THE INCREMENT OF THE LOCAL SCOUR DEPTH AT PIERS BY CONSTRUCTING THE BRIDGE BETWEEN EXISTING BRIDGES

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Abstract: In this paper, the increment of the local scour depth at piers by constructing the bridge between existing bridges is examined through the experiments in which 5 piers in the non-cohesive bed material in the experimental flume were installed. In the experiments the maximum distance of 25 times of the pier length and the maximum distortion width of 8 times of the pier width were utilized. Through the experimental studies, it was indicated that the bed configuration patterns are severely affected when the interaction between adjacent bridge piers exists. In the low flow, which can be characterized as the flow having low Froude numbers, the maximum bed configuration change is obtained when the piers are installed in the straight line in the flow direction without any distortion. However, In the high flow, which can be characterized as the flow having high Froude numbers, the maximum bed configuration change is obtained when the piers are installed with some distortion from the flow direction. The influence of the bed configuration by interaction between bridge piers is changed depending upon the Froude numbers, the distance between piers, and the distortion width between adjacent bridge piers. Also, because the scour patterns are affected by the bed configuration, the maximum scour should be increased by about 60% compared to that in a single pier if the interaction between bridge piers exists. It can be suggested that the maximum scour depth at bridge piers predicted by applying the existing equations should be increased if the interaction between bridge piers exist. Those cases are found when new bridges are constructed successively in the river in the urban area.

Key Words: local scour, distortion width, interaction distance, flow direction, bridge.

1. INTRODUCTION

It is not simple to construct a new bridge in the river in the urban area. Especially, the hydraulic condition and geographical changes in the river are severely indicated. The water depth fluctuation, velocity increment are the main indications of the hydraulic condition changes. The variation of the bed configuration is the main indication of the geographical changes.

It is very important to forecast these geographical and hydraulic changes correctly in the construction of a new bridge between existing bridges in a river.

In the previous days, the researches for forecasting the scour at bridge piers are mainly focused in the case of construction of a single bridge in the river. The results were usually obtained through the analysis of the experimental data. However, in the rivers such as Han River runs through the downtown in the large cities, the bridges are successively constructed for the purpose of the transportation and the delivery of the industrial production. These bridges can be constructed with the very short distance because recently the road is being frequently constructed between the existing roads. In these cases, the different bed configuration patterns compared to that in a single pier are observed.

In this paper, the increment of the local scour depth at piers, which is affected by the bed configuration change depending upon the interaction between bridge piers are examined through the experiments.

2. EXPERIMENTAL EQUIPMENT AND METHODS

The experiments were conducted in the experimental flume which consists with three parts such as pump and distribution pipe system, storage and distribution tanks in the upstream and downstream, and the rectangular channel of 12m. The slope of maximum 2% can be obtained by adjusting the channel. The point gage having the diameter of 4mm were used to measure the flow and scour depths. The gate in the tail water can be adjusted to minimize the unstable velocity at the position in which the piers are installed. Also, to reduce the instability at the beginning of the flume three baffles were used. A pack of the ′sliced tungsten is used to reduce the unsteady effect after baffles. Five elliptical piers are used to investigate the effect of the successive bridge piers as shown in Fig. 1.

The longitudinal distance between bridges and the distortion width between piers in the cross sectional direction are shown as C and B in Fig. 1 and Table 1. In Fig. 1 and Table 1, L and d indicate the length and width of the pier, respectively.

Table 1. Boundary Conditions for Experiments

Interaction Distance (C)	Distortion Width (B)	Froude Number (Fr)
5L, 10L, 15L, 20L, 25L	0d, 2d, 4d, 6d, 8d	0.2, 0.4, 0.6, 0.8

