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Scour around existing bridge piers due to the construction of new bridge piers.

النحر حول دعامات كوبرى قائم نتيجة انشاء دعامات كوبرى جديد

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الملخص العربى

نتيجة زيادة حركة الكثافة السكانية والحركة المرورية مما اضطر لانشاء كبارى جديدة بجوار الكبارى القائمة فان الأمر يحتاج الى دراسة المتغيرات الهيدروليكية والهندسية للحصول على أفضل وأنسب للمسافات الفاصلة بين مجموعة دعامات الكبارى القائمة والكبارى المقرر انشاؤها ودراسة الاثار الجانبية الناتجة عن انشاء دعامات الكبارى الجديدة على عملية نحر القاع حول دعامات الكبارى القائمة. وتهدف هذه الدراسة الى الوصول الى أفضل وأنسب أبعاد هندسية لدعامات الكبارى الجديدة بالمقارنة بالدعامات القائمة. وقد تم اجراء الدراسة المعملية على المتغيرات الهندسية والمسافات البينية تحت تأثير المتغيرات الهيدروليكية من التصرفات وأعماق المياه وقيم فراود.

وقد تم استنباط مجموعة من العلاقات الرياضية التى يمكن من خلالها التنبؤ بالخصائص الهندسية لحفرة النحر الموضعى حول دعامات الكبارى القائمة تحت تأثير خواص السريان المختلفة والمتغيرات الهندسية للدعامات الجديدة والتى أعطت نتائج جيدة.

Abstract

When an old bridge pier is accompanied by another new one , it is of great importance to study the interaction effect between both new and old one on the scour hole characteristics around the old one. Experiments were carried out under steady clear-water scour conditions. The objective of this study is to investigate how the scour hole characteristics around the old bridge pier are affected by the construction of the new one, taking into consideration different hydraulic and geometric parameters. These parameters are Froude criteria, piers separator distance, new pier dimensions which are taken as relative values from the old one. Also, the bridge pier position is considered with respect to the old one. New dimensional relationships are obtained to predict the scour hole characteristics around the old bridge pier with acceptable accuracy.

Key words: Scour; piers; Bridges; New pier geometry, Position.

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1.Introduction

Scour is defined as the erosion of streambed sediment around an obstruction in a flow Field. There are many empirical formulae developed due to the experimental work and field study to estimate local scour around bridge pier , but there is only one research who discussed the effect of constructing new pier in upstream or downstream the old one, but this study was concentrated on changing the shapes of piers [6]. The protection of piers from scour using riprap material is discussed by [2,3]. Results of pier scour equations were compared by many researchers [4,10]. Also, the local scour is predicted at complex pier geometries [5]. They investigated experimentally the effect of foundation geometry on pier scour [7,9]. In transportation highways of countries of old continents, often it is found that the bridges were constructed over rectangular piers aligned or not with the current of the flow. The fast evaluate of the transportation ways usually uses the same trajectory of the ancient ways and it is possible that the newest ones are placed near the ancient ones. Also the new bridges are constructed near the ancient ones with the only difference that the geometry of the piers are not the same [1]. The aim of the study is to investigate the influence of local scour when an old bridge pier is accompanied by another new bridge pier one, and how the scour hole characteristics of the old pier are affected in magnitude by the Froude number, new pier dimensions, separate distance between the two piers, and position of the new pier with respect to the old one.

2.Experimental Setup

The experiments were carried out in a 10 m long, 0.46 m wide, and 0.40 m deep flume. The flume is provided with centrifugal pump to recirculate the water from under ground tank to feed the flume with the required flow discharge. Upstream the flume, a rectangular weir is installed to measure the flow discharge. Figure (1) shows the schema of the experimental set up. The bottom of the flume was covered with 0.12 m sand stratum with d_{50}=0.47mm, σ_g=2.19. The flow discharge was 8.27 lit/s, the range of the flow depths were between (6.0 to 8.0) cm . The control of water depth during experimental work was achieved by using a tail gate located downstream the flume. The water depths upstream the piers were measured by the point gauge of the flume.

As shown in Figure (2), the experimental work in this study was performed on three steps , First step ; consists of runs on old pier only to investigate the Froude number effect on the scour hole dimensions (Froude number is changed for each run). Second step; contains runs which are performed with the existence of the new pier upstream the old one. Third step; contains runs which are performed with the existence of the new pier downstream the old one. For second and third steps, the position of the new pier was changed with respect to the old one. For each position, the Froude number, width of the new pier, separator distance between the new pier and the old one were changed and their effects were considered.

