

Comparison of Symmetrical and Unsymmetrical Rectangular Collars on Scour Reduction of Bridge Abutment

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Abstract: Already many studies have been reported on the mechanism of scour and scour countermeasures for bridges. Most of these researches focused on bridge piers scour. The review of available literature, however, reveals that the major cause of bridge failure is due to abutment scour. Therefore it is important to conduct more research on abutment scour reduction measures. One method which has been studied on bridge pier is collar which is a thin flat plate that is installed around the piers. Since the effect of such technique is not known for bridge abutment, this research was conducted. In this study 35 experimental tests were performed to find out the effect of different dimensions of symmetrical and unsymmetrical collars placed on the bed around abutment to see how it will reduce the scour around bridge abutment. Results show that increasing dimensions of both collars will increase the efficiency of performance. By comparing the two collars it was found, when the upstream width of unsymmetrical collar was larger than its downstream width, its performance will be better than the symmetrical collar with uniform area.

Key words: Scour • Bridge abutment • Collar • Symmetrical • Unsymmetrical

INTRODUCTION

Failure of bridges because of scouring is common occurrence and each year a significant amount of money is spent to repair or reconstruct bridges which its piers and/or abutments have been failed. Because of failure experiences many researchers have worked on scour phenomena during the last decades [1, 2, 3].

Over the past decade attempts have been done to control the bridge pier or abutment scour using riprap, cable tied concrete blocks, submerged vane, slots, vane attached and collar. Among these measures which has been studied for control of scouring around the bridge pier is to install a collar around the pier. Collar diverts the down flow and protects the riverbed from its direct impact. Chiew (1992) [4] showed that, the collar has the effect of shielding the sediment particles from erosion by the down flow. Kumar *et al.*, (1999) investigated that a collar of larger diameter at or near the bed are more effective. Singh *et al.*, (2001) obtained 91% reduction of scour by using a collar-plate of twice diameter of the pier and place

at elevation 0.1D below the average bed level. Mashahir and Zarrati (2002) [5] concluded that the collar is very effective in slowing down the development of scouring around a rectangular pier based on the studies conducted with and without collar.

Since at bridge abutment the major scour is also the result of down flow velocity, using collar can decrease the scour depth too. To determine the design criteria of collar at bridge abutment, this study was conducted. In this study collar-plates of two different types of symmetrical and unsymmetrical are placed at the bed surface [6, 7]. Tests were performed on under clear-water flow conditions.

Experimental Set-up: A rectangular flume 9 m long, 1 m wide, 0.6 m height and constant slope of 0.0003, with side walls of transparent Plexiglas was used in the experiments [8]. A 2.0 m-long reach of the flume bottom was covered with sand of relative density 2.65 having median grain size D_{50} of 0.76 mm. The depth of the sediment bed layer of the test reach was fixed at 30 cm.

