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Estimation of Scour Depth Around the Brigde Pier Using Analytical Method

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Abstract: *Scour depth is the distance between the original elevation of a riverbed or seabed and the lowest point of erosion caused by flowing water. It's the result of running water's erosive action, which can temporarily or permanently remove material from the channel bed or ground. The overall stability and safety of bridge piers, specifically in rivers or streams where the water flow may scour out the sediment surrounding the pier, can be greatly impacted by scour depth. If a scour gets too deep, the footings might have nothing under to provide them with support and so some settling or tilting of the pier takes place which is not good for the structure. Pier bearing capacity: So, scour decreases the bearing soil less than would otherwise be the case around the pier. Global warming seems to have come with a positive aspect on the structure seemed ill to withstand the lots on the foundation, placing its weight as well as dynamic load of the piers, if gone unchecked sufficiency may lead to real catastrophe. In this project it is decided to analyse and calculate scour depth using empirical equations. The different types of Pier and soil beds will be used to conduct experimentation. For this model is prepared. The effect of the water flow on a soil bed will be observed and by conducting analysis the best possible pier shape will be suggested through this project work.*

Keywords: Bridge, Scouring, Peirs, Equilibrium, Soil Erosion.

I. INTRODUCTION

Scour is the erosion or sediment removal, including sand and gravel, from the area surrounding bridge piers and abutments by water flow. When water flows past a bridge pier, it results in a whirling motion, termed a vortex, that may erode the riverbed and undermine the bridge structure. If the scour depth is too large, it may compromise the stability of the bridge, and structural failure may ensue. Estimation of scour depth near bridge piers is critical for the safety and durability of bridges. Engineers apply analytical techniques and computer programs to forecast scour depth. These techniques assist them in designing protective systems and making sound construction and maintenance decisions. The paper seeks to discuss various methods of scour depth estimation with the use of both analytical procedure. It emphasizes the strengths and weaknesses of each method, with emphasis on how each can complement the other and deliver efficient solutions for bridge safety.

II. PROBLEM STATEMENT

The estimation of scour depth around a bridge pier within the study area will be addressed using a two-faceted approach: analytical procedures and computer simulations. Applicable empirical relations, taking into account flow velocity, water depth, pier shape, and sediment properties, will be used to develop an initial estimate. Hydrology, sediment, and pier data from the river reach of the project will be used as input to analytical method. Comparing the results will provide a complete understanding of the scour potential at the specific bridge pier in the specified study area.

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III. OBJECTIVE & ANALYSIS

- To prepare model using different shapes of piers and soil beds.
- To identify pier shape that responses best in order to minimize scouring effect.
- To find out the relationship of scouring depth with flow velocity, discharge, depth of flow.
- To suggest the best pier shape that will produce lesser scour depth

1. Experimental Apparatus and Test

In the present work, investigation of scour depth & measurement of velocity by Tilting Flume was carried out. The experimental set-up of the work is described in detail with the help of diagram shown in figure no.1. All the experiments setup were conducted in the "Thermal & Fluid Lab" in Vidya Pratishthan's Kamalnayan Bajaj Institute of Engineering & Technology, Baramati.

The experiment was carried out in a re-circulating tilting flume 4-m long, 0.25-m wide, 0.37-m deep. The working section of the flume was filled with river sand to a uniform thickness of 0.08-m; the length of the sand bed 2-m & the width 0.15-m. Table 1 summarizes the experimental conditions of all the tests planned for this research.

Table no. 1 Experimental conditions for all tests.

Test no	B (cm)	Q (L/s)	h (cm)	Pier Shape	F (-)	(m/s)	Re (-)	Rp (-)
1	7	23.82	25	Square	0.619	1.082	16807.03	75588.82
2	7	23.82	25	Circular	0.619	1.082	16807.03	75588.82
3	7	23.82	25	Aerofoil	0.619	1.082	16807.03	75588.82

Note: Q is the discharge; uc is the critical velocity; ϕr is the dynamic angle of repose ;F is the Froude number and Re is the flow Reynolds number.

The re-circulating flow was supplied by a 10-hp variable speed centrifugal pump at the upstream end of the tilting flume. The pump's rpm was 1450 with power of 7.5 kW and maximum discharge of 23.82 L/s. Discharge of water was monitored using a flowmeter attached to the upstream pipe at the inlet of the flume. Water is passed through a 25 cm-diameter pipe line, directly into the flume. A trolley with a point gauge was fixed on it and kept on the flume. A vertical scale with the point gauge was attached to measure the water level, initial bed level, and scour depth. Piers were fixed in the middle of the work section of the flume.

