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An Experimental Study Of Local Scour Around Piers In The Curved Channels

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***Abstract*—The local scour around bridge piers is one of the most common causes of bridges failure. In general, scour phenomenon is extremely complex in nature and consequently in the past many investigators have attempted to develop conservation, analytical, semi-empirical or empirical equations based on the understanding of mechanism of local and general scour. However most of the researchers have studied the scour at bridge pier located in a straight channel and no study has been conducted when bridge pier is located in a curved channel. A 30 degrees curved channel (i.e. flume) was investigated with various piers shapes that were placed in middle of the curved part of channel. The flume wall was made of glass with a rectangular cross section of (30x60 cm). Its length is 8 m, the middle segment is curved. Different discharges were considered and three (3) angles of inclination of pier were tested. Measurements using ultrasonic device were undertaken, analyzed, presented and discussed. The efficiencies of the tested types were determined. It was deduced that the piers could be implement in curved channels. The best performance in reducing scour effect when lenticular with curve pier shape was implemented; it's one of non-conventional shapes.**

Keywords—Scour channel; curved channel; pier; Bridge pier.

I. INTRODUCTION

Bridges are the most important structures .Any crack or collapse would lead to major disasters or damage. Many bridges failed, worldwide, due to extreme scour around bridge piers and abutments during floods,. However, there is little knowledge about the scour at bridge piers in curved channels.

Pier scour is the streambed erosion in the vicinity of pier foundation due to complex vortex system. This system consists of a horseshoe vortex that is initiated by the down flow, at the upstream side of the pier.

Accordingly, wake vortices shed out from the sides of the pier due to flow separation. Foundation of a bridge pier in an erodible riverbed is quite expensive, as it should be placed deeply in the soil in order to provide maximum anchorage length for foundation safety. This is attributed to the fact that bridge failures due to scour results in economical loss and losses in human lives.

This paper presents the experimental results of scour, depth length for different pier shapes placed in a curved channel in order to understand the effect of the curvature on the scour hole.

Published researches were assembled and reviewed, from which it was clear that:

Many researchers investigated local scour around bridge piers in water ways, experimentally or numerically or theoretically. In 1977, Breusers et al. tested the influence of alignment and shape of pier on local scour in sand (d 50 = 0.48) mm. He observed that the rectangular shape, the maximum scour depth. When the pier aligned with the flow, he observed that there is no influence of rectangular pier length on scour depth. In 2010, Jueyi et al. identified clear-water scour around semi-elliptical abutments with armored beds. Experimental study has been carried out under a clear-water scour condition to explore the local scour around semi-elliptical model bridge abutments with armor-layer bed, compared with the local scour process around semi-circular abutment. The researcher concluded that for both semi-elliptical and semi-circular abutments, with increase in flow velocity in all of the runs the equilibrium scour depth of the scour hole will be increased. Abdual et al, 2016, studied ten different shapes from the piers, Were used to investigate the effect of the bridge pier's shape on local scour to conclude the optimal shape that gives minimum depth of scour. Comparison of results show that scour at upstream is directly proportional to exposed area of upstream nose of pier. The results showed that the rectangular pier gives the largest scour depth (7.6) cm, while the streamline shape gives the lowest scour depth (3) cm.

As for the curved channels, in 2008, Yaser Emami et al studied both in straight channel and in U-shape channel having a central angle of 180o. In order to study local scour, a 6cm-diameter pier was located in the straight channel and also in sections 30 and 60 degrees in the bend. This study shows that the minimum amount of scour depth (ds) at each discharge can be occurred at straight channel when pier is located in the bend, the amount of scour depth increases as compare to that in a straight channel. The location of scour hole in the bend is close to the outer wall of channel and the point bar is close to the inner wall of channel. Most of these studies have been done in straight channels. There is a few information, to the knowledge of authors, about the scour at bridge pier in a curved channel.

II. THEORETICAL APPROACH

Theoretical study was conducted using numerical analysis method to detect the relationships between various parameters and variables to different pier shapes. All parameters are defined on the figure 1. Functional relationships are obtained between the relative length of the scour hole (Ls / Lsm) for all piers shape.

