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EFFECT OF STREAM-WISE SPACING OF BRIDGE PIERS ON SCOUR DEPTH

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Requirement of new bridges in the proximity of the existing bridge is increasing day by day due to increased traffic volume. Experimental investigation has been carried out for determination of the minimum stream-wise spacing between two bridges that shall not cause an increase in the scour depth around piers of the upstream bridge. Piers/footings used for the experiments have geometries similar to those of existing and proposed bridges on river Brahmputra at Guwahati, India. Results obtained through experimental investigation are discussed in the present paper.

Introduction

Bridges are the lifeline of a transportation system. They are required wherever waterways are crossed by roads, railways etc. Piers, on which the superstructure of the bridge rests, play an important role in their stability and safety. Failure of bridges due to scouring of pier foundation is not an uncommon occurrence. Scour around bridge piers may result in exposure of the foundation and thus reduction of the grip length of pier. Due to rapid urbanization and increased traffic volume, it is needed to construct new bridges across rivers in the proximity of the already existing bridges. There are limitations of spacing between existing bridge and new one due to problem of land acquisition etc. in that context, the scour depth and bed configuration pattern around the old existing bridge and new one need to be examined. Very little information is available on effect the stream-wise location of bridge piers on the scour depth around the piers of existing and the new bridges.

One such type of situation exists on river Brahmaputra in India. The National Highways Authority of India (NHAI), Ministry of Road Transport & Highways, India have planned the construction of a new road bridge just in the down stream of the existing Saraighat Rail-cum-Road Bridge (also known as Pandu bridge) at Guwahati, Assam, India.

The river Brahmaputra at the existing bridge site flows from East to West. The width of the river at this site is about 1.20 Km and the river is straight over a distance of about 3.0 km upstream and about 1.5 Km downstream of the existing bridge. Both banks of the river are high and stable and the river is well confined at this location. Therefore, no guide banks have been provided in the existing bridge and they may not be required for the proposed bridge also. For conditions of design flood: the river discharge = 72028

m^3/s, flow depth = 22.9 m, flow velocity = 2.2 m/s and average size of bed material = 0.3 mm.

An experimental study was conducted by the authors for facilitating the task of examining the minimum safe spacing between the two bridges without endangering the safety of the existing bridge from scour considerations.

Brief Review

The subject of local scour at bridge piers has been extensively investigated. A large amount of literature is available on local scour around the circular bridge piers or the pier with constant cross-sectional dimensions. Only a few investigations are available on the effects of stream-wise spacing of bridge piers on scour depth. These are described below in brief.

Breussers and Raudkivi (1991) indicated an increase in the scour at the upstream bridge when the downstream bridge is located at a stream-wise distance *L* smaller than about 10 *b*. Here *b* is the frontal dimension of the upstream pier/footing, which is equal to the diameter in case of circular piers/footings and *L* is the center-to-center spacing between the piers in the stream-wise direction. Only circular piers were studied by Breussers and Raudkivi (1991). The main cause of increase in the scour at the upstream pier in this case is apparently the erosion of the material, which would otherwise have deposited in the downstream locations (where the new bridge is located). The deposition pattern downstream of the piers is greatly influenced by the geometry of the pier and the footing. The results of Breussers and Raudkivi (1991) are not expected to directly apply to the cases where bridge piers and footings are of non-uniform shape. **Babaeyan-Koopaei and Valentine (1999)** conducted experiments on scour process around the cylindrical bridge pier group models in self-formed laboratory channels. The experiments were conducted in the live-bed condition. They placed the piers in both direction i. e. transverse direction and stream-wise direction. A pier spacing coefficient was proposed to account for the effect of pier spacing on scour depth. They concluded that as the spacing between the piers increases, one would expect pier spacing coefficient converge towards unity. **Choi and Ahn (2001)** have examined experimentally the local scour depth variation due to interaction between stream-wise placed bridge piers. They varied the stream-wise spacing from 5*b* to 25*b* and maximum distortion width of 8*b*. The cross-section of the piers was elliptical. They have collected extensive data on the variation of the scour depth for different sizes of the piers, stream-wise and transverse spacing and Froude numbers. They concluded that the local scour depths are severely affected due to interaction between adjacent stream-wise spaced bridge piers. The maximum scour depth increment (compared to single pier) observed was of about 60%, due to interaction between bridge piers. **Sidek and Ismail (2002)** conducted laboratory experiments concerning scour development around a group of two cylindrical piers. A series of experiments under unidirectional flow and clear-water scour condition were conducted in a flume to obtain the velocity description around the two cylinders. They showed that when piers were arranged in a group of two, factor such as spacing, sheltering, reinforcing and horseshoe vortex greatly influenced the potential formation of the equilibrium scour hole depth. The empirical relationships to predict maximum scour depth in case where two piers (piers in tandem and piers in a side by side arrangement) were developed.