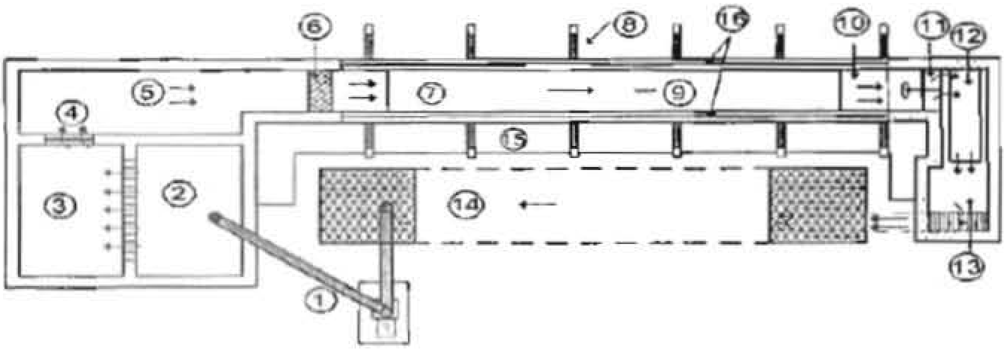


Fig. (1) Schematic representation of the experimental flume.

1)-	Centrifugal pump	9)-	Pier model
2)-	First head tank	10)-	Sand trap
3)-	Second head tank	11)-	Tail gate
4)-	Flow measuring weir	12)-	Collecting tank
5)-	Approach basin	13)-	Graduated tank
6)-	Inlet screen	14)-	Laboratory sump
7)-	Sand bed	15)-	Side walk
8)-	Wood bracing	16)-	Rails for point gague

The old pier model has a constant size of 10 cm length, and 2 cm width. The models of the new pier were divided into two groups, first group; to study the effect of changing the new pier width, the length is 10 cm and the width was varied as (0.50, 0.75, 1.0, 1.25, and 1.5) from the old pier width, second group; to study the effect of the new pier length on the scour hole of the old one, the length of new pier is changed as 20, and 30cm with constant width of (2cm). For the runs performed with the existence of the new and old pier, the separator distance (gap) between the old and new piers is varied from (1.0 to 4.0) times the old pier length .

The size of the models was such that the total blockage area did not exceed 12% of the total flow section for most all the tests in order to minimize contraction scour. The duration of the experimental runs was chosen based on the past investigations on local scour; the experiment duration was kept 2 hours. The present study regards a period of run up to 2 hours, as most of the scour depth occurs through this period.

The experiments were performed in the clear-water scour. The critical flow condition was predicted using a previous method presented in [8]. After each experiment the scour hole dimensions were measured with a point gague with an accuracy of ±1 mm.

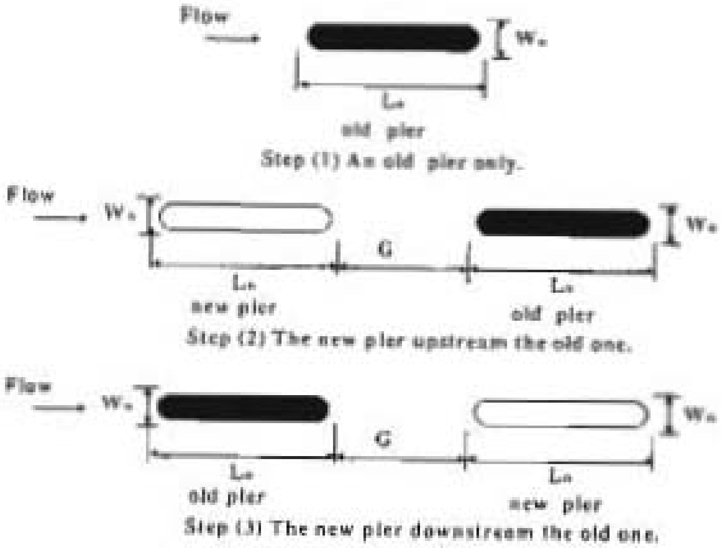


Fig. (2) Definition sketch of experimental works.

3.Results of Experiments and Analysis

3.1 Effect of new pier position on (So/y) of old pier

To study the effect of the new pier position on the maximum relative scour depth (S_o/y), for the old one , two positions were considered. In the first position the new pier is laid upstream the old one. In the second position , the arrangement is reversed. The experimental procedure is accomplished for five values of the relative width of the new pier (W_n/W_o) = 0.50, 0.75, 1.0, 1.25, 1.50, respectively, with (L_n/L_o =1.0). For the same (W_n/W_o) ratio, the relative separator distance (G/L_o) is changed from 1 to 4.

