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Effect of Netted Collar on Maximum Local Scouring Depth of Cubic Bridge Pile Groups

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ABSTRACT: Every year in various parts of the world a number of bridges are destroyed by flood just when we need them. Much of this destruction are due to scour around their piers. Erosion and the movement of the bed material due to the water flow say scouring. During this process, a hole is formed around piers that its depth to reach the depth of equilibrium, increases regularly. In this study a flume is used with 6 m length and width of 73 cm and bed slope near to the zero in the Hydraulic Laboratory of Shahid Chamran University of Ahvaz. In order to reduce the scour around the pile groups, a thin plate so-call "collar" was installed around the middle the pile group. The collars were simple and netted with opening of 30, 50 and 70 Percentage and were installed in three levels including: on the bed, 0.5D and 1D above the bed. The experiments were conducted under the conditions of clear water and three Froude Number equal to 0.12, 0.14 and 0.16 and the results were compared with the case of without collar mode. The results showed that simple collar installed on the bed and 70% netted collar placed at 0.5D level from the bed were reduced scour equal to 95% and 86%, respectively in compare with the non-collar piers.

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1- Introduction

According to the recorded information in different countries, the major cause of the bridges' destruction is scouring around their piers foundations. Scouring around piers occurs due to two processes: horseshoe and wake vortexes. In addition to these factors, the following factors are involved on the scouring of pile groups: reinforcing, sheltering, shed vortices and compressed horseshoe vortex [1].

Collar is a horizontal plate that is placed on the pier and changes the pattern of the flow around the pier and consequently reduce the amount of scour [2]. Zarrati et al. (2006) by placing simple and independent collars on a dual rectangular pile group and combining it with rip-rap reduced 50% of the scouring depth [3]. Alem (1391) using a 33% netted collar on laboratory bridge abutment at the 2 cm and 4 cm above the bed reduced scouring compared to the simple collar about 10.4 and 9.4 percentage, respectively [4].

Due to the lack of investigation of the effect of netted collar on the bridge pier groups, in this study the effect of netted collar on the maximum scour depth of the cubic pile groups are investigated.

2- Methodology

Experiments were carried out in a flume with length of 6 m, width of 73 cm and a slope of the bed near zero at the Hydraulic Lab of Shahid Chamran University of Ahvaz. According to Chiew and Melville's advice (1987), in order to eliminate the effect of channel walls on scour depth, the diameter of the pile should not be greater than 10% of the channel width [5]. Therefore, cubic piers with the side equal to D=2.5 cm were used. The piers were located in three groups of four: the center-to-center distance of the piers of each group was equal to 4D=10 cm, and the center-to-center distance pile group from together was equal to 7.4D=18.5 cm. Also According to Chiew and Melville (1987), in order to prevent the effect of the particle size on the scour depth, the ratio of the diameter of the pier to the average diameter of the sediment particles should be more than 50 and to eliminate the effect of non-uniformity of the sediments on the reduction of scour, the standard deviation of the particles should also be less than 1.3 [5]. Therefore, the average diameter of the selected particles was 0.5 mm and the standard deviation of the particles was 1.18. Collars were made of square Plexiglas plates with side of 3D=7.5 cm and tested in four cases, simple and netted with openings of 30, 50 and 70 Percentage at the levels of D, 0.5D and on the bed surface around middle pile group. To determine the time of experiments, a test with a maximum flow rate of 22 l/s was performed without the presence of collars in long time, and over a period of 4 hours, more than 96% of scour depth occurred. So, the time of experiments was considered to be 4 hours. Table 1 shows the hydraulic conditions of the experiments.

3- Results and Discussion

3- 1- Collar placed in level D:

In this level the simple collar, due to the high elevation of the bed surface and the operation of the vortices under the collar, no reduction on the depth of scouring was shown. 30% and 50% netted collars due to openings on their surface that

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made turbulence of the boundary layer around the collar and weakening of the horseshoe vortices around the piers were reduced the maximum scour depth of the front pier about 22% and 24% respectively. The 70% netted collar, due to greater openings than other collars at the same level, succeeded in weakening the vortices created around the piers and reduced the maximum scour depth of the first pier about 49%. In Figure 1a the longitudinal profile of the scour around middle piel group is shown.

