EXPERIMENTAL STUDY AND PREDICTION MAXIMUM SCOUR DEPTH EQUATION OF LOCAL SCOUR AROUND BRIDGE PIER

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ABSTRACT

Scour is a problem which happen in the flowing stream, rivers and it's a natural phenomenon made due to the erosive action of which removes the sediment particles around the structures placed in water. It means the lowering of the riverbed level by water erosions such that there is a direction to reveal structural foundations. The flowing water cause erosive action, excavating and relocate material from the bed and banks of streams and from around the piers of bridges. In this paper an attempt is made to evaluation the temporal variation of scour depth at non-uniform cylindrical bridge pier, in this paper 3 samples of circular bridge piers tested with different size which conducted in a 8.3 m length and 0.8 m width cannel by analyzing the data from experimental work analyzing the data to estimate equation which predict maximum scour depth.

Keywords: scour, local scour, bridge piers.

1. INTRODUCTION

Scour is defined as the erosion of streambed sediment around an obstruction in a flow field (Chang 1988) [1]. It is movement and removal of the sediment around bridge pier. Bridge scour isusually divided into general scour, contraction scour and local scour. The local scour may happen in any time especially in flood time caused collapse for bridges and loss many lives. Figure 1, shows the complex vortex system occure when down flow waves rolls up as it continues to create a hole through interaction with the oncoming flow. The vortex then extends downstream along the sides of the pier. This vortex is often referred to as horseshoe vortex because of its great similarity to a horseshoe. Even though a lot of work, the predicted of equilibrium depth of maximum scour analyzed depending on both the numerical and experimental studies, many researchers still are interested in the basic understanding of the scour mechanism. Local scour was classified into live-bed scour and clear-water scour depend on the variance of the approach flow sediment transportation pattern, (Chabert and Engeldinger, 1956) [2].

.Therefore, the scour study has become a topic of continued interest to the investigators. Review of the important experiments and field studies was given by Breusers et al. (1977) [3]; Dargahi (1982) [4]; Dey (1997) [5]; Hoffmans and Verheij (1997) [6]; Melville and Coleman (2000) [7]; and Richardson and Davis (2001) [8].

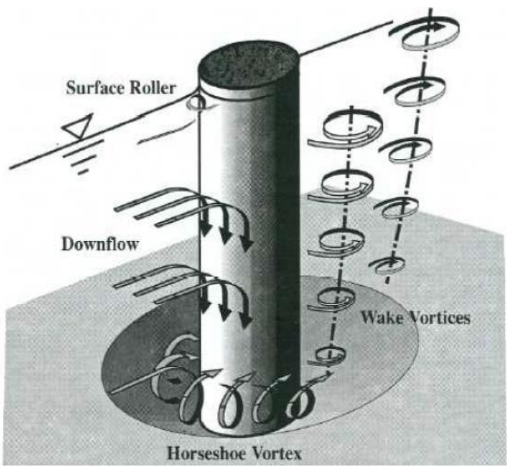

FIGURE 1. Vortex motion around a pier Melville & Coleman (2000) [7]

1.1 . SCOUR PROCESS

The sediment particles close to the pier started to move when flow reaches a certain velocity in the channel; scour is initiated. The eroded particles will carried from the front of the pier to the direction of downstream by following the stream pattern. By flow velocity increase, more particles will get displaced, then creating a scour hole increasing in size and depth. Eventually a maximum scour depth, $(d_s)_{max}$, is reached which corresponds to a flow velocity being near to the critical velocity $U=U_{cr}$. For nonuniform particles, the large size of the particles will be sediment in the scour hole, and an armoring layer forms itself in the scour hole. Then by increasing flow velocity, $U>U_{cr}$, is caused for a transport of sediments *in* and *out* of the scour hole, but the scour depth remains essentially constant. Thus an average equilibrium scour depth, d_s, establishes itself, being slightly smaller than the maximum scour depth, $(d_s)_{max}$ (Figure 2) .