Figure (3) illustrates the influence of changing the separator distance between the two piers (G/L_o) for the considered position on the relative depth of maximum scour around the old pier. For the considered values of Froude criteria, the figure was drawn for relative length (L_n/L_o=1.0) and relative width W_n/W_o=0.50.

From this figure it is clear that, for $1/F^2$ >9.2, the presence of the new pier upstream the old one gives the bigger values of relative maximum scour depth for the case of G/L_o=4.0. While, for $1/F^2$ < 9.2 the relative separate distance G/L_o=1.0 causes the bigger values of relative depth of maximum scour around the old pier.

-The presence of the new pier in front of the old one with a separate distance equals two or three times the length of the old pier decreases the maximum depth of scour for the considered values of Froude criteria, L_n/L_o=1.0 and W_n/W_o=0.5.

- The collected experimental results were divided into four groups depending on dimensional analysis. The following summarized these results and analysis. When the new pier lies upstream the old one at separator distance equal to (2-3) times L_o, it decreases the maximum scour depth for values L_n/L_o=1.0, W_n/W_o=0.5. For all values of $1/F^2$ and L_n/L_o=1.0, W_n/W_o=0.5, the relative scour depth around the old pier decreases where the new one lies upstream with separator distance (2-3) L_o and the minimum relative scour depth is at $G/L_o=2$.

Figures from (4) to (7) show the relationship between S_o/y and $1/F^2$. From these figures, it is clear that, at $1/F^2>9.6$, the scour depth increases around the old pier due to the construction of the new one with all values of separator distance G. But when $1/F^2<9.6$, the scour depth decreased specially at $G/L_o=2.0$. It means that the scour depth decreases with increasing Froude numbers.

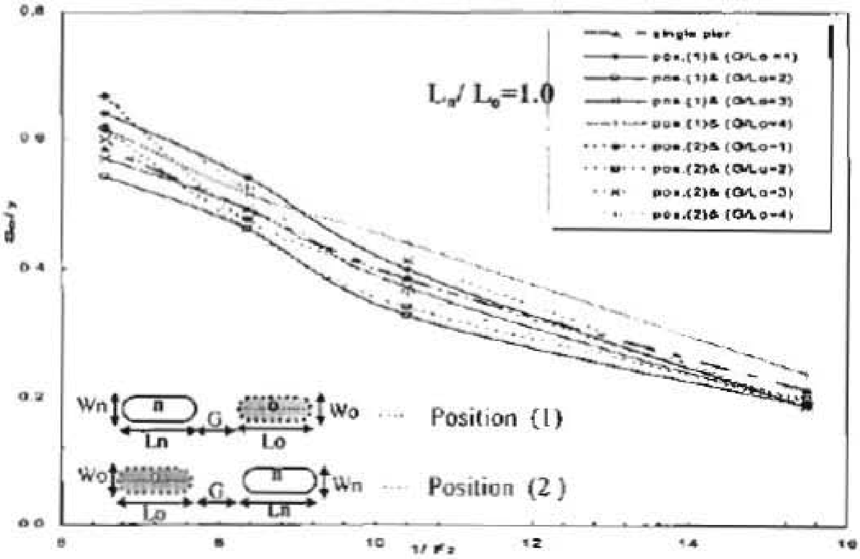


Fig.(3) Effect of new pier position on relative scour depth (S_o/y), (W_n/W_o=0.50) .

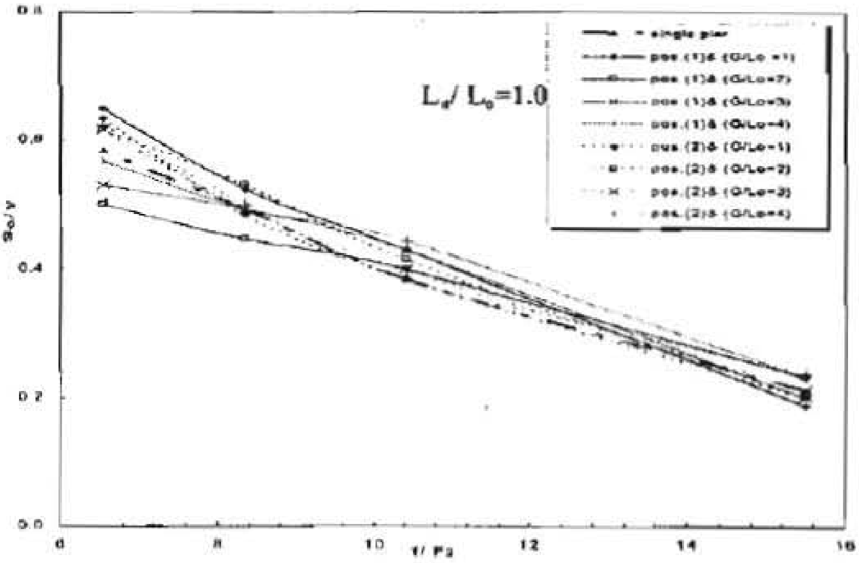


Fig.(4) Effect of new pier position on relative scour depth (S_o/y), (W_n/W_o=0.75) .

