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EXTENDED ABSTRACT

Comparison of Linear and Triangular Arrangements of Submerged Sacrificial Piles on Local Scour Depth around Cylindrical Bridge Piers

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Introduction

The control of local scour around the piers and bridge abutments has been recognized as an issue of considerable importance due to the structural damage of bridges. Many methods have been already proposed by several researchers to tackle this problem, including methods that change the pattern of flow around the piers, such as sacrificial piles (Melville and Hadfield, 1999; Chabert and Engeldinger, 1956), Submerged vanes (Lauchlan, 1999; Grimaldi et al., 2009a), Slot (Chiew, 1992; Grimaldi et al., 2009b), and collars (Zarrati et al., 2006; Alabi, 2006). In addition to the above methods, other methods have been developed to protect the bed against the scour, including the use of riprap around the pier (Parola, 1993; Graziano et al., 1990), sandy bags, gabions, and geotextiles. The sacrificial piles are, indeed, the piers with smaller diameters than the bridge piers, which divert the flow from the bridge pier leading to the reduction of the scour potential. The efficiency of the sacrificial piles in controlling the scour depends on the number and diameter of the piles, the degree of submergence, the arrangement, their relative placement against the piers, the distance between the piles, the distance between the piles and the piers as well as their angles to the flow (Melville and Hadfield, 1999). According to these methods, many studies have been carried out on the effect of the sacrificial piles in reducing the bridge piers scour. However, the use of submerged piles with different degrees of submergence has been less considered. Since the length of sacrificial piles has an effect on the degree of submergence, the length of the sacrificial piles is effective in scouring, as well. In effect, the present study focuses on the scouring around bridge piers by using 2 different arrangements with and without using the sacrificial pile groups at the upstream of the pier.

Methodology

Experiments were conducted in a 0.4 m wide, 0.5 m deep, and 15 m long, concrete flume with the slope of 0.001. The working section, in which piers were located, was 2 m long with a recess on the bed 0.16 m deep and was situated 8 m downstream from the entrance of the flume. The recess was filled with uniform sediment with a diameter of 0.75 mm, and the geometric standard deviation of particles was σg =1.25. Cylindrical Perspex pipes with diameter of 30 mm were used as pier models. Pier diameters were selected so that the effect of flume sidewalls and sediment size on the depth of scour hole became negligible (Raudkivi and Ettema, 1983). The tests showed that with a flow depth of 0.12 m and a flow rate of 0.015 m^3 / s, the bed material would be at incipient motion condition. The ratio of shear velocity in these experiments to the critical shear velocity calculated from Shields' diagram was about 0.91. A laser meter with 1 mm accuracy was used to measure the depth of the scour. The sacrificial pile group was used around the bridge pier by using 2 different conditions with and without submergence at the upstream of the pier. The arrangement of the pile groups is 5 in triangular and 3 in linear patterns. The sacrificial pile groups were studied in different L/y equal to 0.4, 0.6, 0.8 and 1. The distance of the piles from the pier equals 2D and the distance between the piles equals D. Besides, the diameter of the piles was equal to D / 6 and 0.5 cm. In a triangular arrangement, five piles were placed in the form of a triangle with an angle of 30 degrees in front of the pier. In this model, the distance between the piles equals the pier diameter and the distance between the center of the piles from the pier equals 2.5 D and the angle of flow with the center of the piles equals zero. The experiments were carried out until the rate of scouring was negligible. In order to obtain the equilibrium time, a test was performed for 300 minutes in the specified conditions without the presence of the sacrificial pile on a single pier and the scouring changes were recorded. The recorded data showed that more than 90% of the scourging depth occurred in the first three hours of the experiment, and then the scouring changes were considered negligible compared to the time. Therefore, the tests were performed at the duration of three hours.

Results and Discusspn

Scouring non submergence sacrificial pile group

The results showed that in both arrangements (pile groups of 5 in triangular and 3 in linear pattern), the sacrificial piles deviated from the flow approaching the pier, reduced the intensity of the flow and, therefore, reduced the scour around the pier. Moreover, the triangular arrangement of the piles deviated the flow to a greater extent, and the scour depth was, thus, much lower than the linear arrangement. In the triangular arrangement of the sacrificial piles, the scour value decreased by 49%, while in the case of linear piles the scour reduction rate was 33.8%.