Tests were performed utilizing one bed material. The bed material (sand particles) size was d50 (= 0.825mm), d16 (= 0.5 mm), d84 (= 1.62 mm), and d90 (= 1.78 mm), obtained from the sieve analysis test under a vibrating shaker. Geometric standard deviation of sand particle size, σg, expressed as $\sqrt{d84/d16}$ was 1.8. Relative density of sand (s), bed sediment angle of repose in still water (ϕ), mean bed shear stress, and critical bed shear stress were 2.582, 36◦ 0.39 Pa, and 0.40 Pa, respectively. The dynamic angle of repose (or) was approximately 13% higher than the ϕ, while it was approximately 15% as reported earlier. The critical condition of the bed was verified prior to each test run as suggested [39]. The flow depth in the flume was varied by a tailgate. The mean approaching flow depth (h) was kept at 0.125 m by running the tailgate. The bed slope, which was 1:2400, was kept constant for every test. All tests were carried out for the approaching flow with undisturbed flow depth where the ratio of the approach flow depth to pier width (b) was 1.14. The depth-averaged approaching flow velocity (U) was fixed as 0.247 m/s, which corresponds to approximately 68.2% of the critical velocity (uc) to meet the clear water condition, i.e. the current study included only clear water approach flow conditions defined by a velocity ratio U/uc = 0.682. The section averaged approaching flow velocity was established from the measured vertical profile of the approaching flow velocity 2 m upstream of the pier where the pier presence did not influence the approaching flow.

The total duration of each experiment was 30min which was adequate for achieving the equilibrium scour (for square 5.2cm, aero foil 3.8cm, circular 4.5cm). After the run was ended, the max equilibrium scour depth observed at the upstream base of the pier.

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2. Anlysis of Scour Geometry:

The scour affected zones and contour lines of the scour holes at the circular pier, square pier, aerofoil pier. Table 2 summarizes the values obtained for scour parameters for all tests. In Table 2, the values of planner surface area and volume of the equilibrium scour holes were estimated with the help of gauged data.

(a) Square shape cloumn

(b) Circular shape column

(c) Aero-foil shape cloumn

(d) Square shape column

Figure 2. Scour affected zones around piers

Table no. 2 Magnitudes of geometrical scour parameters.

Test no	be (cm)	d se (cm)	l se (cm)	w se
1	8	5.2	13	16
2	8	3.8	12	12
3	8 diameters	4.5	12.5	15

III. DIMENSIONAL ANALYSIS

The maximum or equilibrium depth that the scouring process can reach is the magnitude that the designer is interested in when determining the pier depth. Because of this, the quantitative study is restricted to the maximum equilibrium depth (dse) that the scour hole surrounding the pier can reach after enough time has passed to achieve equilibrium. When a single pier is isolated in a rectangular tilting flume with unidirectional flow and a bed composed of cohesionless sand particles, the equilibrium scour depth is determined by the water's density and viscosity, the sand particles' density and median particle diameter, the channel flow's depth, slope, and gravity—the section averaged velocity—and the pier's geometry (a characteristic width, pier shape coefficient). For The round pier the pier diameter and the characteristic width (bc) are equal. The list of parameters is lengthy, and some of them—like the grain form, particle size distribution, and bed material cohesion—are also challenging to measure. Because of this, the following restrictive conditions were the primary focus of the analysis: Bed material: the sediment has a uniform size (d50) and is non- cohesive Flow: the flume is wide enough to prevent a large contraction from the pier; Pier: a Surface that is flawlessly smooth. The remaining parameters are:

Mannings formula
V =1/n ×Rh^2/3 ×S^1/2
V = Velocity
n = Mannings roughness coefficient R =Hydraulic Radius [m or ft]
Rh = A/P
Where, A= area, P= wetted perimeter, s= slope of channel bed.

Tilting flume dimensions	Millimetre	Meter
B	150 mm	0.15 m
L	3000 mm	3 m
H	150 mm	0.15 m

A = b × h P = b + 2 × h
= 0.15 × 0.15 = 0.15 + 2 × 0.15
= 0.022m = 0.45 m
Rh = A/P = 0.022/0.45 = 0.048 m s = 0.33
n = 0.070 therefore natural river= 0.035 – 0.070
V = 1/0.070 × 0.048^2/3 × 0.33^1/2 V = 1.083 m
Q = A × V = 0.022 × 1.083 = 23.82 lit/sec

IV. CONCLUSION

In this research paper, we conclude that among the various pier shapes analyzed, the aerofoil shape demonstrates superior performance in reducing scouring. This is attributed to its sharp edges, which effectively divide the flow of water, thereby minimizing soil erosion caused by water currents. Several important conclusions about the estimation of scour depth around bridge piers can be made from the experimental and analytical research carried out for this project. The study used a tilting flume to conduct controlled clear water scour tests on square, circular, and aerofoil piers. According to the findings, the pier's shape has a major impact on the equilibrium scour depth; the aerofoil-shaped pier has the lowest scour depth (3.8 cm), followed by the circular pier (4.5 cm) and the square pier (5.2 cm). This implies that streamlined pier designs like the aerofoil are better at reducing the erosive effects of water flow. Additionally, the analysis showed a direct correlation between scour depth and variables like discharge, flow depth, and flow velocity. The equilibrium scour depth tends to rise as these parameters do, which affects the pier foundation's stability.

A useful framework for forecasting scour parameters, such as the depth, length, width, and volume of scour holes, which correlate with the characteristic flow shallowness (h/bc), is provided by dimensional analysis and empirical relationships derived from the experiments. The study comes to the conclusion that the best design for lowering scour depth is an aerofoil-shaped pier, which is a useful suggestion for engineers building bridge structures in scour-prone areas. These results add to a solid body of information that can direct further study and improve the durability and safety of bridge infrastructure.

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