Table 1. Hydraulic conditions of the experiments

Re	Y(m)	Fr	V/V_c	V_c (m/s)	V (m/s)	Q (l/s)
30000	0.15	0.16	0.77	0.26	0.2	22
25500	0.15	0.14	0.65	0.26	0.17	19
22500	0.15	0.12	0.58	0.26	0.15	16

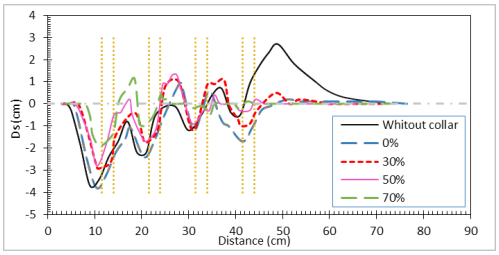
3- 2- Collar placed in level 0.5D:

In the Froude Number of 0.16 the simple collar in level D, due to the less space below the collar for the operation of vortices, the scour depth was decreased. The 50% netted collar, due to flow through its openings, reduced the pier scour about 35% similar to simple collar. The 30% netted collar at this level reduced the depth of scour about 54% due to lower vortices passing through its openings. The 70% netted collar with the full development of the boundary layer around itself had the greatest effect on reducing the depth of the first pier among the netted collars with a yield of 86%. Also other piers of this pile group showed the lowest scour depth among all experiments. Figure 1b shows the longitudinal profile of scouring. On the Froude Number of 0.14 all collars with a 56% reduction in the depth of scouring of the front pier were acted similarly. On the Froude Number of 0.12, none of the collars was effective in reducing the scour depth of the front pier, and only 70% netted collar reduced the scour depth of the first pier by 33% and the other piers of the middle pier group did not show any scouring.

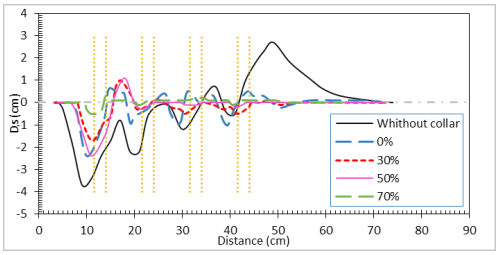
3- 3- Collar placed in bed surface:

Simple collar on the bed level showed the best performance in reducing scour depth with 95% efficiency.. In this level all collars have shown the same results close to each other and only the 50% netted collar has less efficiency than the other collars. In result the 30% netted collar is due to less flow through its openings with 84% efficiency, after the 70% netted collar in the level of 0.5D, had the greatest effect on reducing the scour depth of the first pier among netted collars. In Figure 1c the longitudinal profile of the scour of middle pier group is shown.

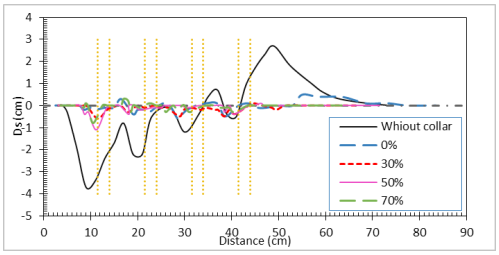
Table 2 shows the scour decreasing percentage of the first pier for collars at different levels and Froude Numbers.



(a)



(b)



(c)

Figure 1. Longitudinal profile of scour middle pile group for collars with different openings and Froude number of 0.16: (a) level D, (b) level 0.5D and (c) bed surface

Table 2. Scouring depth decreasing percentage of the first pier with the presence of collars at different levels

Scouring decrease percentage relative to the non-Collar mode			collar level	Type of collar
Froude Number				
0.12	0.14	0.16		
-	-	-3*	D	0% (Simple)
-108	56	35	0.5D	
-	-	95	0	
-	-	22	D	30%
-75	56	54	0.5D	
-	-	84	0	
-	-	24	D	50%
-83	56	35	0.5D	
-	-	70	0	
-	-	49	D	70%
33	56	86	0.5D	
-	-	78	0	

* Negative percentages show an increase in the depth of scour

4- Conclusions

Among experiments, simple collar on a bed with 95% efficiency and a 70% netted collar in level of 0.5D related to the bed surface with 86% efficiency had the greatest effect on scour depth reduction of the first pier at the Froude Number of 0.16. Unlike the other collars with a decrease in the level from 0.5D above the bed to bed surface, the 70% netted collar showed an increasing in amount of scour depth. The reason may relate to the large opening of the collar surface and, consequently a greater passage of flow from inside of the opening parts of the collar.

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