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EXPERIMENTAL STUDY OF SCOURING AROUND ELLIPTICAL PILE-CAP BY USING THE SUBMERGED BROAD CRESTED TRAPEZOIDAL WEIR AT DOWNSTREAM

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Abstract- Bridge piers fail for a variety of reasons but scouring around the pier is the most common. It is during the scouring procedure that the piers are decontaminated. As a result, the foundation of the bridge is exposed, which ultimately results in its collapse. The scouring effect around bridge piers was reduced by employing a different method. An Elliptical Pile-Cap of dimension (D) six centimeters by six centimeters was installed at the upstream side of a submerged trapezoidal broad crested weir (TBCW), and the height of the weir (Z) was five centimeters without piers and with weirs at various separation distances (S), two-dimensionally (S), and four-dimensionally (S). The experiment was conducted in a channel at the Hydraulics Engineering Laboratory, University of Engineering and Technology Taxila, utilizing a uniform bed material, flow depth-flowing under clear water conditions. The upstream face of the pier had its scouring depth compared to the local scouring in both the presence and absence of TBCW. Experiment results demonstrate that by using the submerged TBCW- at downstream S = 2D, S = 4D, as opposed to without it, the scour depth at Elliptical Pile-Cap may be reduced by 48%.

Keywords- Elliptical Pile, Trapezoidal Broad Crested Weir, Reduction, scouring

1 Introduction

Local scour holes around bridge piers are almost inevitable in alluvial channel beds subjected to the erosive force of oncoming river flows. Building bridges that span alluvial channels demands expertise or at least the ability to design and construct them [1]. This estimate is as close to being precise as feasible in order to predict the maximum scour depth that may occur near the piers over the course of the bridge's expected lifespan. Scour depth estimation is in its infancy because of the complexity of scour problems, which necessitates the development of a unifying theory. This type of scouring is most common during floods, which have unstable flows and may even change direction (Wardhana et al. 2022) [2]. Scrubbing occurs when three-dimensional boundary-layer separation occurs at the dock, resulting in bed material being eroded by high-turbulence and vorticity local flow structures. The examination of scour at bridge piers has been ongoing for several decades. For a variety of approach flows, sediment sizes and grades, pier types and sizes, and other variables, researchers have studied local pier scour extensively in alluvial channels and produced several prediction models to determine the maximum scour depth at bridge pilings [3]. For the hydrodynamic forces in the scour hole to stop removing particles, the local scour persists for an adequate amount of time at the bridge pier's piers. Equilibrium is reached at this point in the scour hole and the scour depth does not change much unless flow conditions or bed material changes (Mohammad Vaghefi et. al 2022) [4].

2 Experimental Procedures

All the experiment was performed in the Water resources & Hydraulics Engineering Laboratory of Department of Civil Engineering, University of Engineering and Technology, Taxila. The channel had specifications of 20 m length, 1 m wide and 0.75 m deep glass-sided flume with an adjustable tailgate at the channel-end to regulate the flow depth used for the experimental depth. Through the centrifugal pump, discharge was supplied to the tank then inter to the main channel by aligned honeycomb diffuser in the direction of flow for smooth and uniformly distribution of flow cross-wise. At the tail of channel water enter in the sediment tank after filling and trapping the flowed sediments, the flow discharges in the main channel. Plan view of the Laboratory channel and experimental setup shown in Figure 1. Also, pictorial representation of experimental setup shown in Fig 2