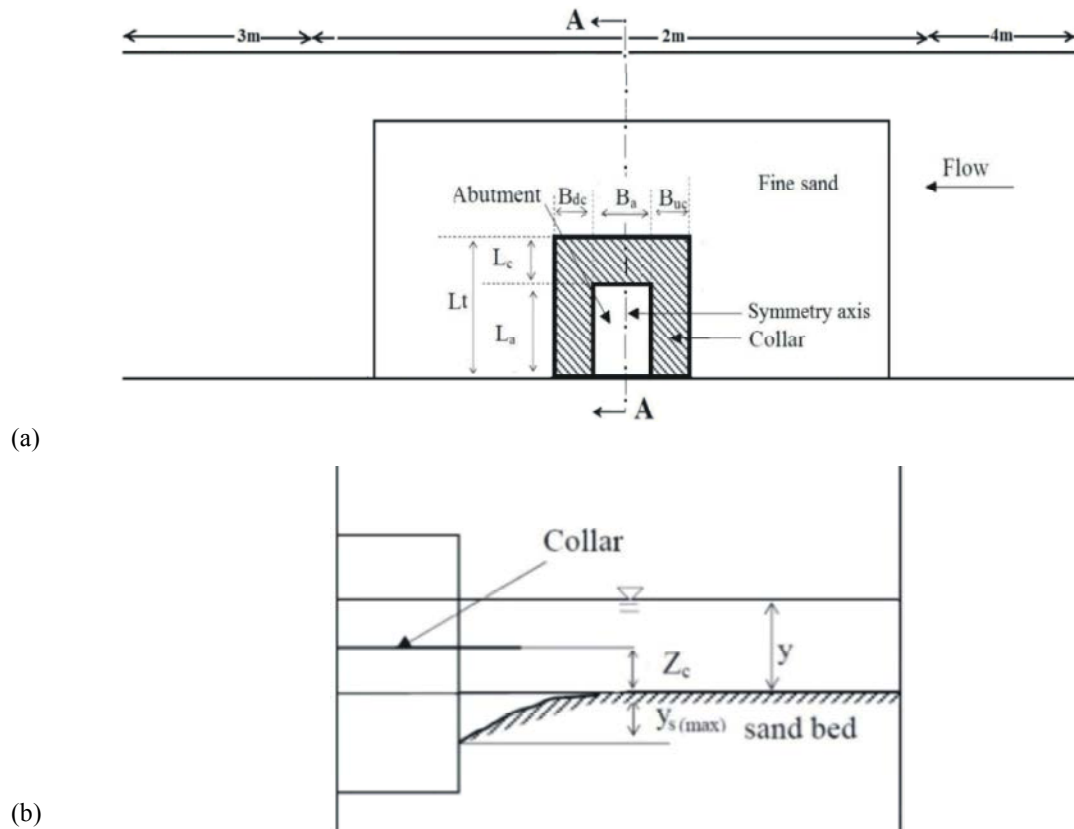


Fig. 1: Definition sketch of collar-abutment arrangement
(a) Plan view (b) Section A-A

A centrifugal pump discharges 40 L/sec water from the ground reservoir into the stilling tank at the entrance of the flume. A tail gate is used to adjust the flow depth (Y) of water in the flume. The flow discharge is measured and adjusted by using a standard 53° triangular weir which was installed at the outlet system of flume [9]. Figure 1 shows a definition sketch with a typical view of a collar-abutment arrangement used in this study.

The abutment, having the length of $L_a=0.20\text{m}$ and the width of $B_a=0.12\text{ m}$ was rectangular shape made of galvanized steel sheet and placed on the left side of the flume within the test section [10, 11]. Since the maximum scour depth occurs at the threshold condition, all experiments were conducted under clear water flow conditions, $V/V_c < 1$, where V is the main velocity of the approach flow and V_c is the value of V at the threshold. The threshold of bed material motion was found by conducting few tests when the abutment was not installed at the discharge of $0.04\text{m}^3/\text{s}$ with the corresponding flow depth of 0.15m . The ratio of V/V_c in all experimental tests

was about 0.95. After each experimental test, the scour and sedimentation pattern was measured in 2×2 mesh grids with the help of a laser distance meter that could be moved along rails fitted at the top of the flume [12]. The collar in this study was made of Plexiglas sheets with thickness of 3 mm. Two different types of collars were used in this research which including symmetrical collars and unsymmetrical collars [13, 14]. Longitudinal axis of abutment was defined as the symmetry axis of collars showed in Figure 1. The dimensions of the mentioned two types of collars are:

Symmetrical Collars: Twelve symmetrical collars were tested. The dimensions ($L_c / L_a, B_c / L_a$) of these are:

$$L_c / L_a = 0.25, 0.375, 0.5, 0.75 \text{ and } B_c / L_a = 0.25, 0.375, 0.5.$$

For ease of comparison of collars performance, they were classified in three groups:

- 1- ($L_c / L_a, 0.25$) 2- ($L_c / L_a, 0.375$) 3- ($L_c / L_a, 0.5$)

Unsymmetrical Collars: Twenty-two unsymmetrical collars were tested which showed as $(L_c / L_a, B_{dc} / L_a, B_{uc} / L_a)$ in this research.

$L_c / L_a = 0.25, 0.375, 0.5, 0.625, 0.75, 1$ and $B_{dc} / L_a = 0, 0.25, 0.5$ and $B_{uc} / L_a = 0.25, 0.5, 0.75$.

For ease of comparison of collars performance, they were classified in four groups:

1- $(L_c / L_a, 0, 0.5)$ 2- $(L_c / L_a, 0.25, 0.5)$ 3- $(L_c / L_a, 0.25, 0.75)$ 4- $(L_c / L_a, 0.5, 0.25)$

The scour hole was obtained by performing a 5-hours continuous run under clear-water condition using constant flow depth of $y=150$ mm corresponding to the discharge of $Q=0.04$ m³/s first without collar and then with collars. At the end of each test bed topography was measured and plotted from which both maximum scour depths and scour holes dimensions were obtained.

