The Experimental Study of Optimum Thickness on Riprap Layer Design

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Abstract: Flow velocity in rivers may have significant effects on flow pattern and velocity distribution, especially for horizontal flow. In river engineering, hydraulics engineering, and river restoration project, it is essential to consider in the analysis if there is a change or modification in the waterway such as the pier of the bridge. The existence of a bridge pier causes a change in the pattern of river flow to vertical water flow, this can cause local scouring. Riprap is one of the protection methods concerning local scouring. Therefore, the main purpose of this study is to determine the optimum thickness of the riprap layer within a certain diameter in the flow under clear water conditions and under sediment-based riprap layer. The experimental study was used to inquire the resulted optimum thickness on the riprap layer design. This study used a cylindrical-shaped of bridge pier to study the scouring pattern, failure mechanism, and riprap stability. This study offered several scenarios. The result indicated that the thickness of the riprap layer affected the depth of local scouring. Further study, it is essential to investigate the relationship among variables of riprap, pier, hydraulics characteristics. The application of the riprap design method is very useful for the long-term protection of river structures.

1 INTRODUCTION

A river has consisted of water flow and flow velocity where moves from the upper area to the lower area, flow velocity in rivers may have a significant effect on flow patterns, especially for horizontal flow. River engineering can be defined as the design and implementation of river works and river restoration (Tallar & Suen, 2017). The existence of a bridge pier causes a change in the pattern of river flow to vertical water flow, this can cause local scouring. There are two types of local scouring, specifically, live bed scour and clear water scour. This study used clear water scour. Scouring is usually interpreted as a local phenomenon, it includes degradation that can cause erosion over a considerable length of a river, scouring on the bridge pier occurs when the base material is carried away by water flow (Arneson, Zevenbergen, Lagasse, & Clopper, 2012), if this happens continuously will cause the failure of the bridge which can endanger the construction of the bridge.

The engineering method used to solve the scouring problem of the pier is to place the riprap around the foundation. Riprap is defined as a layer of facing rock that protects from erosion. Riprap has consisted of a well-graded mixture of rock, broken concrete, or other material, usually dump or hand-placed, therefore the riprap should be hard, durable, and dense. In addition, it should be resistant to weathering, free from overburden, spoil, shale, and organic material. The thickness of the riprap layer affects the depth of the scour, it has criteria depends on the diameter of the rock is used.

The problem of analysing scouring through the pier appears deceptively easy, perhaps because it has been oversimplified by assuming a horizontal channel and flow at the normal depth parallel to the bed (Guan, Chiew, Wei, & Hsieh, 2019). In reality the bed level will vary considerably so that the depth becomes almost meaningless, while the flow may not be at the normal depth (Tallar & Suen, 2015).

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It is sometimes assumed that scour will be a problem only when the bed material consists of fine cohesionless material. This is not true: ultimately the scour depth in cohesive or cemented soils can be just as large, it merely takes longer for the scour hole to develop. For example, under constant flow conditions, scour will reach maximum depth in sand and gravel in a matter of hours (perhaps during one flood); in cohesive materials it will take days; However, the biggest and most frequently encountered scour-related problems usually concern loose sediments that are easily eroded. Scouring is a very serious problem. Floods that result in scour are the principal cause of bridge failure.

2 EXPERIMENTAL SET UP AND SCENARIO

An experimental study to specify the optimum thickness of the riprap layer effected on the depth of local scouring.

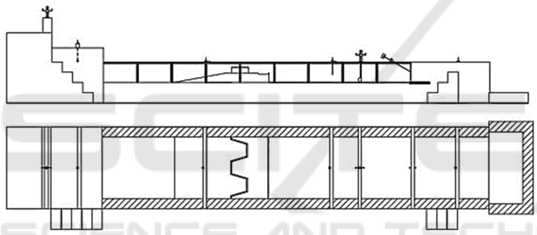

Figure 1: Experimental set up (top view and side view).

2.1 Sediment Sieve Analysis

The sediment factor at bridge piers includes particle size distribution, basic sediment type, and the spatial distribution of sediment size. The difference in basic sediment affects scouring behavior. For example for coarse-grain soil and fine grain soil, scouring behavior will be different although the distribution particle. The purpose of sediment sieve analysis is to specify the distribution or gradation of the sediment used.

Table 1: Sediment sieve analysis result.

No. Sieve	Retained Weight (gram)	Soil Retained (%)
No. 4	83	8.34
No. 8	144	14.47
No. 16	168	16.88
No. 50	349	35.08
No. 100	169	16.98
No. 200	37	3.72
Pan	45	4.52
∑ Restrained Weight	995	

From data (Table 1) by using Soil Classification Chart, it is classified that sediment is categorized in *Poorly Graded Sand.*

2.2 Riprap Sieve Analysis

The riprap sieve analysis is to specify the dr_{50} on riprap. dr_{50} is the middle value of riprap size from the aggregate grading curve.

Table 2: Riprap sieve analysis result.

No. Sieve	Retained Weight (gram)	Soil Retained (%)
19,11 mm	0	0.00%
12,7 mm	1635.2	81.87%
9,52 mm	288.5	96.32%
4,75mm(No. 4)	55.2	99.08%
2,36mm(No. 8)	0.2	99.09%
1,18mm(No. 16)	0.6	99.12%
0,6 mm (No.30)	2	99.22%
0,3 mm(No. 50)	1.1	99.27%
0,15mm(No. 100)	4.1	99.48%
0,075mm(No. 200)	5.4	99.75%
Pan	5	100.00%
∑ Restrained Weight	1997,3	

From data (Table 2) by using Aggregate Distribution Curve, then we get dr_{50} is 10,5 mm, dr_{50} determines the riprap layer thickness (t), which t = $2dr_{50}$ - $3dr_{50}$

2.3 Riprap Layer Thickness

The riprap layer thickness depends on the size of the aggregate, which has been calculated above dr_{50} is 10,5 mm. According to Melville and Coleman (2000), some recommendations in the placement of riprap around bridge piers.

