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Study the Local Scour around different Shapes of Non-Uniform Piers

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Abstract

One of the major causes of serious damage to the bridge is scoured around bridge foundations. In this study, the effect of main parameters (pier shapes, foundations shapes, level of foundation, flow intensity, and Froude number) on local scour with different shapes of non-uniform piers were experimentally investigated. The runs that occurred for three foundation shapes include (rectangular, oblong, and hexagonal), the depth of foundation in this study was 8 cm. The shapes of piers used in this study were (rectangular, oblong, and hexagonal). The results display that the depth of scour depends on the foundation level, shape of pier and foundation. The best foundation shape which gives minimum scour, was hexagonal, oblong, and rectangular shape, respectively. The results also display that positioning of foundation below bed level, leads to less values of scour depth around bridge pier. Also, the best shape of the pier that leads to minimum scour is hexagonal pier because it has minimum exposed area.

Keywords: Local Scour, Non-Uniform Bridge Pier, Foundation Shape, pier shape, level of foundation Position.

1. Introduction

The scour around bridge piers is a great importance problem in the safety estimation of bridges.

Various research studies about local scour around uniform bridge piers but a few research studied the non-uniform bridge pies, non-uniform bridge pier is one for which the cross-sectional dimension varies over the length of the pier (piers with footings). The foundations of bridge pier usually are used for transferring the loads on bridge to safe place like earth. Several searches are obtainable that describe the scour around piers of non-uniform geometry in respect of the foundation. Reading to non-uniform bridge pier as cited by Melville and Raudkivi (1996) [1]. A laboratory study by Tsujimoto et al. (1987) [2], and a numerical exploration by Imamoto and Ohtoshi of the local scour at non-uniform cylindrical piers also displayed that the scour was reduced for certain geometries.

Breusers and Raudkivi (1991) [3] found that reduction of scour depth due to a foundation located at an appropriate level below the initial bed level, should not be reposed on unless: Definite foretelling of bed level are possible, because (the level of the river bed can go down extraordinarily during a flood in a particular spread of the river, or the place of the pier may correspond with that of a moving stream channel in the cross section). This exemplary note, which has been signified by others one of them was Melville (1988) [4] has main implying for design. Sterling Jones (1992) [5] occurred a study in the laboratory to research the influences of foundation place on the scour depth. The purpose of the study was to find various techniques for describing the pier effectual dimensions or foundation texture when both are displayed to the flow field. The HEC-18 pier-scour equation is a design equation used that contains an implicit over prediction factor 1.2 to 1.3. Both the governing component and weighted pier width techniques are superior to the 10 % depth approach in cases in which the foundation expands into the flow field. This addresses the significant arresting influences of scour caused by foundations placed at or below the bed. Foundations at such places can supply effectual protection against local scour of pier if they are extensive enough.

Fotherby and Jones (1993) [6] classified foundations as deep or shallow, according to whether the foundation was undercut by scour. Deep foundations expand below the base of the scour hole. They displayed that for piers placed on shallow slab foundations the depth of scour was decreased when the foundation was undercut, probably because the stagnation pressures accountable for the formulation of the horseshoe vortex were decreased when the flow could go along down the upstream edge of the foundation. Of course, an undercut foundation is an unfavorable design condition.

Parola et al. (1996) [7] carried out a search of scouring at piers with rectangular footings. They also noted the preventive ability of foundations place below bed level and indicated on the high sensitivity of depth of scour to footing parameters, especially to the elevation of footing and displayed the influence of rectangular footings over the whole range of possible pier to footing width ratios and through the whole range of footing elevations. They studied the influence of an upstream footing expansion on the scour depth and they attained to conclusion that the expansion of footing in upstream increased the depth of upstream scour decreases.

Melville and Raudkivi (1996) [1] occurred test on non-uniform piers, the non-uniform pier was cylindrical pier place on larger cylinder footing. Besides the factors that influence scour at a uniform pier, the depth of scour at a non-uniform pier is reposed on the ratio D/D^*(where D is diameter of pier and *D** diameter of foundation) and the depth from the top footing to bed level.