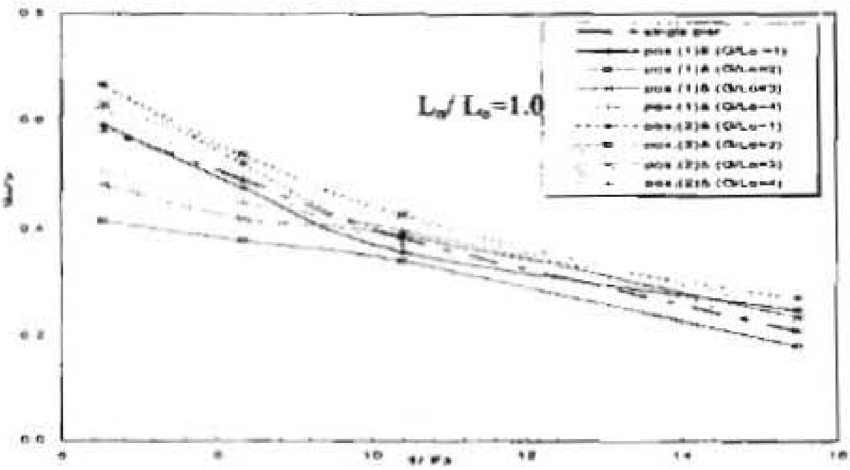


Fig.(5) Effect of new pier position on relative scour depth (S_o/y), (W_n/W_o=1.0) .

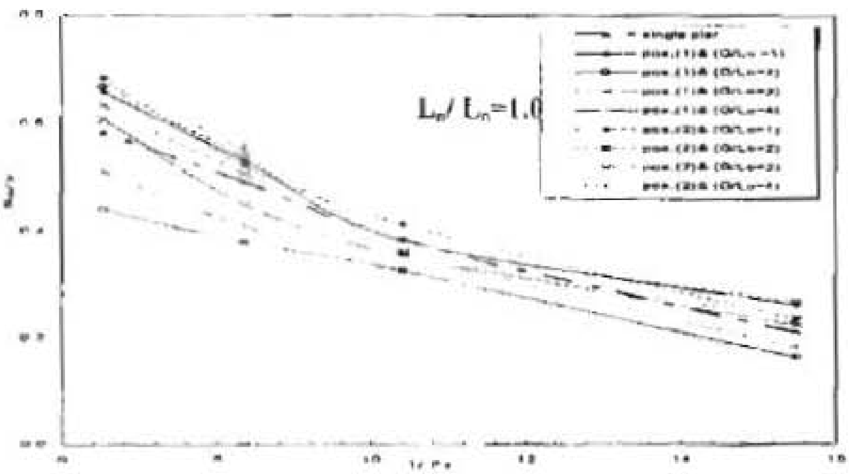


Fig.(6) Effect of new pier position on relative scour depth (S_o/y), (W_n/W_o=1.25) .

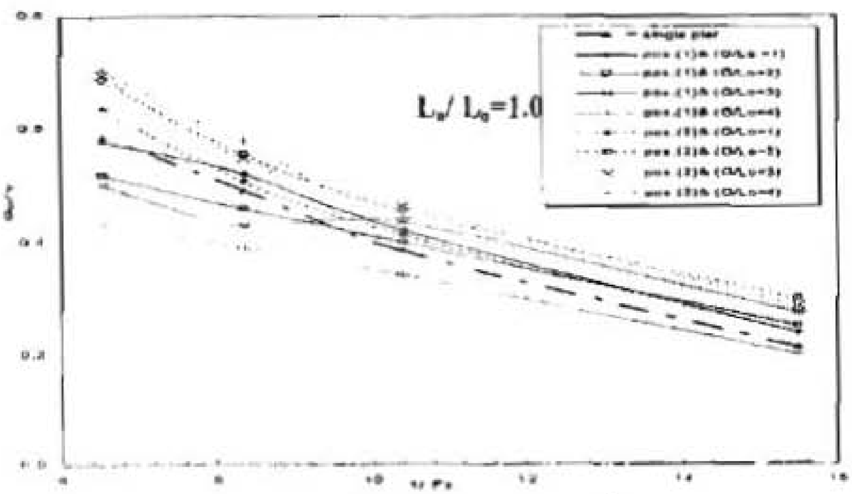
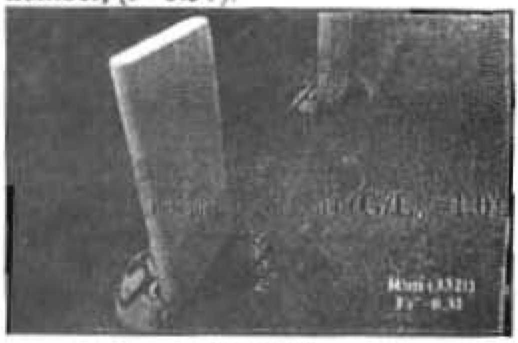


