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Reduction of Local Scour around Bridge Piers Using Different Countermeasures

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KEYWORDS:
Clear water, Flow depth, Straight slot, Curved face, Sacrificial piles

***Abstract*— Local scour around bridge piers is one of the main causes of bridge failure. Experimental and hydraulic models were carried out to investigate three types of scour reduction methods around a single oblong pier, called slots, upstream curved face and sacrificial piles. First, these methods were used alone then combination of them was made to achieve the minimum scour depth. The results revealed that slots, in general, have more influence in reducing scour depth than upstream curved face, with a reduction in the scour depth of about 25% of maximum scour. On the other hand, the upstream curved face and straight slot together appeared to be the most effective in reducing the scour around the bridge oblong pier, with a percentage reduction equal to about 30%. When using two sacrificial piles with upstream curved face slotted oblong pier were used, the least scour amongst all the arrangement with about 49% reduction in maximum scour depth upstream of the pier was achieved.**

I. INTRODUCTION

SCOUR is a common phenomenon caused by the erosive behavior of flowing water on river and alluvial channel beds and side slopes. Scour is defined as the erosion of the streaming sediment in a flow field around a blockage. Breusers et al. [1] defined scour as a natural phenomenon caused by the accumulation and movement of water in rivers and alluvial channel. Scouring process has the ability to damage the structural integrity of bridges and hydraulic structures. It can eventually lead to failure when systemic foundations are compromised. Due to the pier scour, a series of bridge failures during floods have rekindled the value of developing better ways to protect bridges against scour ravages. Building bridges in alluvial canals triggers a contraction of the waterway at bridge location. The contraction of waterway at that site may cause extreme scour. Hoffmans and Verheij, [2] noted that local scouring around bridge piers and foundations is believed to be the key cause of bridges failure during floods. It occurs due to increasing velocity of flow, creating vortices that take away the sediment material in surroundings of bridge piers or abutments. Researchers also performed various laboratory experiments and numerical models to determine the extent of scour equilibrium in specific types of soil material. Furthermore, though much was done to establish equations for the depth of scour, the scouring process is not well understood.

Protection against local scour by slotted piers was experimented by Kumar and Raju [3], Setia and Bhatia [4] and Bestawy et al. [5]. But they used slots on circular piers not on oblong piers and also, the study of EL-Ghorab [6] showed that, the local scour can reduced using internal openings , openings has been used as T-openings. Laboratory studies of sacrificial piles for pier scour protection have been reported in previous studies by Park et al. [7] and

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Zomorodianet al. [8]. The efficiency of this technique as scour countermeasure is dependent on number of piles, geometric configuration, the approach flow angle, and flow intensity V/Vc Increase in the number of sacrificial piles is advantageous for both the skewed and aligned piers. When the number of piles is increased, the wake region produced by sacrificial piles gets enlarged and therefore mitigation of local scour gets improved. Finally Aghaee-Shalmani, and Hakimzadeh. [9] and Al-tameemi et al. [10] used in their research works semi conical pier but Al-tameemi et al. [10] used upstream curved face too with the conical pier .The study was confined to clear-water flow around bridge piers with non-uniform sediment sizes.The main objective of the present study was to determine the best system which combines several countermeasures to reduce the local scour as much as possible.

II. MATERIALS AND METHODS

A. Experimental Set-Up

Experimental investigations were conducted in a straight rectangular channel located in laboratory of irrigation and hydraulics department, faculty of engineering, Mansoura university. This channel has length of about 7.0 m, 0.4 m in height and 0.74 m in width. Two centrifugal pumps were used to supply water from the underground storage tank. The pumps delivered water through two head tanks to the basin. A tail gate is fixed to control the flow depth. A rectangular weir at the entrance to basin is utilized to calculate the discharge. A gravel-filled inlet screen was installed at the downstream of basin to reduce water turbulence. Flume has a vertical and vernier point gage has vertical scale measuring accuracy of 0.1 mm. At the end of the flume a sand trap was used to avoid transfer of sand to underground tank. A wooden tool was used for preparing the sand bed. Before experiments are done, the flume bed was covered by a 15 cm thick sand layer. The sand median diameter d_{50}= 0.63 mm and the geometric standard deviation of particle size distribution ratio σ_g= 2.335. Sketch of flume used in the present study is shown in Fig. (1).

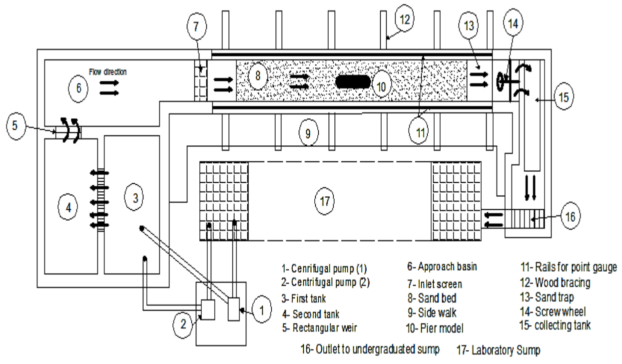

Fig. (1): Sketch of flume used in the present study.