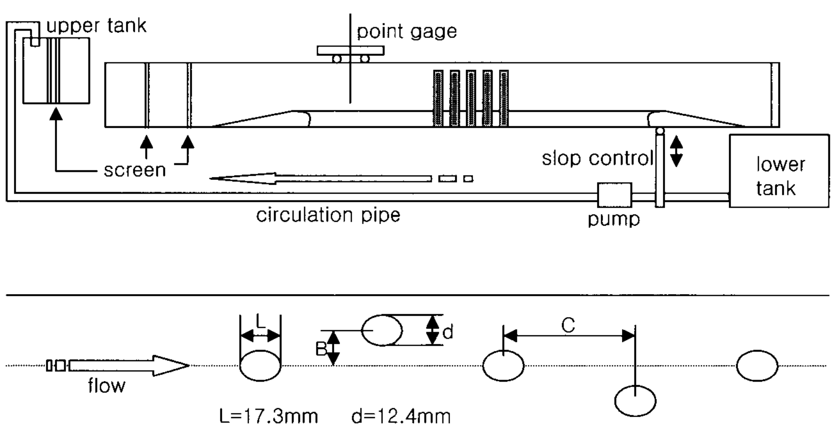
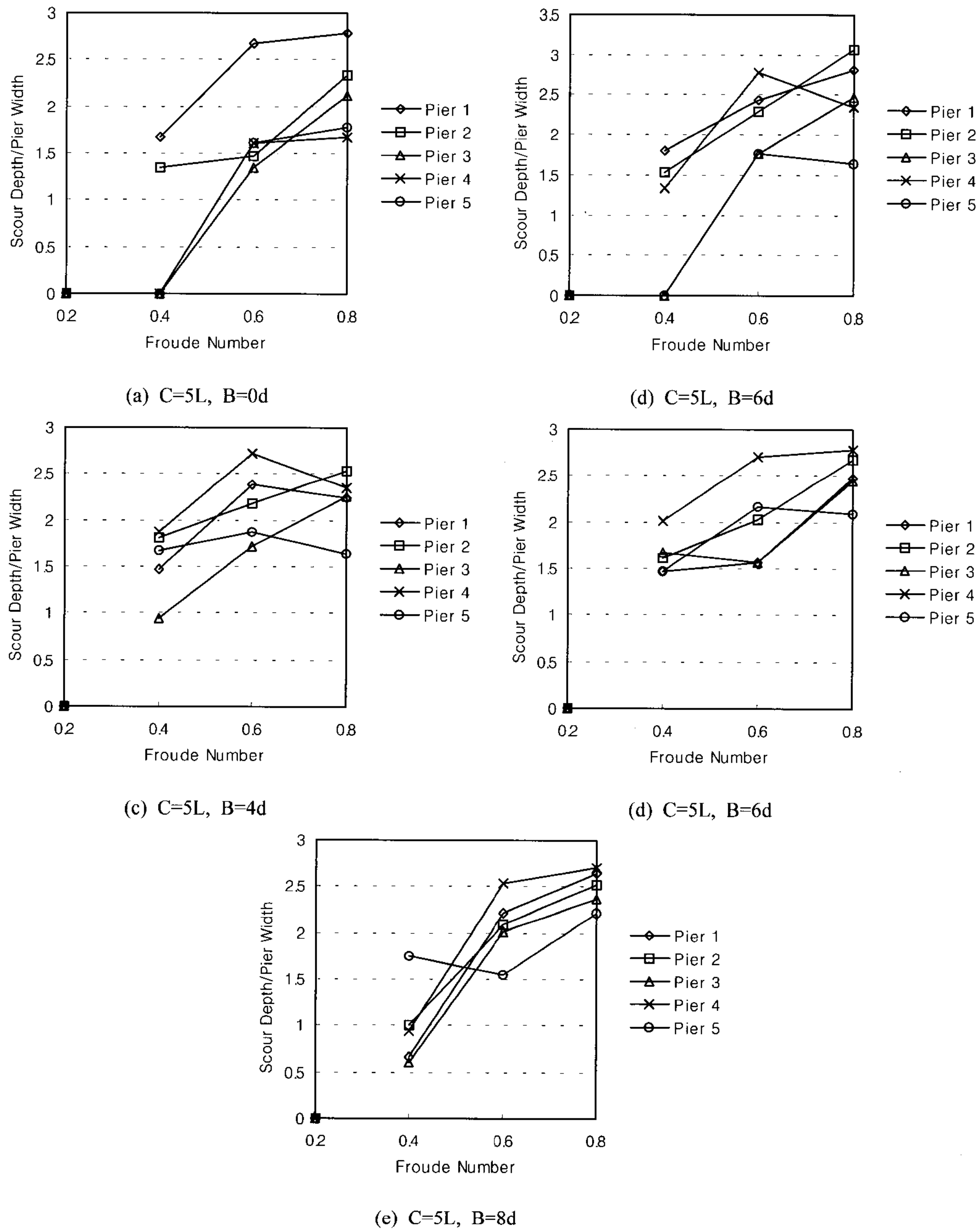