RESULTS

In this paper the results of thirty-five experimental tests, one test without collar lasted for 13 hours to reach almost the equilibrium scour depth and thirty-four tests were conducted with two different types of collar placed on the bed level.

Time Development of Scour Depth: A long duration test conducted using maximum flow discharge of 0.04 m³/s was conducted to see the behavior of scour depth and to plot the time development scour depth. The results are plotted in Figure 2. As it can be seen from this figure, the scour depth after 5 hours corresponds to about 91 percent of long duration scour depth. Therefore all other tests were run for 5 h. Although this length of time does not yield the maximum scour depth, it does provide approximately 91% of the maximum. Because the main goal of the study was to determine any change in the scour pattern with different size and elevation in collar layout rather than the determination of the maximum scour depth, the 5-h time interval was chosen to be adequate time period.

The Effect of Sizes of Symmetrical and Unsymmetrical Collar: As it was stated earlier a baseline tests was conducted without collar and other tests were conducted collar of different dimensions. To see the effect of different collar size on scour depth, the percent of reduction of scour depth by collar, " P_r ", was calculated for each collar size using the following equation:

Table 1: Symmetrical and unsymmetrical collars with the same area

No	Symmetrical collar	Unsymmetrical collar
1	$(L_c / L_a, 0.25)$	$(L_c / L_a, 0, 0.5)$
2	$(L_c / L_a, 0.375)$	$(L_c / L_a, 0.25, 0.5)$ $(L_c / L_a, 0.5, 0.25)$
3	$(L_c / L_a, 0.5)$	$(L_c / L_a, 0.25, 0.75)$

$$P_r = \frac{d_s(\text{without..collar}) - d_s(\text{with..collar})}{d_s(\text{without..collar})} \times 100 \quad (1)$$

In which d_s is the scour depth.

For baseline tests, without collar, maximum scour depth occurred at the corner of the upstream of the abutment. For tests with collar, after test duration and draining the flume the collar was removed and the bed topography was measured. For these tests scour depth at the same location was used in Eq. (1), Although the scour depth at other location may be greater than this location.

Figure 3 shows the effect of different sizes of symmetrical and unsymmetrical collars on the scour dept. The results showed generally as the size of each two types of collar plate increases, the scour depth decreases.

Comparison of Symmetrical and Unsymmetrical Collar Performance: In general seven groups of collars, including three symmetrical groups of collars and four unsymmetrical groups of collars are made so that for every group of unsymmetrical collars a symmetrical group with the same area exists. This point will help to compare the symmetrical and unsymmetrical collars performance. In Table 1 the symmetrical and unsymmetrical collars with equal area is shown. In this table, the collars in each row have equal area.

In Figure 4 the results of comparison of the symmetrical and unsymmetrical collars with the same area is shown.

As it can be seen in Figure (4-a), unsymmetrical collars of group of $(L_c / L_a, 0, 0.5)$ have shown better performance on reduction of scour depth than the collars in group of $(L_c / L_a, 0.25)$.

The difference in collars performance for smallest and largest collar is about 4 and 23 percent respectively. In Figure (4-b), this state is repeated for two others groups of symmetrical and unsymmetrical collars with the same area. With the exception of smallest collar in other collars, the unsymmetrical collars performance of group of $(L_c / L_a, 0.25, 0.75)$ was more than symmetrical collars performance of group of $(L_c / L_a, 0.5)$ and in one of the collars, this difference become about 40 percent but in Figure (4-c), the situation is different. In this figure, the