The preliminary preparations were performed through many runs at the beginning of experimental work in order to achieve more accuracy in reading using oblong pier and slotted oblong pier at a maximum Froude number F_r = 0.328. During the first 90 minutes 90 percent of the total scour depth was established and more than 98 percent of the scour was measured in the first 2 hours. Measures were recorded every 20 minutes until the depth of equilibrium was reached. The equilibrium condition for all pier shapes was attained at about 4 hours, so that the flow was stopped and the scour depth stability occurred as shown in Fig. (2)

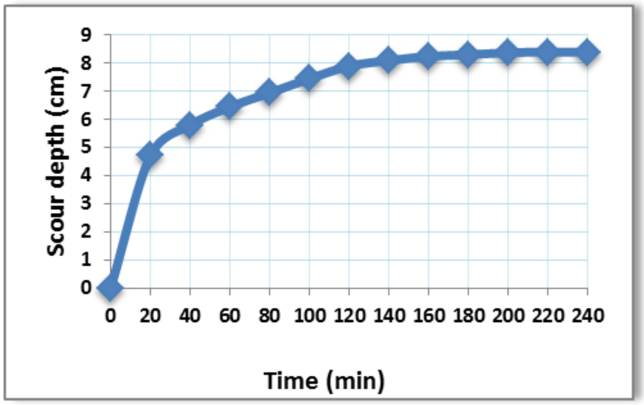

Fig. (2): Equilibrium time of scour depth at F_r=0.3286.

B. Bed Material

Sand with a thickness of 15 cm was spread over 90 percent of flume bed. The width and length of the section being examined is therefore 0.74 and 6.1 m, respectively. In addition, the characteristic properties of the sand are: the geometric standard deviation (σ_g)= 2.335 and the median particle size (d_{50})= 0.63 mm. Standard geometric deviation used to classify the sediment as uniform or non-uniform. Thus, the bed material is classified as the non-uniform material as σ_g >1.3 and armoring occurs in the scour hole and on the channel bed as stated by Setia and Bhatia [4] and Melville [11]. Soil sieve analysis is shown in Fig. (3).

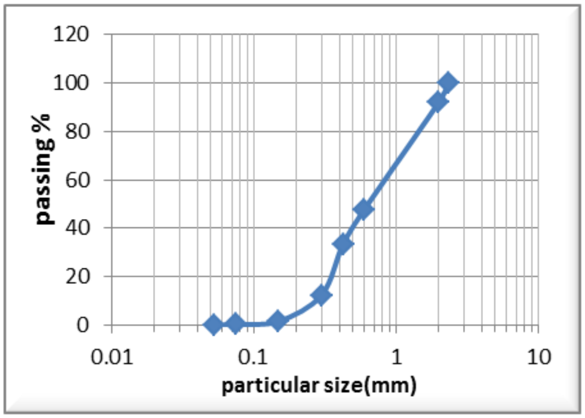

Fig. (3): Soil sieve analysis.

C. Piers

Four piers of different shapes of equal width were used as pier model as shown in Figs. (4) through (7). Since it was recommended by Alwan et al and Shen et al that the flume width has to be at least eight times the pier width for clear-water scouring conditions. The pier width in each case was 8 cm besides sacrificial piles have diameter 2.5 cm. All pier models and sacrificial piles were made of wood and painted with a glue material to prevent penetration of water when piers are used in the flume. After sand leveling, piers were mounted in the flume center to prevent the influence of flume sidewalls and to attain the condition of fully developed flow.

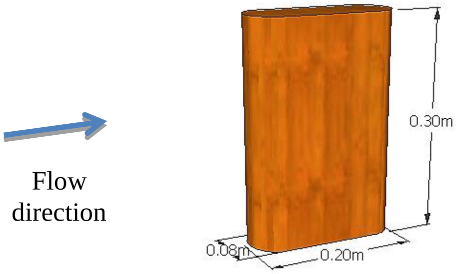

Fig. (4): Oblong pier without any countermeasures.

(a) (b)

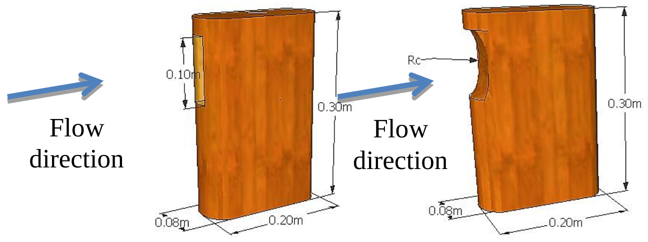

Fig. (5): (a) Slotted oblong pier and (b) Upstream curved face oblong pier.

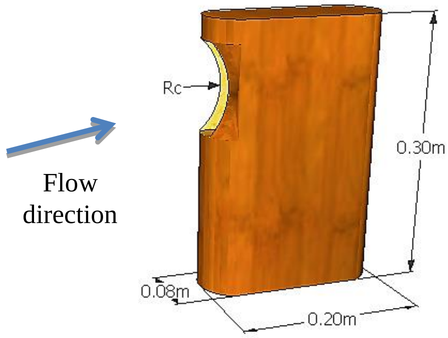

Fig. (6): Upstream curved face slotted oblong pier.

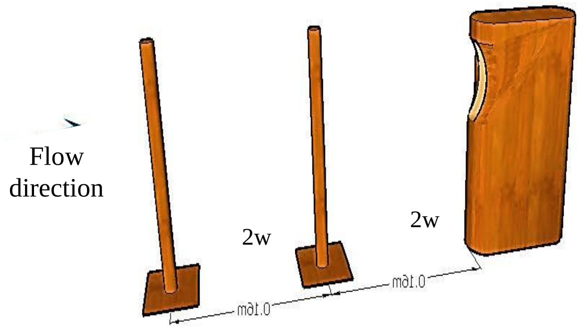

Fig. (7): Upstream curved face slotted oblong pier with two sacrificial piles.

