ISSN 0974-5904, Volume 10, No. 02

DOI:10.21276/ijee.2017.10.0234

www.cafetinnova.org

International Journal of Earth Sciences and Engineering

April 2017, P.P. 374-377

Effect of Bridge Pier Geometry on Local Scouring

CHANDAN ROY

Department of Civil Engineering, Maharishi Markandeshwar University, Mullana, Ambala, Haryana, INDIA

Email: *chandanroy.bankura@gmail.com*

Abstract: *Local scour around bridge pier is the main reason for failure of a hydraulic structure like as bridge piers, abutment etc. Local scour around a bridge pier is largely depending on the shape of the bridge pier and how the design is fashionable from the view of construction. Local scour is a complex phenomenon which depends on the discharge, depth of flow, geometry of the pier and type of sediment particle. In this study, geometry i.e. shape of the pier is the main concern. Research is carried out by considering three different geometry pier of rectangular, circular and oblong shape to conclude the optimal shape of the pier at a different flow velocity of 0.146m/s, 0.231 m/s & 0.323 m/s on 15m hydraulic flume under clear water condition using natural sand as the bed material in the university laboratory. Results show an idea that the scouring at the upstream face is directly proportional to the exposed upstream nose area of the pier. It is also shows that the scouring is highest in all cases for the rectangular pier and minimum for the oblong pier.*

Keywords: *Local scour, Pier shape, Pier Geometry, Depth of flow.*

1. Introduction

Scour depth variations at abutments is a crucial aspects in design of bridge piers. Local scour type is distinguished according to the mode of scour in the approaching flow. Local scour is classified in general as clear water scour and live bed scour. Clear water scour is that when sediment is removed from the scour hole but not filled up by the upcoming flow; whereas the live bed scour is a continuous phenomenon of carrying and refilling of sediment in the scour hole by the upcoming flow [1]. This is already analyzed by Lacey at the beginning of the early 20th century in the Indo-Gangetic Plain from stable irrigation channel data. Scouring in practical means lowering of the river bed due to erosion by the action of water current resulting a risk to expose the bridge pier foundation piers and abutments.

Removal of sediment near or around a structure in flowing water is termed as scour. Such scour in and around a pier or abutments causes a structural collapse resulting in loss of property and life without any warning. In our present age of fast life bridge occupy the heart of connection and communication across a river or any drainage network. Its failure causes a loss in economy and social status of the region. Scour depth below a normal river bed level around a bridge pier in an alluvial bed varies greatly depending on the flow depth, shape & size of the piers, attack angle of flow and sediment characteristics [2]. The main concern is the stability of the bridge piers due to lowering of the normal river bed level around the bridge element. So estimation of maximum local scour depth is very much necessary for selection and safe design of pier foundation.

Turbulence around the bridge piers in a loose foundation is the one main cause of bridge failure. The characteristic of turbulence around the foundation of a hydraulic structure is governed by the Froude number and the depth of flow in the section. In New Zealand scouring problem causes on an average one bridge failure each and every year [3] and a recent study quoted by Federal Highway Administration (FHWA) and stated that 383 bridge collapsed because of flooding of which 25% were due to pier damage and 75% due to abutment damage [4].

There are different factor which affect the scouring around a bridge pier. Among that, the shape of the bridge pier is one of them. Shape of the bridge pier regulates the boundary layer and flow pattern formation around the bridge pier. On this study shape of the pier is considered in minimizing the local scouring. Shape of the pier is also plays a important role on creation and strength of the vortex. The system of vortex consists of horse shoe vortex, wake vortex system, trailing vortex system, and bow wave vortex [5]. Piers are again simple piers (uniform) or complex piers (non-uniform). Uniform piers have constant section throughout its depth and a non-uniform pier includes pile foundation, tapered piers or slab footings [3]. In this study only uniform piers are considered.