Fig. 1. Installation of the Experimental Piers in the Flume

3. ANALYSIS OF THE EXPERIMENTAL DATA

About 100 figures for analyzing the increment of the scour by constructing a new pier between bridge piers were obtained. Fig. 2 indicates the maximum scour depth change of the five piers by increasing Froude Numbers. A new pier was installed with the distance of 5 times as much as the pier length



(a) C=5L, B=0d

(d) C=5L, B=6d

(c) C=5L, B=4d

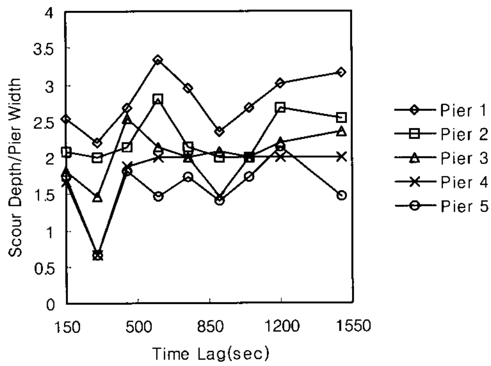
(d) C=5L, B=6d

(e) C=5L, B=8d

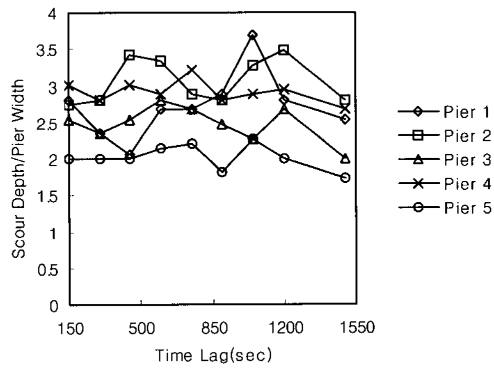
Fig. 2. Maximum Scour Depth Indication by Distortion Widths and Froude Numbers

and with the distortion width of 0d ~ 8d with the flow direction. As shown in the Fig. 2(a), when distortion width is not existed, the maximum scour is occurred in the Pier No. 1, which is installed in the upper position. However, as shown in the Fig. 2(b) ~ Fig. 2(e), when the distortion width is exists, the maximum scour is occurred in the piers, which is installed in the lower position.

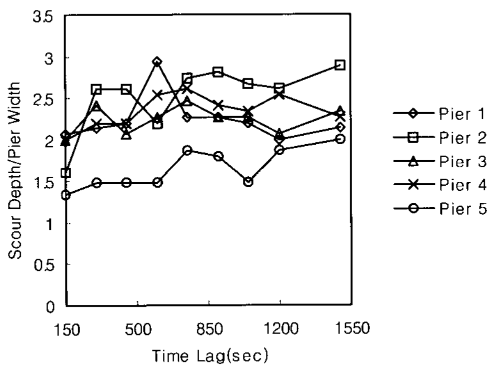
Fig. 3 indicates the maximum scour depth