D. Lab Procedures

To achieve the aims of this paper, three depths of flow with three discharges were used. Also, all experiments were carried out under condition of steady clear-water. The used bed material was non-uniform, so the formulas, which suggested by Melville and Coleman [13], were used to measure critical shear velocity and its corresponding critical velocity. These formulas are as follows:-

$$d_{50} = d_{max} / 1.8 \qquad (1)$$

if

$0.1 \text{ mm} < d_{50} < 1 \text{ mm}$

$$u_c^* = 0.0115 + 0.012\, d_{50} \qquad (2)$$

If

$1 \text{ mm} < d_{50} < 100 \text{ mm}$

$$u_c^* = (0.0305\, d_{50})^{0.5} - (0.0065\, d_{50})^{-1} \qquad (3)$$

$$\frac{V_c}{u_c^*} = 5.75 \log\left(\frac{5.53 * y}{d_{50}}\right) \qquad (4)$$

$$V_a = 0.8 V_c \qquad (5)$$

Where V_a is the critical mean velocity and it is used to mark the transition from condition of clear-water to the condition of live-bed for non-uniform sediments transported by the flow, V_c is critical mean approach velocity for non-uniform sediment bed is not possible, u^*_c is the critical shear velocity, d_{50} is size of median soil, and d_{max} is size of maximum particle and it is obtained from the particle size distribution curve. For selection of certain water depth, it was adjusted to obtain the ratio of bed shear velocity to critical value less than one to achieve clear water condition so, flow depth must achieve that $V/V_a < 1$, various values of selected water depths were given with these values of Froude number and flow intensity in Table (1)

TABLE (1)
FLOW CHARACTERISTICS

Q (lit/sec)	water depth (cm)	V (m/sec)	u*c	V_c	V_a = 0.8 V_c	(V/V_a)	F_r
28.1	11.5	0.349	0.030	0.463	0.370	0.943	0.329
	12	0.335	0.030	0.466	0.373	0.897	0.308
	13	0.309	0.030	0.472	0.378	0.818	0.273
24.35	11.5	0.303	0.030	0.463	0.370	0.817	0.285
	12	0.290	0.030	0.466	0.373	0.778	0.267
	13	0.268	0.030	0.472	0.378	0.709	0.237
16.14	11.5	0.200	0.030	0.463	0.370	0.541	0.189
	10.0	0.231	0.030	0.452	0.362	0.637	0.233
	8.5	0.271	0.030	0.440	0.352	0.770	0.297

III. DIMENSIONAL ANALYSIS

It is a mathematical method used to infer a homogeneous relationship,

$ds = \phi\ (L, W, \rho_s, \sigma_g, G, y, V, \rho, \nu, g, d_{50}, V_c, P_D, \Theta)$… (6)

Where; ds is maximum depth of scour hole around pier, L is length of pier, W is width of pier, ρ_s is density of sediment, σ_g is the geometric standard deviation of the distribution of sediment particle size , G is gap between pier and pile, y is depth of approach flow upstream the piers, V is mean flow velocity, ρ is water density, ν is fluid kinematics viscosity, g is gravitational acceleration, d_{50} is median diameter of the sediment, V_c is the critical mean approach velocity , P_D is diameter of sacrificial piles and Θ is the shape factor. Using Buckingham's π theorem, new dimensionless relationships can be written as follows:

$ds/y = \phi\ (L/y, W/y, V/V_c, \sigma_g, G/y, R_e, F_r, d_{50}/y, \rho_s/\rho, R_{ep}, P_D/y, \Theta)$……………………………………………..….(7)

After the removing of the non-influential parameters, the final relation could be written as:

$ds/y = \phi\ (L/y, W/y, V/V_c, G/y, F_r, d_{50}/y, R_{ep}, \Theta)$…………………………..………………………....(8)

Where R_{ep} is Reynolds number based on pier width instead of water depth ($\frac{v.w}{\upsilon_v}$) used by Apsilidis et al.[14] and F_r is the Froude number($\frac{}{\sqrt{g*y}}$). Various models of piers have been investigated to predict the depth of scour for each type. Statistical Package for the Social Sciences (SPSS) program was used to derive four empirical equations for estimating ds/y around different models of piers. Statistical performance indicators as coefficient of determination (R^2) have been used to check the accuracy of these proposed relationships.

IV. EXPERIMENTAL RESULTS AND ANALYSIS

A. Influence of Upstream Curved Face Oblong Pier and Slotted Oblong Pier on Scour Depth.

The outcomes of the experiments performed in the first three forms of the pier were shown in Table (2). The analysis shows that the pier shape and flow velocity have modified dramatically in the scour depth. The results showed that although the upstream curved face oblong pier had reducer scour depth than oblong pier without curved face, the slotted pier had the lowest scour depth , for standard deviation σ_g=2.335, d_{50}=0.63 mm . May be this result due to the presence of slot provides a passage of water reducing the formation of adverse pressure gradient leading to lesser strength of horseshoe vortex and reducing the downflow impinging on the bed or divert the downflow away. Figs. (8) through (10) show the relationships between the relative scour depth and Froude number for oblong, upstream curved and slotted piers, respectively. It is noticed from these figures that, the relative scour depth increases with increasing the value of Froude number and the upstream curve pier exhibits smaller value of scour depth than the oblong pier at the same value of Froude number, while the slotted pier highlights the smallest value. Fig. (11) gives the comparison between relative scour depth for studied pier and different values of F_r.

