EXPERIMENTAL STUDY ON EFFECT OF SLOT LEVEL ON LOCAL SCOUR AROUND BRIDGE PIER

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Abstract

Many bridges in the world every year for Failure to consider in the design of hydraulic elements are destroyed. During the spring floods of 1987, 17 bridges in New York and New England were damaged or destroyed by scour. In 1985, 73 bridges were destroyed by floods in Pennsylvania, Virginia, and West Virginia. In the present study investigate effect application a slot , height "D" , width" D/4"in a circular pier ,where "D" is diameter of bridge pier and the size of 6 centimeters under 3 different discharges (values 35 , 40 , 45 Liter per second) and 4 different location of slot in a flume ,length 14 meters ,height 60 and width 60 centimeters. The experimental results show when height of slot is below the stream bed as D, scour depth will be reduced about 20.34% to 39.73% in front of the pier and scour volume approximately 46.84% to 75.74%

Keywords: *Bridge pier, Slot, Scour, scour depth, scour volume*

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1. INTRODUCTION

Structures built in or near rivers and other channels can be vulnerable to scour around their foundations .If the depth of scour becomes significant the stability of the foundations may be endangered , with a consequent risk to the structure of damage or failure[1]and since during the spring floods of 1987, 17bridges in New York and New England were damaged or destroyed by scour. In 1985, 73 bridges were destroyed by floods in Pennsylvania, Virginia, and West Virginia.[2] So could tell that one of the most reason of damage or failure of bridges are local scour around their piers.[3] Local scour at bridge piers may be defined as a local lowering of the bed elevation around a pier. This lowering is mainly caused by the horseshoe vortex combined with the down flow in front of the pier, the vortex shedding at the back of the pier and the flow contraction.[4]

To control the phenomenon of erosion around bridge foundations 3 major following ways are common:

- Locating the foundation in the lower level of the scour depth of erosion when the erosion depth is projected to more than 6 meters.
- Reducing power of generated vortex around the bridge pier.
- Create a protective coating of riprap around the pier.

Two recent methods are used when the hole depth of erosion is less than 6 meters.[5]

One of ways to reduce the power of the horseshoe vortex is use of slots which includes create a conduit for passing the flow through the pier of the bridge.

Chiew et al studied the protection bridge piers against scouring using slots and collars. The test results demonstrated that using only one slot can lead to a 20% reduction in scouring specially if the slot is close to the water surface or bed surface. He also found that the combination of slot and collar can reduce scouring depth to greater extent. [6]

Kumar, et al investigated the reduction of local scouring around bridge piers in a direct stream with the use of a slot and a collar. Their findings showed that the slot was effective in decreasing scouring but the slotted pier would not be effective if the flow approaching the pier shows great deviation. [7]

Heydarpour et al The findings revealed that the group of bridge piers has a great impact on the depth of scouring on the front part of the pier compared with an individual pier. They also concluded that the effect of the slot on reducing scouring depth increases in parallel with the increase in the pier area. [8]

M.Heydarnejad et al investigate the effect of slots on scouring around piers in different positions of 180-degrees bends and found that the maximum reduction scour depth is 24%.[9]

Grimaldi et alby examining the behavior of slot on local scour around the bridge pier found scour depth reduce approximately 30%.[10]

Zan Michael Christensen carried out his research on reduction of local scour around Bridge Piers combined system of aerofoil and slot. He found that slot could lead to reduce scour around the piers of these bridges compared with circular piers. [11]

A.T.Monakada and et al by examining effect of a rectangular slot (width 1.8cm and varied height)told that A slot in the pier considerably reduces the scour depth. When the slot length increases from the water surface to the bed Level, the efficiency was between 48% and 85%, while when it increased from the bed level to the water surface, it was between 60% and 88%. Therefore, the slot location is a parameter that has a direct effect on the scour depth, with the best location near the bed. [12]

2. MATERIAL AND METHODS

In order to investigate the mentioned purpose in this study, the researchers made use of a physical hydraulic model under clear water conditions in non-adhesive materials. This model, located in the hydraulic laboratory in Soil Conservation and Watershed Management Research Institute (SCWMRI) in Tehran include a rectangular flume (length 14meters, height 60and width 60 centimeters).measuring discharge was possible by a triangular weir and gage-point and depth of flow was regulate by a sluice at the end of flume.(figure 1and 2 show a view of flume).