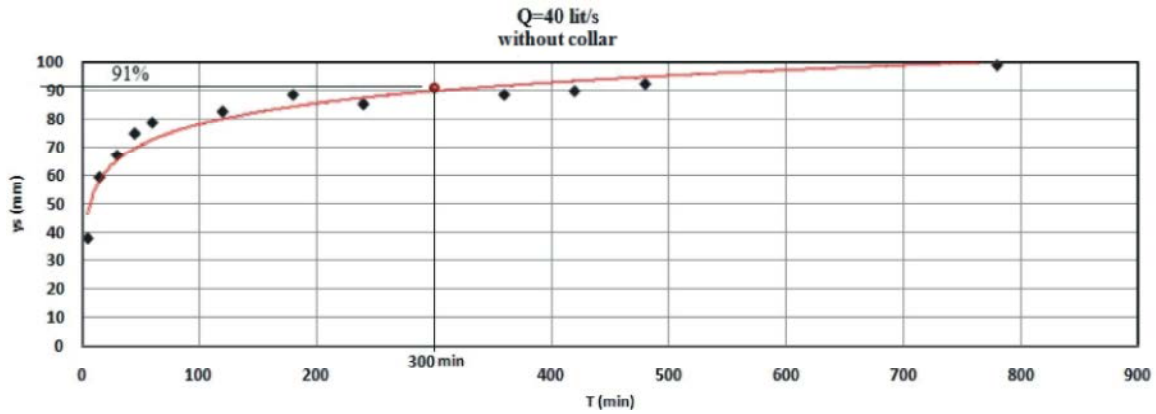


Fig. 2: Variation of scour depth versus time in the case without collar

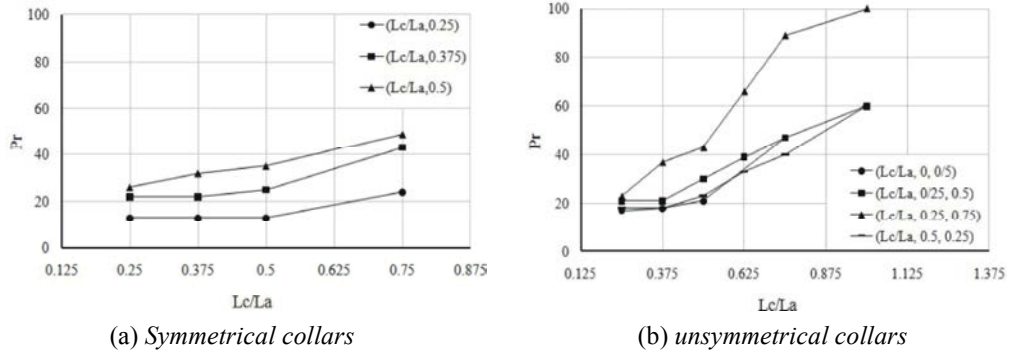


Fig. 3: Influence of dimensions of collars in reduction of scour depth

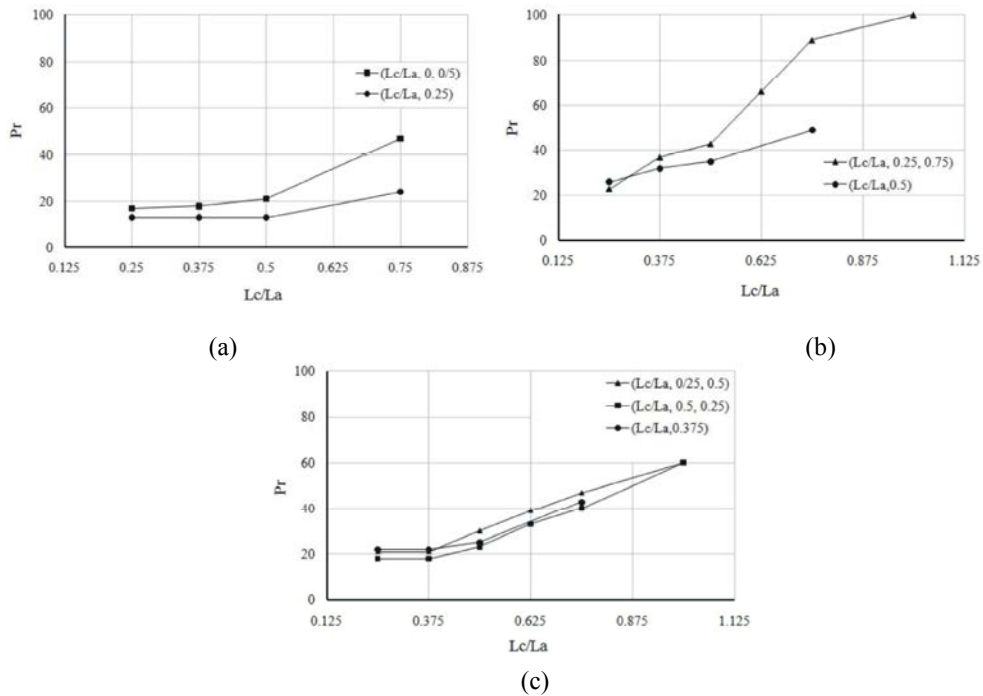
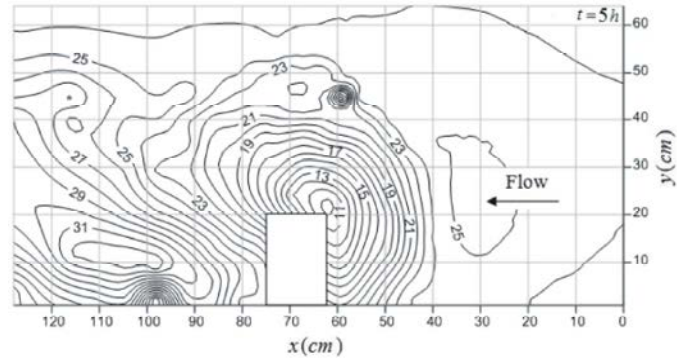
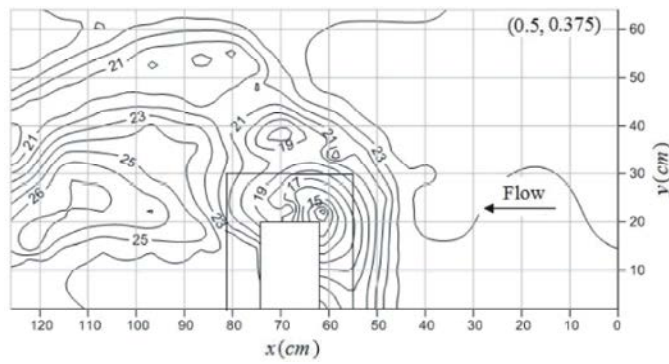