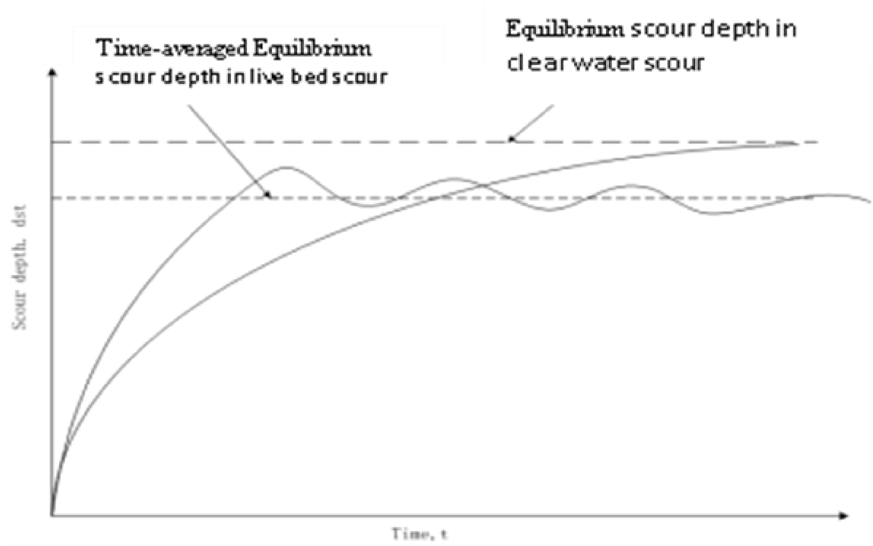

FIGURE 2. Time-dependent development of scour depth (Raudlivi and Ettema 1983) [9].

2. EXPERIMENTAL SETUP

A circulating flume used in this study for the experiment work as shown in figure 3 and figure 4. The size of the flume are (8.3 0.8, 0.9) m. The study section was setup about 2.8 m from inlet of the flume which is filled with sand according to the literature study the medium size of the particles d_{50}= 4mm and gradation coefficient σ_g=1.15 the depth of the section is 20 cm and with a length of 1.5m. The shape of the models is circular with a diameter of 5cm and 7.5 cm 11.1cm respectively. The pump ability 25 l/sec located at the left of the channel served the system and by a valve the flow in the channel controlled. A rectangular weir located at the end of the channel to measure the discharge and there is a point gage to measure the depth of the scour hole. To keep the flow uniform before and after the bridge pier, a ramp was constructed and fastened to the upstream and downstream of the test section of the channel. The detail of experimental data given in Table 1. The variation of local scour depth with time is measured at various time by stopping the experiments and run it again.