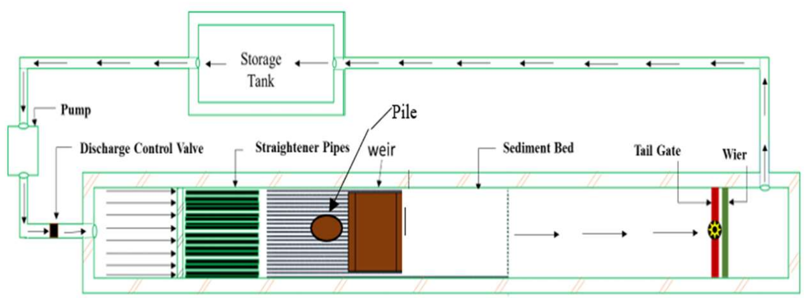

Fig 1: Plan View of Channel

Fig 2: Pictorial View of Experimental Setup

Fig 1: Plan View of Channel A 9m long, 0.20m deep and .96m wide false bottom of uniform, medium size (d_{50}=.51mm) bed material and pier base was introduce, sand size considered in this study stood in compliance to the condition of *D/d50 > 50* in order to dominate the sediment size effect on the scour evolution process guaranteeing non ripple-forming sand (Raudkivi & Ettema, 1983) (Ettema, Melville, & Barkdoll, 1998). The diameter of the pile was not more than 10% of the channel width to prevent the effect of walls on scouring (Chiew and Melville, 1987) [5], therefore double square pile modelled by 0.06m dimension of wood material. The trapezoidal broad crested weir *(TBCW)* modelled by wood material, weir width equal to the full width of channel, crest length was 50cm, the weir was 5cm above the flat bed, the sides slopes of the TBCW was 1V:2H, which is more stable and seepage control. (Fritzi & Hager, 1998). The dimension of *TBCW* was within the limits (Sturm, 2001) (Henderson 1966) (Chanson, 2004) [6].

Elliptical Pile was placed at the equal distance the from edges of the flume, at the upstream of the TBCW. In start the elliptical pile was placed near the upstream of the weir, separation distance from the TBCW was 0D, then increase the separation distance (S) with respect to the diameter of pier as 2D and 4D. The sand bed was carefully levelled to flat bed with upstream and downstream flume bed, before performing every experiment. The discharge was then allowed to enter flume gradually and attained the flow depth and velocity became low with the help of tailgate channel. The discharge was set and flow depth was regulated manually to maintain constant and then stabilized flume slowly. After the completion of drainage, point gauge was used to measure the scouring around the pier having an accuracy of ± 0.5 mm. The experimental minimum time, allowed to run was 3 hours for each experiment. The suitable equilibrium time is 3 hours for the experiment (Karimi et al., 2017). Therefore, average time taken for each experiment was 3 hours. After completion of the above procedure, measured the geometrical dimensions of the scoured hole.

3 Research Methodology

There were three distinct discharges tested, with Froude numbers ranging from 0.189 to 0.26, to see if scouring around an elliptical pile cap was possible. Two studies were conducted using a Broad crested trapezoidal weir at the downstream end of each discharge. The third set of trials used a Broad crested trapezoidal weir at downstream and an elliptical pile cap at three different discharge distances (0D,2 D and 4 D), all of which were done simultaneously. All the tests were completed in crystal-clear water with a constant depth of flow and three distinct discharges.

4 Results

Table 1: Experimental Condition and Result

Case	S (m)	Q (m^3/s)	T (hr)	h (m)	ys_f (cm)	ys_ f/D
1	Without weir	0.023	3	0.15	5.3	1.03
2		0.027	3	0.15	5.8	1.08
3		0.032	3	0.15	6.4	1.15
4	2D	0.023	3	0.15	3.3	0.65
5		0.027	3	0.15	4.0	0.73
6		0.032	3	0.15	4.7	0.84
7	4D	0.023	3	0.15	5.1	0.88
8		0.027	3	0.15	5.6	0.95
9		0.032	3	0.15	5.2	1.04