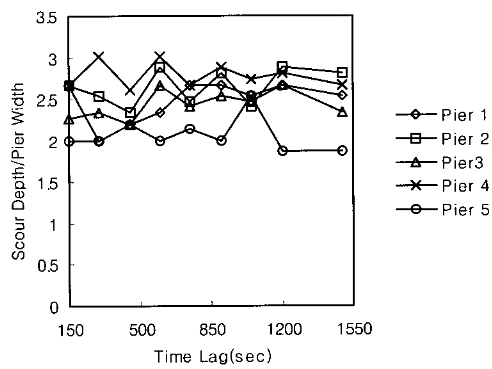
(a) C=5L, B=0d



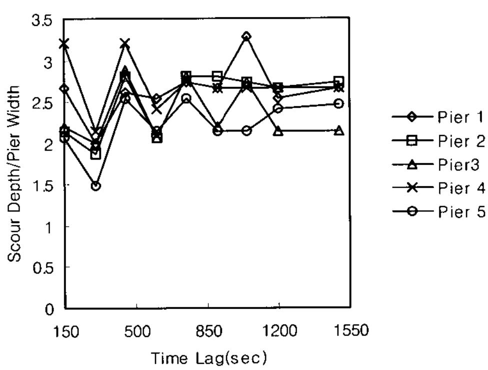
(b) C=5L, B=2d



(c) C=5L, B=4d



(d) C=5L, B=6d

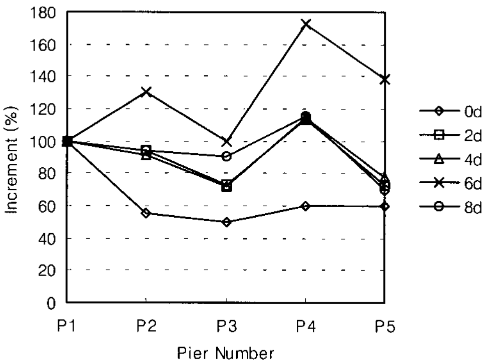


(e) C=5L, B=8d

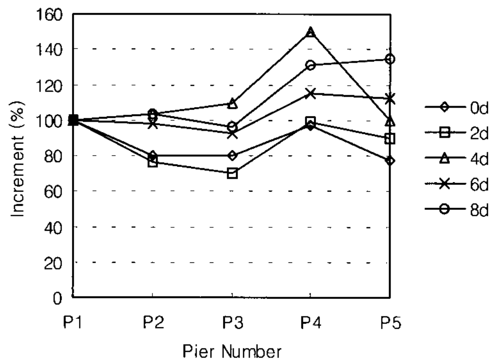
Fig. 3. Maximum Scour Depth Variation by Increasing Time

change by increasing time in Froude number of 0.8. The piers are installed with 5 times as much as the pier length and the distortion width between bridge piers is 0~8 times as much as the pier width.

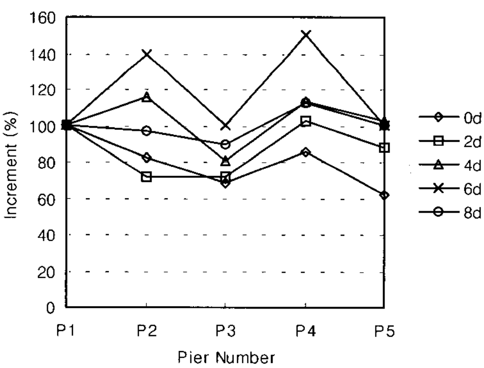
As shown in the figures, the maximum scour depth is varied by changing time. Also, Fig. 3(a) shows that the maximum scour depth is usually indicated in the upper pier to the flow direction when distortion width is not