TABLE (2)
MAXIMUM LOCAL SCOUR FOR FIRST THREE PIERS

No	Type of pier	Q(lit/sec)	Flow depth(cm)	F_r	Scour depth (cm)	ds/y
1	Oblong pier	28.1	11.5	0.3286	9.69	0.843
			12.0	0.3083	8.76	0.730
			13.0	0.2734	7.12	0.548
		24.35	11.5	0.285	7.1	0.617
			12.0	0.267	6.5	0.542
			13.0	0.237	5.51	0.424
		16.14	8.5	0.297	5.77	0.679
			10.0	0.2327	3.9	0.390
			11.5	0.1887	2.8	0.243
2	Upstream curved face oblong pier	28.1	11.5	0.3286	8.12	0.706
			12.0	0.3083	7.4	0.617
			13.0	0.2734	5.95	0.458
		24.35	11.5	0.285	6.31	0.549
			12.0	0.267	5.45	0.454
			13.0	0.237	4.52	0.348
		16.14	8.5	0.297	4.79	0.564
			10.0	0.2327	3.22	0.322
			11.5	0.1887	2.39	0.208
3	Slotted oblong pier	28.1	11.5	0.3286	7.28	0.633
			12.0	0.3083	6.51	0.543
			13.0	0.2734	5.37	0.413
		24.35	11.5	0.285	5.35	0.465
			12.0	0.267	4.85	0.404
			13.0	0.237	4	0.308
		16.14	8.5	0.297	4.29	0.505
			10.0	0.2327	2.76	0.276
			11.5	0.1887	1.9	0.165

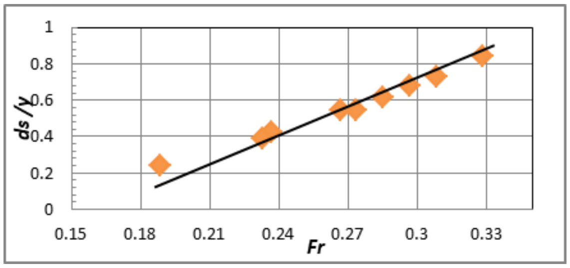

Fig. (8): Relationship between relative scour depth (ds/y) and Froude number (Fr) around oblong pier.

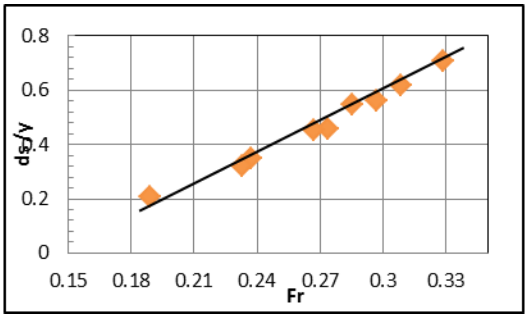

Fig. (9): Relationship between relative scour depth (ds/y) and Froude number (Fr) around upstream curved face oblong pier.

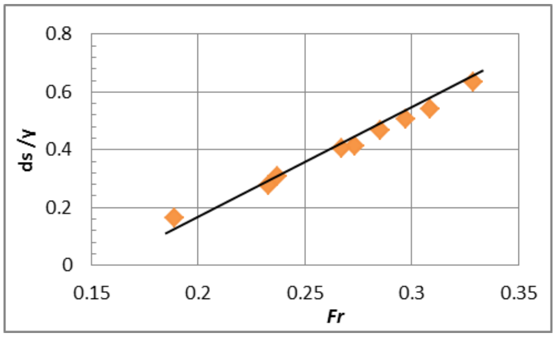

Fig. (10): Relationship between relative scour depth (ds/y) and Froude number (Fr) around Slotted oblong pier.

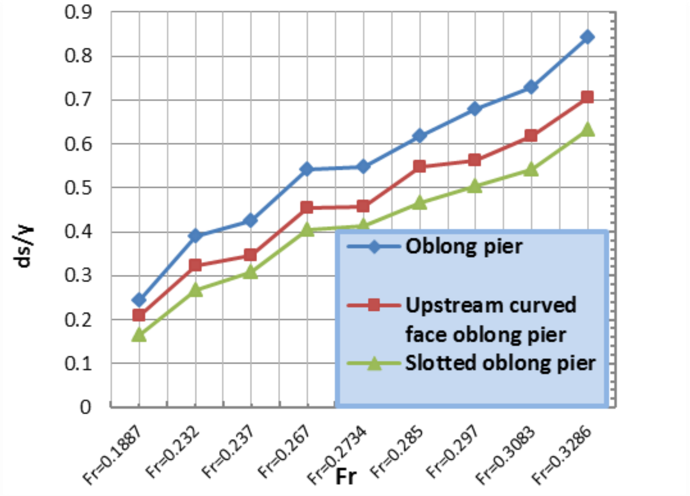

Fig.(11): Relationship between relative scour depth (ds/y) and Froude number (Fr) around studied piers

B. Influence of Upstream Curved Face Slotted Oblong Pier on Scour Depth.

The first set showed that the upstream curved face oblong pier and the slotted oblong one reduced the scour depth comparing to oblong pier only by about 16% and 25%, respectively. In the second set upstream curved face slotted oblong pier was used. It was found the scour depth was reduced by about 30%. This experimental work was conducted for maximum Froude number F_r =0.3286. Figs. (12) through (15) presented the bed contour maps around oblong pier for different cases and Fig.(16) shows the upstream scour depth along longitudinal axis (X).

