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# REVIEW ON ESTIMATION OF SCOURING AROUND BRIDGE PIER

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## ABSTRACT

The review of past few studies on the critical shear stress near bridge pier for non-uniform sediments, the various circumstances that cause the bridges while during heavy flood range and normal flowing water. As a scour around bridge support (piers) can result in structural collapse.

Scour which the natural phenomenon caused due to the erosive action of flowing stream on alluvial beds which removes the sediment around or near structures located in flowing water. It means by the lowering of the riverbed level by water erosions such that there is a tendency to expose the foundations of a structure. This analysis is the result of the erosive action of flowing water, excavating and carrying away material from the bed and banks of streams and from around the piers and abutments of bridges. Scouring has been the main cause for failures of marine structures throughout the world.

Using the various results and their comparison this study leads to determine the changes in the shear stress around the pier with respect to time and flow of water.

***Keywords***: *scour, scour mechanism, bed material, bridge pier, time effect.*

## I. INTRODUCTION

Scour is a natural phenomenon caused by erosive action of the flowing water on the bed and banks of alluvial channels. Scour also occurs at the coastal regions as a result of the passage of waves. It is the removal of sediment around or near structures located in flowing water. It means the lowering of the riverbed level by water erosions such that there is a tendency to expose the foundations of a bridge as a result of the erosive action of flowing water, excavating and carrying away material from the bed and banks of streams and from around the piers and abutments of bridges. Such scour around pier and pile supported structures and abutments can result in structural collapse and loss of life and property. The construction of bridges in alluvial channels causes a contraction in the waterway at the bridge site and hence gives rise to significant scour at that site. As the scour continuously progresses at the site, it undermines the foundations of the structure leading to possible failure. Many bridges failed around the world because of extreme scour around piers. Failure of bridges due to scour at their foundations, which consist of abutments and piers, is a common occurrence.

Since 1950 over 500 in USA fails due to scouring around bridge pier such scour around pier and pile supported structures and abutments can result in structural collapse and loss of life and property. An estimate of the maximum possible scour around a bridge pier is necessary for its secure design. Numerous investigations have been done since the late 1950s to understand the flow and the erosion mechanisms around bridge piers and to estimate the scour depth and critical shear stress. Scouring is local lowering of bed stream elevation which takes place around structure in flowing water. Hence for safe and economical design, scour around the bridge piers is required to be controlled The present work is concerned with the flow as it is slowed and little deflected around the bridge pier, the bed shear stress distribution, and the effects of roughness and the scour hole. A lack of understanding of the structure of the flow and erosion mechanism seems to be at least partly responsible for this state.

The basic aim of this paper is to review the available literature on scour with emphasis on the mechanism, prediction and reduction techniques of local scour around vertical piers.

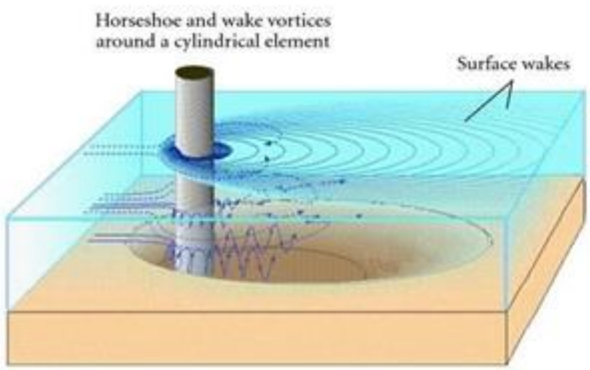


*Figure1. Flow and scour pattern at a circular pier*

## II. REVIEW OF DIFFERENT METHODS USED FOR SCOUR COMPUTATIONS

As already discussed, scour around piers can be sub-divided into three major components, namely, general scour, constriction scour and local scour. Methods of estimation of the different components of total scour in a bridge pier are briefly discussed in the following paragraphs.

a) General Scour:-

General scour is the scour which occurs irrespective of the presence of the bridge due to the morphological behaviour of a river, namely, the processes of aggradation and degradation of river bed, meandering, braiding, cut-off formation, confluence of streams upstream of bridge sites, etc. Long-term behaviour of a river in the vicinity of a bridge must be thoroughly explored to find the likely change in river bed elevation at the proposed bridge site.