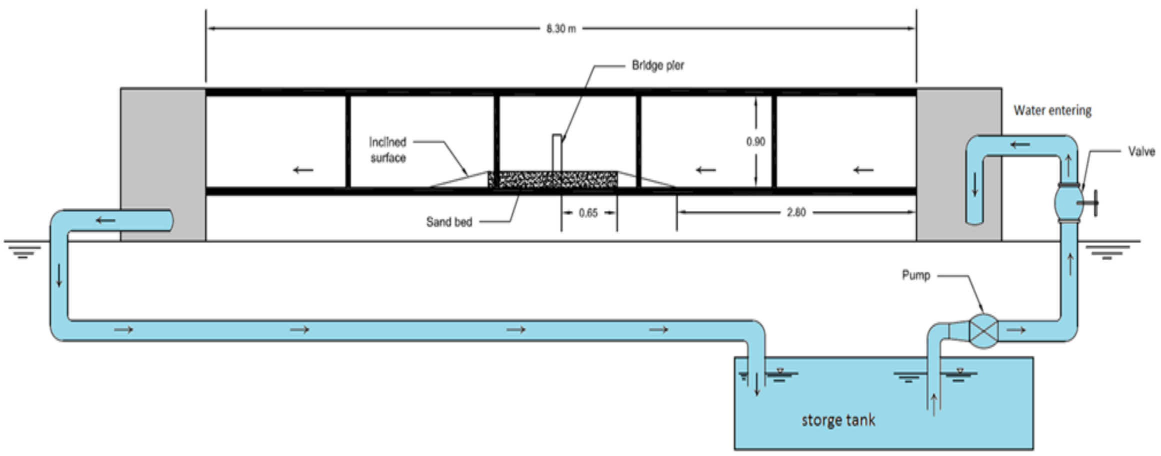

FIGURE 3. Schematic illustration of the experimental flume system

FIGURE 4. View of experimental work

TABLE 1.

Experimental conditions

Run	diameter (cm)	h (cm)	time (min)	discharge (m3/s)	observed ds (cm)	computed ds (cm)
A1	5	2.5	15	0.00629	6	5.482703675
A2	5	4.4	30	0.016	7.7	6.496038265
A3	5	5.4	30	0.02326	8.2	6.907659147
A4	5	5.7	30	0.02519	8.5	7.057342092
B1	7.5	2.5	50	0.00629	6.1	7.28213382
B2	7.5	4.4	30	0.016	9.1	8.628046079
B3	7.5	5.4	30	0.02326	9.7	9.174761444
B4	7.5	5.8	50	0.02519	10.5	9.373570517
C1	11.1	2.5	30	0.00629	6.4	9.805482815
C2	11.1	4.4	40	0.016	11.2	11.35260838
C3	11.1	5.4	35	0.02326	11.7	12.07196539
C4	11.1	5.8	30	0.02519	11.9	12.33355434

*A: code for 5 cm circular pier *B: code for 11 cm circular pier *C: code for 7.5 cm circular pier

3. PREDICTED MAXIMUM SCOUR DEPTH

In this study there are parameters effects on maximum scour depth; results of Group 3 tests show us the relation between these parameters and maximum scour depth. Computer software Step-wise Regression© which it was one of the regression analysis methods and fitted data, Step-wise Regression used in this study to analyses the results of the maximum scour depth to get formula which give us maximum scour depth (d_s). The parameters like (d) pier width, (t) time of equilibrium, (Q) discharge, (h) flow depth, used to analyses a formula for maximum scour depth. In the program, there are many types of regression method as shown in Figure 4, it will necessary to try all methods to know the best one. In this study, linear method, linear+ interaction method, and full quadratic method are used to predict maximum scour depth, it is seen that the last method is the best method in this study to predict maximum scour depth.

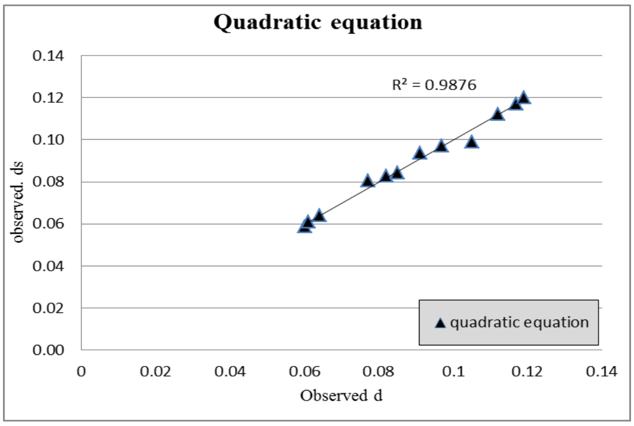

FIGURE 5. Step-wise regression input window

3.1. QUADRATIC REGRESSION METHOD

The formule rusults acoording to this method depending on, (h) depth flow, (d) pier diameter, (Q) discharge, with R- square value R^2= 0.988 and Standard Error of 0.00260. According to this results the quadratic method was an best suited method to predict eqilibrium scour depth by Equation (1) for this study. Figure 5, shows the comparison between determined and observed maximum scour depths using quadratic equation.