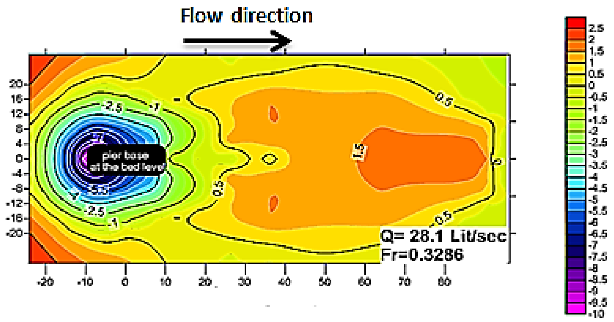

Fig. (12): Bed contour map around the oblong pier at Fr =0.3286

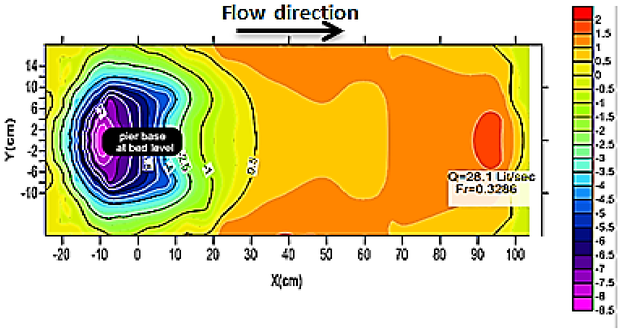

Fig. (13): Bed contour map around the upstream curved face oblong pier at Fr =0.3286

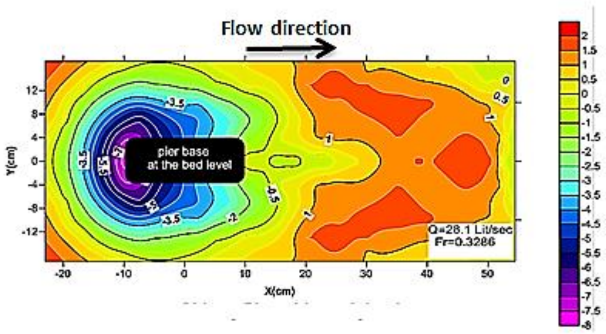

Fig. (14): Bed contour map around the slotted oblong pier at Fr =0.3286

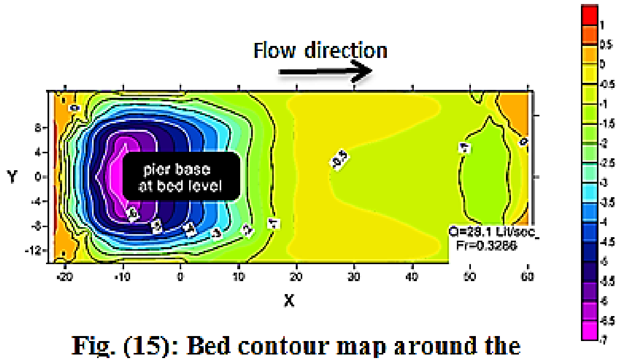

Fig. (15): Bed contour map around the upstream curved face slotted oblong pier at Fr =0.3286

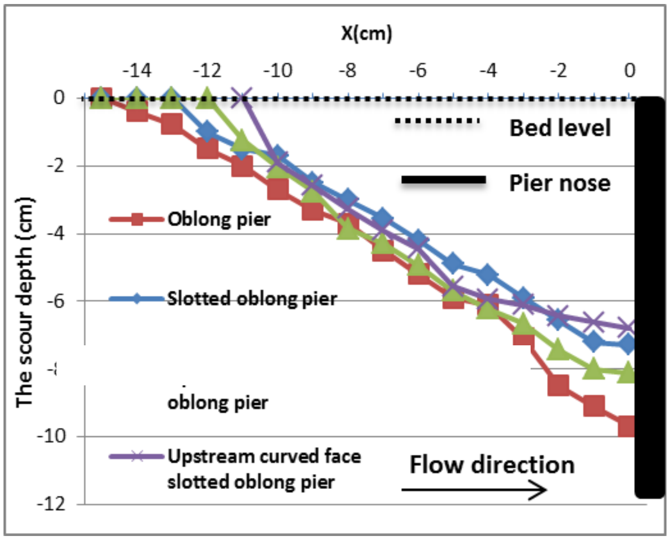

Fig. (16): Variations of upstream scour depth along the longitudinal axis(X) for Fr=0.3286 around different shapes of piers.

C. Influence of Sacrificial Piles on Scour Depth around Upstream Curved Face Slotted Oblong Pier.

The first and second experimental works showed that the lowest scour depth occurred with upstream curved face slotted oblong pier. The third experiments were two runs at maximum Froude number (F_r) =0.3286; the first run was adding one sacrificial pile with diameter 2.5 cm upstream of the best pier which occurred the lowest scour depth at distance equals 2W =16 cm from the pier nose where W is the width of pier. This distance was used by Melville and Hadfield [15] but with triangular arrangement not linear and achieved good results. In the second run, another sacrificial pile with the same diameter was added upstream the first one at distance equal 2W=16 cm from the center of first pile. The sacrificial piles are able to deflect the flow and create a low velocity wake region behind. The reduced erosive energy reduces the generation of local scour around the pier. From the results illustrated in Figs. (17) through (19). It was found that increasing the number of piles, the wake region produced by sacrificial piles gets enlarged and therefore mitigation of local scour gets improved, so the reduction percentage reached about 49%.