Experimental Work

Experiments were conducted in a 30.0 m long, 1.0 m wide, and 0.30 m deep flume, located in the Hydraulics Laboratory of the Indian Institute of Technology Roorkee (formerly; University of Roorkee), India. A working section 3.0 m long, 1.0 m wide and 0.5 m deep was located 12.0 m downstream of the flume entrance. Non-cohesive riverbed sediment was used in all the experiments as the sediment. The sediment used was uniform in size having the d_{50} size of 0.3 mm.

The flow dimensions and pier geometry were modeled to correspond to those for the river Brahmaputra at Guwahati, India. A model to prototype scale of 1:100 was chosen which corresponded to a flow depth = 0.22 m, and flow velocity = 0.22 m/s in the model for the design flood conditions in the prototype. The pier/footing of existing and proposed bridges were scaled at 1:100.

Experiments were conducted on clear-water conditions. Experiments on scour were conducted first by using isolated pier/footing of the existing bridge. The experiments were run for sufficiently long-time for obtaining equilibrium scour conditions. Experimental data collected in present study are summarized in Table 1.

Analysis, Results And Discussion

Study of the effects of stream-wise spacing on scour around upstream bridge pier was primary object of present study. The experiments were repeated by placing the pier/footing of the proposed bridge in stream-wise direction in the downstream at chosen values of *L/b*. The spacing *L/b* was systematically varied from 3.0 to 8.0.

Table 1: Summary of Experimental data

S. No.	Pier Spacing *L/b* (mm)	Maximum Scour depth (mm)		Deposition in between the piers (mm)
		Front Pier	Rear Pier	
1	Single Pier	67	67	
2	300	66	24	17 (erosion)
3	400	65	31	18(deposition)
4	500	70	14	43 (deposition)
5	600	67	38	58 (deposition)
6	700	68	42	50 (deposition)
7	800	68	38	61 (deposition)

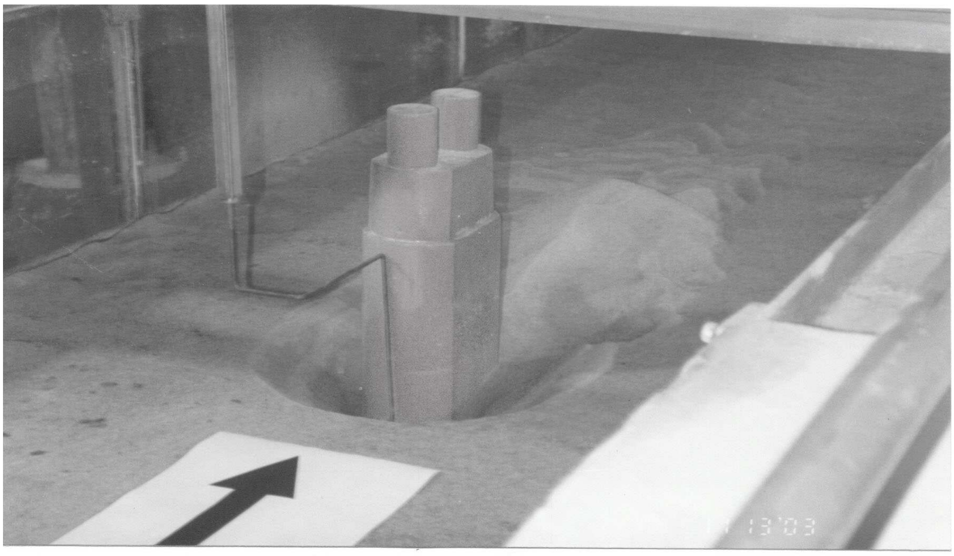
Photograph1 shows the scour and deposition pattern around the pier/footing of the existing bridge and photograph 2 shows as illustration, the scour and deposition pattern for *L/b* = 4. Figure 1 gives the extent of scour and deposition around a pier of the existing bridge in the absence of the proposed bridge while Fig. 2 depicts as illustration the extent of scour and deposition while *L/b*= 3. Length dimensions shown in Figs.1 and 2 correspond to prototype conditions (i.e. site of bridge pier on Brahmputra river at Guwahati, India). It was apparent from above and other such figures that the area of the scour hole around the pier of the existing bridge is much more than the area of scour hole around the downstream pier for all values of *L/b* studied.