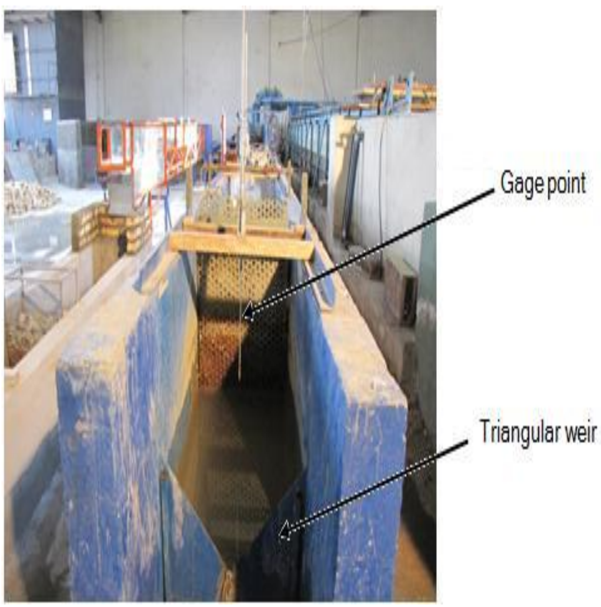


Fig .1

Fig. 2

In order to develop the scour , length of test was elected 2.5 meters from 5 meters at beginning the flume.

For laboratory purposes, the flume width must be at least as 10 times as the size of the pier for scouring conditions in clear waters so that the effect of the channel walls on scouring depth can be eschewed .To prevent the ripple on bed , median grain size (d_{50}) must be more than 0.7mm and for eliminating the effect of grain on scour depth ratio of pier diameter (D) on median grain size must be greater than 20-25($D/d_{50}>20$-25).[13] so for the pier model a cylinder shape of Teflon which has diameter equal 6 cm and average grain size equal to 1.86 mm were elected. For minimize the effect of flow depth on scour ratio flow depth to pier diameter must be greater than 2 ($y/d>2$)[14] thus flow depth was elected equal to 18 cm to mean 3 times of pier diameter($y/d=3$).In view of the fact that experiments design according to clear water conditions ,ratio flow velocity (u)to threshold velocity for the beginning of sediment motion (u_c) must be smaller than 1($u/u_c<1$).[15]so three velocities (0.334,0.37,0.417 m/s) equivalent 35,40,45 Lit/s were considered. To calculate threshold velocity for the beginning of sediment motion many relationship have been proposed, particularly, Chang's method [16] which used in this research:

For $d_{50}>0.03$ m

$$u_c= k_u(11.5)y^{1/6}d_{50}^{1/3} \quad (1)$$

For 0.03 m$>d_{50}>$0.0003m

$$u_c=k_{u1}(11.5)y^x d_{50}^{0.35} \quad (2)$$

$$x=k_{u2}(0.312/d_{50}^{0.2}) \quad (3)$$

For $d_{50}<0.0003$ m

$$u_c=k_u(y^{0.5}) \quad (4)$$

where u_c: threshold velocity for the beginning of sediment motion (m/s), u: flow velocity (m/s), y: flow depth (m),d_{50}: average grain size(m), k_u= 0.55217, $k_{u1}=0.3048^{(0.65-x)}$,k_{u2}=0.788.

Table (1) show properties of physical model .For leveling survey of bed, a profiler with its voltmeter have been used and after ever test result analyzed by a software as Surfer .8 and drawn 3d shape and topography of bed around the pier. (i.e figure No 3 and 4).

Table 1 properties of physical model

Q(Lit/s)	y(cm)	B(cm)	D(cm)	d_{50}(mm)	t(sec)	b(cm)	h(cm)
35	18	60	6	1.86	5400	1.5	6
40	18	60	6	1.86	5400	1.5	6
45	18	60	6	1.86	5400	1.5	6

Q: discharge (Lit/s), B: flume width(cm),D: diameter of pier(cm),d_{50}: average grain size, t :time of test duration, b: slot width (b=D/4), h: slot height (h=D).