The results are showed that there found three scour zones, namely: zone 1 where the footing is below the bottom of the scour hole and does not influence the scour, zone 2 where the top of the footing is within the scour hole and decreases the scour, and zone 3 where the top of the footing is above bed level and grows the scour confronted to that at a uniform pier. Also, they obtain the optimum value of ratio of diameter of pier to depth of footing to find less scour. The notion of an effective pier size (*De*) is introduced, and it is displayed that use of (*De*) lead to conservative valuations of scour depth for non-uniform piers.

2. Materials and Methods

Tests were occurred in a 0.615 m wide, 0.97 m height and 5.72 m long rectangular flume at the hydraulic laboratory, of University of Al-Basrah College. Uniform sediment with a mean size diameter d_{50} = 0.4 mm. All tests were carried out with condition of clear water, steady flow, subcritical flow and plain bed. A screen are located inlet of the flume in order to repel any trouble and smoother the flow to ban any undesired forms of bed (dune or ripple) at the working section.

The flow is controlled by regulating a valve which opens and closes manually by hands. A sharp crested rectangular weir is used to measured discharge, it is located at upstream of the flume.

The flow depth is kept by an adjustable tail gate located at the downstream of the flume. A point gauge is used to measure flow depth, which has an accuracy of (± 0.1 mm), point gauge is ridded on a carriage which can be shifted to any portion above the flume by a pair of parallel rails reposed on walls of the flume.

Table 1 Flow Conditions.

Fr	0.431	0.383	0.335	0.288	0.256
y (cm)	3	3	3	3	3
V (m/s)	0.27	0.24	0.21	0.18	0.16
Q (m^3/s)	0.0048	0.0043	0.0038	0.0033	0.0028

Three different foundation shapes including (rectangular, oblong, and hexagonal) are display Fig. 1. Three different piers shapes are modeled including (rectangular, oblong, and hexagonal) as show in Fig. 2, the width of piers was 4 cm and length was 16 cm. The foundation top elevation Z is measured from the initial bed level and is positive if the top of the foundation is below the initial bed level and vice versa. For all of foundation shapes three different levels of Z/D = 0, + 0.25, − 0.25 were used.

Fig.1 Different shapes of foundation.

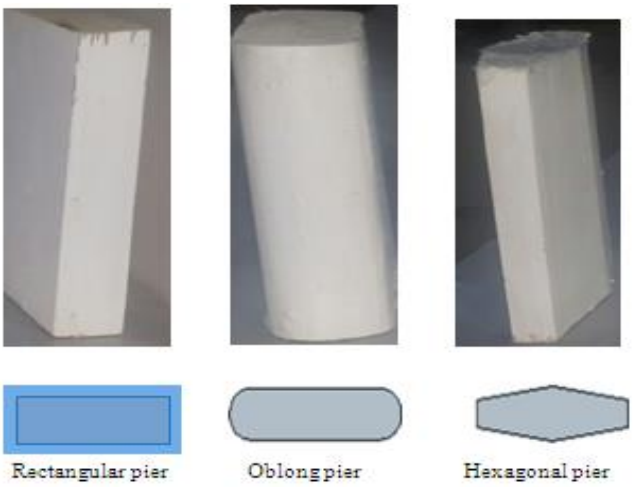

Fig. 2 Different shape of piers.

3. Results and Discussion

In the following the influence of foundation level, shape of foundation and shape of pier on scour depth is considered separately.

3.1. Level of foundation position

Result showed the impact of foundation level position that found the maximum scour depth occurred when the foundation prominent above the bed level, but minimum scour depth occurred when foundation level below bed level therefore the best level of foundation when it's found below bed level because the maximum reduction of scour depth found in this case.

The samples of temporal development of scour depth for different foundation shape in different foundation level are present in Figs. 3, 4 and 5, respectively.

