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A Review of Experimental Approach for Scour Reduction in the Vicinity of Bridge Abutment

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Abstract. In hydraulic engineering and design of infrastructure, scour, the erosive process that threatens the integrity of bridge abutments, is a crucial problem. This review study seeks to give a thorough examination of scour reduction tactics near bridge abutments, with an emphasis on the precision, efficacy, and novel methodologies used in recent studies. We summarize and critically evaluate the primary approaches and results from research in the scour reduction sector. We examine fundamental scour mechanisms, cutting-edge scour reduction methods, numerical modeling and simulations, and real-world case studies throughout the study. Our study indicates the need for more research to close existing gaps and illustrates the advantages and disadvantages of the present scour mitigation measures. This work aims to combine this multitude of information in order to advise and direct academics, designers, and planners in their efforts to reduce scour-related hazards to bridge abutments, therefore maintaining the durability and resilience of crucial infrastructure. This provides analysis of scour mitigation methods provides insightful tips for boosting the durability and safety of bridge structures across the world.

Keywords: Scour, short abutments, horseshoe vortex, infrastructure.

1. Introduction

Scouring is a significant and crucial process that may take place near the piers and abutments and cause the bridge to collapse catastrophically [1]. There are significant parallels between the local scour process and what happens around piers and abutments [2-4]. As a result, it's crucial to accurately and thoroughly estimate the local scour around piers and abutments. Alternatively, local scour could lead the entire bridge structure to collapse, perhaps leaving a large number of people wounded or dead [5, 6]. The flow splits off and comes together downstream as it approaches the pier or abutment, creating a vortex. Local scours may occur at the abutment's upstream face as an outcome of the downstream water flow and vortices it generates [7] (Figure 1).

For determining the local scour depths at piers and abutments, analytical formulae have been developed in previous research [8-10]. [10] used laboratory and field data to assess 23 widely used scour forecasting approaches. The mathematical models of [9] and [11] were combined and briefly modified to create an alternative formula that

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produced an acceptable overall variance. However, the highest scour depth projections made using several mathematical models varied by nearly 100%, highlighting the necessity for new formulas [12]. The scouring mechanism might become enhanced with the use of flow field analysis. Utilizing an acoustic Doppler velocimeter (ADV), [13] studied the turbulence of the flow field surrounding a small square abutment. In varied configurations, [14] looked at the flow properties and velocity patterns surrounding circular piers. They noticed that flow divergence took place behind upstream piers and that the downflow located in front of the upstream pier caused a main vortex to form.

Several studies have been conducted to minimize the scouring in the vicinity of the bridge abutment such as [16-24]. [16] used industrial by-products such as marble and brick waste to encounter scour around the bridge abutment and a significant reduction was observed in the vicinity of the bridge abutment. According to [17], the slot would be more efficient the farther it is from the abutment nose and the nearer it is to the channel wall. Consequently, a particularly appropriate slot configuration is fastened to the flume wall and has a slot height equal to the depth beneath the level of the water. [18] found experimentally that hooked-collar on vertical-wall under sediment bed level reduces abutment scouring by 83% and hooked-collar on wing-wall at sediment bed level reduces scouring by 74.2%. As a result, hooked-collar is discovered to be an efficient scouring reduction for vertical-wall and wing-wall abutments. [23] investigate the impact of the collar modeling on the decrease in scour and deposit of sediment trends at bridge abutments, portions, or full collars. Even while full collars have a bigger cross-sectional area than fractional ones, they are not more effective. For different models, the scour depth is reduced by 24-68% and by 24-97% in the erodible bed and at the lowest point, respectively.

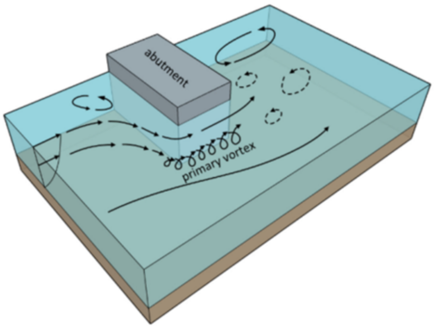

Figure 1. Scour Mechanism around bridge abutment [15].

2. Scour Profile around the Abutment

Initially, the wing-wall (45°) and vertical-wall abutments had been evaluated without any sort of safeguarding. It was discovered that the gradual velocity of the particles moving downstream began in the depression at the upstream border of the abutments (Figure 2). The greatest level of scour was 118mm along vertical-wall and wing-wall abutments, correspondingly. The most significant percentage of decreased depth of scour for wing-wall abutments with collars at bed level and vertical-wall abutments with collars beneath the sedimentary surface corresponds to 65.6% and 78.9%. [18].

[16] discovered that raising the velocity of the flow enhances the erosion level at the bridge abutment because increasing the discharge raises the flow velocity at the abutment's outward borders, which causes sediment flow on the abutment's outside border. Their findings revealed that raising the flow velocity increased the scour depth near bridge abutments by a factor of 9%. For two distinct flow discharge levels, the scour depth may be minimized by approximately 33%, and the resulting decrease in scour rises when flow intensity is decreased (Figure 3). [17] studied the percentage by which scour depth decreases at various levels over the bed in 5 distinct locations to the abutment tip. These statistics show that as the Fr increases, so does the rate of the scouring depth reduction. As a result, the lower the Froude number, the greater the slot's performance. The percent of the depth of scouring decrease for Fr= 0.31 is 34.67-55.16%, for Fr=0.28 are 45.23-59.03%, and for Fr= 0.22 are 56.46-100%, respectively (Figures 4).

