.66 cm and 3.2 cm. The results show that ring net can retain more sediment if the net is placed 3.2 cm deep. Therefore, the sediment trap capacity of ring net barrier that is applied in Lumajang can be optimized by shifting the basal opening’s position to 1.92 meters deep from the river bed.

1. Introduction
Due to its geographical and topographical location, Indonesia is strongly linked with debris flow hazard, both volcanic and non-volcanic. Debris flow play an important role in moving sediment from steep area into river system [1]. Sabo dam is built as a prevention to control potential damage caused by debris flow. As a response to newly invented and innovation in technology, Sabo Research and Development Office has done a pilot project of ring net barrier in Lumajang Region, East Java Province.

Ring net barrier was first developed as protection from rocks slides [2]. Some countries, for instance Switzerland [2], Hongkong [3] and Italy [1], have proven that this method is most effective to retain sediment during debris flow. This open-type sabo dam do not block the river course, so it is ecologically friendly [4]. The sediment trapped upstream a ring net barrier is flushed out effectively, so the barrier will maintain the storage capacity to control the next event [5]. In Indonesia, the pilot project of ring net barrier is applied as a retainer at upstream Leprak River, near Gladak Perak Bridge, Lumajang Region, East Java Province with a slope of 3.48° and basal opening is positioned at 0.8 meter above river bed [6].

To understand how sediment trap capacity varies once basal opening’s position change, a laboratory experiment is carried out. The objective is to identify positions that can capture more sediment. During
this test, the structure’s strength is neglected because this study focuses only on the sediment trap capacity.

Some studies of sabo dam function as a sediment controller [4,7–9] were done to compare trapped sediment by altering the grid type sabo dam [4,7,10,11]. Meanwhile, sediment trap capacity-related experiment based on basal opening variation to ring net has never been done.

2. Methods
This study used a hydraulic model test as a method. It is used rectangular flume of 200 cm long, 37 cm width and 30 cm. First to do during the experiment is scaling, and then parameter and test scenarios identification followed by ring net construction and river modeling in a flume. Basic principles modeling of hydraulics bases modeling scale identification where flow condition is assumed as similar to those in the prototype if there is similarity of form (geographic similarity), similarity of motion (kinematic similarity) and similarity of forces (dynamic similarity) [12]. Geographic similarity is fulfilled if there is a scale connection between model and prototype. This model follows a function below.

\[ L_r = \frac{L_p}{L_m} = \frac{d_p}{d_m} = \frac{H_p}{H_m} \]  

(1)

Kinematic similarity is when flow lines between model and prototype are related. The function which explains this similarity is below.

\[ V_r = \frac{V_p}{V_m} \]  

(2)

Dynamic similarity is when acting forces between model and prototype are related. The function which explains this similarity is below.

\[ F_r = \frac{F_p}{F_m} \]  

(3)

Symbol r refers to ration, p refers to (full scale) prototype and m is model [12]. Based on this principle and by considering the hydraulic pump capacity available, that is 0.039 m$^3$/s, so the decided modeling scale is 1:60 with ring net diameter of 0.6 cm using the testing parameter as described in table 1 below.

Table 1. Testing parameter.

| No. | Parameter                     | Unit | Prototype Size | Model Size 1:60 |
|-----|-------------------------------|------|----------------|-----------------|
| 1   | River Width                   | m    | 22             | 0.37            |
| 2   | River Depth                   | m    | 7.8            | 0.13            |
| 3   | Ring Net Upper Width          | m    | 20.88          | 0.348           |
| 4   | Ring Net Bottom Width         | m    | 16.5           | 0.275           |
| 5   | Ring Net Height               | m    | 6              | 0.1             |
| 6   | Sediment Diameter             |       |                |                 |
|     | D$_{50}$                      | mm   | 6.96           | 0.12            |
|     | D$_{90}$                      | mm   | 57.86          | 0.96            |
|     | D$_{92}$                      | mm   | 400            | 6.67            |
|     | D$_{94}$                      | mm   | 800            | 13.33           |
|     | D$_{96}$                      | mm   | 1000           | 16.67           |
|     | D$_{98}$                      | mm   | 1350           | 22.5            |
|     | D$_{100}$                     | mm   | 1750           | 29.17           |
| 7   | Debit (Q100)                  | m$^3$/s | 308.66        |                 |
|     | Debit Scale 1:60              | m$^3$/s |              | 0.011           |
|     | Debit Scale 1:70              | m$^3$/s |              | 0.008           |
|     | Debit Priority                | m$^3$/s |              | 0.0018          |
Model material is a string of ring net with 0.6 cm of diameter which is flanked with steels (figure 1) before it was attached to the flume to ease position change according to the basal opening in modeling scenario.

There are 3 indicators, debit, 3.48° slope based on existing condition and sediment concentration of 10% as described below in table 2.

| No. | Debit (l/s) | Duration (s) | Sediment volume (l) |
|-----|-------------|--------------|---------------------|
| 1   | 8           | 144          | 115.2               |
| 2   | 11          | 144          | 158.4               |
| 3   | 17          | 144          | 244.8               |

Figure 2 shows experimental flume with tool positioning and testing material which is illustrated with a sketch (figure 3).
Trapped sediment volume is estimated using the average cross-section method. This function is described in equation (4). $A_1$ is the first cross-sectional area, $A_2$ is the second area and L is the distance between two areas. Meanwhile, the area is measured using the trapezoidal rule method based on equation (5). Elevation is represented as h [13].

$$\text{Volume} = \left( \frac{A_1-A_2}{2} \right) L$$  \tag{4}

$$A_1 = \frac{L (h_1+h_2)}{2}$$  \tag{5}

3. Results and discussion

The volume graphic shown in Figure 4 illustrates trapped sediment by ring net which is flown by 11 l/s debit. In this condition, the model with basal opening that is placed 3.2 cm below river bed trapped sediment higher, which is approximately 27.33% of debris flow sediment. Figure 5 describes a similar result but with a debit capacity of 8 l/s. Ring net’s position with basal opening that is placed 3.2 cm below river bed can accommodate 30.64% of sediment during debris flow. Similar to the other two results, for 1.8 l/s (figure 6) the sediment is mostly trapped by ring-net with the same basal opening position (13.45%).

![Figure 3](image3.png)

**Figure 3.** Schematics of experimental flume.

![Figure 4](image4.png)

**Figure 4.** Test result with 11 l/s.
There is a significant difference in sediment volume trapped by ring net with the basal opening of 0 cm (or flat as riverbed) compared to 3.2 cm below, in the experiment with 11 l/s. This condition is caused by the amount of sediment with a smaller diameter than the ring’s diameter causing it to pass through the basal opening when the ring net is positioned as flat as the riverbed. On the other hand, with 1.8 l/s there is a small gap of trapped volume in three locations of basal opening. This is consistent with the existing condition during small debit debris flow, so the material bed will be scraped eventually with or without basal opening.

4. Conclusion
Based on the result, it can be concluded that the deeper basal opening is positioned the more sediment can be trapped by ring net barrier. In that case, ring net barrier’s sediment storage applied in Lumajang Region can still be optimized by changing basal opening depth to 1.92 m from the water surface. Even so, a further study is required to determine the depth limitation of basal opening compared to ring net’s height to optimize the sediment trap’s function and also to consider the working forces of the anchor.

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