The Effect of Check Dam Stones Installation and Gabions with Combination Variations in River Bends Using a Laboratory Model Test

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Abstract. Scour or landslide has been a frequent problem at river bends. The common protection for this area is an installation of check dam stones at 90° and gabions at 45° at the outer cliffs of the channel. This study aims at determining the effect of variations in the placement of check dam stones and gabions on river bends through an experimental test of the hydraulic model. It used a river model flume with a curve length of 5 m, a width of 0.8 m, a height of 0.5 m, and a constant flow rate of 7.07 lt/sec. Variation of placement was done twice with the first variation of 3 check dam stones, 4 gabions, 3 check dam stones, and the second variation of 3 gabions, 4 check dam stones, 3 gabions. The test results showed that the scour in variation 1 for STA 01 was -0.8 cm, STA 11 was -0.4 cm, STA 19 was -2.3 cm, respectively. The analysis results indicate that it is effective to use check dam stones for STA 00 to STA 07, gabions for STA 08 to STA 17, but STA 18 to STA 24 is not effective using check dam stones.

1. Introduction
Landslides are the displacement or movement of a slope-forming material in the form of rock, soil, or mixed material due to the water seeping into the ground that increases the soil load. It often occurs around riverbanks due to continuous scouring on the riverbanks caused by quick water flows at the bend areas. After a long time, the cliffs at the bend of the river can collapse.

One of the rivers with a high risk of landslide is the Bedog River that flows through the Special Region of Yogyakarta, Indonesia. The upstream of this river is located around the Merapi National Park in Sleman Regency and the downstream is in Pantai Baru, Bantul Regency. Along the upper, middle, and lower of the Bedog River, it has different environments due to the use of land functions in the watershed. In Figure 1, the upstream of the Bedog River is shown in number 1 and number 5 for the downstream [1].
Figure 1. Location of Bedog River

There are many interesting phenomena in river bends to be studied. In the river bends, scouring or river wall slides are inevitably cases which will create sediment on the river bed. Scour is a natural phenomenon caused by erosion of the water flow at the bottom and cliffs of rivers. Also, scouring can be referred to as the process of deepening the riverbed below the natural surface elevation because of the interaction between the water flow and the river bed material. This condition threatens the stability of the buildings and facilities around the river. It is necessary to build a control building to balance and reduce the occurrence of river widening.

Control buildings in the form of check dam stones and gabions will be beneficial if they are built in large numbers and placed in the same river channel, but the use of check dam stones only hold the moving sediment at the base of the bed load [2] [3]. Krib or gabions are often used because they can withstand both vertical and horizontal movements. With the retained sediment, the water flow velocity can be reduced and the critical velocity can be controlled [4] [5]. Cliffs and riverbeds around the bend area in this study have been damaged after heavy river flow resulting in erosion. The researchers try to use reinforcement buildings with various combinations of check dam stones to test at the bottom of the channel and gabions to examine the channel cliffs that have been validated at laboratory scale.

A river refers to a channel in which water flows with a free water level. At all points along the line, the surface pressure of the water is similar to the atmospheric pressure. Flow variables are completely different for time and space. These variables are the cross-section of the channel, roughness, bottom slope, bends, flow rate, and so on [6].

Water flow on the surface of the land is forming a river like rainwater, springs, or glacial fluid flowing through a channel to a lower place. Naturally, this flow erodes the areas in which it passes. As a result, this channel is getting wider and longer forming a river. The development of a river valley shows the age of the river. Age here is the relative period based on the appearance of the valley shape in several levels (stages) [7].

In an open channel, for example, a river (natural channel), the flow variable is very irregular based on space and time. The variables are the cross-section of the channel, hardness, base slope, turn, flow rate, and the like.