Fig.(7) Effect of new pier position on relative scour depth (S_o/y), (W_n/W_o=1.50)

3.2 Effect of separator distance between the piers on scour depth

To study the effect of separator distance between the piers due to the existence of the new pier upstream the old one. Four values of relative distance (G/L_o) is taken from 1.0 to 4.0. This procedure is accomplished for four relative widths ,W_n/W_o=0.5, 0.75, 1.0, and 1.25, respectively. For the same relative width (W_n/W_o), the Froude number was changed from 0.254 to 0.391 .

From figure (8) it is clarified that the scour effect of new pier on the old terminates at low Froude number (F=0.254) with (G/L_o=4.0). For smaller values of Froude number, The maximum scour depth is not approximately affected by varied (G/L_o) ratios. Plate (1) and (2) present the effect of (G/L_o) ratio between the piers on scour hole dimensions with Froude number, (F=0.31).



Plate(1)

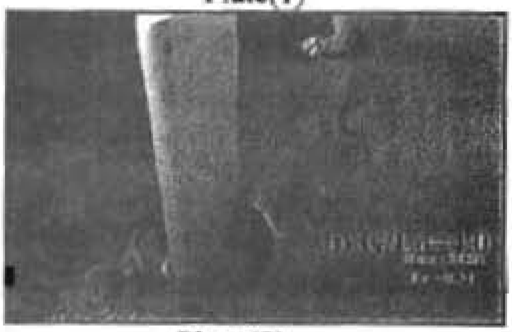


Plate (2)
Effect of separator distance

3.3 Effect of Froude number on scour depth

Four different Froude numbers was considered from (0.254 to 0.391). This procedure is accomplished for five relative widths (W_n/W_o=0.5, 0.75, 1.0, 1.25, and 1.50), respectively. For the same relative width (W_n/W_o), the relative separate distance (G/L_o) is changed from 1.0 to 4.0 .

From figure (9), it was clear that scour hole dimensions were increased by the increasing of Froude criteria.
Plate (3) and (4) show the effect of Froude number on the scour hole dimension.

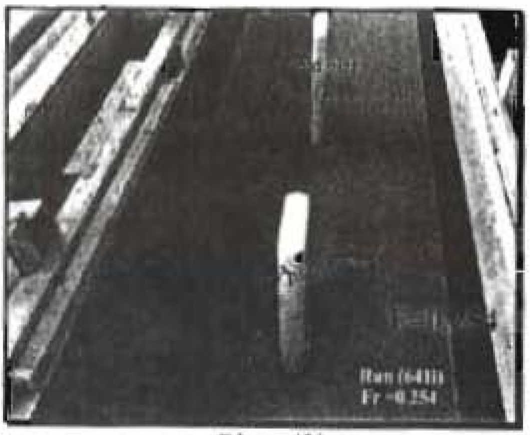


Plate (3)