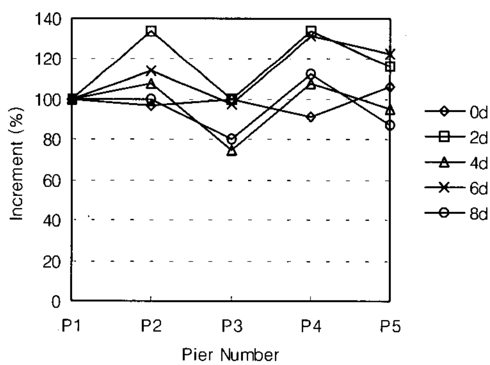
(a) C=5L, Fr=0.6



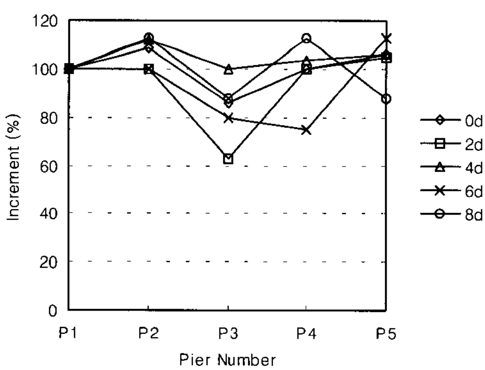
(b) C=10L, Fr=0.6



(c) C=15L, Fr=0.6



(d) C=20L, Fr=0.6

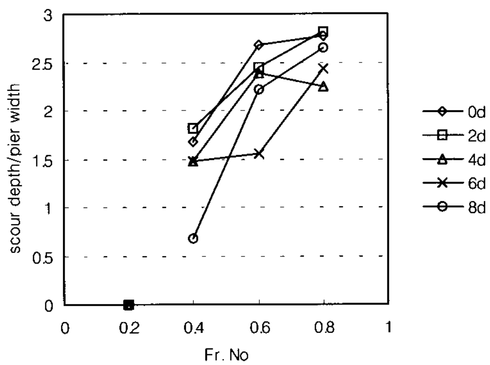


(e) C=25L, Fr=0.6

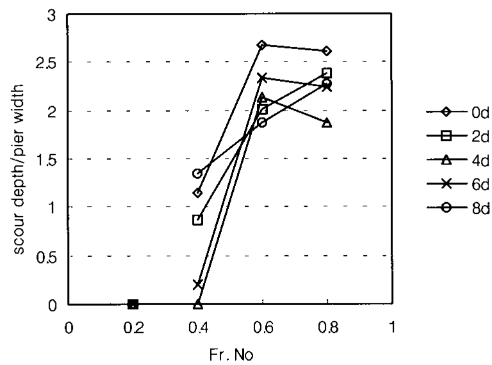
Fig. 4. Scour Depth Increment Rate by Increasing Pier Numbers

existed. However, as shown in the Fig. 3(b) ~ Fig. 3(e), when the distortion width is increased from 2d to 8d, the maximum scour is occurred in the pier which is installed in the lower position. The scour patterns in the Fig. 3 is changed by the distortion width even through the maximum scour depth is not severely changed.

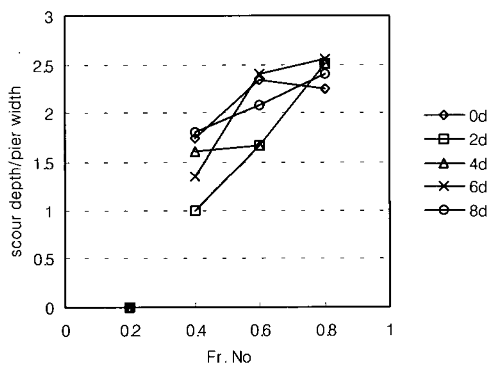
Fig. 4 indicates the scour depth increment rate compared to the individual pier in case