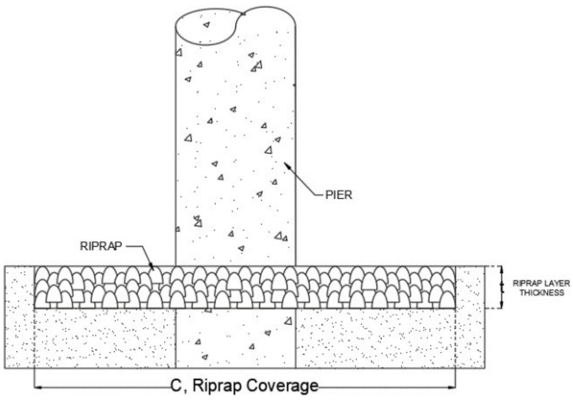

Figure 2: Detail sketch of the riprap layer.

The riprap layer thickness (t) = $2dr_{50}$ - $3dr_{50}$. Riprap coverage (C) = 3 – 4 diameters of pier The riprap layer thickness effects the depth of local scouring. In Figure 2 the diameter of pier is eight centimeters (80 mm) and the riprap coverage (C) is twenty-eight centimeters (280 mm) and scenario (Table 3).

Table 3: Scenarios of study.

Scenario	Riprap Layer Thickness
Scenario 1	22 mm
Scenario 2	26 mm
Scenario 3	30 mm

3 RESULTS AND DISCUSSION

The result indicated that the thickness of the riprap layer effected on the depth of local scouring. Figure 3 to 5 shows the contour pattern and Figure 6 shows before and after the experiments.

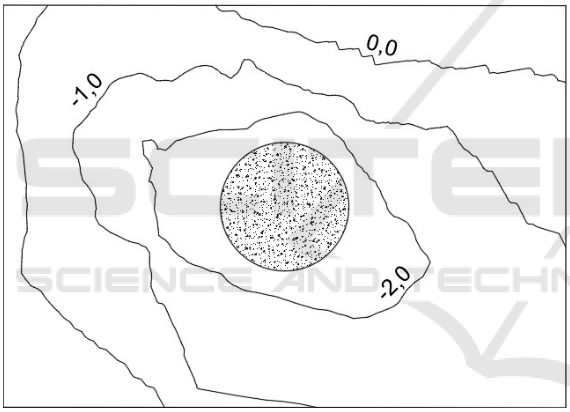

Figure 3: Grind Contour Scenario 1.

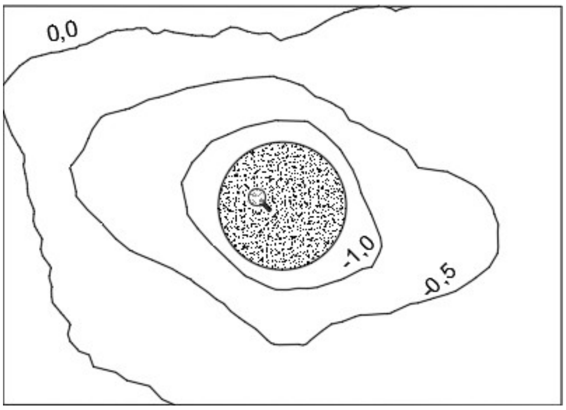

Figure 4: Grind Contour Scenario 2.

In scenario 1 there is scouring around the piers and has a deepest point of -2 cm. In scenario 2 there is scouring on the side of the piers and has a deepest point -1 cm. In scenario 3 there is no scouring around, the sediment remains unchanged at -3,0 cm according to the planned riprap layer depth.

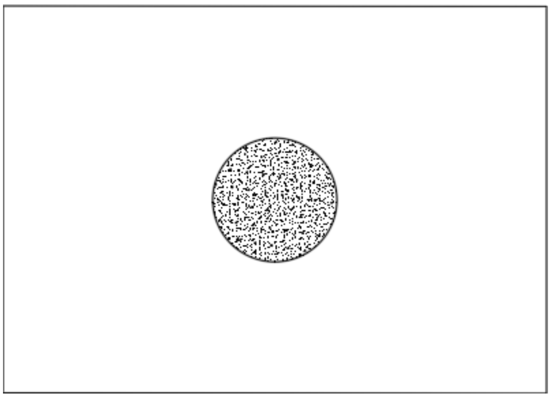

Figure 5: Grind Contour Scenario 3.

Figure 6: Modeling in the laboratory before and after the experiment.

Table 4 gives the results of the riprap experiment scenarios.

Table 4: Results of the riprap experiments.

Scenario	d_s	Information
Scenario 1	-2	Partial failure, there is scour around the piers and the area the layer changes in thickness
Scenario 2	-1	There is scouring on the side of the piers, riprap rock on the side right and left of the pier carried by the flow towards the downstream of the pier
Scenario 3	0	No significant failures were seen, the seams were thinned in some areas but still provided full protection to the piers

4 CONCLUSIONS

In this paper local scouring around a circular bridge pier has been examined experimentally under clear water scouring and under sediment-base riprap layer. This research has looked at certain aspects of riprap design like the size of stone, systematically investigates flow, sediment, and pillar parameters against scouring.

Each parameter involved in the riprap layer performance of the pillar is identified visually. Results of this study show that the optimum thickness is at 30mm because there is no significant failures were seen and increasing the riprap size has a significant effect on depth scour.

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