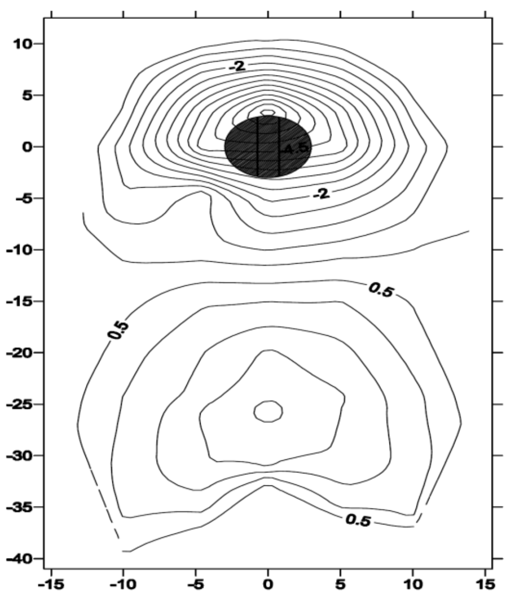


Fig 3

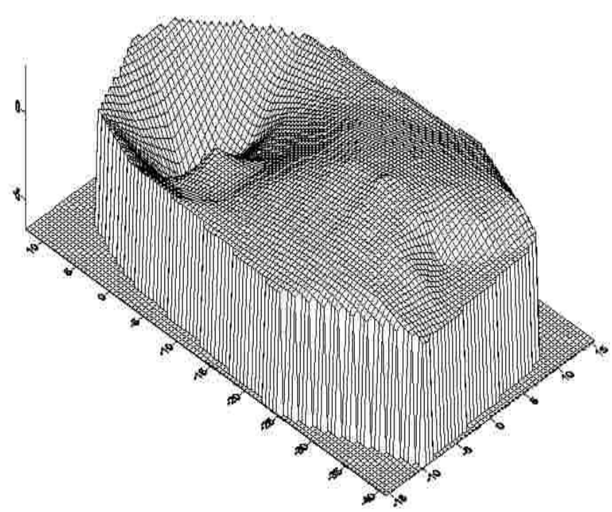


Fig 4

3. RESULT AND DISCUSSION

According to mentioned formula u_c and u/u_c calculated and presented in table (2).

Due to u/u_c smaller than 1 thus scour process carried out under clear water condition.($0.695<u/u_c<0.8434$).

Table 2 Calculation of u_c

Q(Lit/s)	y(m)	u(m/s)	k_{u2}	x	k_{u1}	u_c(m/s)	u/u_c
35	0.18	0.324	0.788	0.341	0.6927	0.4916	0.695
40	0.18	0.37	0.788	0.341	0.6927	0.4916	0.7526
45	0.18	0.417	0.788	0.341	0.6927	0.4916	0.8434

Table (3) show changes depth of scour upstream the pier and figures 5and 6 longitudinal and transverse profile on control model and figures 7, 8 and 9 comparison longitudinal profile on control model and slotted pier when height of slot is below the bed at 4 position (1.5,3,4.5,6 cm) on 3 different discharges and figure 10 show percentage reduce of scour depth.

Table 3 scour depth

Q(Lit/s)	Fr	u/u_c	Control	Z_s/D			
				1	0.75	0.5	0.25
			d_s(cm)				
35	0.244	0.695	7.013	4.277	4.3	4.294	4.235
40	0.279	0.7526	8.211	6.533	7.607	6.863	6.929
45	0.314	0.8434	8.979	7.153	8.867	7.171	7.22

Z_s: height of slot below the bed, d_s: scour depth upstream the pier, Fr: Froude number of flow

