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Experimental Study on the Effect of Circular Collar on Cylindrical Bridge Pier Scour in Unsteady Flow

Y. Rajabizadeh[1], S. A. Ayyoubzadeh[1,*] , K. Qaderi[2]

[1] Depatment of Water Engineering and Management, Tarbiat Modares University, Tehran, Iran.
[2] Water Engineering Department, Shahid Bahonar University of Kerman, Kerman, Iran.

ABSTRACT: The bridge pier scour is one of the major causes of bridge destruction worldwide. Despite extensive research in this field, the study of this topic has always been of interest to researchers and it is necessary to study different methods to counter it. The collar is a simple and inexpensive structure for protection against bridge pier scour. In this study, the effect of collar size and height on bridge pier scour and determination of the best collar performance conditions in steady and unsteady flow conditions were investigated. The experiments used three different collar sizes and three different mounting heights relative to the substrate surface. After calculating the percentage of scour reduction in all test cases and comparing them, investigation of time evolution diagram of scour hole and comparison of maximum depth of scouring created in different states, It was found that increasing the size of the collar and decreasing the height of the collar installation relative to the substrate surface resulted in a further decrease in the depth of the bridge pier scour and this change was more evident in the unsteady flow state. Also by comparing the two variables of size and height of collar installation, it was found that the height of collar with dimensionless ratio H/D=0.5 in steady and unsteady flow had the best performance and the greatest effect in reduction scour around bridge pier.

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1- Introduction

There are several methods for protecting the river bed against flood that makes this important due to the weakening mechanism of vortex flows. One of the methods that reduce erosion by weakening the vortices around the structure is using a collar. The collar can block downflow upstream of the pier and greatly counteract the erosive effect of these factors [1]. Due to the practical and engineering importance of bridge protection, it is imperative to investigate various protection methods in different physical and hydraulic conditions. In the present research, the effect of size and height mounting characteristics of the collar on the scour around the bridge pier under steady and unsteady flow conditions was studied to compare the impact of the collars under these conditions and to complete previous research.

2- Methodology

The main channel had a rectangular cross-section with an internal width of 80 cm, a depth of 60 cm, a length of 8 m, and a constant floor slope equal to 0.0022. In this research, sediment with D_{50}=0.91 mm was used. The standard deviation of sedimentary particles is σ_g=1.29 and the uniformity coefficient for sediments is $Cu=D_{60}/D_{10}$=1.4. In the laboratory, on a canal bed with a constant flow rate of 34.8 liters/s, different depths of 30 to 10 cm were created without the pier, to study the movement or non-movement of bed sediment. Finally, the depth of water was 12 cm. The equilibrium time is the time when the scour changes are not more than one millimeter in three consecutive hours [2]. In the present research, the equilibrium time scour was estimated to be 34.8 lit/s for 5 hours. A stepwise hydrograph was used to create unsteady flow. In this way, an unsteady flow was created from the sum of steady flows with different discharges at specified time steps. According to Fig. 1, the peak hydrograph is considered to be equal to the steady flow rate and the shape of the hydrograph is symmetric. In this study, according to the existing laboratory conditions, hydrograph sequences were used to reduce the time steps of discharge change and more similarity to unsteady flow.

Experiments were performed using a steel cylinder pier of 3 cm in diameter. The ratio of pier diameter to flow depth should be less than 0.7 to prevent the effect of flow depth [3]. The collars used in this research were galvanized, circular, with three diameters that were considered a factor of pier bridge diameter and were designed from small to large with diameters of 2*D*, 2.5*D,* and 3*D*. The mounting heights of the collar were also investigated at three elevations 0.5*D*, 1*D,* and 2*D* above the bed surface. A calibrated depth gauge was used to measure bed changes. In these experiments, the scour properties were finally measured for the bridge pier and were plotted based on the collar type of their dimensionless diagrams.

