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Impact of the Number of Non-Submerged Piles and Their Distance from the Edge of Flow Path in Reducing the Scour at Bridge Abutment

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ABSTRACT

Scour around hydraulic structures is an inevitable phenomenon. Recognizing this phenomenon and dealing with it is an issue upon which the plan's success is warranted. Local scour at the abutments is reported as the most significant cause of bridge failures. Utilizing submerged and non-submerged piles are one of the scour countermeasure methods. Non-submerged piles are rarely used in investigating the amount of scour. In the present study, the results obtained from a series of tests performed with diverse flow rates and different number of piles (6 and 7 numbers), (non-submerged ones) with different locating distance (5 types), at the bridge lateral abutment, is presented. The tests have been carried out in clear water conditions and in a flume with 14 meters length, 60 centimetres wide, and 60 centimetres height. The findings show that the number of piles and their locating distance from the wall have great influence on the reduction of abutment scour.

Key words: Local scour, Bridge lateral abutment, Non-submerged pile, River engineering

INTRODUCTION

Bridge abutment cause contraction in the river channel and deflect the path of flow. Because of single-span in the river, high concentration of velocities, bed shear stresses, vortices, and turbulence occur in the upstream abutment nose (Melville, 1992). These entire factors lead to erosion of materials around the abutment and expansion of a ravine hole. Protecting the abutments from local scour is one of the requirements in designing structures built in rivers. According to laboratory studies, stress concentration area corresponds to a region where the maximum scour occurs (Beheshti & Ataee ahtiani, 2008). In order to prevent from and reduce the scour around the bridge abutment, researchers offer different methods among which revetment, submerged vanes, protective piles (Pourhadi & Godsian, 2002), slit, (Aghakhani & Maghrebi, 2010), and collar are the most important ones. Utilization of piles as a tool to reduce local scour around bridge abutments has long been considered. The basic idea is to use pile, deflect the flow from around the abutment, and reduce the velocity of flow and intensity of scour. (Beheshti & Ataee Ashtiani, 2004) Designers need to be aware of maximum scour depth, and also the geometry and shape of a scour hole to immunize structure against failure. Local scour reduction around these types of structures is therefore so significant issue, as a standpoint, for designers (Pirayesh & Saneie, 2011).

In the above test, there is no vertical motion of bed materials in upstream flume, and so it is categorized into the clear water scour classification. (Arounaghi & Farsadi zade, 2009) Most bridges in Taiwan are built across the river, so the stability of the bridge foundation is an important issue.

As the bridge is burst, it may cause the damage for the human life, the interruption of the traffic, and the economic loss. When the typhoon invades, the bridge foundation may be scouring and cause the bridge collapse. Therefore, the bridge foundation scour depth can be applied to judge whether the bridge is in danger or not. However, it is difficult to measure the bridge foundation scour depth directly because most bridge foundations in Taiwan are under water, especially when the floods come. A field experiment was performed in this thesis. By measuring the frequencies of the Sih-tsau Bridge, the random decrement method, Fast Fourier Transform method, and the Ibrahim time domain method is applied to identify the true natural frequency of the bridge (Karami & ardeshiri, 2010). Failure of bridges due to local scour has motivated many investigators to explore the causes of scouring and to predict the maximum scour depth at the abutments. In this paper, a detailed review of the up-to-date work on scour at the abutments is presented including all possible aspects, such as flow field, scouring process, parameters affecting scour depth, time-variation of scour and scour depth estimation formulae.

MATERIALS AND METHODS

The tests were carried out in a flume with 14m length, 0.6m width, 0.6m height, and 0.001 longitudinal slopes.

In general, a layer of sand with 30cm thickness and average diameter of 0.9 mm, and its level, in all tests, were aligned with the bottom of the flume. The tests were all carried out under critical conditions. The bridge abutment is made from wood with 20 cm length and 10cm width. The piles are made from iron in cylindrical form with a diameter of 0.6cm where axis-to-axis distance of piles is 1cm. In order to locate 6 to 7 piles appropriately in the flume's bed, a template with the same properties placed at 90 angles to the flume's wall was utilized. In all tests, abutments and piles were non-submerged. A pump with maximum 40 lit/s flow rate was applied in upstream of the flume. Flow rate control, (Fig 1), is performed using a triangular weir in downstream of the flume.