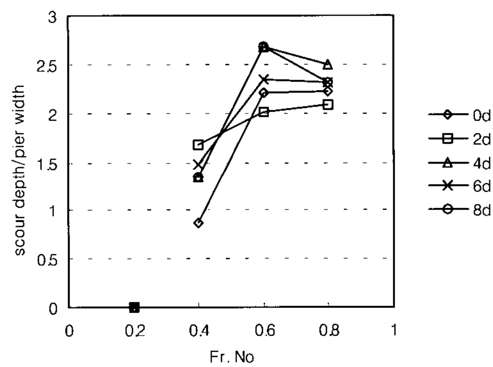
(a) C=5L, Pier No.1



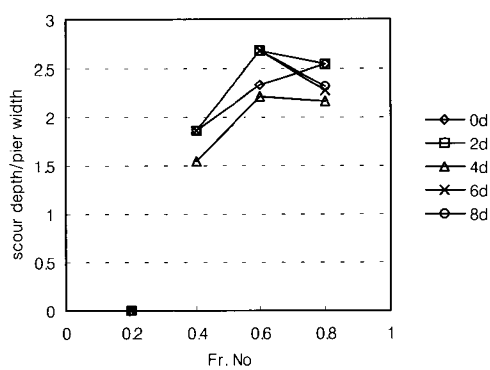
(b) C=10L, Pier No.1



(c) C=15L, Pier No.1



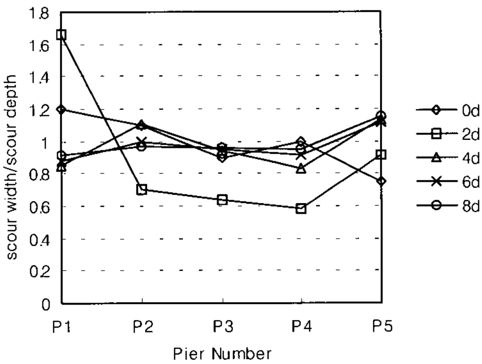
(d) C=20L, Pier No.1



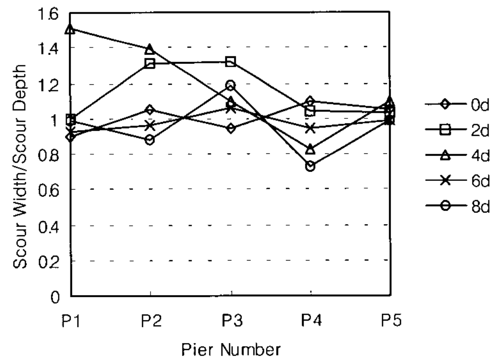
(e) C=25L, Pier No.1

Fig. 5. Maximum Scour Depth Change by Changing Froude Numbers

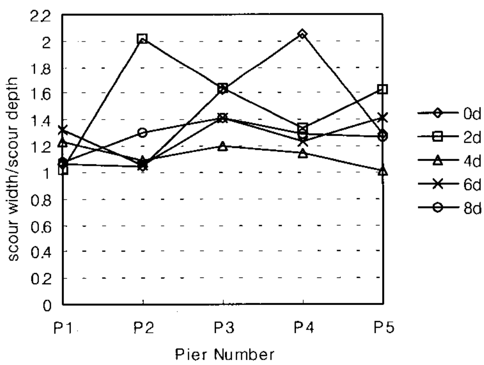
the interaction distance between bridge piers in Froude number of 0.6 exists. The distance between bridge piers which is given as 5~25 times as much as the pier length. In the Fig. 4, "d" indicates the pier width and 0d, 2d, 4d, 6d, 8d are the distortion widths between bridge piers. The increment rate was given by the maximum scour depth increment rate compared to the maximum scour depth in a single pier. From the Fig. 4(a), about 60%