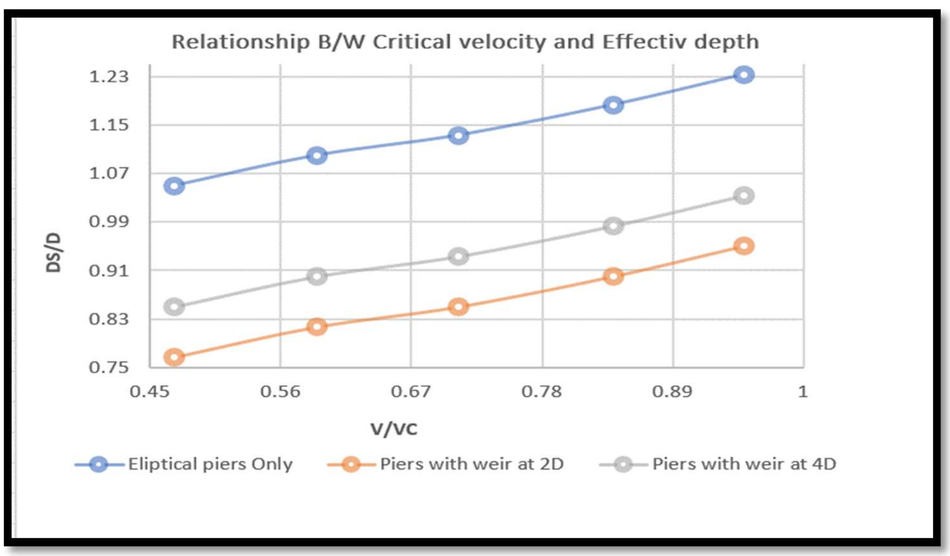

Fig 3: Scour Depth verses flow intensities

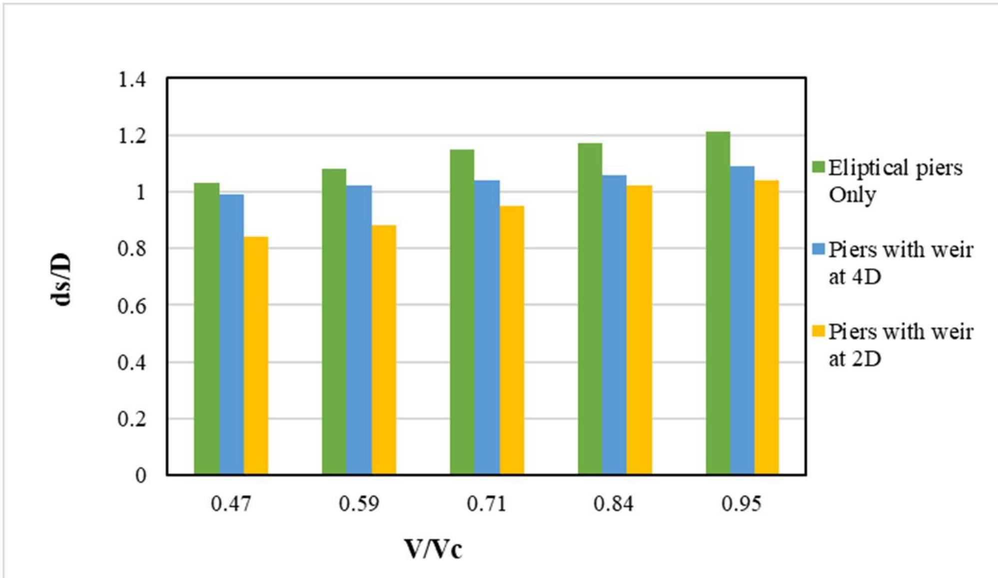

Fig 4: Comparison of elliptical piers only, TBCW at 2D, and 4D

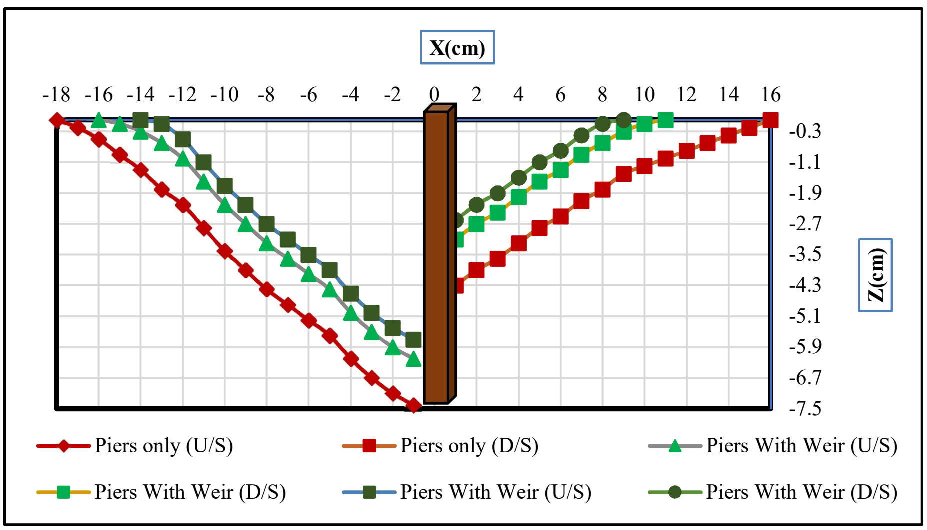

Fig 5a: Longitudinal Scour Profile

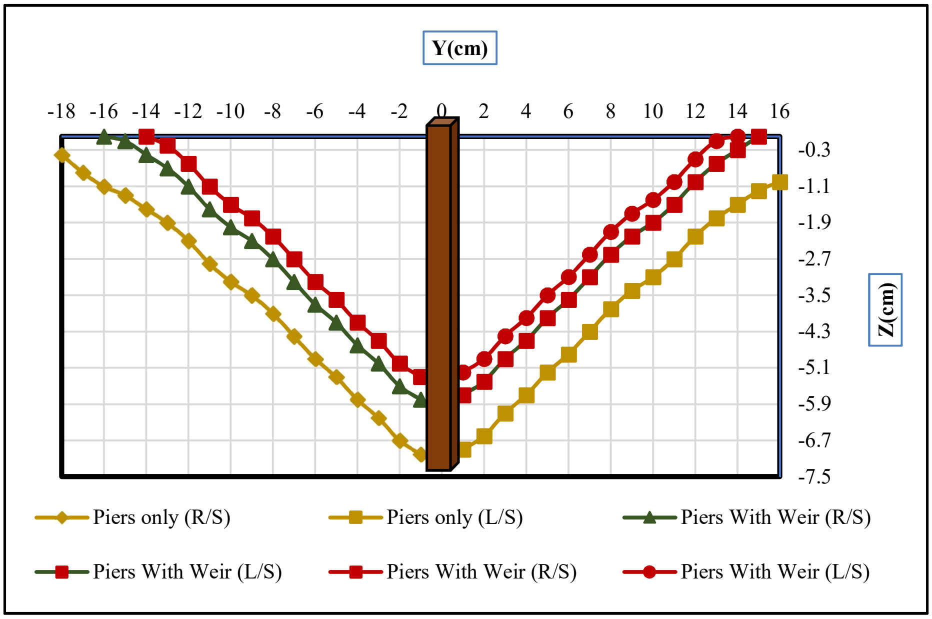

Fig 5b: Lateral Scour Profile

In first case scouring around Elliptical pile-cap was measured without presence of TBCW, then installed the Elliptical pile-cap at the upstream of submerged TBCW and varies the separation distance (S) between TBCW with respect to pier dimension of pier as 2D, and 4D measure the scouring around the pier and compare the result of elliptical pier scouring with or without presence of submerged TBCW. During experiment it was observed that scouring was minimum when the piers was installed at distance of 2D from the upstream sides of weir and it will increase as we move from the upstream of weir at 2D and 4D.

Fig. 3 represents the plot of pier scour depth versus various flow intensity shows that the pier scour depth increases with the increase in flow intensity and vice versa. It is since due to the increase in intensity that both the flow depth and velocity increases, which in turn cause an increase pier scour depth. This trend is shown in Fig1 for elliptical piers only, piers with *TBCW* at *2D, and 4D* separation distance *(S)* for time interval of *3h*, respectively. Fig. 4 shows the comparison between pier installed without *TBCW* and piers installed with weir separation distance between the pier and weir.

Fig 5 (a and b) shows the scour the longitudinal and lateral profiles of scour holes which shows that the scour hole was increased due to increasing the flow intensity. Fig. 5a shows that the scour depth on upstream side of the pier was approximate same as the scour depth of the lateral profiles of the piers due to swirling effect generated along the sides of the pier as shown in Fig. 5b

5 Conclusion

This study concluded that:

- The Scouring depth around the pile increases by increasing Froude Number in clear water condition.
- The depth of scour hole increases with the increase of distance from the weir.
- By the increase of separation distance from 2D to 4D between elliptical pile and weir, scouring reduction is reduced; 42% reduction in scouring at 2D and 33% reduction in scouring at 4D.
- Reduction in scouring was 27% around elliptical pile-cap without presence of TBCW; 6% greater reduction than previous study with only Elliptical pile.

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