Scouring in a Submerged Sacrificial Piles with triangular arrangement

It is observed that increasing the ratio of L / y with a more deviation of the flow around the pier had a significant effect on decreasing the pier scour. Thus, the L / y equals 8.0 when scouring decreased to a greater extent (44.6 percent).

Scouring in a Submerged Sacrificial Piles with linear pattern

The linear arrangement of the submerged sacrificial piles also reduced scouring in the main pier. However, compared with the triangular arrangement, the amount of scour reduction decreased due to the less deviation of the flow. In effect, the efficiency of the linear arrangement in reducing pier scour depends on the local scour around the piles and the amount of sediment trapped by the scouring hole around the main pier. The submerged sacrificial piles reduced the scouring around the pier, but compared with the non-submerged sacrificial piles, scouring reduced to a lesser extent. Besides, by increasing the L / y ratio of the linear sacrificial piles, the scour depth decreased around the pier. By increasing the L /y ratio, more and more vortexes resulted in more turbulence in the area of the sacrificial piles, leading to more local scour around the piles. Accordingly, the scoured sediment entry to the scoured hole around the main pier resulted in the reduction of the scour in the pier.

Conclusions

1- The sacrificial piles with deviation of the flow around the piers, especially in front of the piers, reduced scouring. With the use of a non-submergence sacrificial piles group with triangular pattern, scouring reduced to a greater degree (49 %) in comparison with the linear arrangement (33.8%).

2- Non-submerged sacrificial piles were more effective in reducing scouring than the submerged sacrificial piles in both triangular and linear arrangements.

3- Using the submerged sacrificial piles group decreased the scour around the piers. In the triangular arrangement, the scouring reduced to a greater degree which increased L/y. At L/y 0.8, the highest scour reduction was equal to 44.6%, and there was no big difference between L/y of 1 and L/y of 0.8. The scour reduction in linear arrangements with L/y of 1 was 30.8%. Therefore, the group of submerged sacrificial piles with triangular arrangement was found to have a more protective effect on the control of scouring than the linear arrangements.

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References

1- Alabi, P.D., 2006. *Time development of local scour at a bridge pier fitted with a collar*. Master Degree Thesis. University of Saskatchewan, Saskatoon, Saskatchewan, CA.

2- Chabert, J. and Engeldinger, P., 1956. *Etude des affouillements autour des piles des ponts*. Study on scour around bridge piers, Laboratoire National d'Hydraulique, Chatou, France (in French)

3- Chiew, Y.M., 1992. Scour protection at bridge piers. *Journal of Hydraulic Engineering, 118(9)*, pp. 1260–1269.

4- Graziano, F. G., Jones, J. S. and Parola, A. C., 1990. Design of riprap to protect bridge Piers from local scour. *Journal of Highway Research and Development, Public Roads, 54(2)*, pp. 193–199.

5- Grimaldi, C., Gaudio, R., Calomino, F. and Cardoso, A.H., 2009a. Control of scour at bridge piers by a downstream bed sill. *Journal of Hydraulic Engineering, 135(1)*, pp. 13–21.

6- Grimaldi, C., Gaudio, R., Calomino, F. and Cardoso, A.H., 2009b. Countermeasures against local scouring at bridge piers: Slot and combined system of slot and bed sill. *Journal of Hydraulic Engineering, 135(5)*, pp. 425–431.

7- Lauchlan, C.S., 1999. *Pier scour countermeasures*. PhD Thesis, University of Auckland, Auckland, NZ.

8- Melville, B. W. and Hadfield, A. C., 1999. Use of sacrificial piles as pier scour countermeasures. *Journal of hydraulic engineering, ASCE, 125(11).*

9- Parola, A. C., 1993. Stability of riprap at bridge piers. *Journal of Hydraulic Engineering, 119 (10)*, pp. 1080–1093.

10- Raudkivi, A.J. and Ettema, R., 1983. Clear-water scour at cylindrical piers. *Journal of Hydraulic Engineering, 109(3)*, pp. 338–350.

11- Zarrati, A.R., Nazariha, M. and Mashahir, M.B., 2006. Reduction of local scour in the vicinity of bridge pier groups using collars and riprap. *Journal of Hydraulic Engineering, 132(2)*, pp. 154–162.