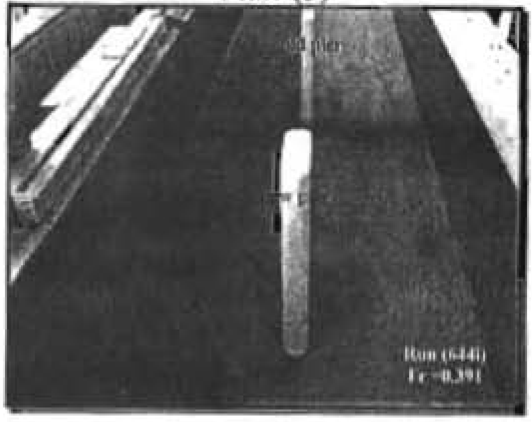


Plate (4)
Effect of Froude number

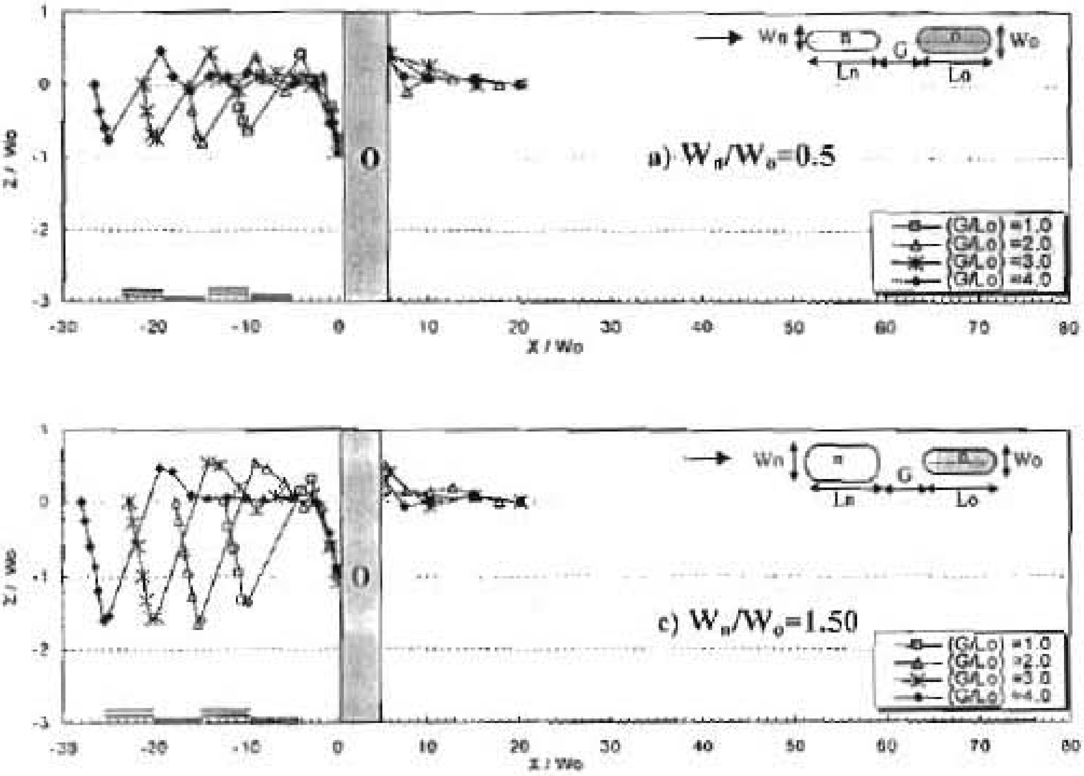


Fig.(8) Scour profile along (C) of the piers, (L_n/L_o=1), (F=0.254).

