

## **Sustainable Innovative Technique for Reduction of Local Scour around Bridge Pier**

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### **Abstract**

Huge money is incurred on the construction of bridges in alluvial channels. Therefore, failure of bridges causes tremendous loss of money, miseries to the people and adversely affects the development of the country. This has a negative impact on sustainable development of a country and causes extra burden on the government for restoration/reconstruction of bridges. As a result, the government has to spend that money on restoration/reconstruction of bridges which could otherwise be spent on other developmental works of the country. This retards the sustainability of development.

In these perspectives, an effort has been made in this paper to investigate experimentally the efficacy of application of collars to a round nosed rectangular bridge pier in reducing the scour depth. The experiments were carried out under steady state clear water scour uniform flow condition at flow intensity equal to 0.95. Round nosed rectangular pier was tested with and without collars at low angles of attack of flow. The tests were run for sufficient time such that maximum scour was occurred. Temporal scour depth was measured at varied intervals of time at nose of the pier. After the tests were over, the flow was stopped carefully such that scour patterns developed around the pier by the flowing water were not disturbed. Then the area around the pier was surveyed by point gauge and scour depths were measured at several points along and across the flow direction. Application of collars to round nosed rectangular pier upto 15° angle of attack resulted in considerable reduction in scour depth. At 0° angle of attack, 100% reduction in scour depth was achieved. This research causes considerable reduction in construction cost of bridge piers.

Hence sufficient money can be saved in construction of the bridges which ultimately results in sustainable development of the country.

**Keywords:** Local Scour; Bridge Pier; Sediment; Angle of Attack; Collar.

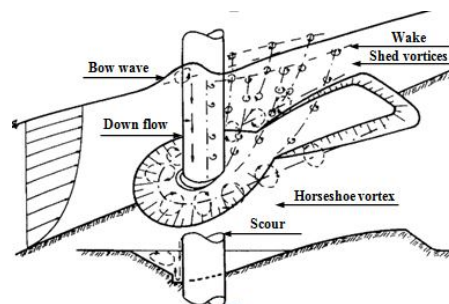
## 1. Introduction

The bridge failures result in excessive repairs, loss of accessibility, or even death (Chiew, 1995). The potential cost including human toll and monetary cost of bridge failure due to scour damage has highlighted the need for scour protection/reduction methods. A large depth of foundation is required for bridge piers to overcome the effect of scour which is a costly proportion. Therefore, for safe and economical design, scour around the bridge piers is required to be controlled.

The bridge piers require deep and expensive pier embedment in rivers. To reduce this depth of embedment, efforts have been made by armoring devices like the riprap around the pier (Brice *et. al.*, 1978; Croad, 1993; Parola, 1993; Yoon *et. al.*, 1995; Worman 1989, (Lim and Chiew, 1996 and 1997); Lim, 1998; Chiew and Lim, 2000; Lim and Chiew, 2001) and by flow altering devices like an array of piles in front of the pier (Chabert and Engeldinger, 1956 and Melville and Hadfield, 1999), a collar around the pier (Schneible, 1951; Thomas 1967; Tanaka and Yano 1967; Ettema 1980; Chiew, 1992; kumar *et. al.*, 1999, Zarrati *et. al.*, 2004, Zarrati *et. al.*, 2006), submerged vanes (Odgard and Wang 1987), a delta-wing-like fin in front of the pier (Gupta and Gangadharaiyah, 1992), a slot through the pier (Chiew, 1992; Kumar *et. al.*, 1999) and partial pier-groups (Vittal *et. al.*, 1994).

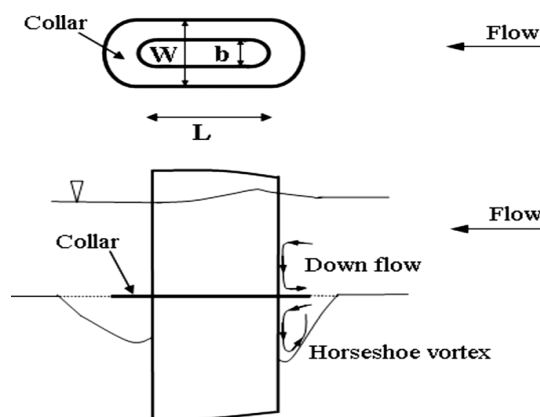
## 2. Flow Pattern and Mechanism of Scouring

The vortex system and down-flow are the principal causes of local scour. At the upstream face of the pier, the approach flow velocity goes to zero. This causes an increase in pressure. Due to this phenomenon the water surface level in front of pier increases. As the flow velocity decreases from the surface to the bed, the dynamic pressure on the pier face also decreases downwards. The downflow digs a hole in front of the base of the pier, rolls up and by interaction with the coming flow forms a complex vortex system (Fig.1.).