As (Fig 2) shows, to adjust the depth of water over the bed a hatch (tail-water), was used at the end of the flume. (Fig 3) To measure the profile of the bed, a device called a profile indicating which is capable of longitudinal and transverse mobility was utilized at the end of each test. (Fig 4) shows the shape of abutment and piles applied in the flume. As the water inlet pipe enters into the flume directly from the pump, there was a large inflow turbulence which negatively impacted proceeding of the tests. For the purpose of reducing the flow turbulence at depth, a perforated metal plate was placed in front of the entrance to provide a smoother transition. In addition, to reduce the turbulence in the flow polystyrene sheets were applied, providing smoother transition.

Figure.1 The triangular weir to measure the flow rate (Source: author)

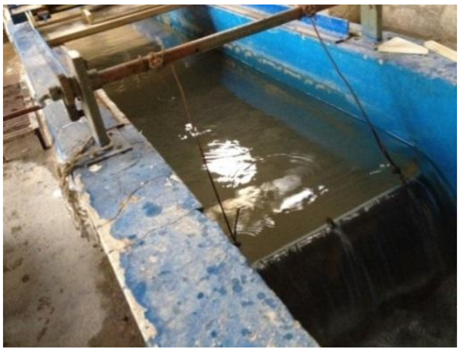


Figure.2 The tail-water to adjust the downstream depth (Source: author)

Figure.3 The profile indicator to measure changes in bed depth (Source: author)

Figure.4 The abutment and piles (Source: author)

To determine the test duration, a balance test was carried just to the abutment out for 240 minutes, in which the maximum scour depth reached a constant value (ds).Finally it was determined that if the test takes two hours, at least 90 percent of maximum scour depth would occur, (Fig 5).

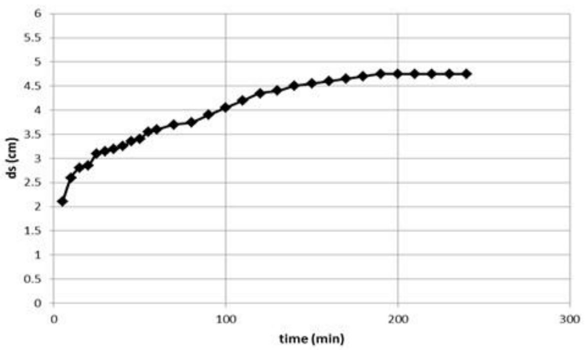


Figure.5 Balance test diagram (Source: author)

Before each test, a trowel was used to smooth the bed at all critical areas. Doing so, the bottom of the bed was considered as the basis. Then, without turning on the pump, water flow firstly entered into the flume, and next the depth control hatches adjusted in a way to increase the height of water over the bed to the extent that by turning on the pump for the intended time necessary for adjusting the flow rate, bed materials turbulence, caused by high shear stress, does not occur. After that water covered the bed across the flume, the pump was operated and the intended flow rate was reached by opening the valve gradually. After each test during a read of topography, the pump was turned off and the depth control hatches rolled up letting water drain without causing any damage to scour hole, resulting in error in the test. At the end, as (Fig 3) shows, bed varieties were read using profile indicator. The view presented in (Fig 6), reveals how piles, type I to V in turn from left to right, are located in front of the abutment in the flume. In order to read the bed varieties by using a profile indicator, the device was first calibrated so as its blade tip is located at a constant distance from the intended location and error percentage caused by it decreases. Then, more varieties were read by moving the profile indicator in longitudinal and transverse directions. After the data were gathered, Surfer 10.0 was utilized to analyze and trace the bed's profile, and calculating the volume of scouring (v), (Fig 7). During the tests, the stages of scour phenomenon happening, including early, development, consolidation, and balance condition, and the dependency of local scour to time were observed.