2. Experimental Set-Up:

Experiments was conducted in a rectangular tilting flume in Hydraulic Research laboratory at Civil Engineering Department of Maharishi Markandeshwar Engineering College, Mullana having 0.6 m width, 15 m length and 0.75 m depth having maximum discharge up to 45lt/s and the setup is shown in Figure 1. A series of experiments was conducted at round nosed rectangular and triangular bridge piers models without collar plate skirted around the pier. Orifice meter is used for discharge

Received: December 13, 2016; Accepted: February 17, 2017; Published: April 26, 2017
International Journal of Earth Sciences and Engineering, 10(02), 374-377, 2017, DOI:10.21276/ijee.2017.10.0234

measurement, which is fitted on delivery pipe of centrifugal pump. The flow rate is adjusted by control valve and the flow is re-circulated. The valve is operated gently without disturbing the bed surface until the desired depth of flow is obtained. And further to obtain the required depth of flow the tail gate is operated. The water surface is measured using point gauge which is sensitive to an extent of 0.1 mm. The scour depth is measured through the point gauge by illumination of halogen light focused on the base of the piers [6]. The flume is filled with sediment of a particle size about 1.10 mm.

Figure1: *Experimental Setup: Tilting Flume*

2.1 Water Circulating System: Discharge control and depth of flow:

The upstream end of the experimental setup is designed to behave as a transition zone, which is accomplished of coarse aggregate (small pebbles), with a hyperbolic profile and allow to provide excess friction to cause fully developed of turbulent flow. The scour depth variation on the channel and in the vicinity of the pier can be easily noticed through the gauging scale drawn on the Plexiglas's of the pier face. Before the start of experiment on different flow depth, separate experiments were carried-out to maintain clear water scour for given fluvial bed without pier. Rectangular and Oblong pier were used to determine only a local scour without a contraction effect depending on the flow depth and the flow velocity. Piers were placed vertically at the centre of sediment bed which was leveled before starting the experiment. The control valve was adjusted in such a fashion that clear water condition would get developed without causing any disturbance to the bed material. Every time experiment was started by allowing the water to flow over horizontal bed with a defined flow rate.

For each pier, experiments were conducted by keeping all experimental parameters same i.e., bed slope and sediment except for flow depth which was varied depending upon shape of pier used. The scour depth was measured at different time intervals from the rail arrangement with pointer scale attached on it. Each run was of conducted for 3hours duration. Details of the experiments are summarized in Table 2. The present study of clear-water runs was conducted on uniform coarse sediment bed of average diameter 0.95 mm.

3. Experimental Procedure:

The following procedure is followed in the experiment:

- A wooden pier models were placed at the middle of the channel section of the flume at 3.5 m from the upstream.
- The bed was levelled thorough out the sand bed and was taken with the rail arrangement sliding point gauge prior to the start of flow in the channel.
- Scouring bed level reading is taken in different time intervals with the same moving gauge installed in both upstream as well as in downstream separately at the same time.
- Water was supplied into the channel by pumping water by 15HP centrifugal pump from the sump tank into the flumed channel.
- The water passed through the baffle wall before entering the channel section to minimize the turbulence of flow. The flow can be regulated by the valve attached with the outlet pipe of the pump. The water after flowing into the channel re-circulates through the pump.
- The required experimental discharge and depth of flow in the channel was regulated by gate valve controlling system fitted in the delivery pipe. The discharge was measured through the orifice meter and the mercury column.
- Point gauge is used for measuring the depth and depth of flow alteration is done by the help of the scale provided on the channel wall.
- At the end of each experiment the water is drained off the flume carefully so that the scour hole and scour patterns developed by the flow around the model piers, are not disturbed.

3.1 Discharge & Depth of Measurement:

Required discharge and depth of flow in the channel was controlled by regulating valve fitted in the delivery pipe. Discharge is measured by applying the orifice meter discharge equation and taking the pressure difference at manometer in the upstream and downstream of the orifice meter. Depth of flow in the flume is measured by taking the difference between the bed level reading and the top water level during experiment [7].

3.2 Pier Model Selection:

Experiment is carried out by taking into consideration of shape and shape factor of the pile. For the study Rectangular, circular and oblong piers are used which is shown in Figure 2. Table 1 shows the shape of the pier model.