The ratio of the forces of inertia to the forces of gravity (per unit volume) is known as Froude’s number that can be written as Equation 1 and the flow rate $Q$ at a channel cross-section for any cross-flow is calculated by Equation 2.

\[
Fr = \frac{u}{\sqrt{gD}} \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (1)
\]

\[
Q = U \times A \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (2)
\]
where $Fr$ is the Froude number, $U$ is the flow velocity (m/s), $D$ is hydraulic depth (m), $g$ is gravity acceleration, $Q$ is flow rate (m$^3$/s), and $A$ is the cross-sectional area perpendicular to the flow direction, m$^2$. For the calculation of the basic roughness coefficient, several experts have proposed several forms of the Chezy coefficient ($C$) from the Equation 3.

$$U = C\sqrt{RI}$$  

where $R$ is the hydraulic radius of channel, $I$ is the slope of the channel, and $C$ is chezy coefficient.

2. Research Method

This test aimed at revealing the amount of scouring and examining the effectiveness of installing check dam stones and gabions. This test was done by modeling a river on a laboratory scale with a trapezoidal shape printed on a flume channel with a 5m turn length, 0.5 m high angle, 0.8 m width, and 90 ° turn. The placement variation test was carried out twice with the installation of 3 check dam stones, 4 gabions, and 3 check dam stones for Installation Formation 1 (IF1) and Installation Formation 2 (IF2) containing 3 gabions, 4 check dam stones, 3 gabions. The measurement and data collection of scouring were carried out before and after the running process, then the data were analyzed using Microsoft Excel and Surfer programs.

2.1 Data Collection Technique

The data were taken using the same and stable flow rate and flow depth by observing the stable scour around the cliff and riverbed. The data collection process was carried out by (1) making markers for measuring stations starting from 0 to 24, (2) assembling and marking a scaled motor track with a horizontal spacing of 1 cm, 21 points, and 5 cm and, 8 points afterward, (3) attaching the distometers to the motorized track mount, (4) positioning scalable track motor starting at the 0 stations, the condition of the right and left wheels occupying exactly the reviewed station, (5) pressing the enter key on the laptop for each spacer to start the measurement, (6) moving the holder of the distometers horizontally based on the spacers that had been prepared, (7) repeating the process for stations 0 to 24. (8) conducting the data measurement process twice for each variation, before and after running, the data then were analyzed using Microsoft Excel and Surfer programs.

2.2 Testing Stage

This research was done by strengthening the river channel model with the installation of check dam stones and gabions. The test was in the form of the reinforcement on check dam stones and gabions which were divided into two placement variations. The scour results will be compared to the other results without the reinforcement model. The stages of reinforcement testing in this study are described in Figure 2.
This test was in the form of calculation results of scouring at the bottom and cliffs of river bends using Microsoft Excel and Surfer programs.

3. Results and Discussion

The observation results on the depth of the scour that occurred in the early minutes showed a quite large scour due to unstable flow conditions. At the last minute, it became stable because the scouring state had reached equilibrium. The observation on the depth of scour as a result of the installation of check dam stones and gabions at the beginning, middle, and end of the bends was carried out in three parts, the beginning, middle, and end of the channel.

Based on the research results, it can be seen that the IF1 for STA 01 experienced a decrease in scour towards the TP where the TP experienced scour by -4.4 cm. After strengthening IF1, the scour became -0.8 cm or a decrease of -3.6 cm or 81.8%. On the outer wall of the channel in which the TP experienced scour of -4.8 cm, the outer wall of the channel experienced a reduction in scouring by -2 cm or 41.8% after IF1 reinforcement. Meanwhile, in IF2 of STA 01, there was a decrease in scouring towards the TP where the TP experienced scour by -4.4 cm. After reinforcing the IF2, the scour became -2.8 cm, there was a decrease in scouring by -1.6 cm or by 36.4%. On the outer wall of the channel with the TP scour of -2.8 cm, it decreased by -2 cm or by 41.7% after the FP2 reinforcement.
From the results of the research, it can be seen that at STA 11 there had been a decrease in scour towards TP where the TP got scour of -0.8 cm. After reinforcing TP1, scour becomes -0.4 cm or a decrease by -0.4 cm or 50%. On the outer wall of the channel with the TP scour of -3.8 cm, after reinforcing IF1, the outer wall of the channel bends experienced a reduction in scouring by -3.7 cm or 2.6%. For IF2 at STA 11, there was an escalation of scouring against the TP by -0.8 cm. After strengthening the IF2, the scour became-3.7 cm. It indicated an escalation of scouring by -2.9 cm or by 362.5%. The outer wall of the channel with the TP scour of -3.8 cm experienced an escalation of scouring by -6.2 cm or 63.2%.