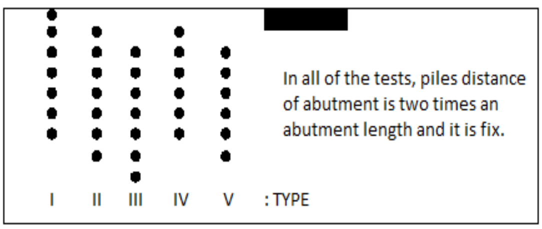


Figure.6 A view of locating abutment and piles (Source: author)

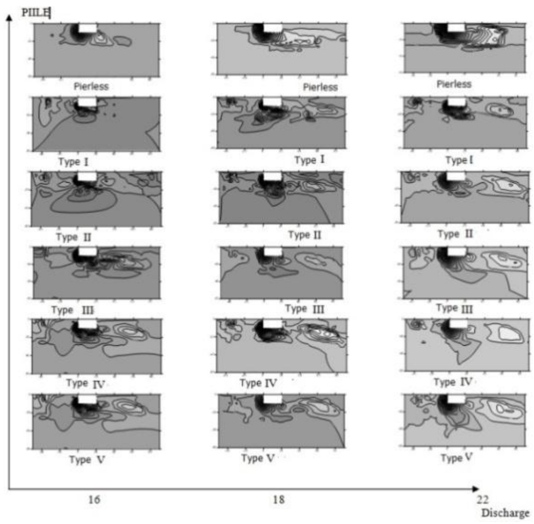
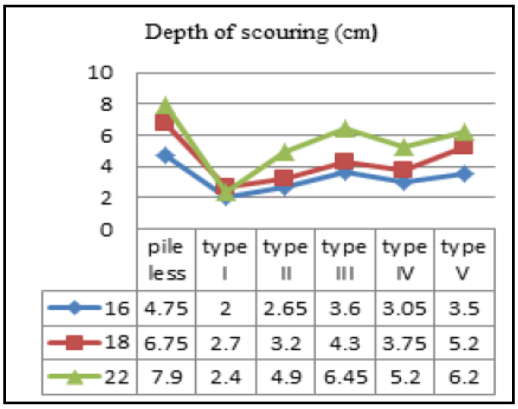


Figure.7 The bed profiles of experiments 1 to 18. (Source: author)

RESULTS AND DISCUSSION

Two different types of tests, which are the change in flow rate and the change in the number of piles and their distance to the side of flow path, have been performed. The experiment was carried out in a way that at the first abutment was tested for three different inflow rates (16, 18, 22) entering the flume. Then, the coordination of its hole was measured and recorded. Next, by locating 6 and 7 different types (5 types) of piles with a distance two times an abutment length at the upstream of it, the test was repeated again. The characteristics of all experiments are presented in (Table 1). In the experiments, it was observed that preliminary scour has progressed very rapidly, and some 60 percent of maximum scour depth occurs about 20 minutes after beginning of the test; however, over the time, the progress rate slows down. At the beginning, scour initiated from upstream corner of the edge parallel to the flow and then gradually progressed to the downstream. The flow rate has a direct impact on the dimensions of scour hole and sedimentation, and by flow rate reduction, scour was separated from the wall of the flume at the upstream and the duration of sedimentation decreased. There was not any sediment motion except around the abutment. In addition, the volumes of scour hole and of sediment mound were in excellent balance with a very minor difference. Finally, by locating piles with a distance two times an abutment length, and also by changing the number of and the locating distance of piles to flume sides, the bed profile was taken and the maximum scour depth and volume of scour, obtained in the experiments, were compared. Finally, it was seen that pile has considerable impact on reducing the volume and the maximum scour depth. In addition, when 7 piles are located in a row without distance from the sides of flow path, the highest reduction in the maximum scour depth and the volume of scour occurs type I. As can be observed, the amounts of maximum scour depth and volume reduction in types II and IV are within a same range, less than type I. The highest amount of reduction in maximum scour depth and volume is seen in types III and V. In the diagrams illustrated in (Fig 8), the maximum scour depth and volume are presented given the different types of piles positioning. In (Fig 9), the reduction percent of maximum scour depth and volume in different types of piles positioning from the abutment is presented. As it is seen, the maximum reduction percent is related to type I, that occurred inflow rate of 22 (lit/s).