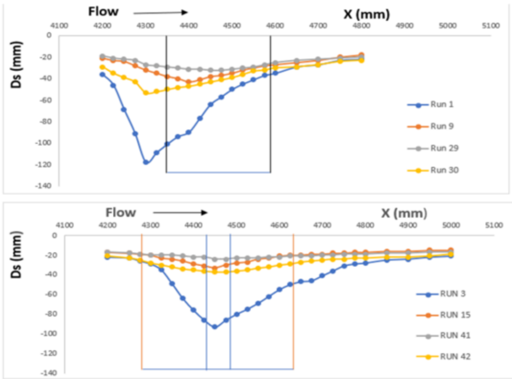

Figure 2. Comparison of longitudinal profiles of unprotected and collar, hooked-collar protected abutments; (a) vertical-wall (b) wing-wall [18].

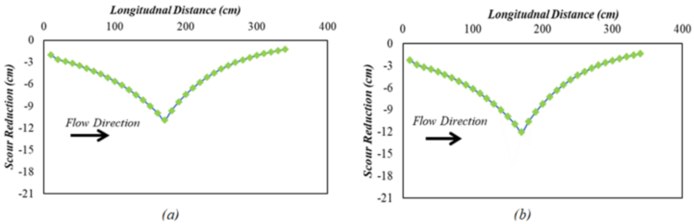

Figure 3. Scour reduction using countermeasures (a) Scour reduction under flow discharge of $0.016 m^3/s$ (b) scour reduction under flow discharge of $0.022 m^3/s$ [16].

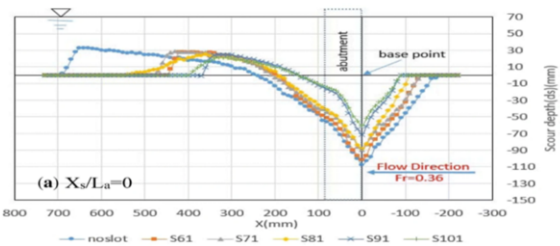

Figure 4. longitudinal profile of the scour around the abutment for Fr= 0.36 and different vertical slot positions [17].

3. Previous literature of experimental Investigation on Scour Reduction around the Abutment

We reviewed the relevant papers of hydraulics researchers mentioned in table 1. The experimental setups of flumes, application, perimeters, and conditions of different countermeasures of piers and abutments, different flow conditions, and percentage reduction in their respective scour holes were observed and studied.

Table 1. Previous literature for scour reduction in the vicinity of bridge abutment.

Reference	Flow conditions	Countermeasure	Flume specification	Measured data	Scour reduction
[17]	Sub-critical	Slot with different positions	Length =13m, width=0.5m, height= 0.6m	Scour, scour reduction, temporal evaluation of scour,	20-100%
[16]	Sub-critical	Bricks and Marble waste	Length=20m, width=1m, height= 0.96m	Scour depth, scour reduction in the vicinity of the abutment	33%
[18]	Sub-critical	Collar and hooked collar	Length=20m, width=1m, height= 0.96m	Scour depth, scour reduction in the vicinity of the abutment	78.9%
[21]	Clear water conditions	Collar with different width	Length=14m, width=1m, height=1m	Scour depth, scour reduction, Reynolds stresses, bed shear stress	88.9%
[22]	Sub-critical	Vertical slots	Length=13m, width=0.5m, height=0.6m	Scour depth, scour reduction,	67.29%
[23]	Sub-critical	Partially/Full collar	Length=13m, width=0.5m, height=0.6m	Scour depth, scour reduction,	24-97%

4. Discussion

In this review paper, the results of different experimental studies on scour reduction in the vicinity of the bridge abutment using different countermeasures have been discussed. Different researchers used different countermeasures such as bricks and marble waste, collars, hooked collars, and slots to minimize the scour in the vicinity of the bridge abutment [16-18,21-23]. The scour reduction in the vicinity of the bridge abutment using a collar as a countermeasure has been studied to minimize the scour depth under sub-critical flow conditions [18,21,23]. Their results show that scour reduced up to 78.9%, 88.9%, and 24-97% when rectangular collar, collar with different width compared to abutment length, and the partial and full collar was used in the vicinity of bridge abutment respectively. The maximum scour was observed to be 88.9% when a collar of a different width was used as a countermeasure around the bridge abutment which shows the efficiency of the collar in the vicinity of abutment. [16] Their result suggested that using industrial by-products such as marble and brick waste would be economical and would reduce maximum scour depth by up to 33% which should be increased when the size of bricks and marble waste increased. The position of the vertical slot in the vicinity of the abutment was an important factor for scour reduction around an abutment [17,22]. Their results showed that the position of the slot in the vicinity of the bridge abutment can reduce scour depth by up to 100%.

5. Conclusions

This review of different experimental research for scour reduction in the vicinity of the bridge abutment concludes the following conclusions.

a) Scour in the vicinity of the bridge abutment is one of the crucial processes that need to be minimized for the safety and stability of the bridge abutment.
b) Position of the slots in the vicinity of the bridge abutment is important and when slots are positioned near the base of the abutment can be reduced scour depth up to 100%.
c) The size, shape, and width of the collar play an important role in a scour reduction in the vicinity of the abutment. Rectangular collar reduced scour depth up to 78.9%, the collar having width more than the length of the abutment reduced scour depth up to 88.9%.
d) Using industrial by-products such as marble and brick waste is an economical and immediately providing solution to encounter scour depth in the vicinity of the abutment.

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