A close scrutiny of the laboratory data collected on scour and deposition around piers/footings spaced at different *L/b* values reveals that the depth of scour at the (upstream) existing bridge is practically unaltered due to change in stream-wise spacing of the (downstream) proposed bridge. However, scour at the new bridge is always smaller than that at the existing bridge. These results are however, valid only for the case that there is no change in approach angle of the flow.

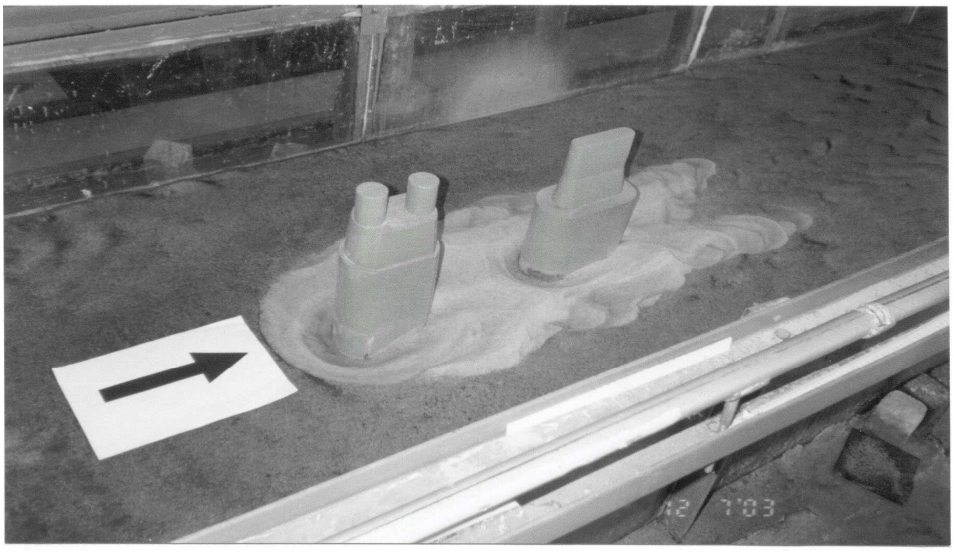
Results obtained are also presented in Fig. (3) for the upstream pier and downstream pier. Fig. 3 shows the variation of scour depth at both piers and bed levels between the piers with respect to pier spacing. Results presented in Fig.3 indicate that when site condition do not permit a larger spacing the existing (upstream) bridge would not be subjected to any scour in excess of that at present, if the new bridge is located in the downstream at a minimum center to center spacing of between *L/b* equal to 3 to 5 from the existing bridge.

Conclusions

For the pier/ footing geometries studied herein, no adverse effect on scour is observed around the piers of the existing (upstream) bridge in case the proposed bridge on the downstream side is located with its axis at a distance *L/b* equal to 3 or more from the axis of the existing bridge. It is important that piers/footing of the proposed bridge are in line with those of the existing bridge. For the experiments conducted herein, the scour around the piers of the downstream bridge is always smaller than the scour depth for the upstream pier.



Photograph 1-Scour and deposition pattern around the pier of the existing bridge



Photograph 2 - Scour and deposition pattern around the piers of the existing and proposed bridges for *L/b*=4.0