$$dse = 0.0548 - 0.0427\, d * 1/h - 0.351\, d * \ln Q \quad (1)$$

Where d_{se}: Equilibrium scour depth (m), d: Pier diameter (m), Q: Flow discharge (m^3/s)

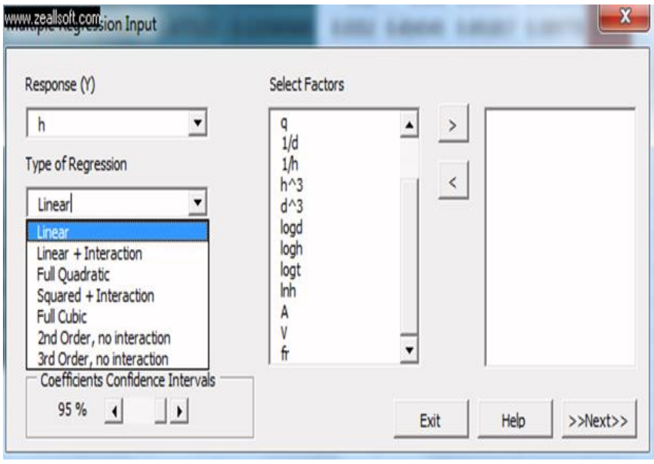

FIGURE 6. Comparing between determined and observed scour depth for quadratic equation

3.2. COMPARISON BETWEEN PREDICTED EQUATION AND EQUATIONS FROM LITERATURE

In this study, the experiments were carried with (5, 7.5 and 11) cm circular piers with four discharges. Shen II [10] developed an equation to predicted maximum scour depth by depending on Froude number (Fr), Flow depth and pier size

$$d_{sp} = 3.4\, {b_p}^{0.67} F^{0.67} Y^{0.33} \qquad (2)$$

Laursen and Toch (1956) [11] developed equations by depend on experimental work in Iowa institute of hydraulic research, laursen and Toch equations assumes that flow depth is the most important factor in determining scour depth

$$d_{sp} = 1.5\, {b_p}^{0.7} Y^{0.3} \qquad (3)$$

(Figure 6a,6b,6c) shows the comparison between Shen II [10], Laursen and Toch (1956) [11], with experimental data and the predicted maximum scour depth, it's clear from the figure that maximum scour depth in experimental work close to the results of predicted equations from this study and the results of Laursen and Toch (1956) [11] for the three sections, the results of Shen II equations shows some variance with other results and this due to "Laursen and Toch (1956) [11] equation assumes that the flow depth is most important factor in determining the scour depth, whereas the Shen II [10] equation assumes that velocity is important by including the Freud number" (Les Hamill, 1999) [12].