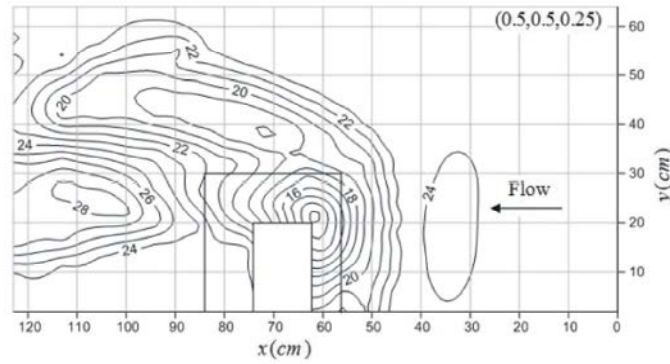
Fig. 4: Comparison of symmetrical and unsymmetrical collar efficiency



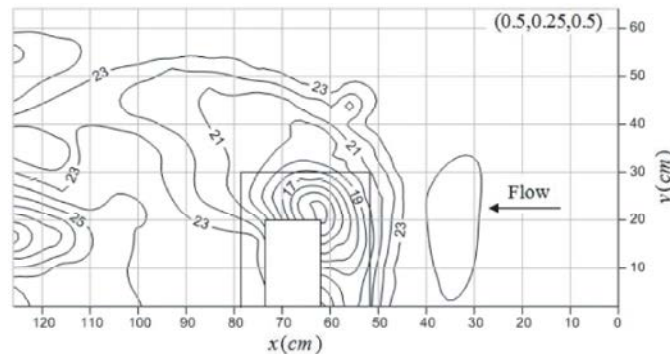
(a) without collar



(b) With collar (0.5, 0.375)



(c) With collar (0.5, 0.25, 0.5)



(d) With collar (0.5, 0.5, 0.25)

Fig. 5: Bed topography (for) in the case

symmetrical collars performance of group of ($L_c / L_a, 0.375$) was less than symmetrical collars performance of group of ($L_c / L_a, 0.25, 0.5$) and more than unsymmetrical collars performance of group of ($L_c / L_a, 0.5, 0.25$). So it can be concluded that unsymmetrical collars performance in which parameter of (B_{uc} / L_a) is greater than the parameter of (B_{dc} / L_a) has better performance than symmetrical collars with the same area and in contrast of this situation, they have less performance than symmetrical collars with the same area.

In the Figure (5), the bed topography is shown after tests conducted using collars of (0.5, 375), (0.5, 0.5, 0.25) and (0.5, 0.25, 0.5).

CONCLUSION

This paper presents the results of tests conducted on collar as a countermeasure for reducing the abutment scour. In this paper two different types of collar placed on the bed surface were tested and the measured scour depth at the upstream corner of abutment was compared with the case of no collar. In addition to the efficiency of two different types of collar was compared. It was found that, the generally collars decreases the maximum scour depth around the abutment. By increasing the width and length of both types of collars the scour depth reduction increases. By comparing the two types of collars, it was found that as the upstream width of unsymmetrical collar was larger than its downstream width, its performance will be better than the symmetrical collar with the same area.

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