b) Constriction Scour:-

Constriction or contraction scour occurs in a bridge where the road or railway approach embankment restricts the normal waterway. It occurs also at such section where the bridge is sited at a natural contraction of a river usually selected as bridge site for reducing the cost of superstructure. Lowering of the bed occurs locally within the contracted reach (i.e. under the bridge) due to flow acceleration and increased velocity of flow. Excessive contraction of normal waterway (to reduce the cost of superstructure) increases construction cost of substructure due to excessive scour.

c) Local Scour :-

Local scour in bridge piers occur due to obstruction by pier and pier foundation and the consequent changes in the flow field around the piers. Because of variation in velocity from top to bottom of a pier, the stagnation pressure head is the highest at top and lowest at the bottom of pier, there by inducing a pressure gradient, since the potential head is highest at the top and lowest at the bottom of the pier.

## III. FACTORS AFFECTING SCOUR DEPTH:-

Based on the experimental work and some theoretical analysis, it is found that various factor affect the scour depth at the bridge pier. Many researches are conducted for the depth of scour.

1) Flow condition of river
2) Structure of bridge

3) Material of river bed
4) Frequency of flood in river
5) Velocity of flow
6) Bed slope
7) Erosion action of flowing river or stream

This factor plays vital role in scour depth formation. And due to this the critical shear stress formation occurs.

## IV. AIM & OBJECTIVES

Aim of this experimental work is to determine the scouring and determine relation between various flow parameters.

- To determine the scouring depth around pier.
- To establish a relation between velocity of flow and scouring at bridge pier.
- Flow pattern around the pier.
- To estimate the maximum scour depth.
- To find out conditions for this maximum scour depth.
- Influence of the pier angle
- Maximum velocities
- Possible Armoring Effect

## V. FUTURE SCOPE:

1. This analysis is useful to establish sufficient depth of foundation for bridge pier.
2. Estimation of maximum scouring is required to avoid possibility of undermining.

## VI. RELATED TERMS

- Scouring - Scouring is local lowering of stream bed elevation which takes place around pier, abutment in flowing water.
- Incipient motion - The water exert tractive force on bed material in the direction of flow, this results in to particle lift from the bed and just start to moving in the direction of flow this condition is called as incipient motion.
- Bed material- It is the portion of sediment that is transported by stream that contains material derived from the bed.
- Flow velocity- It is the vector field that is used to describe fluid motion in mathematical manner.

## VII. LITERATURE REVIEW

### 1) Local Scour Around Hydraulic Structures

**Padmini Khwairakpam, ACEEE**

In this paper researcher conclude that Scour has been the major concern for safety of marine and hydraulic structures. A large number of hydraulic structures failed as the local scour progresses which gradually undermines the foundations. It is important to control the local scour depth at downstream of hydraulic structures to ensure safety of these structures. In spite of numerous investigations by many researchers, the problem of scour has not been effectively resolved as yet. By adopting different techniques, scour could be reduced up to approximately 60% as per reports available in literature. Though scour depth could be approximately predicted using various available ways, full-proof protection of scour is yet to be achieved. Further studies are still required to correctly predict the scour depth and to find techniques to prevent or reduce the scour in a cost effective manner in order to save the structures from the imminent danger of failure due to scour. On the other hand, the natural phenomenon of scour may be investigated for its possible use as an alternative to expensive dredging operations in rivers and channels.

2) **Scour Reduction around Bridge Piers: A Review.**

**Mubeen Beg and Salman Beg, ISSN.**
In this paper, a detailed review of the up-to-date work on scour reduction around bridge piers is presented including all possible aspects, such as flow field, scouring process, parameters affecting scour depth, time variation of scour. For safe and economical design, scour around the bridge piers is required to be controlled. The performance of any scour protection/controlling device around bridge piers depends on how the device counters the scouring process. Efforts have been made to reduce the depth of scour by placing the riprap around the pier, providing an array of piles in front of the pier, a collar around the pier, submerged vanes, a delta-wing-like fin in front of the pier, a slot through the pier and partial pier-groups and tetrahedron frames placed around the pier.