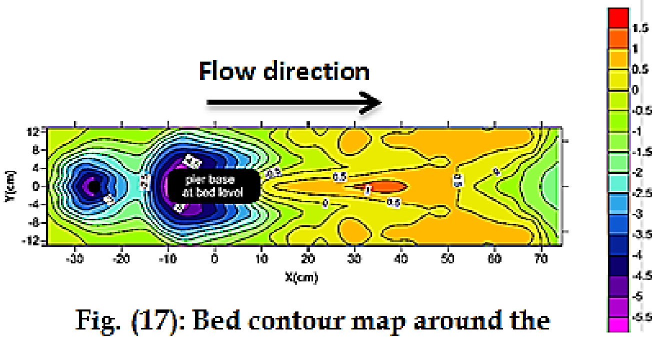

Fig. (17): Bed contour map around the upstream curved face slotted oblong pier with one sacrificial pile at Fr =0.3286

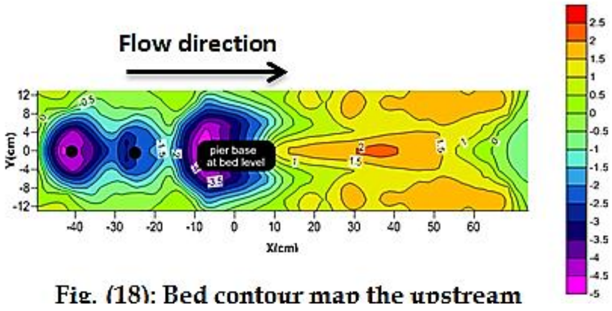

Fig. (18): Bed contour map around the upstream curved face slotted oblong pier with two sacrificial piles at Fr =0.3286

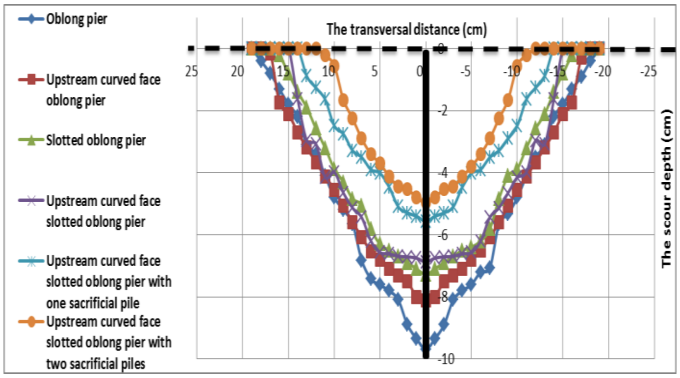

Fig. (19): Transversal profiles of maximum scour depth at the nose of piers for Fr =0.3286.

V. EMPIRICAL RELATIONSHIPS

Using Statistical Package for the Social Sciences (SPSS) program to generate relationships of different types of piers. Empirical relations were deduced between Froude number only with relative scour depth and relations between Froude number and Reynolds number based on pier width as used by Apsilidis et al. [14] with relative scour depth shown in Tables (3,4).

TABLE (3)
EMPIRICAL RELATIONSHIPS BETWEEN RELATIVE SCOUR DEPTH (DS/Y) AND FROUDE NUMBER (FR)

Type	Eqn.	Determina-tion coefficient
Oblong pier	$ds/y = 9.464*Fr^{2.173}$ (9)	0.99
Upstream curved face oblong pier	$ds/y = 8.139*Fr^{2.189}$ (10)	0.975
Slotted oblong pier	$ds/y = 8.171*Fr^{2.293}$ (11)	0.9621
Upstream curved face Slotted oblong pier	$ds/y = 8.362*Fr^{2.368}$ (12)	0.9813
Upstream curved face Slotted oblong pier + one pile	$ds/y = 6.346*Fr^{2.308}$ (13)	0.9394
Upstream curved face Slotted oblong pier + two piles	$ds/y = 5.806*Fr^{2.332}$ (14)	0.993

TABLE (4)
EMPIRICAL RELATIONSHIPS BETWEEN RELATIVE SCOUR DEPTH (DS/Y) AND BOTH FROUDE NUMBER (FR) AND PIER REYNOLDS NUMBER (REP)

Type	**Eqn.**	**Determina-tion coefficient**
Oblong pier	$ds/y= 1.024*10^{-3}*Fr^{1.4}*Rep^{0.808}$ (15)	0.9703
Upstream curved face oblong pier	$ds/y= 5*10^{-4}*Fr^{1.372}*Rep^{0.858}$ (16)	0.9674
Slotted oblong pier	$ds/y= 5.6*10^{-4}*Fr^{1.483}Rep^{0.848}$ (17)	0.973
Upstream curved face Slotted oblong pier	$ds/y= 4.23*10^{-4}*Fr^{1.525}Rep^{0.876}$ (18)	0.9641
Upstream curved face Slotted oblong pier + one pile	$ds/y= 7*10^{-4}*Fr^{1.535}Rep^{0.807}$ (19)	0.9706
Upstream curved face Slotted oblong pier + two piles	$ds/y= 5.49*10^{-4}*Fr^{1.413}Rep^{0.804}$ (20)	0.9615

Figs. (20) through (25) Indicate comparison between the values of calculated and measured ds/y .

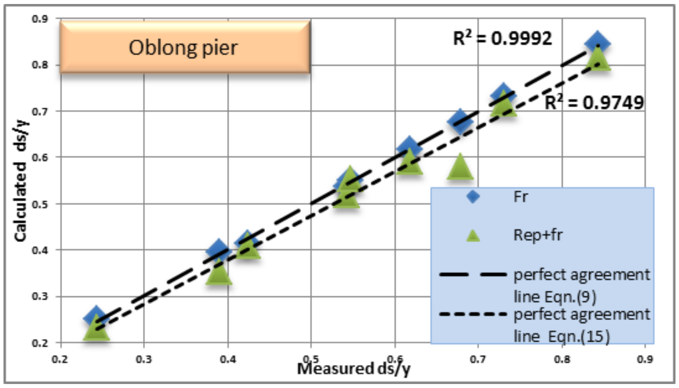

Fig. (20): Comparison between calculated and measured relative scour depth for oblong pier using Eqns. (9) and (15).