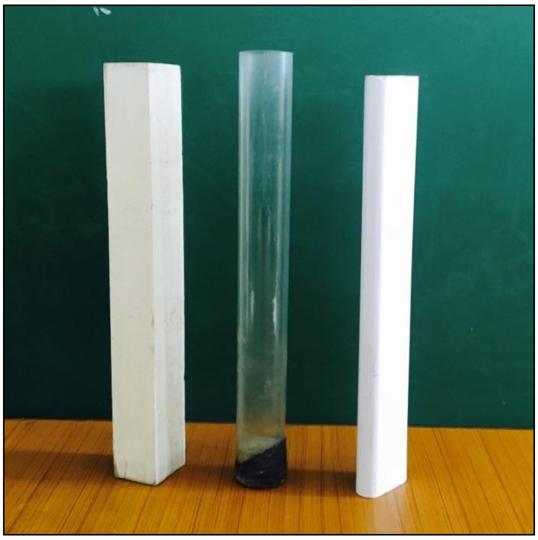

Figure 2: *Piers models used in Experiment*

Table 1: *Pier Geometry*

	Pier Shape	Shape Factor
Rectangular		1.1
Circular		1
Oblong		0.85

4. Results & Discussion:

Experiment were conducted under clear water at different discharge condition 35.73 lt/s, 28.51 lt/s and 21.55 lt/s. Test condition of each different shape pier is summarized in Table 2:

Table 2: *Flow condition for the experiment*

Q(lt/s)	Y(cm)	Velocity of flow in flume (m/s)	Fr
21.55	13.2	0.146	0.128
28.5	17.2	0.231	0.177
35.73	21.1	0.323	0.224

Main objective of the experiment is to examine the minimum scour depth condition among rectangular circular and oblong pier with major focus on the time after which equilibrium scour condition is achieved. Maximum scour depth in different flow depth and at different velocity is shown in Table 3.

Table 3*: Maximum scour depth in the experiment*

Pier Shape	V=0.146	V=0.231	V=0.323
	Measured scour depth in cm	Measured scour depth in cm	Measured scour depth in cm
Rectangular	4.1	5.2	6.3
Circular	2.9	4.2	5.4
Oblong	2.6	3.09	4

From the series of test conducted on different flow velocity for all three piers it is observed that scouring is drastically reduced with change of pier geometry and increases with increase in flow velocity. Among all the three different geometry piers in all different flow condition rectangular pier shows the maximum scouring and minimum in oblong shape pier. The highest scouring occurs at for the rectangular pier is 6.3 cm, for circular pier is 5.2 cm and for oblong pier is 4.1 cm and this all are seen for the flow velocity V = 0.323 m/s.

The scour depth variation for different flow condition and different pier geometry are shown in the Figure 3, Figure 4 and Figure 5 respectively.