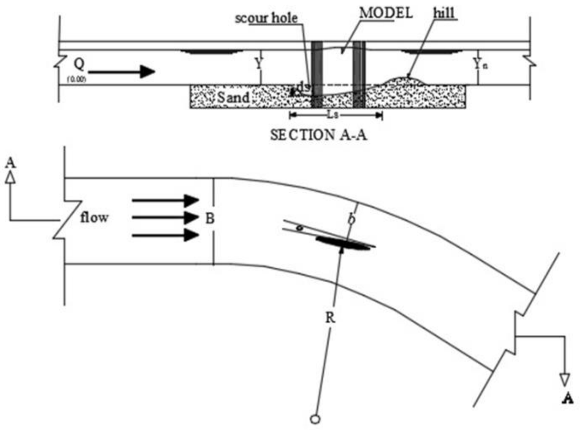

Fig1. Definition sketch of all parameters.

In this studying the depth of scour, ds, is the dependent variable. It is expressed as a function of all other independent variables as follows:

$d_S = \Phi$ (B, b, Ls, T, T_o, t, L_b, y, Q, ρ, g, μ, Ø, D_{50}, R, S.G, θ)

These variables are defined on figure 1 and are classified into five groups, as follows:

- Boundary Characteristics
  - B Width of channel.
  - b Distance from pier to the cannel side.
  - R The radius of curvature
  - t Thickens of piers.
- Flow characteristics
  - Q Discharge. Y water depth.
- Fluid characteristics
  - P Mass density of fluid.
  - V Kinematic viscosity.
  - G Gravitational acceleration
  - T Time interval. T_O Final time.
- Scour hole parameters
  - ds scour depth.
  - L_S scour length.
  - θ Angle Tilt pier with the direction of flow
- Soil characteristics
  - S.G Soil Specific gravity.
  - D50 mean diameter of sediments.

where

Q the discharge.

P the density of fluid.

μ the dynamic viscosity.

S.G the specific density.

Ø the selected soil diameter .

R The radius of curvature.

The soil was not altered. Accordingly, the parameters Ø and S.G could be removed from the variables.

Applying Buckingham π-theorem, 9 variables are π-terms and two are repeated variables. These variables are easily arranged to the following non-dimensional π-terms:

π_1 = ds/Y π_2 = b/B π_3 = T/T_O

π_4 = LS/ Y π_5 = B/Y π_7= QT/Y3

π_8= D50/ Y π_8 = Q2 / Y5g π_9 = Ls / L_b

Taking the properties of π-terms into account, the following relationship is obtained.

$$\phi = \left(\frac{ds}{y}, \frac{Ls}{y}, \frac{b}{B}, \frac{Ls}{L_b} \frac{D_{50}}{B}, \frac{T}{T_O}, Fr, \theta \right) \quad (1)$$

where:

ds/y the relative scour depth

Ls/y the relative length of scour hole to be protected

b/B the contraction ratio QT/y2 is the time factor

Accordingly, the following function is

$$\frac{ds}{y} = \phi\left(\frac{Ls}{y}, \frac{b}{B}, \frac{Ls}{L_b} \frac{D_{50}}{B}, \frac{T}{T_O}, Fr, \theta \right) \quad (2)$$

III. EXPERIMENTAL

An experimental flume was constructed by the researchers. An experimental investigation was conducted in an experimental flume at Hydraulic Laboratory of the Faculty of Engineering, Al-Azhar University Cairo, Egypt. Fig 2. The flume is 8.0 m long with rectangular cross section supported by steel frames of 60x30 cm. The sides are made of visible clear polycarbonate to allow visual observation of the water surface. The flume layout is presented on photo 1.