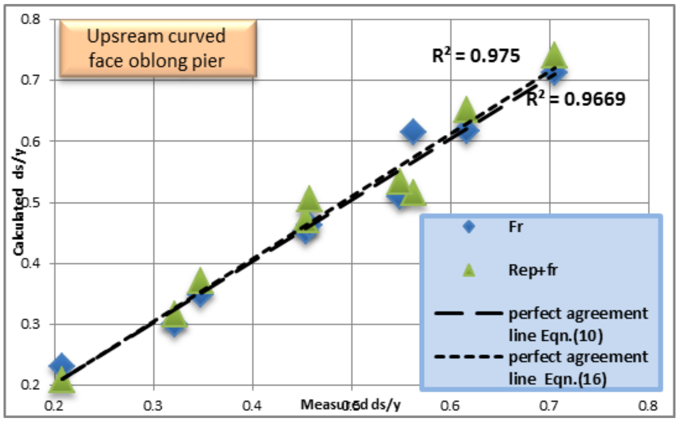

Fig. (21): Comparison between calculated and measured relative scour depth for upstream curved face oblong pier using Eqns. (10) and (16)

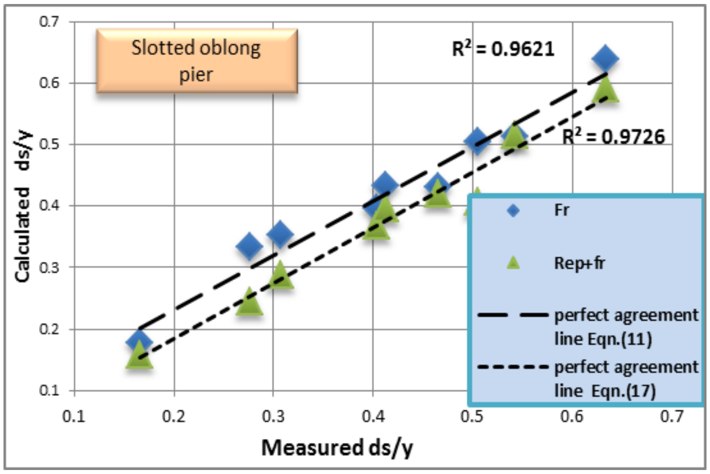

Fig. (22): Comparison between calculated and measured relative scour depth for Slotted oblong pier using Eqns. (11) and (17)

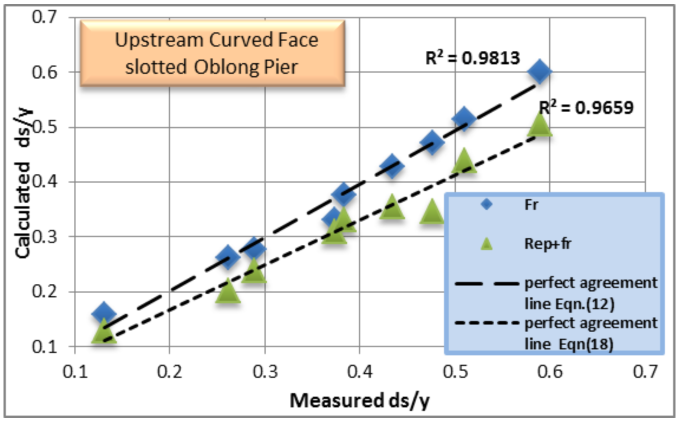

Fig. (23): Comparison between calculated and measured relative scour depth for Upstream curved face Slotted oblong pier using Eqns. (12) and (18)

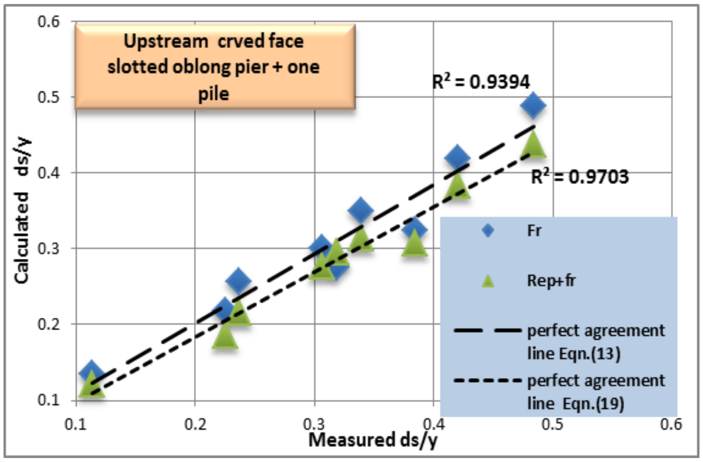

Fig. (24): Comparison between calculated and measured relative scour depth for Upstream curved face Slotted oblong pier and one pile using Eqns. (13) and (19)

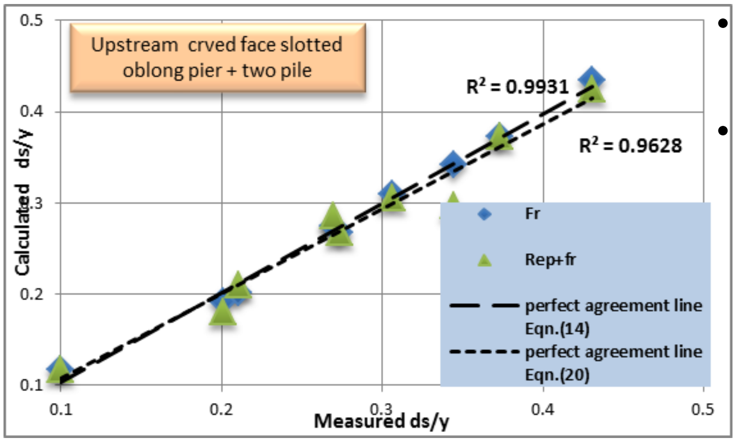

Fig. (25): Comparison between calculated and measured relative scour depth for Upstream curved face Slotted oblong pier and two piles using Eqns. (14) and (20)