*Corresponding author's email: ayyoub@modares.ac.ir

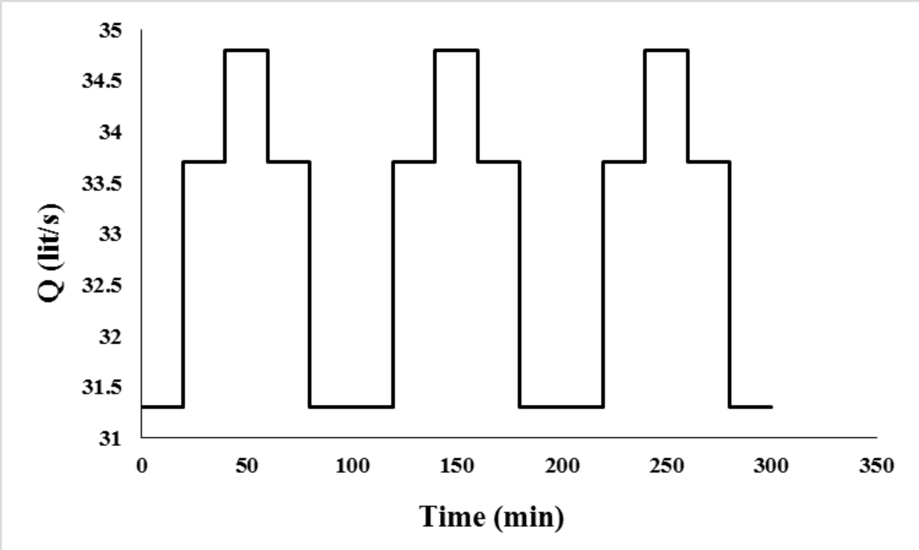

Fig. 1. The hydrograph used in the research

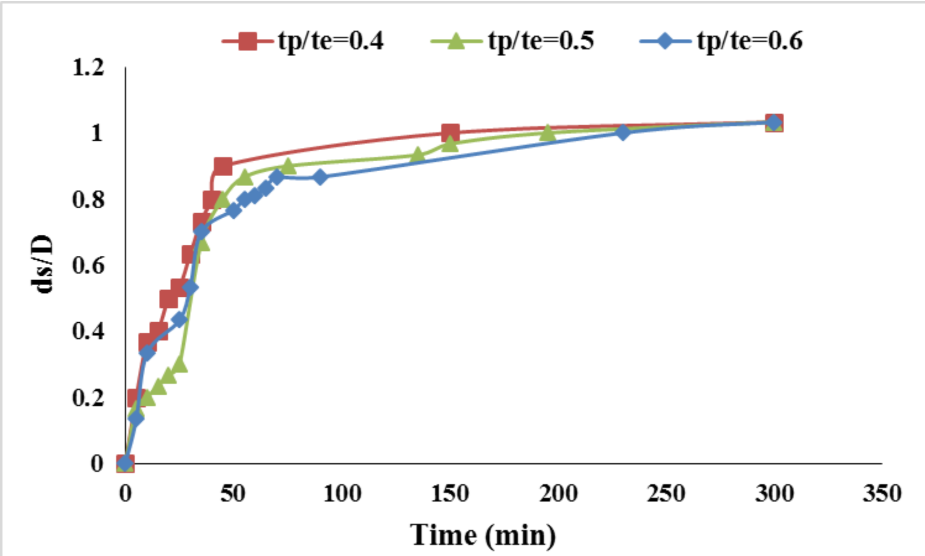

Fig. 2. Temporal development scour diagram with three different discharge peak times

3- Results and Discussion

Initially, the experiment was performed without a collar. In the first hour of the experiment, the speed of scour was higher, with more than 84% of scour occurring during this time interval. In the following hours, the development of scouring decreased less and increased slightly from the third to the fifth hour. Finally, the final scour depth in the reference experiment was 3.8 cm. Experimental was performed without a collar with the unsteady flow. Due to the shorter duration of maximum discharge than the steady flow, the maximum scour depth was reduced in this case. Compared to the steady flow, the scour depth decreased by 18%. Two other experiments were performed for unsteady reference mode with peak discharge time (*tp*) different from the original hydrograph (*tp*/*te*=0.5) to determine the effect of changing this hydrograph parameter on the scour around the bridge pier. The results showed that the scour depth in both cases is similar to the original hydrograph (3.1 cm) and the only difference in the temporal development process is the scour hole (Fig. 2).

In different sizes of the collar and at different mounting height experiments were performed using the collar, which revealed that the scour bed removal profiles were different. In 3*D* collar size and 0.5*D* installation height, it had the best performance in maximum scour reduction compared to without collar experiment in both steady and unsteady flow conditions. Results showed that in a steady flow, 3*D* collar size and 0.5*D* mount height are better suited for protection against scour around bridge pier than other modes with a