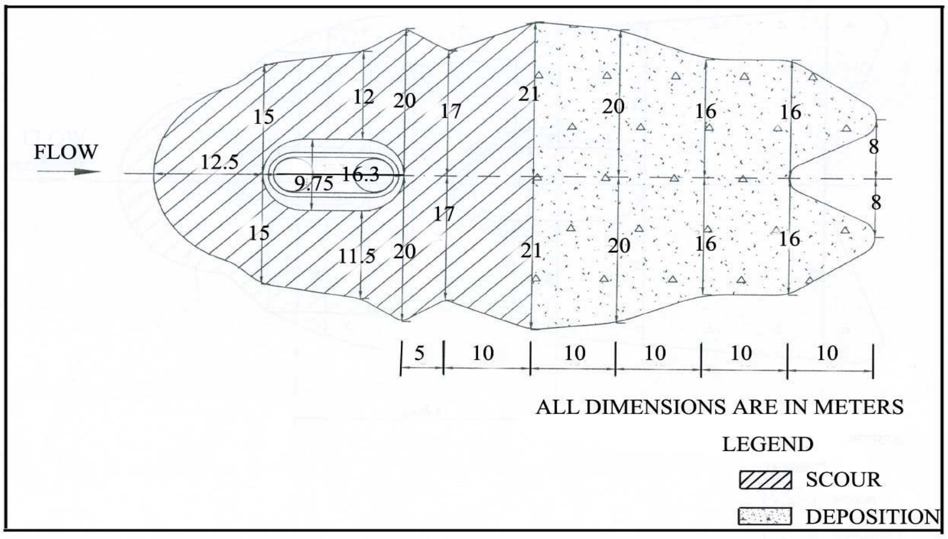


Fig. 1 Scour and deposition pattern around a pier of the existing bridge in the absence of the proposed pier

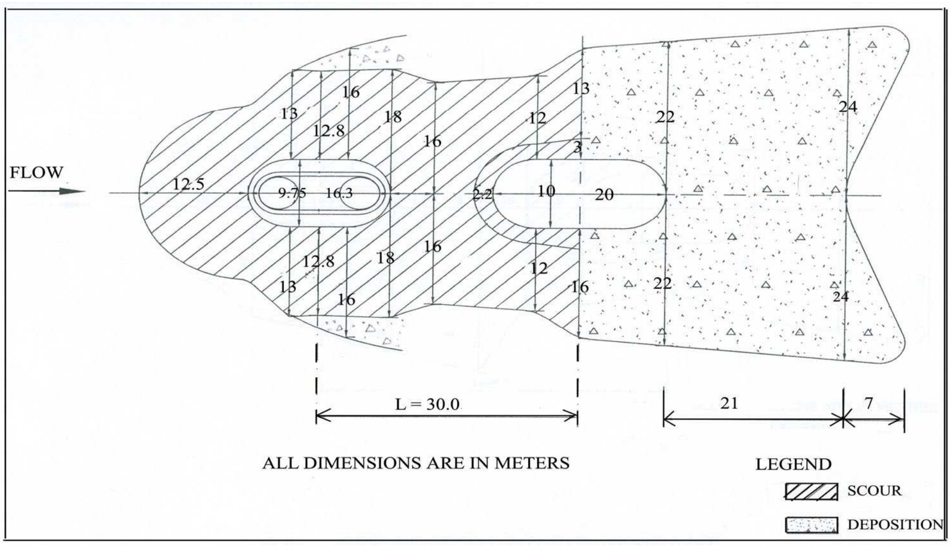


Fig. 2 Scour and deposition pattern around a pier of the existing bridge in the presence of the proposed pier for L/b = 3.0

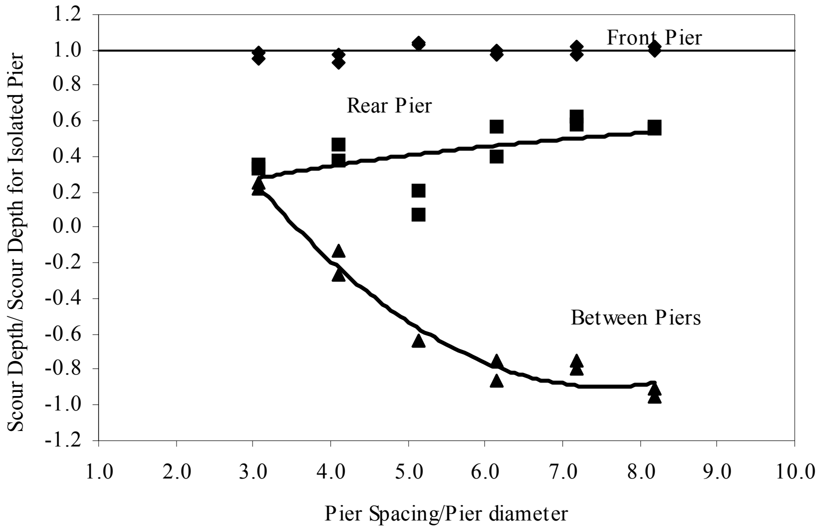


Figure 3. Scour depth variation of two piers placed in stream-wise direction as a function of pier spacing

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