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ORIGINAL ARTICLE

The Effect of Pile Group Arrangements on Local Scour Using Numerical Models

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Ahmed W. Abdeldayem, Gamal H. Elsaeed, Ahmed A. Ghareeb; The Effect of Pile Group Arrangements on Local Scour Using Numerical Models

ABSTRACT

The objective of this study is to compare the effect of pile groups on the local scour around bridge piers, while changing the pile number and spacing in both longitudinal and transversal directions. Different arrangements of square pile groups have been studied, where the pile numbers range from 2 to 9, and are separated by a clear spacing that ranges from 50 to 200mm. The numerical model "Sediment Simulation In Intakes with Multiblock Option" was used to evaluate different arrangements and their effect on the local scour.

Key words: Numerical models; Longitudinal and transversal pile groups; Scour around bridge piers.

Introduction

Local scour is the removal of sediments from stream beds around or near structures located in flowing water. It is a result of the erosion caused by flowing water, excavating and carrying away material from the bed and banks of streams, as well as from around piers and abutments of bridges. Therefore, this increases the tendency to expose and erode bridge foundations, which may lead to bridge failure and loss of both life and property.

Methods

Pile Groups Scour Prediction:

Different arrangements of rectangular pile groups have been studied, where the number of piles range from 2 to 9 piles. The transverse spacing ratios were ST/b = 1, 2, 3 and 4. For each ratio in the transverse spacing ratios, the longitudinal spacing ratios were SL/b = 1, 2, 3 and 4.

Figure 1 represents a schematic diagram of the different arrangements.

Effect of Transversal Spacing:

Figure 2 to 7 represent the relation between the transverse spacing ratio (ST/b) and the relative scour (ds/b). It is clear from these figures that the scour depth decreases by increasing the transverse spacing between piles, where each pile within the group tends to behave as a single pile.

In order to obtain the spacing at which piles will behave as single one, a curve fitting has been done, and two equations have been developed for G1 and G2 respectively. These equations have been resolved to get the maximum ST/b by substituting the value of ds/b for a single pile. It was found that ST/b was 6.56 and 6.38 respectively.

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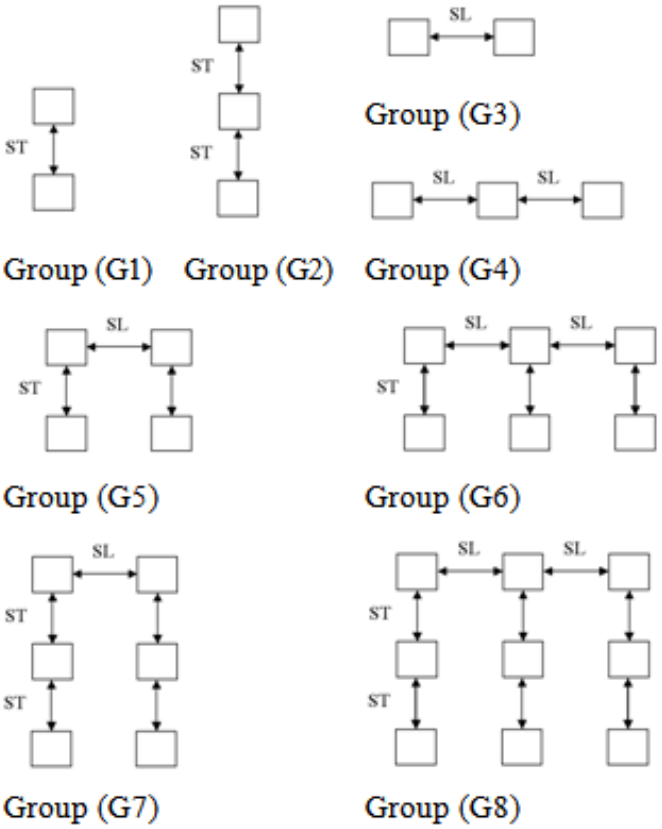

Fig. 1: Different arrangements of pile groups.

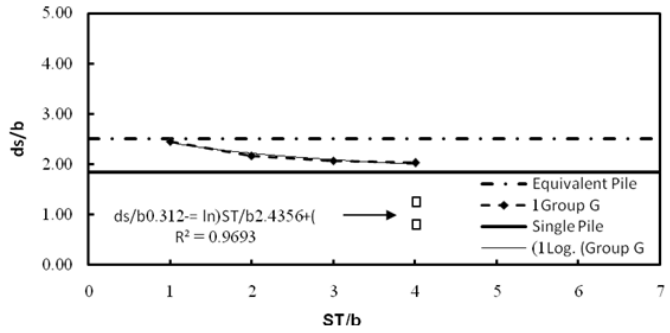

Fig. 2: Transverse spacing effect for group G1.