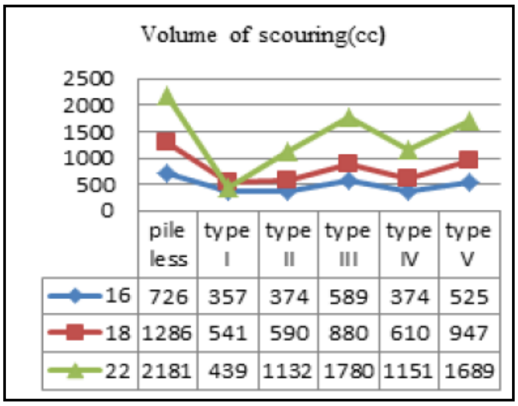
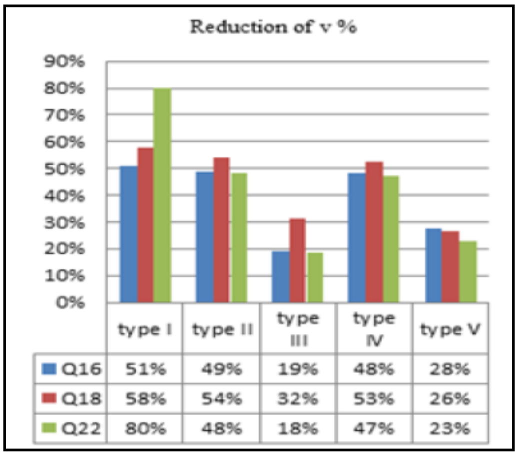


Figure.8 The diagram of maximum scour depth and volume given different types of pile positioning (Source: author)



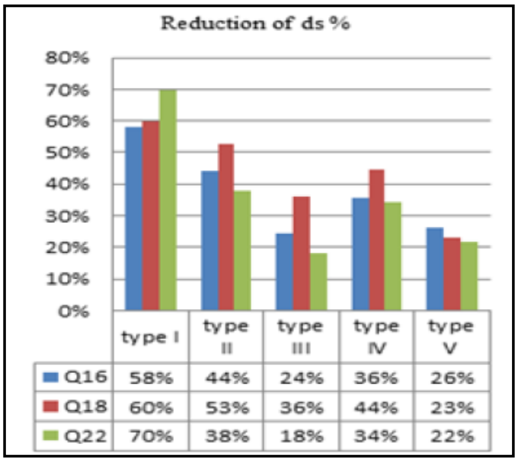


Figure.9 The diagram of reduction percent of maximum scour depth and volume given different types of piles positioning (Source: author)

Table.1 Characteristics of the experiments

Piles Arrangement	Flume's water Flow Rate (Lit/s)	Flow Depth (Cm)	Number of Test
Pile less	16	9.5	1
Seven-pile in a row (type I)	16	9.5	2
Seven-pile with one-pile distance from the side in a row (Type II)	16	9.5	3
Seven-pile with two-pile distance from the side in a row (Type III)	16	9.5	4
Six-pile with one-pile distance from the side in a row (Type IV)	16	9.5	5
Seven-pile with two-pile distance from the side in a row (Type V)	16	9.5	6
Pile less	18	10.5	7
Type I	18	10.5	8
Type II	18	10.5	9
Type III	18	10.5	10
Type IV	18	10.5	11
Type V	18	10.5	12
Pile less	22	12	13
Type I	22	12	14
Type II	22	12	15
Type III	22	12	16
Type IV	22	12	17
Type V	22	12	18

CONCLUSIONS

The experiments showed that the highest reduction in the maximum scour depth and volume occurs when 7 piles with no distance from the side of flow route are used. By increasing the flow rate, reduction percent of the maximum scour depth and volume increases. Using piles result in scour volume reduction from 18% to 80% as well as a maximum scour depth reduction from 18% to 70%. The more values are related to type I in which 7 piles are used in linear form and without distance from the side of flow path. The lower values are related to type III where 7 piles with a two-pile diameter distance from the side of the canal are used. It is so because by moving away from the wall of flow path, water velocity increases in the empty space created, and causes more disturbance flow pattern and increases the amount of scour. This is clearly seen in type V, which in comparison with type IV with one pier diameter distance from the side, has increased the amount of scour.

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