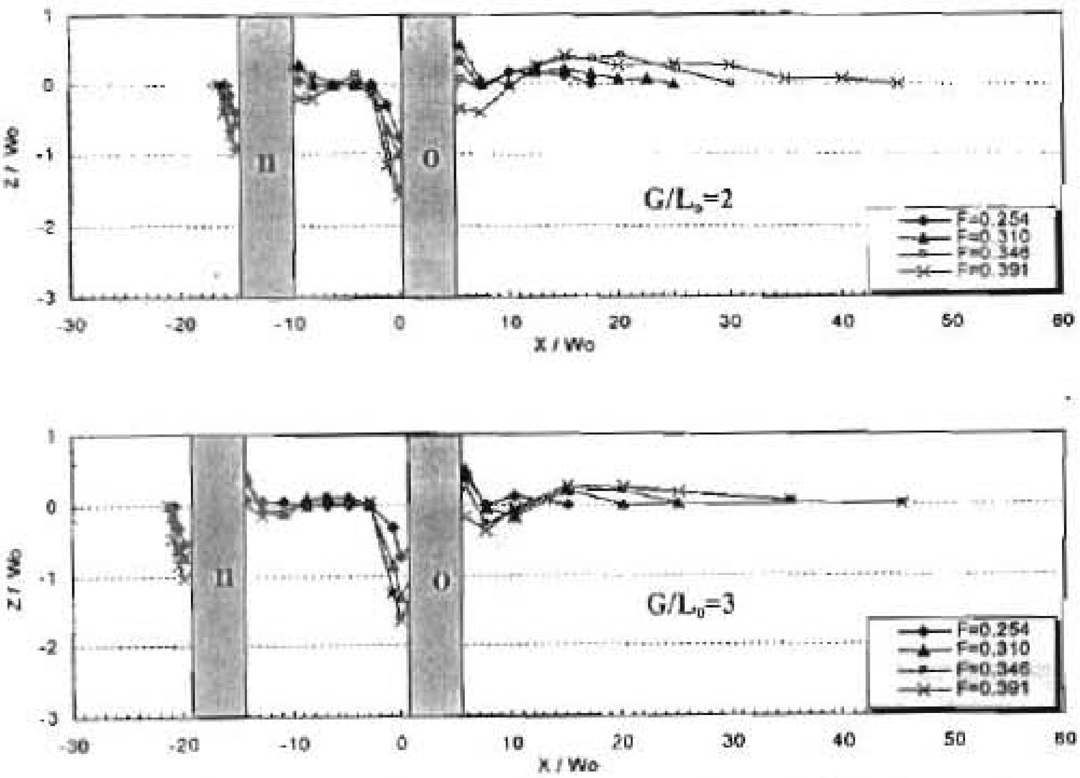


Fig.(9) Scour profile along (C) of the piers, (L_n/L_o=1), (W_n/W_o=0.5).

3.4 Effect of new pier width on scour depth

A study of the effect of new pier width on scour hole dimensions is made. For the position of the new pier upstream the old one, five relative widths were considered as (W_n/W_o)= 0.50, 0.75, 1.0, 1.25, and 1.50, respectively , and (L_n/L_o) =1.0 . This procedure was accomplished for four relative separate lengths as $(G/L_o$ = 1.0, 2.0, 3.0 , and 4.0), respectively. For the same relative separate distance (G/L_o), the Froude number was changed from 0.254 to 0.391. Plate (5) to (6) show the effect of new pier width on scour hole profile for F= 0.31, G/L_o=4.0 From figure (10), it is concluded that, the maximum scour hole depth decreases by increasing relative width of the new pier.

A mathematical formulas have been found to predict maximum scour depth in the clear water scour condition. The formulae is given below for each position of the new pier. The values of relative scour depth (S_o/y) of the old pier are compared with the measured data as shown in figure (11), and (12).

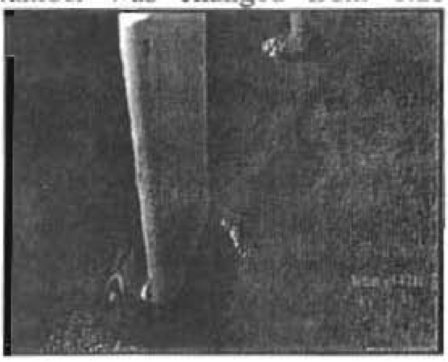


Plate (5), $(W_n/W_o$=0.75)

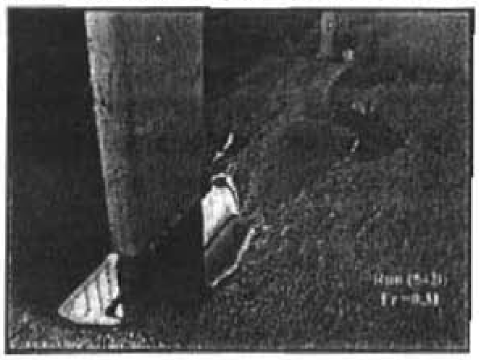


Plate (6), $(W_n/W_o$=1.25)