**Figure 1:** Diagrammatic flow pattern at a cylindrical pier (after Raudkivi, 1986).

Flow altering devices can be more economical, especially when the riprap material in required amount is not available near the bridge site or is expensive. However, there are certain limitations on the use of these flow altering devices to reduce the scour depth at piers. A slot may be blocked by floating debris. In addition to this, its construction is difficult. Sacrificial piles may become ineffective when the flow approaching the piers changes its direction. A thin collar plate skirting around bridge piers (Fig. 2) at or below the bed level which diverts the down flow and shields the streambed from its direct impact is therefore, a very effective mean of protection against scour.



**Figure 2:** Collar around round nosed rectangular pier.

### 3. Experimental Set-Up

A series of experiments was conducted at round nosed rectangular bridge piers models with and without collar plate skirted around the pier in uniform cohesionless sediment in steady stated uniform flow clear water conditions at flow intensity of 0.95.

Experiments were conducted in a glass sided rectangular re-circulating tilting flume, 11.0 m long, 0.756 m wide and 0.55 m deep. Water was supplied to the flume from an overhead tank, which got its supply from the laboratory water supply system. The scour depth at the piers was measured with a 3 mm diameter point gauge mounted on the mobile carriage that traversed the flume. The scour depths could be measured to within 0.1 mm using point gauge.

At the end of each experiment the water supply to the flume was gradually stopped and the water was drained off the flume with extreme care so that the scour hole and scour patterns developed by the flow around the model piers, were not disturbed.

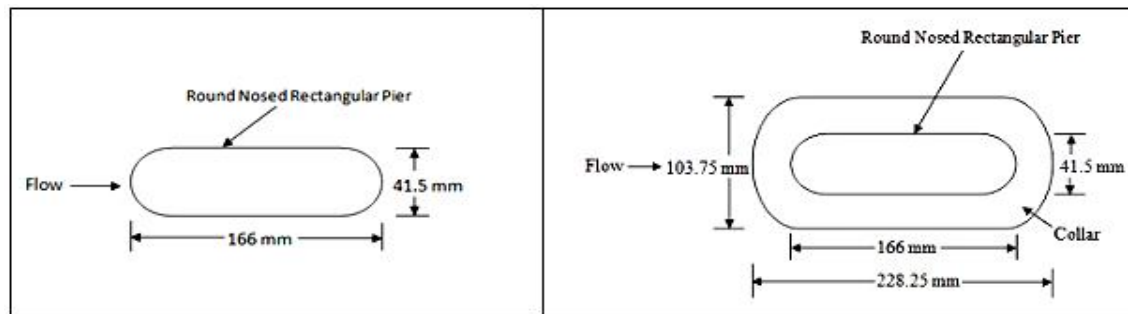
The sediment and mean flow parameters used in this investigation are listed in table 1.

Since in present study clear-water experiments were conducted using uniform coarse sediment of 0.95 mm median diameter, duration of 6 hours was considered adequate. In the case of experiments with collar, test duration was more.

**Table 1:** The mean flow parameters and Properties of sediment used in present study.

The mean flow parameters used in this investigation	Properties of sediment used
Depth of flow, $Y_0$ (m) = 0.14	$d_{84.1}$ (mm) = 1.03
Mean velocity, $U_0$ (m/s) = 0.391	$d_{15.9}$ (mm) = 0.73
Threshold velocity, $U_c$ (m/s) = 0.4127	Median Size, $d_{50}$ (mm) = 0.95
Critical shear velocity, $U^*c$ (m/s) = 0.029	Geometric Mean Size, $d_g$ (mm) = 0.867
Froude Number, $Fr = 0.3328$	Geometric Standard, $\sigma_G$ (mm) = 1.187
Average energy slope, $S_0 = 0.001$	Specific Gravity, $S_s = 2.65$
	Fall Velocity of Sediment, $W_0$ (m/s) = 0.1
	Shape Factor, $\Psi = 1$
	Angle of Repose, $\phi = 32^\circ$

The dimensions of pier and collar are shown in Fig.3.



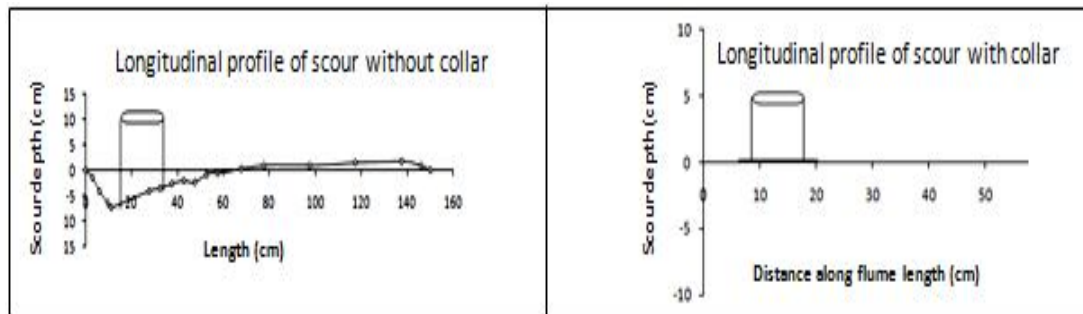
**Figure 3:** Round nosed rectangular pier without and with collar at  $0^\circ$  angle of attack respectively.