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The physical models of piers are made of Polly carbonate. Four models were suggested (i.e. elliptical, polygon (hexagonal), lenticular and lenticular with curve). As shown in photo 2 .The radius of the curved pier (lenticular with curve) is the same as radius of the curved channel. The test program was designed to investigate the pier shapes after the equilibrium scour condition is reached. The test conditions for each pier are summarized in table (1). Experiments were conducted under clear-water conditions at different discharges (i.e. 13.89, 19.41, 23.77, 28.04 and 30.64 l/s).Also three (3) angles for the inclination piers (i.e. 0.0, 2.5 and 5.0).The scour depth and lengths were measured. Each model was placed at a position relative b/B=0.5.The bed material (sand) was accurately leveled and the leveling accuracy was checked by means of a water gauge and ultrasonic meter. Each model was fitted at certain position. During the running, ultrasonic device was used to measures the water levels and depths as well as the scour lengths.

photo. 1: the experimental flume.

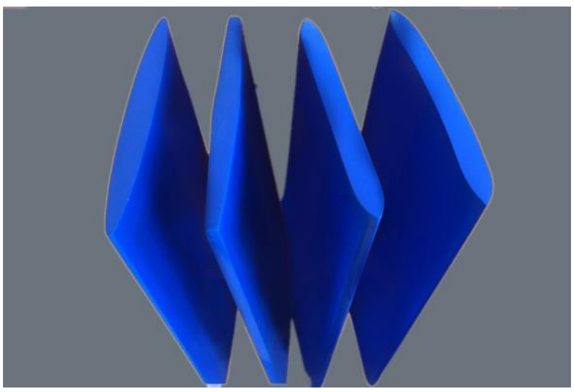

photo. 2: tested models.

TABLE I. *Test conditions for test series*

NO	Shapes	Y (cm)	θ° (degree)	Velocity in channel cm/s
M_1	 Elliptical	13.5	0	17.15
				23.93
			2.5	29.34
				34.62
			5	37.83
M_2	 polygon (Hexagonal)	13.5	0	17.15
				23.93
			2.5	29.34
				34.62
			5	37.83
M_3	 lenticular	13.5	0	17.15
				23.93
			2.5	29.34
				34.62
			5	37.83
M_4	 Lenticular (curve)	13.5	0	17.15
				23.93
			2.5	29.34
				34.62
			5	37.83

IV. ANALYSIS

Twenty (20) experiments were carried out, where three (3) angles were used at five (5) different discharges. Measurements were undertaken. Observations were recognized and the photos were captured. These measurements, observations and photos were documented and archived. They were analyzed, comprehended and plotted on graphs. These graphs are presented here. They are interpreted from the scour depth point of view, as follows.

A. Scour depth Results

The formation of horseshoe and wake vortices depends on shape of pier. Therefore, main intention of studying was to investigate effect of pier's shape as protecting measure reduce local scour. Through a series of experiment on different shapes like, Elliptical, Hexagonal, lenticular and lenticular (curve), It was observed that shape curved pier is best protecting measure reduce scour depth instead of other conventional shapes like Elliptical, Hexagonal in the part curved of the channels.

The formation of horseshoe and wake vortices depends on shape of pier. Therefore, main intention of studying was to investigate effect of pier's shape as protecting measure against local scour. Through a series of experiment on different shapes like Elliptical, Hexagonal, lenticular and lenticular (curve), it was observed that shape curved pier is the best in protecting measure reduce scour depth instead of other conventional shapes like Elliptical, Hexagonal in the part curved of the channels, as show in figures 2 to 6and the photos (3,4,5and 6).

Theoretical explanation for it, the curved shape of the pier is the same curvature of the channel, which makes them take the same direction of flow. This reduces the formation of vortices (horseshoe) in the front of the pier, thus reducing the scour depth.

The polygon (Hexagonal), it is the best shape from the conventional shapes, but it needed to Inclination angle to reduce of the scour depth. The front of the pier in the conventional shapes, a significant impact in reducing the Scour depth, because they serve to dissipate energy in front of the pier.