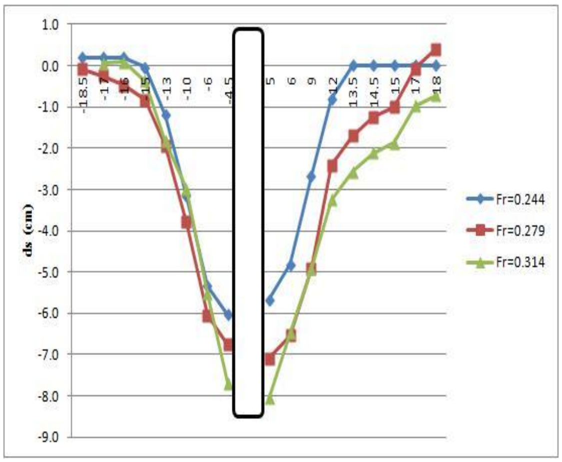


Fig 5 Longitudinal profile of control model

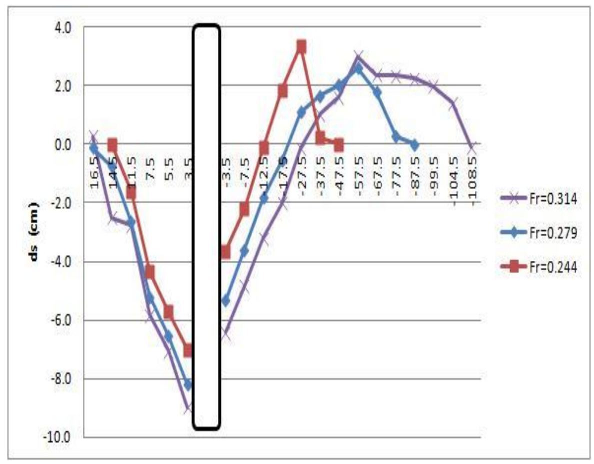


Fig 6 Transverse profile of control model

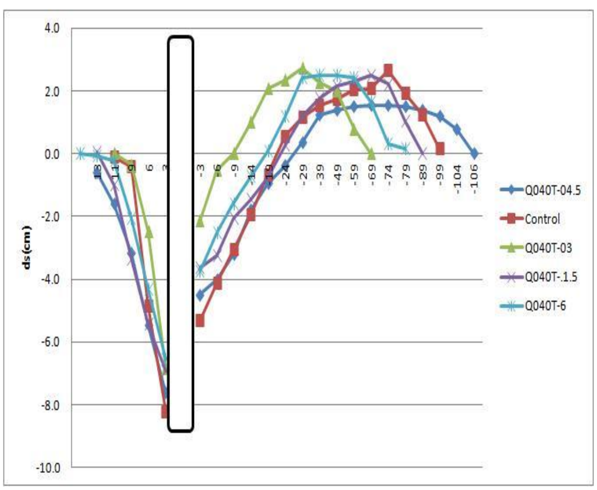


Fig 7.Longitudinal profile of 35(Lit/s)

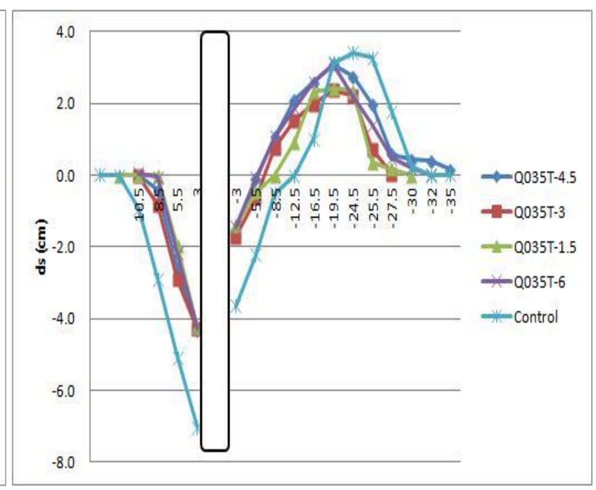
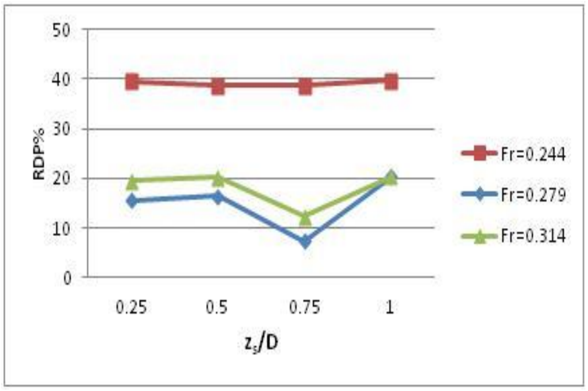


