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Effect of Roughness of Cylindrical Pier on Maximum Scour Depth

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Abstract—*Sediment erosion in the region of bridge piers is a potential hazard to the safety of bridges. The presence of various roughness heights on the surface of bridge piers was explored as a scour countermeasure. Laboratory experiments under clear-water conditions are to be conducted using different roughness heights with different pier diameters under different flow water depths. The test program included a case of a smooth pier to determine the performance of the roughened piers and to benchmark some existing formulas of local scour around bridge piers. Although the roughened piers produced an extended scour hole length upstream of the bridge piers, results revealed the effectiveness of the roughened piers in decreasing the maximum scour depth, angle of upstream slope, planner area, and volume of the scour hole upstream of the pier.*

Keywords: *Scour, Roughness, Pier.*

1. INTRODUCTION

Scour is the process of removal of bed material by erosion by the flowing water in streams, rivers etc. Scour is one of the main reasons because of which a bridge fails. One of the most common reasons for the structural failure of the bridge piers are 'local scour'. Local scour is one of the most researched topics in which its estimation, countermeasures etc. has been extensively researched. Local scours are classified according to the capacity of flow approaching bridge which will transport bed material. Literature categorized pier-scour countermeasures into bed armoring and flow altering countermeasures. Bed armoring countermeasures uses massive and heavy armor stones which will diminish the force and velocity of the down-flow and the horseshoe vortex and these stones cannot be moved by the flow. Bed attachments such as riprap blocks, gabions or cabled-tied blocks were used to protect the movable canal bed (e.g. Cardoso and Fael 2009; Chiew 1995; Chiew 2004; Chiew and Lim 2000;) , Pagliara et al (2015) positioned macro elements at the bed in the region of a circular pier within the sight of debris accumulation to control scouring. Their method confirmed the effectiveness of these macro elements in decreasing the maximum scour depth. The foremost focus of these flow-altering countermeasures is to diminish the down-flow and the horseshoe vortex which are the main components which is responsible for the scouring of bed material. Like armor beds there are many more countermeasures which have been introduced and have been studied extensively such as collars and slots (e.g. Alabi 2006; Grimaldi et al 2009; Heidarpour et al. 2003; Heiderpour et al. 2010), Plates and bottom vanes (Ghorbani and Kells 2008; Johnson et al. 2001; Li et al. 2006; Parker et al. 1998), sacrificial piles (e.g. Chang and Karim 1972; Elnikhely 2014), bed sills (Chiew and Lim 2003; Grimaldi et al. 2009), opening through pier (Abd El-Razel et al. 2003; Elnikhley 2017) etc.

The present paper aims to experimentally and using computational analysis to examine a method of a flow altering countermeasure to decrease pier scour by using roughness height with uniform grain sizes that are glued around the surface of the circular piers and also comparing these setups with the pier being in an inclined position. Inclined piers to the downstream side has been proved to decrease the maximum scour depth and we are experimentally checking that how much there will be a decrease in maximum scour depth as compared to non-inclined piers and that too by using roughness on them. This idea of using roughness as a countermeasure arises with the help of results obtained from researches that employs roughened horizontal aprons behind the hydraulic structures to disintegrate the energy arising from the turbulent flow of the water and to reduce the corresponding scour depth.

2. OBJECTIVES AND AIMS OF PRESENT STUDY:

This study investigate the effect of roughness on local scour depth and extant of the scour hole around cylindrical piers by using the parameters like velocity, roughness and angle of inclination of the structure. We were also investigate and done comparison of followings:

- To study the scour around cylindrical piers.
- To study the effect of inclination on scour depth around cylindrical piers.

- To study the effect of roughness on local scour depth and extant of the scour hole around cylindrical piers.

3. LABORATORY EXPERIMENTS

The experimental work was performed at hydraulics laboratory, National Institute of Technology Kurukshetra Harayana (India). A re-circulating flume of 15m long, 0.65m wide and .85m height was used. The bed material used were sand (having d_{50}= 0.26mm). The flume was provided with transparent glass on both side of the channel to view the flow conditions and flow mechanisms inside the channel. Scour depth measured the downstream of the channel. Scour depth measured with the help of Z-shaped pointer gauge. Three different sizes of cylindrical models are used piers.