B. Comoarison between scoure depth in straight and curved channels at the same condion

In an effort to analyze the data in the straight channel, Colorado state university (CSU) and Breusers et al., 1977, common equilibrium scour depth prediction equations as published in the literature were used to compare and compute the equilibrium scour depth to be expected for the test conditions applicable to each pier geometry. The reason for the analysis is to evaluate the usefulness of some of the famous equation. In the literature with a view of testing how reasonably they can predict the equilibrium scour depth based on the flow and sediment conditions used in this study. CSU and Breusers et al., 1977 formulas can be written as shown in equations (3), (4), respectively.

$$y_{se} = 2k_{sh}\, y_0 Fr^{0.43} \left(\frac{b}{y}\right)^{0.65} \quad (3)$$

$$y_{se} = 1.35\, k_{sh}\; b^{0.7} y^{0.3} \quad (4)$$

Also, In 2016, Hassan et al, he made a Comparison with Colorado state university (CSU) and Breusers et al. as same condition (1977) formulas (V=0.3 m/sec). Comparative results are shown in the table (5.3) between the Straight and curved channels. The parameters are the same condition (flow depth, Froude number, pier shape). The following table (II) shows these comparisons.

Table (II) *Comparison between scour depth in straight and curved channels at the same conidian Fr = 0.33.*

No	Shape	Measured ds(cm) Present study	Hassan et al.,2016 ds (cm)	Theoretical value (cm)	
				CSU	Breusers et al.
M_1	Elliptical	4.4	5.6	5.91	6.52
M_2	Hexagonal	4.0	4.1	—	—
M_3	lenticular	4.5	—	—	—
M_4	Lenticular (curve)	3.5	—	—	—

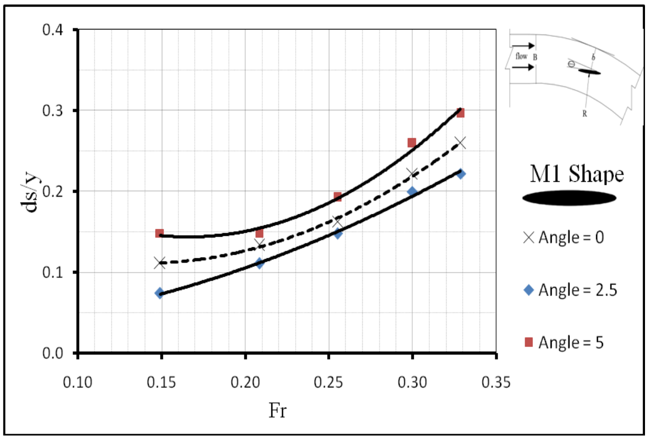

Fig. 2: The relation between (Fr) and (ds/y)

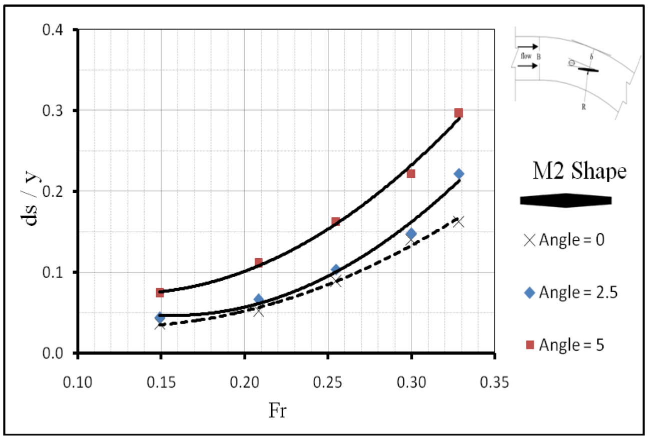

Fig. 3: The relation between (Fr) and (ds/y)

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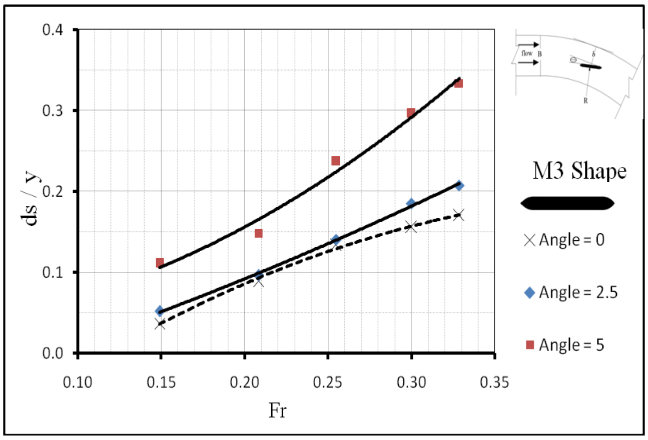