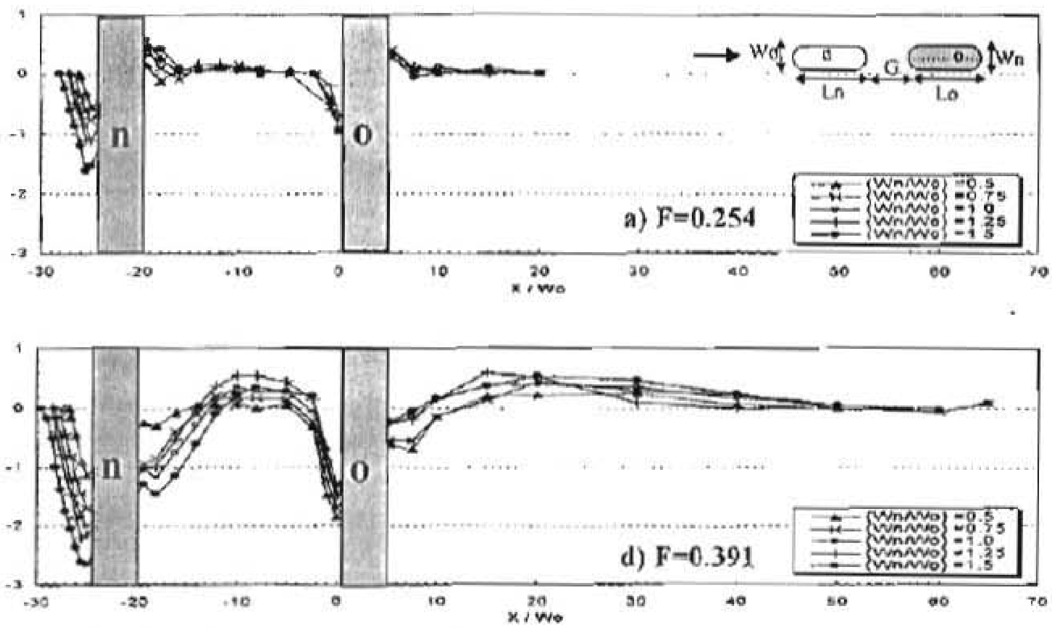


Fig.(10) Scour profile along (C) of the piers, $(L_n/L_o$=1), $(G/L_o$=4.0).

1- Formula of two piers, (new pier upstream the old one)

$$S_o/y = 4.173\,(F)^{2.097}\,(G/L_o)^{-0.064}\,(W_n/W_o)^{-0.059} \quad , R = 0.913 \qquad (1.1)$$

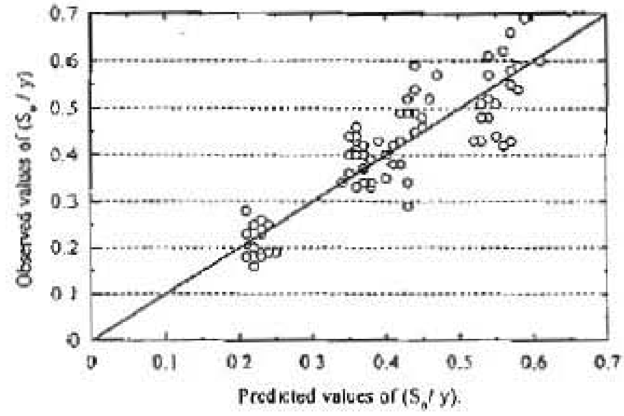


Fig. (11) Relationship between observed values of (S_o/y) and predicted ones.

2- Formula of two piers, (new pier downstream the old one)

$$S_o/y = 6.594\,(F)^{2.437}\,(G/L_o)^{0.005}\,(W_n/W_o)^{0.147} \quad , R = 0.983 \qquad (1.2)$$

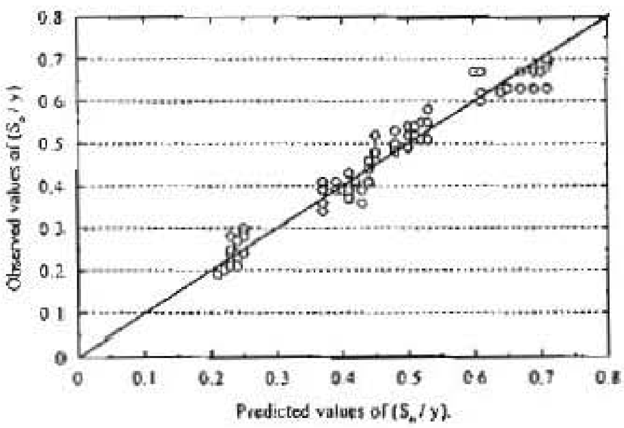


Fig. (12) Relationship between observed values of (S_o/y) and predicted ones.

4.Conclusions

From this research , it is concluded that,:

1- To minimize the effect of constructing new pier on the scour hole depth around the old one , it is recommended to :-

a. Put the new one upstream the old pier with any separator distance at W_n/W_o=1.0 to 1.50 for the studied values of Froude number . But for W_n/W_o=0.5 to 0.75 , and higher values of Froude numbers, put the new pier downstream the old one with separator distance equal to (2-3)L_o . While for smaller values of F , put new pier downstream with smaller separator distance.

b. The existence of new pier upstream the old one, reduces the scour depth values compared with the corresponding to the values in case of single old pier.

2- For low values of F, it is found that there is no interference between the effect of each pier on the other for higher values of relative separator distance (G/L_o=4.0). Also, the maximum scour depth values are not affected by the separator distances.

3- The scour phenomenon depends on the Froude number. It is clear that scour hole dimensions are increased by increasing the Froude number.

4- The scouring process is affected by the new pier width. The present study clarifies that; the maximum scour hole depth decreases by increasing relative width of the new pier.

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Notation

The following symbols are used in this technical note:

d_{50} = mean particle size diameter,

F = Froude number,

G = separate distance length between piers,

L_n = length of the new pier,

L_o = length of the old pier,

S_o = old pier maximum scour depth,

W_n = new pier width,

W_o= old pier width,

σ_g = geometric standard deviation of particles,

y = depth of approach flow.