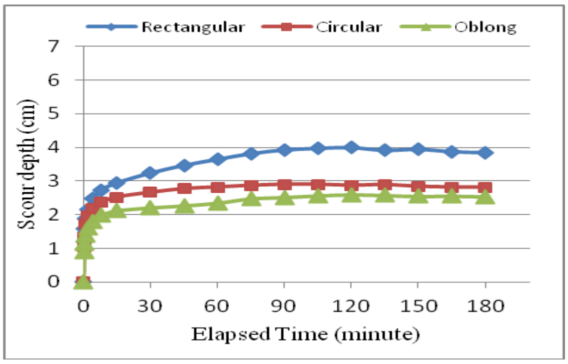

Figure 3: *Scour depth with time for V=0.146 m/s*

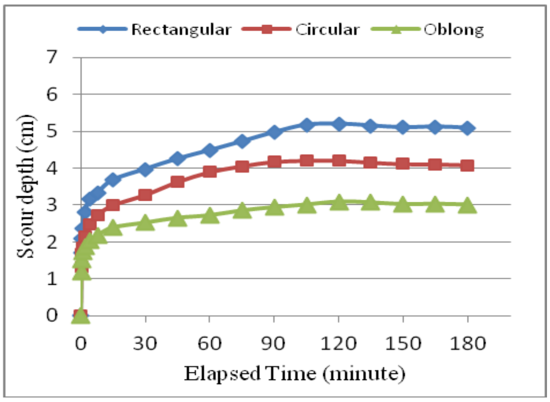

Figure 4: *Scour depth with time for V=0.231 m/s*

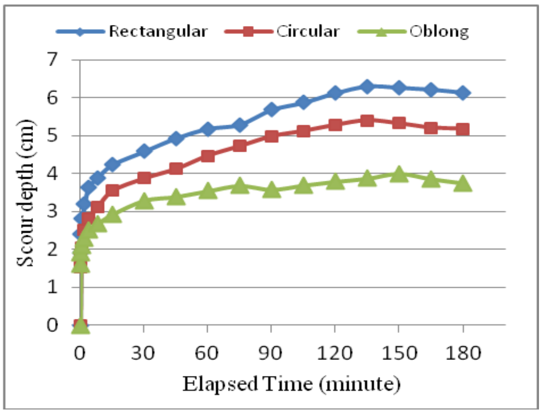

Figure 5: *Scour depth with time for V=0.323 m/s*

Maximum depth variation of the scouring with the scour depth is represented in the Figure 6, which shows that for rectangular pier, maximum scour depth increases in a linear fashion. For circular pier it is also same as linear fashion and for oblong it is in non-linear fashion.

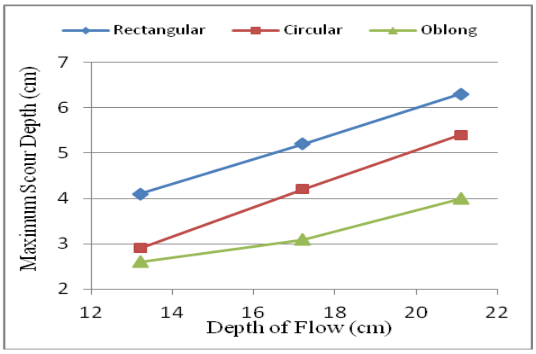

Figure 6: *Depth of flow and maximum scour depth*

5. Conclusions

The scouring is high at the initial stage and the backwater flow. Rectangular pier shows the maximum scour depth of 6.3 cm and 2.6 cm which is minimum for oblong pier. The scouring is directly depending on the exposed open face of the pier nose in contact with the approaching clear-water. Scour depth increases with the increase in the intensity of flow parameters and vice versa. The oblong shape is considered as the best among the three piers which restrict the local scour by 50% from maximum scouring for rectangular pier. After attending the equilibrium scour depth the scour depth is somewhat reduced due to the river bed armoring effect and the deposition of the sediment carried from the upstream bed.

References

[1] Dey, S., Bose Sujit K. and Sastry, L. N., “Clear Water Scour at Circular Piers: A model”, Journal of Hydraulic Engineering, 121(12), PP. 869-876, 1995, DOI: 10.1061/(ASCE)0733-9429(1995)121:12(869).

[2] Garde, R.J. and Kothyari, U.C, “Scour around Bridge piers”, PINSA, 64(4), pp. 569-580, 1998.

[3] Melville, B.W., Coleman, S.E., “Bridge Scour”, Water Resources Publications, LLC, Colorado, U.S.A., 2000

[4] Arneson, L.A., Zevenbergen, L.W., Lagasse, P.F., Clopper, P.E., “Evaluating scour at bridges – Fifth edition”, Federal highway administration Hydraulic Engineering circular No. 18, FHWA-HIF-12-003, FHWA, Washington, DC, 2012.

[5] Chiew, W.M., “Local Scour at Bridge Piers”, School of Engineering, New Zealand, Ph.D. Thesis, Dept. of Civil Engg., Report No. 355, 1984.

[6] Faruque, Mia, MD and Nago, H., “Dynamic behavior of bed material around bridge pier under water pressure variation”, 43(1), PP. 23-30, 2005, DOI: 10.1080/00221680509500108

[7] Ansari, S.A., Kothyari, U.C., Raju, R., K.G., “Influence of cohesion on scour around bridge piers”, Journal of Hydraulic Research, 40(6), PP 717-729, 2002, DOI: 10.1080/00221680209499918.