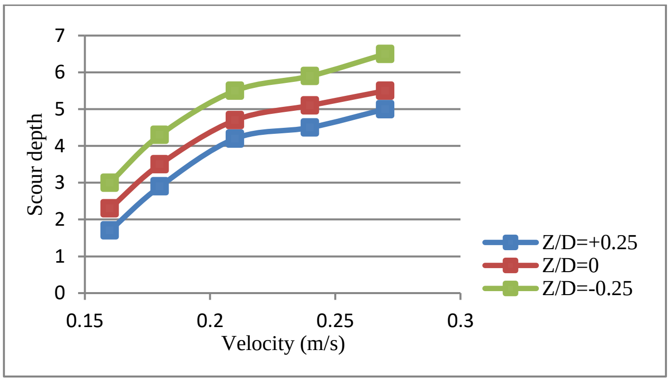

Fig. 3 Relationship between velocity and scour depth for rectangular foundation.

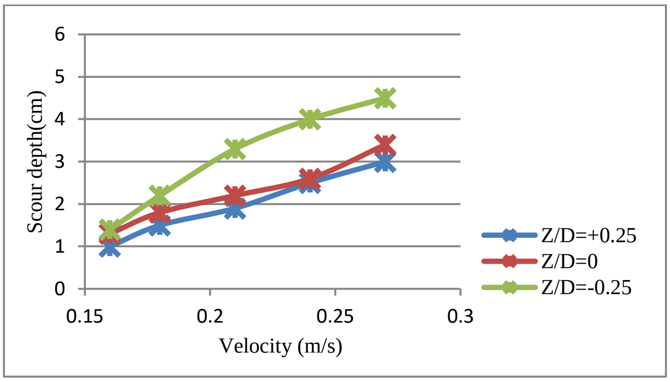

Fig. 4 The relationship between velocity and scour depth for oblong foundation.

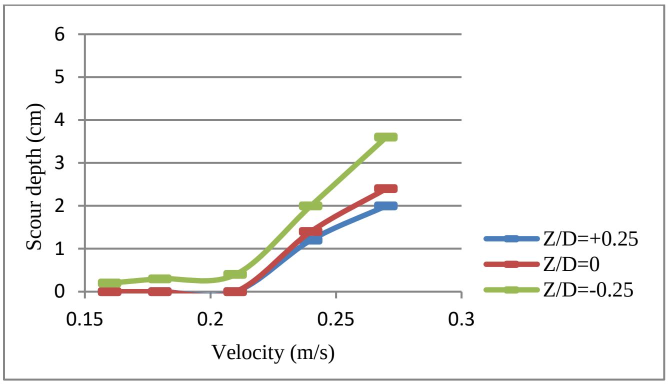

Fig. 5 The relationship between velocity and scour depth for hexagonal foundation.

3.2. Effect of Non-uniform Pier shape

In Figs. 6 and 7 the samples of temporal development diagram of scour depth with Z/D = − 0.25 and Z/D = + 0.25 are presented for three foundation shapes. The scour in hexagonal foundation is less and using the foundation on the level of Z/D = + 0.25 decreases the scour of front of pier to uniform pier up to 85 %. The maximum scour occurs in the bridge pier with rectangular foundation, oblong foundation, and hexagonal foundation, respective.

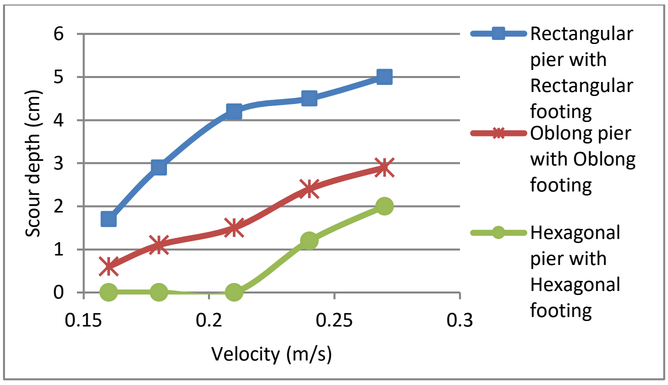

Fig. 6 The relationship between velocity and scour depth of different non-uniform pier when the level of foundation below bed level, Z/D = 0.25.