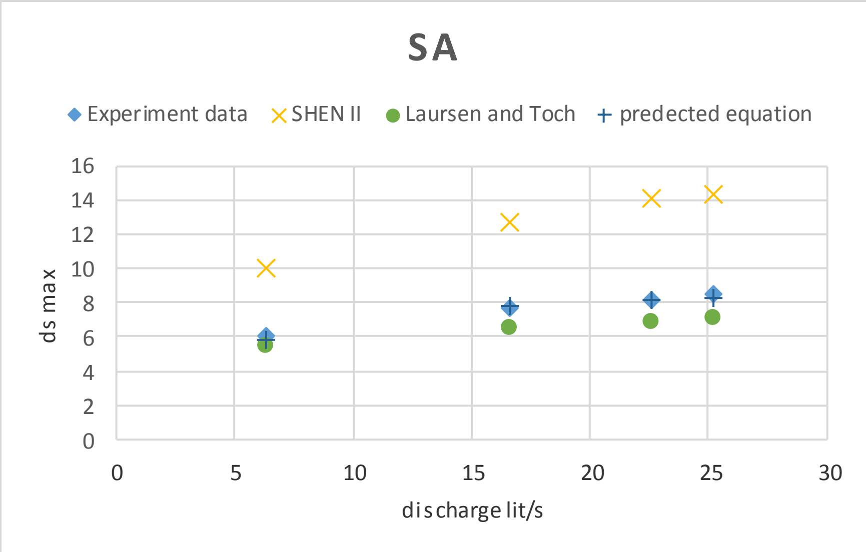

FIGURE 7. (a) Comparison between m.s.d results for sample A

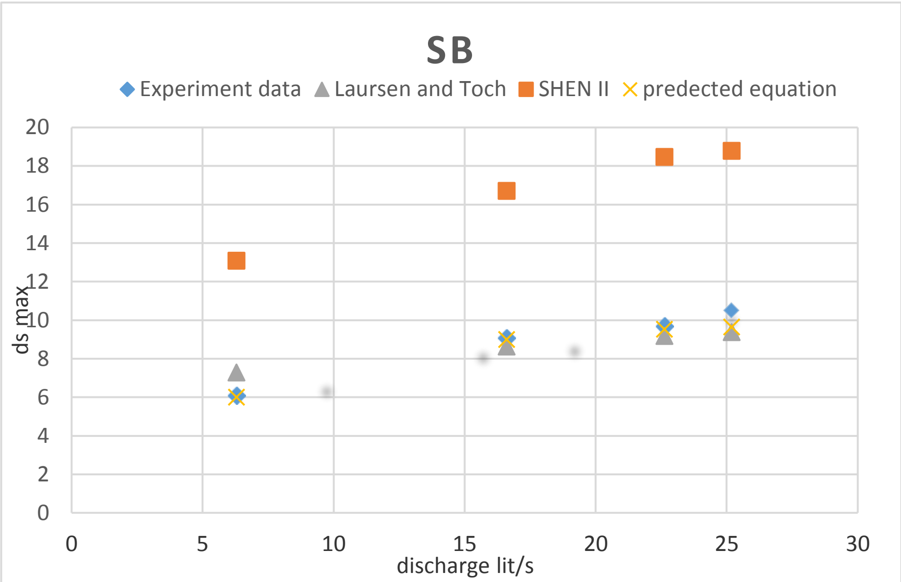

FIGURE 7. (b) Comparison between m.s.d results for sample B

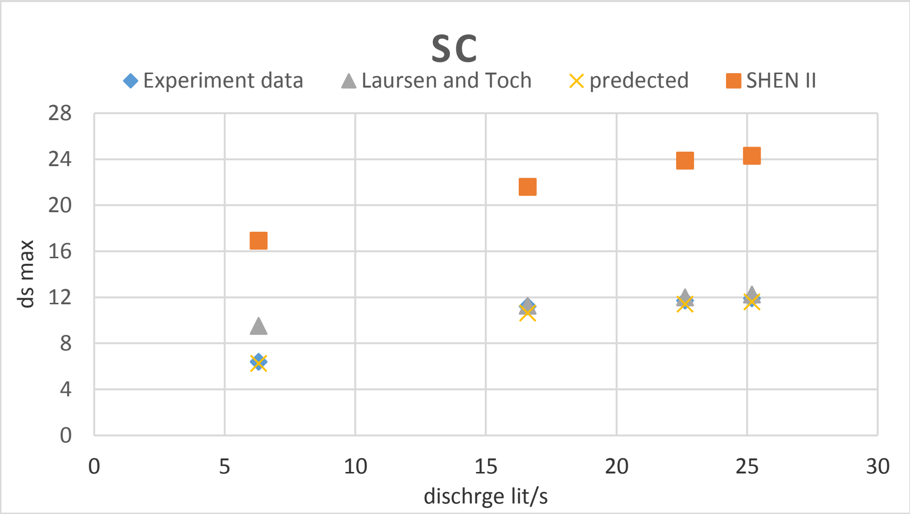

FIGURE 7. (c) Comparison between m.s.d results for sample C

4. CONCLUSIONS

1. The present experimental results showed that for the same sediments size and discharge the depth of scour is directly proportional with pier diameter
2. The results of the predicted equation of this work regarding the flow depth factor indicated a good agreement with Laursen and Toch (1956) [11].

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