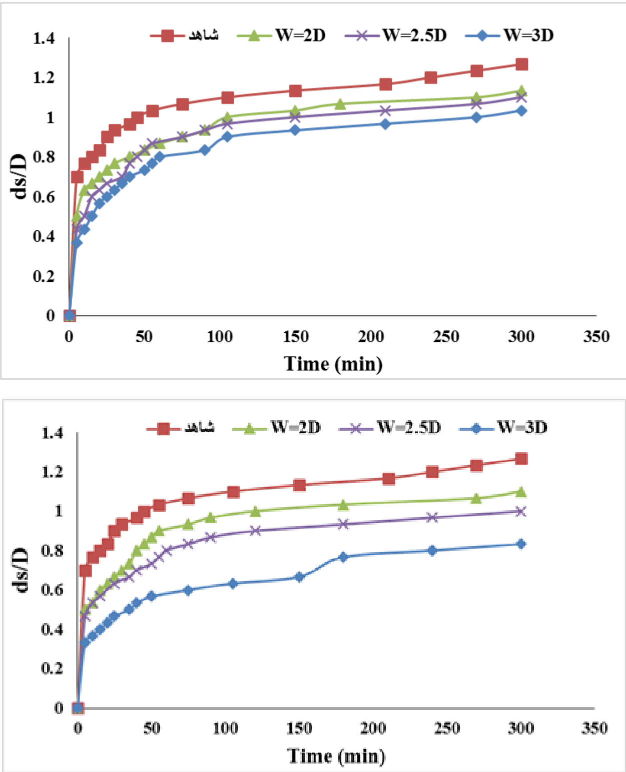

Fig. 3. Temporal development scour diagram in steady flow a) H=2D b) H=1D

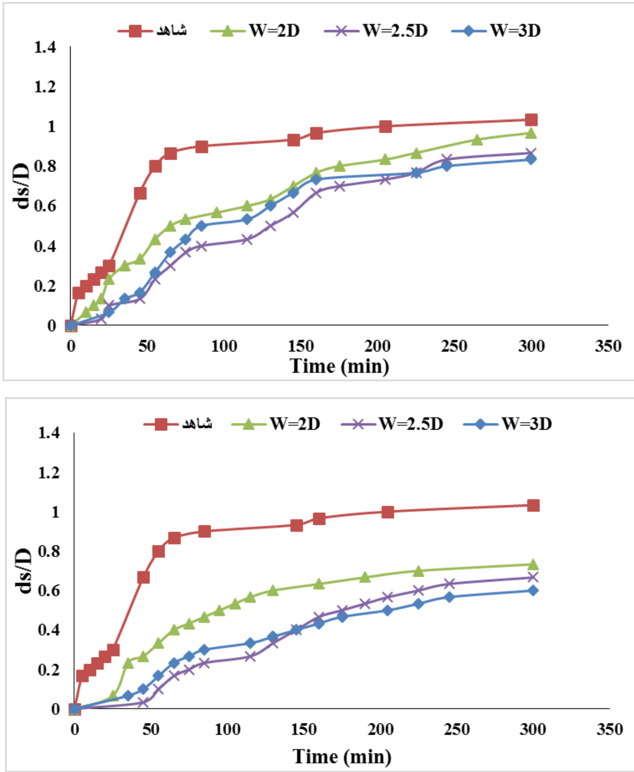

Fig. 4. Temporal development scour diagram in unsteady flow a) H=2D b) H=1D

42.10% reduction. But in unsteady flow, it had the highest percentage of possible scour reduction, 100% reduction even for the smallest collar size, size 2*D* at 0.5*D* height, compared with lower installation height at 1*D*, which decreased 41.93% of depth scour had a significant effect of the mounting height to reduce the scour around the bridge pier. Concerning comparison of two variables of size and height of collar installation, by averaging the scour depths of each variable for both steady and unsteady flows, it was found that the height of collar installation H/D=0.5 decreased 39.47% in a steady flow and 100% in unsteady flow. Percentage of unsteady flow is more effective in reduction scour depth than other variables and has the best performance. By evaluating the time development scour under Figs. 3 and 4, it was found that in both steady and unsteady flow conditions, if the collar is used, it will occur later than in reference mode and in 3*D* size collar at both installation heights (H=2D and H=1D) tested. It is more noticeable than the other collars. Also, for a fixed size of the collar and comparing the two heights of installation tested, it occurred at H=1D temporal development scour lower than the other diagrams. Therefore, the temporal development scours in collar with W=3D and H=1D. In both steady and unsteady flows, it is lower than the rest.

4- Conclusion

The results indicated that the collar generally reduced the depth of scour around the bridge pier. Also, the larger collar size and closer collar height of installation to the bed surface reduced the dimensions of the scour hole compared to the without collar one. Also, the hydrograph sequence characteristic in unsteady flow showed the most impact on the scour around the bridge pier occurs in the first sequence.

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