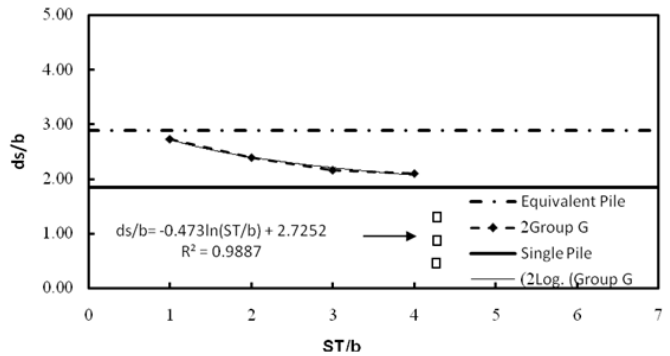

Fig. 3: Transverse spacing effect for group G2.

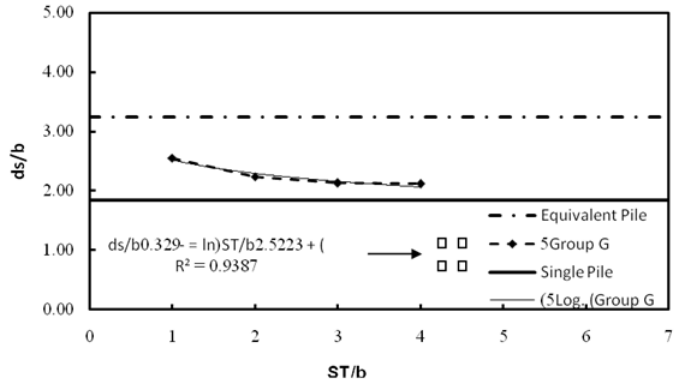

Fig. 4: Transverse spacing effect for group G5, SL/b=1.

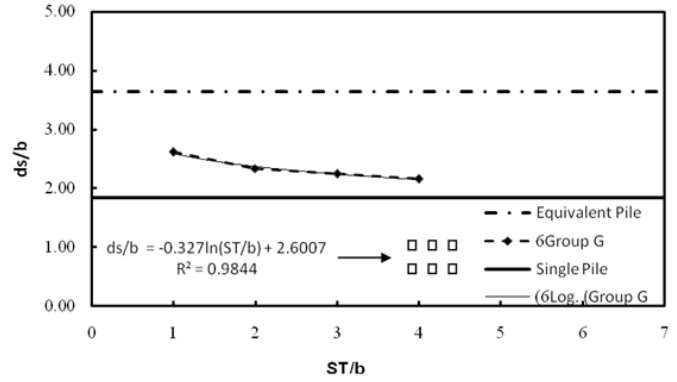

Fig. 5: Transverse spacing effect for group G6, SL/b=2.

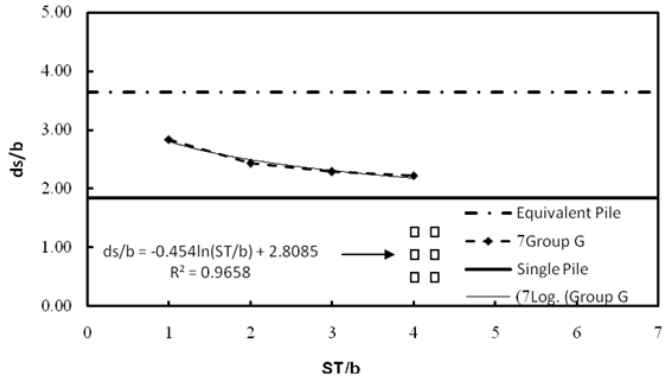

Fig. 6: Transverse spacing effect for group G7, SL/b=3.

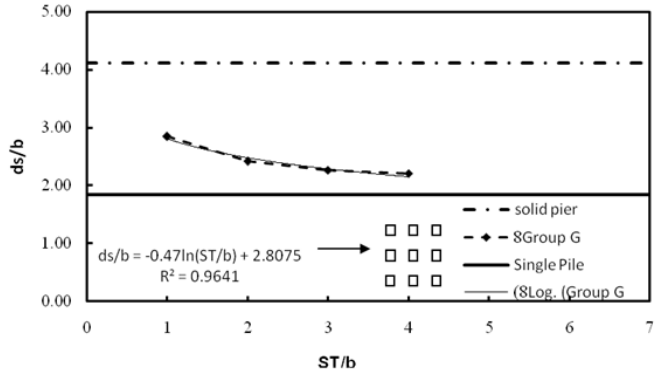

Fig. 7: Transverse spacing effect for group G8, SL/b=4.