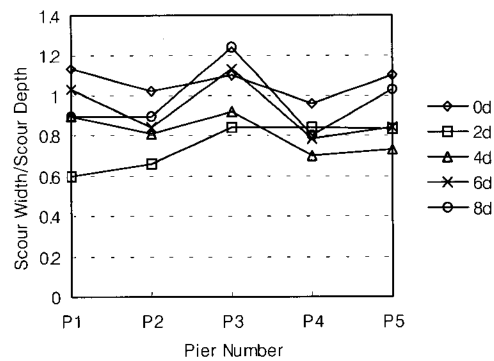
(a) C=5L, Fr=0.6



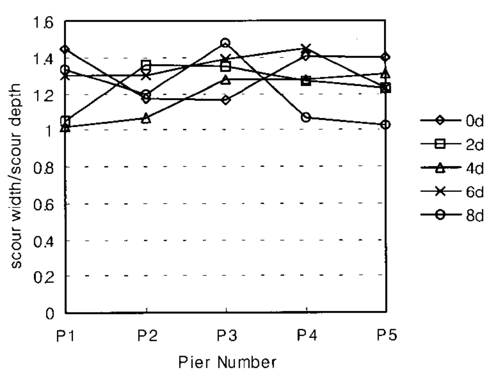
(b) C=10L, Fr=0.6



(c) C=15L, Fr=0.6



(d) C=20L, Fr=0.6

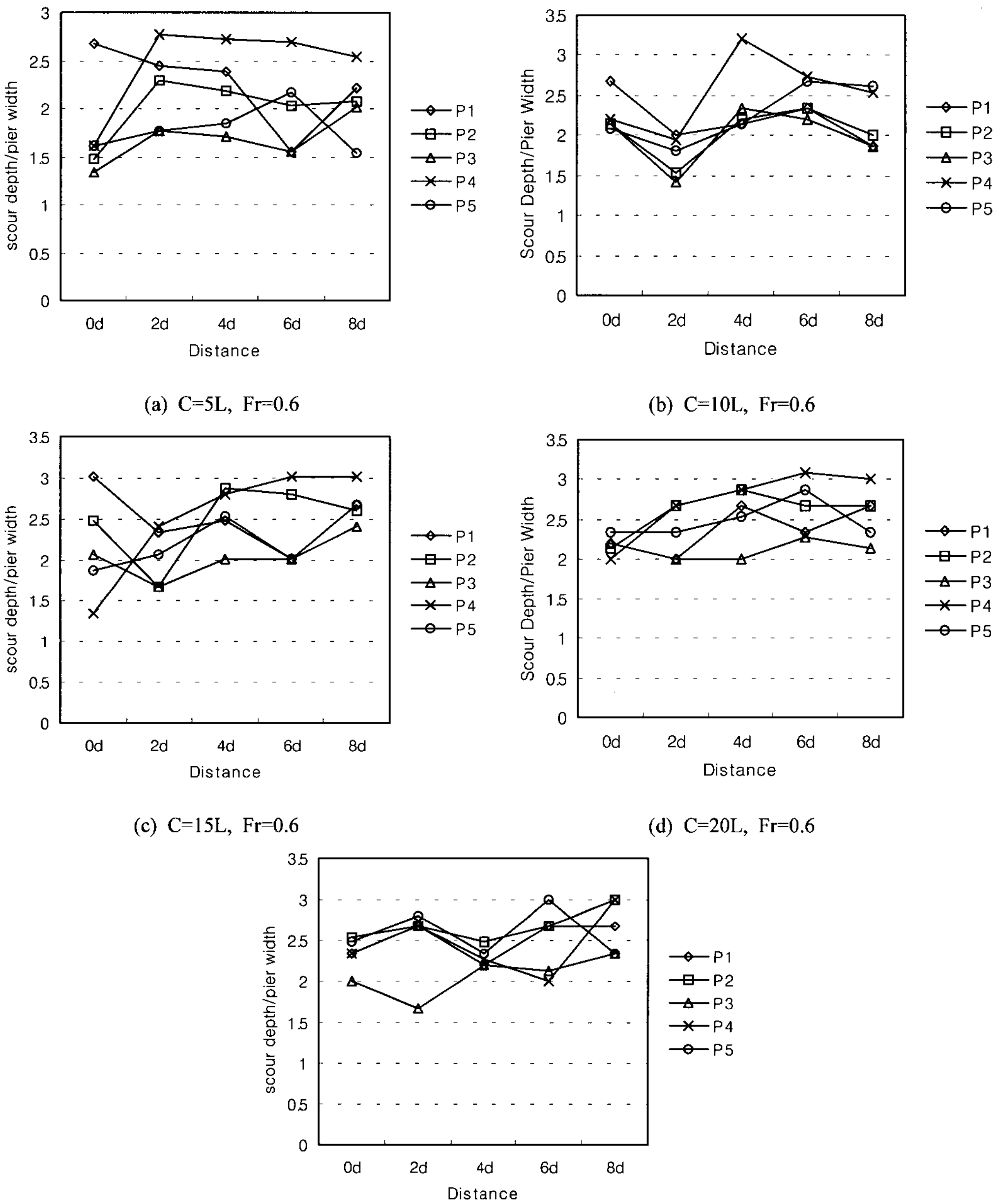


(e) C=25L, Fr=0.6

Fig. 6. Maximum Scour Width Variation by Changing the Distance Between Bridge Piers

maximum scour depth increment rate is obtained at Pier No. 4. Also, from the Fig. 4(b) and Fig. 4(c), about 50% maximum scour depth increment rate is obtained at Pier No. 4.