Fig. 4: The relation between (Fr) and (ds/y)

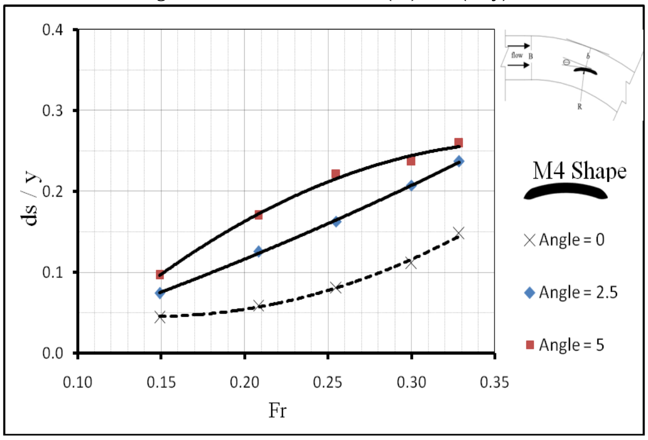

Fig. 5: The relation between (Fr) and (ds/y)

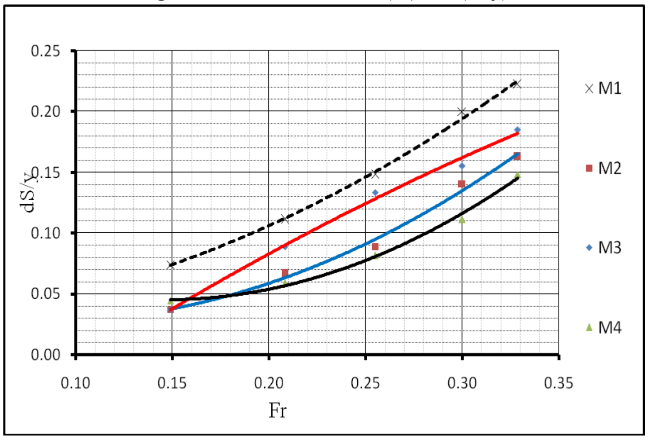

Fig.6: The relation between (Fr) and (ds/y) For all best angle

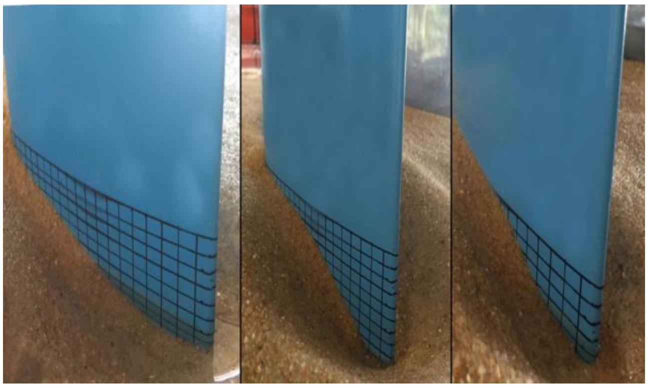

Photo. 3: the Elliptical pier with inclination different angles

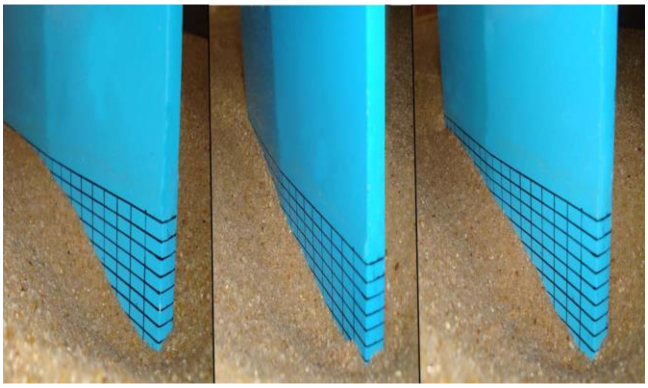

Photo. 4: the Hexagonal pier with inclination different angles

Photo. 5: the lenticular pier with inclination different angles

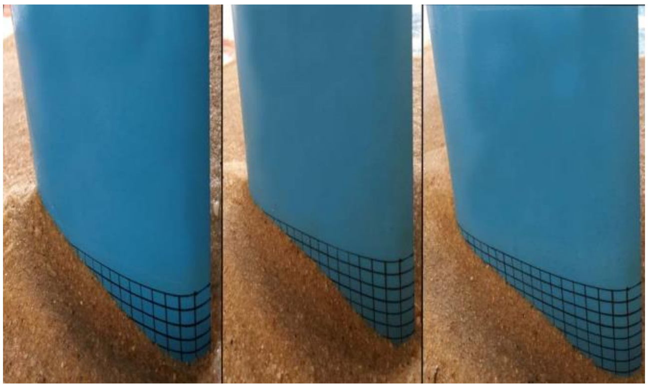

Photo.6: the lenticular pier with inclination different angles

V. Conclusion

In this study, the hydraulic performance and efficiency of using conventional and non-conventional of piers were investigated, theoretically, experimentally and inferentially. Regarding the theoretical phase, a literature review survey was carried out from which it was clear that intensive experimental work is needed, as it was concluded that:

1- We can implement piers in the curved parts of the channels.
2- It was concluded from figures (3) to (7), that the inclination angle of the pier has low-impact the relative scour depth (ds/y) for all studied shapes of the piers. Except for the polygon (Hexagonal)

(M_2), the inclination angle of the pier has good effect in reducing the scour depth.

3- The polygon (Hexagonal) (M_2), it was the best shape in the conventional shapes with angle 2.5 degree. It was the best in the ability to reduce of the scour depth by rate about 36% of the maximum scour depth.

4- As for the non-conventional shapes, it was the Lenticular (curve) (M_4) the best in the ability to reduce of the scour depth by rate about 44% of the maximum scour depth.

5- In general, for all the studied shapes. the inclination angle zero is the best in the ability to reduce the scour depth, but in the case of the polygon (Hexagonal) shape, it need a inclination angle on the tangent curve.