Fig 8 Longitudinal profile of 40 (Lit/S)

Q***T*** is symbol of each test for example Q035T-4.5 show a test with discharge 35Lit/s and T mean Z_s



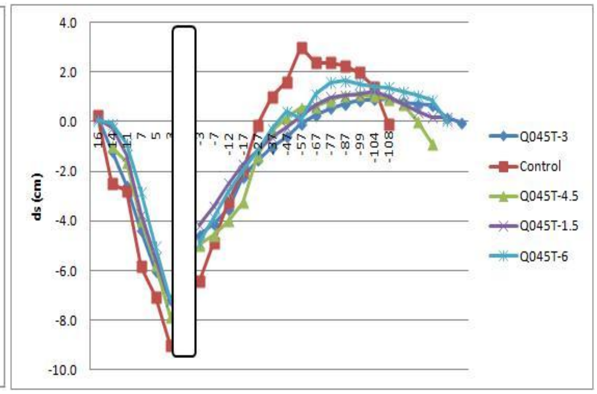


Fig 9 Longitudinal profile of 45 (Lit/s) **Fig 10** percentage reduce of scour depth.

RDP% : percentage reduce of scour depth.

Table 4 and 5 present volume and area of scour hole around the pier and figures 11 and 12 show changes at volume and area in different experiments.

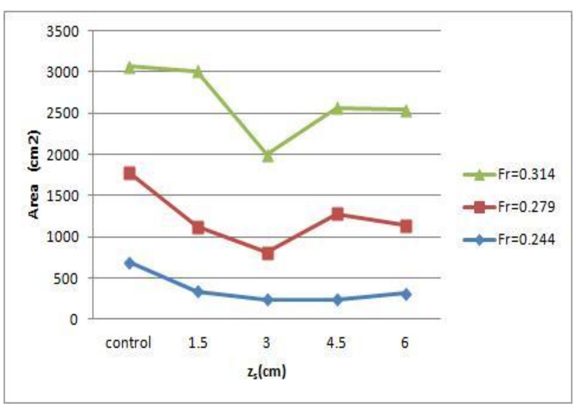
Table 4 volume of scour hole

Q(Lit/s)	Fr	u/u_c	Control	Z_s/D			
				1	0.75	0.5	0.25
			$v_s(cm^3)$				
35	0.244	0.695	1400.72	339.88	313.352	426.199	426.199
40	0.279	0.7526	2230.71	1181.64	1564.07	1362.04	1362.04
45	0.314	0.8434	3006.16	1597.95	2621.07	1891.25	1891.25

Table 5 area of scour hole

Q(Lit/s)	Fr	u/u_c	Control	Z_s/D			
				1	0.75	0.5	0.25
			$A (cm^2)$				
35	0.244	0.695	695.176	311.978	239.203	241.987	339.822
40	0.279	0.7526	1092.25	825.643	1039.81	564.13	780.26
45	0.314	0.8434	1280.5	1400.72	1286.76	1192.98	1890.37

V_s: volume of scour, A:area of scour hole



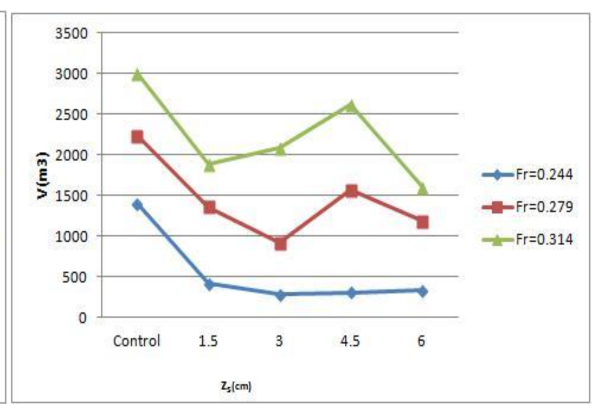


Fig 11 volume of scour hole **Fig 12** area of scour hole

4. CONCLUSIONS

- With increasing the F_r and u/u_c , depth and volume of scour will also increase.
- Slot would be affected on scour depth to extent that completely below the bed cause reduce it about 20.34 to 39.73 percent and volume of scour hole around the pier reduce 46.84 to 74.74 percent.

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