**Figure 3.** Graph of beginning turn comparison

The results of the research showed that there was a scour decrease against the TP of -2.2 cm at STA 9. After strengthening TP1, scour became -2.1 cm, or a decrease in scouring by -0.1 cm, or 4.5%. The outer wall of the channel that the TP experienced scour of -2.1 cm, after IF1 reinforcement, the outer wall of the channel experienced an escalation of scouring by -3.4 cm or 61.9%. The IF2 at STA 19 experienced an escalation of scouring in TP that experienced scour of -2.2 cm in which the scour became -2.8 cm or 27.3% after IF2 reinforcement. On the outer wall of the channel that TP experienced scour of -2.1 cm after being given FP2 reinforcement, the outer wall of the channel experienced an escalation of -3.2 cm or 52.5%. Figure 6 shows the research results in the form of a bar chart to give a clearer presentation of the study.

**Figure 4.** Graph of middle turn comparison
The research results indicate that IF1 is more effective to reduce scour than IF2. The scour that occurred in IF1 of STA 01 was -0.8 cm or 81.1%, while IF2 in STA 01 was -2.8 cm or 36.4%. IF1 in STA 11 was -0.4 cm or 50% and IF2 in STA 11 was -3.7 cm or 362.5%. Lastly, IF1 in STA 19 was -2.1 cm or 4.5%, and IF2 in STA 19 was -2.8 cm or 27.3%

The shape of the contour image and the scouring pattern after running due to the effect of the installation check dam stones, gabions and check dam stones (FP1) with variation combination are described through the Surfer program.
Figure 7. The contour of IF1 installation after Running

In Figure 7, it can be seen that the material at the bottom of the channel is dark blue. The biggest scour that occurs in the channel is in black on the outer wall of the channel at the beginning to the middle of the channel bend. The deposition that occurs on the inner channel wall is in light blue in the middle of the channel bends.

Figure 8. The contour of IF2 installation after running

Figure 8 shows that the material at the bottom of the channel is dark purple. The maximum scours that occurs in the channel has light purple color on the outer wall of the channel along the center of the bend to the end. Meanwhile, the deposition on the inner channel wall is indicated by a bluish-purple color at the beginning to the middle of the channel bend.

4. Conclusion

Based on data analysis from the tests, several conclusions can be drawn as follow (1) the scour in the various combinations of IF1 installation including check dam stones - gabions - check dam stones obtains that the bottom of the beginning of the bend with scours of -0.8 cm, the bottom center of the bend of -0.4 cm, the bottom at the bend end of -2.3 cm, respectively. The scour in the combination variation of gabion - check dam stones - gabion (IF2) shows that the bottom of the beginning of the bend experiencing scour of -2.8 cm, the middle of the bend of -3.7 cm, the bottom of the end of - 2.8 cm. (2) the recommended installation of check dam stones - gabions - check dam stones is effective to
reduce scouring that occurs in the channel. At the beginning of the channel bend from STA 00-07, check dam stones is effective with scouring at -0.8 cm, gabions are good in the middle of the channel turn from STA 08-17 with scouring of -0.4 cm, but at the end of the bend of the channel from STA 17-24 is not effective for check dam stones installation which experienced scour of -2.3 cm.

Based on the tests and obtained results, some issues should be emphasized as the inputs for the future tests, such as (1) the further studies on the effect of check dam stones installation and gabions on a laboratory of river bends model to obtain the complete and perfect results, (2) the development on the installation and the distance between the gabions to enhance the variety of the installation. (3) the canal bed material that should be made as identical as river conditions. (4) mixed materials, sandy loam, or solid clay that can be used in making the channel walls.

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