VI. SUMMARY AND CONCLUSIONS

Three sets of experiments were carried out:

1. Investigating the effect of upstream curved face oblong pier and slotted oblong pier on reduction of the scour.
2. Using upstream curved face slotted oblong pier to get its effect on the scour.
3. Making a combination of three different countermeasures (i.e. upstream curved face, straight slot, and two sacrificial piles) to see their effects on the scour.

The main conclusions which can be drawn from this study are as follows:

- The slotted oblong pier performs better than the upstream curved face oblong pier in terms of controlling and reducing the scour depth upstream of the pier with a reduction in the scour depth of about 25% regarding oblong pier. On the other hand, using upstream curved face only reduces the scour depth by about 16% from the scour around oblong pier.
- The upstream curved face slotted oblong pier behaves better than the above mentioned case with a reduction in the scour depths of about 30% referring to oblong pier.
- Sacrificial piles are placed on the upstream of the pier, they support pier against the scour and the best arrangement of sacrificial piles is using two sacrificial piles along stream line flow. This arrangement achieves the best result with about 49% reduction in the scour depth upstream of the pier.
- Two systems of equations are given: The first one is relationship between the relative scour depth (ds/y) and Froude number (F_r) for different shapes of pier. The second system is the relationship between the relative scour depth (ds/y) and both Froude number (F_r) and pier Reynolds number (R_{ep}) for different shapes of pier.

VII. RECOMMENDATIONS

It is recommended to:

- Develop a new combination of other countermeasures to minimize the scour around bridge piers such as slots, collars and sacrificial piles.
- Study scour phenomenon around pier models using different types of soil to see the effect of soil characteristics on this phenomenon.
- Investigate pier models under the conditions of live-bed to see the effect of live bed on the scour dimensions.

NOTATION

The following symbols are used in this paper:

d_{50} = Median sediment size for the possible coarsest armor (mm);
d_{max} = Maximum particle size (mm);
d_s = Maximum scour depth around piers (cm);
F_r = Froude number;
g = Acceleration due to gravity;
L = Pier length (cm);
N = Number of piles;
Q = Discharge of flow (L/s);
Re = Reynolds number;
R_{ep} = Pier Reynolds number;
T = Time (s);
u^*_c = Critical shear velocity;
V = Mean velocity (m/s);
V_a = Critical mean velocity (m/s) for non-uniform sediment;
V_c = Critical mean approach velocity (m/s) for uniform sediment;
y =Approach flow depth (cm);
Θ = Shape factor;
υ = Kinematic viscosity;
ρ = Water density;
ρ_s = Sediment density; and
σ_g = Geometric standard deviation.

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AUTHORS CONTRIBUTION

Mohamed Tarek El Said Shamaa and Abdel Razek Ahmed El Sayed Zidan conceived of the presented idea.

Abd Allah Mohammed Allam developed the theory and performed the experiments and computations.

Mohamed Tarek El Said Shamaa and Abd Allah Mohammed Allam verified the analytical methods.

Mohamed Tarek El Said Shamaa and Abdel Razek Ahmed El Sayed Zidan have supervised the findings of this work.

All authors discussed the results and contributed to the final manuscript.

Abd Allah M. Allam wrote the manuscript with support from Abdel Razek A. Zidan and Mohamed T. Shamaa

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Title Arabic:

تقليل النحر المحلي حول بغال الكباري باستخدام طرق مختلفة للحماية

Arabic Abstract:

يعد النحر المحلي حول بغال الكباري أحد الأسباب الرئيسية لانهيارهذه الكباري. لذلك يتناول هذا البحث دراسة معملية للتأكد من فاعلية ثلاث طرق مختلفة تستخدم لتقليل هذا النحر ومحاولة الدمج بينهم للوصول إلى أفضل نظام يساعد في تقليل النحر إلي اكبر قدر ممكن وهذه الطرق الثلاث هي الفتحات الداخلية المستقيمة والوجهات ذات الشكل المنحني إضافة إلى استعمال الخوازيق .أولاً تم دراسة هذه الطرق بمفردها ثم تم دمجها لتحقيق الحد الأدنى من النحر. أوضحت النتائج أن الفتحات الداخلية بشكل عام لها تأثير أكبر في تقليل عمق النحر مقارنة بالوجهات ذات الشكل المنحني فقد خفضت النحر حول البغال بنسبة 25% ومن ناحية أخرى يبدو أن الوجهات ذات الشكل المنحني اذا دمجت مع الفتحات الداخلية كانت أكثر فاعلية من استخدام كل منهما على حدة حيث ساعد هذا الدمج في تخفيض نسبة النحر إلى حوالى 30% ثم استخدمت الخوازيق مع هذا النظام السابق الناتج من الدمج فكانت النتيجة مرضية بنسبة كبيرة فقد تم تقليل النحر بنسبة حوالى 49% وكانت هذه أكبر نسبة تخفيض قد تم الوصول إليها ، ومن هذا اتضح أن الدمج بين الطرق المختلفة المستعملة لتقليل النحر قد ينشأ عنها نظام جديد يساهم في علاج هذه المشكلة أكثر من مساهمة كل منهم على حدة.