Groups G5 to G8 consist of multiple rows and columns, where by increasing the transverse spacing between piles, each pile would tend to behave as a single one. 16 equations were developed, where each group had four equations, by substituting the value of ds/b for a single pile. Results have shown that the S/b at which the piles behave as a single pile are 8.58, 9.31, 7.94 and 9.28 for G5 to G8 respectively. This is in agreement with Salim & Jones (1996), that conclude that the depth reaches to a scour depth of a single pile for the S/b ratio of approximately nine or greater.

Effects of Longitudinal Spacing:

Figures 8 to 11 represent the relation between the longitudinal spacing ratio (SL/b) and the relative scour (ds/b). It is clear from these figures that the longitudinal spacing has little influence on the maximum scour depth for the piles' columns aligned with flow. The overall increasing average of the scour depth for G4 and G5 are 5% and 4% respectively. A similar conclusion was found for other groups.

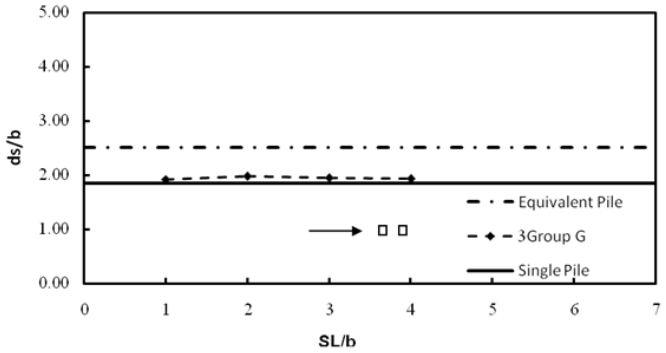

Fig. 8: Longitudinal spacing effect for group G3.

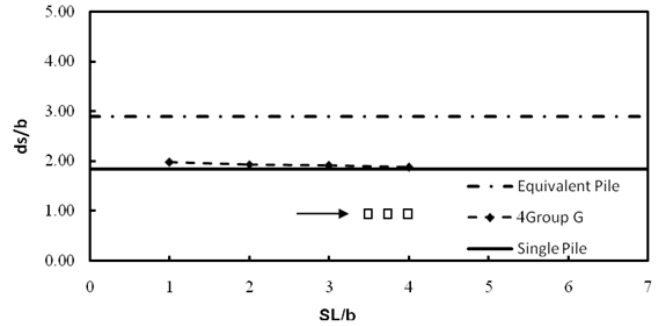

Fig. 9: Longitudinal spacing effect for group G4.

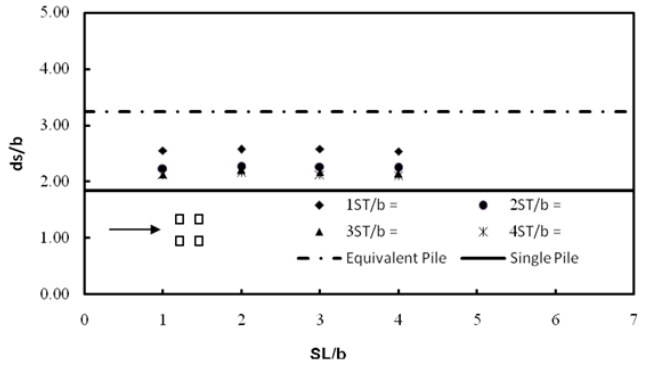

Fig. 10: Longitudinal spacing effect for group G5.

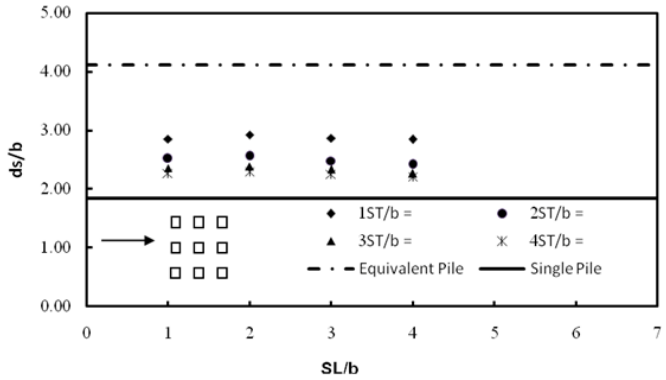

Fig. 11: Longitudinal spacing effect for group G8.