S no.	Diameter (mm)	Length (cm)
1	45	50
2	55	50
3	65	50

(Figure 1- pictorial view of laboratory flume)

(Figure 2- piers with roughness 7.5 mm)

3. Results and discussion

S no.	SIZE OF PIER (DP) (mm)	ROUGHNESS (R) (mm)	VELOCITY (V) (m/s)	ANGLE (A)	SCOUR DEPTH(DS) (cm)
1	45	0.05	0.155	0	3.45
2	45	0.26	0.155	0	3.32
3	45	0.62	0.155	0	3.22
4	45	2.6	0.155	0	3.05
5	45	7.5	0.155	0	2.59
6	45	0.05	0.155	10	2.67
7	45	0.26	0.155	10	2.52
8	45	0.62	0.155	10	2.4
9	45	2.6	0.155	10	2.3
10	45	7.5	0.155	10	1.94
11	45	0.05	0.1669	0	3.64
12	45	0.26	0.1669	0	3.5
13	45	0.62	0.1669	0	3.3
14	45	2.6	0.1669	0	3.19
15	45	7.5	0.1669	0	2.8
16	45	0.05	0.1669	10	2.78
17	45	0.26	0.1669	10	2.65
18	45	0.62	0.1669	10	2.54
19	45	2.6	0.1669	10	2.43
20	45	7.5	0.1669	10	2.24
21	55	0.05	0.155	0	3.95
22	55	0.26	0.155	0	3.63
23	55	0.62	0.155	0	3.34
24	55	2.6	0.155	0	3.23
25	55	7.5	0.155	0	2.85
26	55	0.05	0.155	10	3.33
27	55	0.26	0.155	10	3.12
28	55	0.62	0.155	10	2.95
29	55	2.6	0.155	10	2.64
30	55	7.5	0.155	10	2.31
31	55	0.05	0.1669	0	4.12
32	55	0.26	0.1669	0	3.83
33	55	0.62	0.1669	0	3.46
34	55	2.6	0.1669	0	3.38
35	55	7.5	0.1669	0	3.09
36	55	0.05	0.1669	10	3.54
37	55	0.26	0.1669	10	3.26
38	55	0.62	0.1669	10	3.17
39	55	2.6	0.1669	10	2.92
40	55	7.5	0.1669	10	2.59
41	65	0.05	0.155	0	4.09
42	65	0.26	0.155	0	3.92
43	65	0.62	0.155	0	3.45
44	65	2.6	0.155	0	3.31
45	65	7.5	0.155	0	3.04
46	65	0.05	0.155	10	3.54
47	65	0.26	0.155	10	3.31
48	65	0.62	0.155	10	3.16
49	65	2.6	0.155	10	2.99
50	65	7.5	0.155	10	2.63
51	65	0.05	0.1669	0	4.35
52	65	0.26	0.1669	0	4.13
53	65	0.62	0.1669	0	3.83

54	65	2.6	0.1669	0	3.47
55	65	7.5	0.1669	0	3.21
56	65	0.05	0.1669	10	3.72
57	65	0.26	0.1669	10	3.55
58	65	0.62	0.1669	10	3.27
59	65	2.6	0.1669	10	3.13
60	65	7.5	0.1669	10	2.89

- As we can see that with increase in roughness of piers there is a decrease in maximum scour depth as compared to the smooth piers.
- AS we can also see that with the inclination of piers in the downstream side by 10 degree also decrease the maximum scour depth and with increase in roughness, it decreases more scour depth as compared to the roughened piers in vertical setup.

4. CONCLUSION

As we have discussed in results, our experimental work has duly satisfied our hypothesis that roughness and inclined piers can decrease the maximum scour depth.

Notation

D_{50} = Mean size of bed material

DP= diameter of pier.

R= roughness heights.

V= velocity of flow of water

A= angle of pier wrt vertical.

DS= scour depth

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