However, Fig. 4(d) shows that the scour depth increment rate is obtained at Pier No. 2 with the increment rate of maximum 33%. In the Fig. 4(e), the maximum scour depth increment rate is given at Pier No. 2, with the scour depth increment rate of maximum 13%.



(a) C=5L, Fr=0.6

(b) C=10L, Fr=0.6

(c) C=15L, Fr=0.6

(d) C=20L, Fr=0.6

(e) C=25L, Fr=0.6

Fig. 7. Maximum Scour Depth Variation by Changing the Distortion Rate

Fig. 4 indicates the maximum scour depth is usually occurred in the distorted piers rather than in the piers in the straight line.

Fig. 5 indicates the maximum scour depth change by changing Froude numbers. The maximum scour depths were obtained from the Pier No. 1.

The scour depths are usually increased by increasing Froude numbers even though the increment of the maximum scour depths is very small in the high Froude numbers.

The maximum scour depths compared to the pier width does not exceed 3.0 even though the maximum scour depth is occurred in the different piers by changing the distance between bridge piers.

The distance between bridge piers is changed from 5L to 25L. The maximum scour depths were usually obtained from the distorted piers which are Pier No. 2 and Pier No. 4.

Fig. 6 shows the maximum scour width variation by changing the distance between bridge piers. The experiment were conducted in the condition of Froude number of 0.6.

The distance between bridge piers were changed from 5L to 25L. The maximum scour width compared to the maximum scour depth does not exceed 2.1 in the every experiments. However, the common values does not exceed 1.6 as shown from Fig. 6(a), (b), (d), (e). The maximum pier width to the maximum pier depth is indicated in the different piers by changing the distance between bridge piers.

Fig. 7 shows the maximum scour depth variation by changing the distortion rate in Froude number of 0.6. The distance between bridge piers is 5~25 times as much as the length of the bridge pier. From the Fig. 7 it is indicated the maximum scour depth is occurred at the distorted piers. Fig. 7(a) and Fig. 7(b) show the maximum scour depth is occurred at the distorted piers and the scour depth is decreased by increasing the distortion width when the distance between bridge piers is relatively short(C=5L, 10L).

In the Fig. 7(c) ~ Fig. 7(e), it is indicated the maximum scour depth is occurred at the distorted piers and the scour depth is increased by increasing the distortion width when the distance between bridge piers is relatively long(C=15L, 20L, 25L).

4. CONCLUSIONS

To find out the influence of the local scour from configuration change by interaction between bridge piers, 100 experiments were conducted. The experimental conditions are obtained based upon the variations of the distance between bridge piers, the distortion width between adjacent bridge piers and Froude number. The distance between bridge piers of 5L to 25L in the longitudinal direction and the distortion width of 0d to 8d in the cross sectional direction were utilized. In the experiment, L and d indicate the length and the width of the bridge pier. In this paper, the following conclusions were obtained based upon the analysis of the results of the experiments.

First, the bed configuration of a pier, when the interaction between bridge piers exists, is severely affected by that of the other piers and the maximum local scour depth is influenced by the bed configuration change.

Second, when the interaction between bridge piers exists, the maximum scour depth is increased by about 60% compared to that in the case of a single pier. However, the increasing rate is changed depending upon the distance between bridge piers in the longitudinal direction and the distorted width between adjacent bridge piers in the cross sectional direction.

Third, in the low flow, which can be characterized as the flow having the low Froude number, the maximum scour depth is obtained when the piers are installed in the straight line in the flow direction. However, by increasing Froude number, the maximum scour depth is obtained when the piers are installed with some distortion in the flow direction.

Fourth, it can be inferred that the existing equations to predict the maximum scour depth at bridge piers should be changed when the interaction between bridge piers exists.

Fifth, the ratio between the maximum scour width and the maximum scour depth is varied if the interaction between bridge piers exists.

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