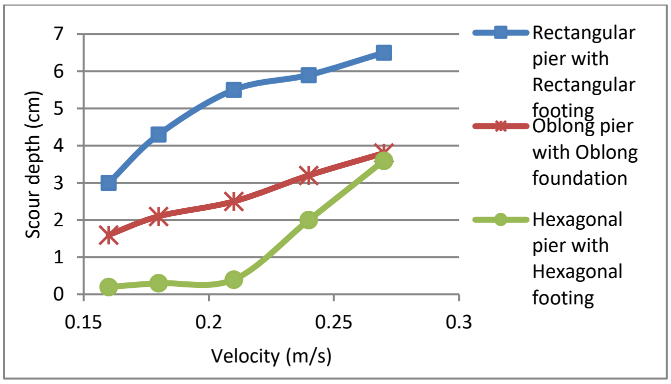

Fig. 7 The relationship between velocity and scour depth of different non-uniform pier when the level of foundation below bed level, Z/D = − 0.25.

4. Conclusions

The following conclusions are based on this experiment on the process of the scour development around a pier with foundation of varying depth from an initial bed level, shape of foundation.

1. The position level of foundation relative to bed level has significant impact on scour depth around non-uniform piers, it was found that the reduction and limiting the scour due to the footing happen when it is located below the bed. The scour depth increases with footing level when the footing located above the initial bed level.
2. The best level of footing for various footing shapes is different. The result displays rectangular, oblong and hexagonal footing when located below the bed level gives a maximum reduction in scour depth equal to (47 %, 49 %, 56 %) respectively, as compared of the scour depth without footing scour depth.
3. Non-uniform pier shape has important effect on equilibrium depth of scour and initial scour rate. Rectangular pier with rectangular foundation has a maximum scour depth of 6.5 cm, it is higher than others shapes, while the scour depth for hexagonal pier with hexagonal foundation was 2 cm because it has a minimum exposed area.
4. According to this study results show that the hexagonal pier shape with hexagonal foundation can be considered as the best shape of non-uniform piers where it reduces the maximum scour depth by 69 % as compared with rectangular pier shape with rectangular foundation.
5. The best footing shape which gives minimum scour around it, was hexagonal shape, oblong, and rectangular shape, respectively.

Notation

The following symbols are used in this paper:

D : Pier diameter or width (L).
Fr : Froude number of pier.
d_{50}: Median size of sand (L).
Q : Calculated discharge (L).
V : Approach flow velocity (LT-1).
y : Approach flow depth (L).
Z : Top elevation of foundation measured from initial bad level.

References

[1] B. W. Melville, and A. J. Raudkivi, "Effects of Foundation Geometry on Bridge Pier Scour", Journal of Hydraulic Engineering, ASCE, Vol. 122, No. 4, pp. 203-209, 1996.
[2] T. Tsujimoto, S. Murakami, T. Fukushima, and R. Shibata, "Local Scour around Bridge Piers and its' Protection Works", Mem. Foc. Technol. Kanazawa University, Vol. 20, pp. 11-21, 1987.
[3] H. N. C. Breusers, and A. J. Raudkivi, "Scouring-Hydraulic Structures Design Manual", IAHR, A. A. Balkema, Rotterdam, 1991.
[4] B. W. Melville, "Scour at Bridge Sites", Civil Engineering Practice, Vol. 2, pp. 327-362, 1988.
[5] G. S. Jone, R. T. Kilgore, and M. P. Mistichelli, "Effects of Footing Location on Bridge Pier Scour", Journal of Hydraulic Engineering, Vol. 118, No. 2, 1992.
[6] L. M. Fotherby, and L. S. Lones, "The Influence of Exposed Footings on Pier Scour Depths", Proceeding of Hydraulic, Hydraulic Engineering Conference, pp. 922-927, 1993.
[7] A. C. Parola, S. K. Mahavadi, B. M. Brown, and A. El-Khoury, "Effects of Rectangular Foundation Geometry on Local Pier Scour", Journal of Hydraulic Engineering, Vol. 122, No. 1, pp. 35-40, 1996.