6- Finally, the non-conventional shapes of piers give better results than using other geometrical shapes.

References:

[1] A Breusers, H.N.C., Nicollet, G. and Shen, H.W. (1977) “Local Scour Around Cylindrical piers.” Journal of Hydraulic Research, 15(3), 211-252

[2] Breusers, H.N.C., Nicollet, G., & Shen, H.W. (1977).Local scour around cylindrical piers, Journal of Hydraulic Research, Vol. 15 No, 211-252.

[3] Chiew, Y.M. & Melville, B.M. (1987).Local scour around piers, Journal of Hydraulic Research, Vol. 25 No. 1, 15-26.

[4] Ali Khodabakhshi, MojtabaSaneie, AbdolnabiAbdohKolahchi (2014), Study on Effect of Slot Level on Local Scour around Bridge Pier, IJRET: International Journal of Research in Engineering and Technology, Volume: 03, Feb-2014.

[5] Mubeen Beg (2013) “Predictive competence of Existing Bridge Pier Scour Depth Predictors”, European International Journal of Science and Technology Vol. 2 No. 1 February 2013.

[6] Hassan el al (2016),experimental study of bridge pier shape to minimize local scour, international Journal of Civil Engineering and Technology (IJCIET (Volume 7, Issue 1, Jan-Feb 2016, pp.

[7] Mubeen Beg (2013) “Predictive competence of Existing Bridge Pier Scour Depth Predictors”, European International Journal of Science and Technology Vol. 2 No. 1 February 2013.

[8] Emami et al, (2008), Scour at Cylindrical Bridge Pier in A 180 Degree Channel Bend, Fourth International Conference on Scour and Erosion 2008.

[9] Jueyi sui, Hossein, A, Abdolreza, K, Samani, and Mehrnoosh, M, 2010, Clearwater scour around semi-elliptical abutments with armored beds, International Journal of Sediment Research 25 - 233-245.

[10] Melville, B.W. and Coleman, S.E., 2000, Bridge scour, Water Resources Publications, LLC, Colorado, U.S.A.