#### 4. Collection of Data and Analysis

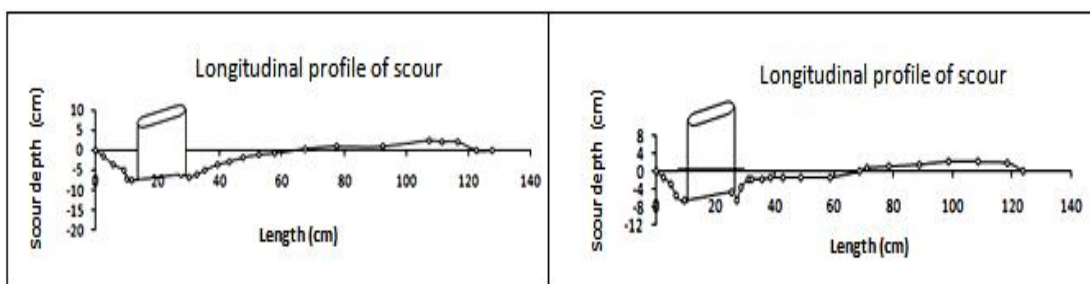
Detailed measurements of the scoured area around the model piers were made with the help of point gauge and finally photographs were taken as shown in Fig 6. . .

##### 4.1 Experimental data

The data on scour depth variation along and across the flow direction at round nose rectangular pier with and without collars were collected from the experiments. The observed scour profiles along flow direction at  $0^\circ$  and  $15^\circ$  angles of attack are shown in figure 4 and Fig.5 respectively. Similar profiles were drawn for other cases considered in present study.



**Figure 4:** Experimental data observed at round nosed rectangular pier without and with collar at  $0^\circ$  angle of attack.



**Figure 5:** Experimental data observed at round nosed rectangular pier without and with collar at  $0^\circ$  angle of attack.



**Figure 6:** Photographs showing placement of collars around pier and scour pattern formed after the experiment.

## 5. Results and Analysis

The analysis of results obtained from present experimental study was made for the following cases:

- Round nosed rectangular pier without collar.
- Round nosed rectangular pier with one collar.
- Round nosed rectangular pier with two collars

The percent reduction in scour depth, length of scour hole and width of scour hole at round nose rectangular pier with and without collar at  $0^\circ$  and  $15^\circ$  angles of attack are shown in table 2.

**Table 2:** Maximum Scour Depth, Length of scour hole and width of Scour hole observed at round nose rectangular pier without and with collar.

<b>Observed Maximum Scour Depth at round nose rectangular pier without and with collar (cm)</b>		
<b>Angle of Attack</b>	<b>Without Collar</b>	<b>With one Collar</b>
0°	7.9	0.0
15°	9.1	6.65
<b>Angle of Attack</b>	<b>Without Collar</b>	<b>With two Collars</b>
0°	7.9	0.0
15°	9.1	2.75

<b>Observed Length of Scour Hole at round nose rectangular pier without and with collar (cm)</b>		
<b>Angle of Attack</b>	<b>Without Collar</b>	<b>With one Collar</b>
0°	60	0.0
15°	60	65
<b>Angle of Attack</b>	<b>Without Collar</b>	<b>With two Collars</b>
0°	60	0.0
15°	60	19

<b>Table Observed Width of Scour Hole at round nose rectangular pier without and with collar (cm)</b>		
<b>Angle of Attack</b>	<b>Without Collar</b>	<b>With one Collar</b>
0°	25	0.0
15°	30	22.5
<b>Angle of Attack</b>	<b>Without Collar</b>	<b>With two Collars</b>
0°	25	0.0
15°	30	8.0

## 6. Conclusions

The reduction in scour depth, length of scour hole and width of scour hole with one collar and two collars with respect to the pier without collar at 0° angle is found to be 100.0 %.

Scour reduction at the pier with one collar at 15° angle of attack is observed as 26.92 %.

Scour reduction at the pier with two collars at 15° angle of attack is observed as 69.78 %.

As compared to pier without collar, the length of scour hole with one collar at 15° angle of attack increases by 7.69% while the width of scour hole at 15° angle of attack reduces by 25%.

As compared to pier without collar, the length of scour hole with one collar at 15° angle of attack reduces by 68.33% and the width of scour hole at 15° angle of attack reduces by 73.33%.

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