Results and Discussion

Modification Factor Assessment:

The relation between the pile groups' scour depth and its equivalent pile scour depth is an important factor for selecting the optimal arrangement. Equation (1) shows how the modification factor is calculated:

$$\zeta = \frac{ds_{PG}}{ds_{EP}} \tag{1}$$

ζ is the modification factor, ds_{PG} is the pile group scour depth, and ds_{EP} is the equivalent pile scour depth. Three assumptions were made in the assessment. The first one is that the previously developed equations for the different pile groups will be applied to predict the scour depths for other pile groups; the second assumption is that the piles in each group are spaced equally in the transverse and longitudinal direction, and the last assumption is that one equivalent area is used to represent the different pile groups. Figure 12 and 13 represent the relation between the modification factor and S/b for each group.

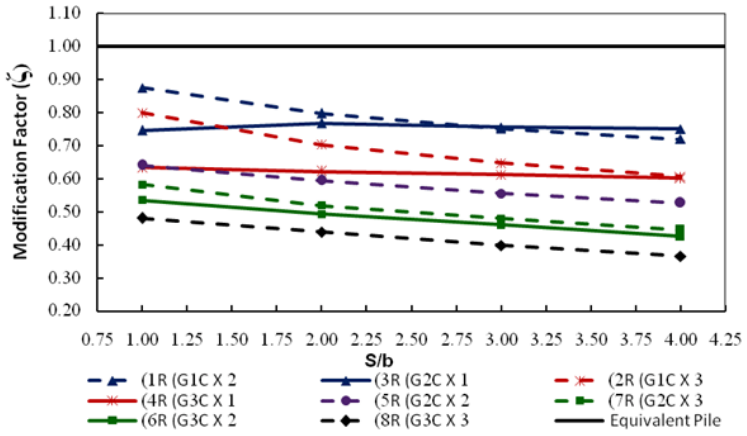

Fig. 12: Modification factor vs. pile spacing ratio (S/b) at Y/b=8.

Equation (2) represents an equation used to predict the modification factor for any pile group arrangement with the correlation coefficient R= 0.94 and R^2 = 0.88

$$\zeta = 1488.5\text{-}0.19(\mathrm{NC})^{0.63}\text{-}421.82(NR)^{0.0007} - 0.08\left(\frac{S}{b}\right)^{0.66} - 1065.2\left(\frac{Y}{b}\right)^{0.0001} \tag{2}$$

NC in this equation is the number of columns, NR is number of rows, S/b is the pile spacing ratio, and Y/b is the water depth to pier width ratio.

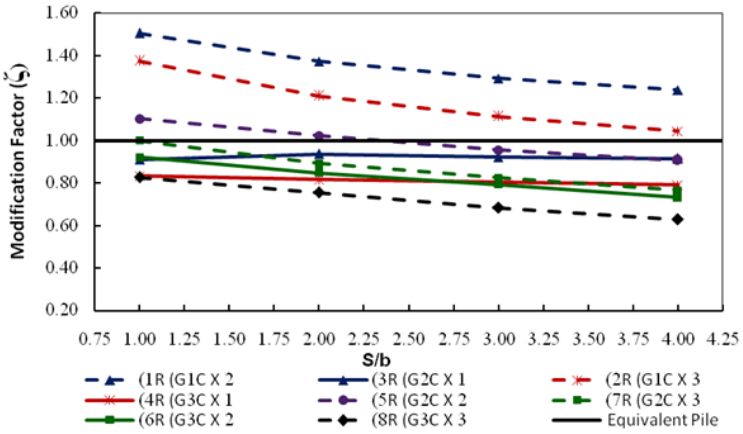

Fig. 13: Modification factor vs. pile spacing ratio (S/b) at Y/b=1.

Conclusions

From the above study, the following conclusions can be drawn:

1. For pile groups arranged transversally in one row with flow, each pile tends to behave as a single pile when the pile spacing ratio is equal to or greater than 6.5 times the pile width.
2. For pile groups arranged in line with flow direction, increasing of the longitudinal spacing ratio between piles has little influence on the maximum scour depth compared to the single pile scour.
3. For pile groups arranged in multiple columns and rows, the transverse spacing has a significant effect compared to longitudinal spacing.
4. For pile groups arranged in multiple columns and rows, the scour depth decreases as the spacing between piles increase and reaches the scour depth of a single pile at a spacing ratio ranging from 7.7 to 10.3, which is in excellent agreement with results previously determined by Salim & Jones (1996).
5. For two pile groups containing the same number of piles, it is recommended to arrange piles in line with flow. as it gives smaller scour than piles arranged transversely with flow.

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