3) **Critical shear stress near bridge pier for non-uniform sediments. (nctdcme-18)**

**Prof. U.S. Patil Sir and Abhishek Chougule,**
This paper describes the main reason of local scour are generally classified into flow condition, structure, and riverbed material used in it and to obtain the simple critical shear stress for the non-uniform sediments. Scouring is significant factor which effects on the safety of bridges. Scouring develops around the pier on the bed channel with non-uniform sediments achieve the great on scour depth prediction. In this a flume experiment has been conducted to predict the relative parameters of shear stress for various size of pier diameter and scour depth using the non-uniform sediments. From the analysis a relationship between shear stress and its scour depth may be developed.

4) **Shear Stress Variation at Scour Hole of Circular Pier (SciRes)**

**Joongu Kang, And Hongkoo Yeo**
The changes along the time and particles were determined in this study through real-time measurement, using various particles and the image method. The changes in the local scour along the time and the hydraulic condition of the generation of the initial scour in accordance with the size difference of the diameters of seven types of riverbed materials, and their results, were compared to the results of the past studies. Based on the data that were obtained, the changes in shear stress around the pier along the scour depth ($S$, $S_{max}$) were examined. Experimental analysis was carried out for the reduction model of the shear stress along each particle and along the influence of time on scour depth, and a trend was found for each condition. The changes in shear stress show a difference between the assumption of the research and the suggested equations, which can be attributed to the difficulty of accurately measuring and analysing the turbulent flow. An accurate measurement and analysis of the turbulent flow should be carried out in future studies on this subject. A similar study should be conducted, with a slightly modified methodology. In this study, the particles and flood phase should be analysed via the scour reduction and the reduction rate.

5) **Flow around bridge piers:**

**Ferdous Amed and Nallamuthu Rajaratnam, Fellow, ASCE.**
In this paper researcher conclude that the results of a laboratory study on flow past cylindrical piers placed on smooth, rough, and movable beds. Experimental results are analysed on the flow in the plane of symmetry, including the frontal down flow and the effects of bed roughness and the scour hole on it. The Clauser-type defect scheme describes the velocity profiles better than the log-law and defect law. Frontal down flows is as large as 95% of the approach flows were seen. Experimental results are also analysed on the deflection of flow and bed shear stress field. Bed roughness increased the magnitude of bed shear stress and the area over which the shear amplification was felt and also resisted.

6) **Bridge pier scour model with non-uniform sediments By Shaghayegh Pournazeri, Fariborz Haghighat**

Pier scour is a core problem affecting the safety of bridges. For given hydraulic and geometric conditions, perfect determination of scour with non-uniform sediments is important, but this need has not been fulfilled. The purpose of this research was to develop a three-dimensional model for scour prediction and to verify the model using laboratory measurements. The model allows for selective transport of non-uniform sediments, particle hiding and bed-level change in response to scour and deposition. The development of scouring around a circular pier on a mobile channel bed with non-uniform sediments was successfully predicted and scours depth prediction agreed well with the measurements. It was found that scour patterns emerge from the lateral sides of the pier and migrate towards its upstream nose. Upstream of the pier, strong down flow and vortex motions develop and effectively remove sediments from the foot of the pier; at equilibrium, the bed-surface slope almost reaches the angle of repose of sediments.

## VIII. METHODOLOGY

- **Data collection**
- **Materials and testing:** Sediments

i. Sieve analysis
ii. Specific gravity
iii. Density of sediments

- **Experimental arrangement:-**

The experiment was conducted in tilting flume of dimensions 20m length, 0.7m wide and 1m in depth. The flume is provided with baffle walls at inlet and outlet chambers. The circular shape pier was made of acrylic sheet and having thickness 12mm, length 900 mm and diameter 70 mm The pier was placed at center of section and then bed material (sieved sand) was placed around it. The flume was kept horizontal while doing the experiment and flume was provided with gate to control discharge of flow and maintain the uniformity. The depth of scour was measured with point gauge. Also velocity is measured by taking numerous readings (runs).

- **Parameters:-**

Shape of Pier – Circular pier

Velocity of Flow
1) V1
2) V2
3) V3

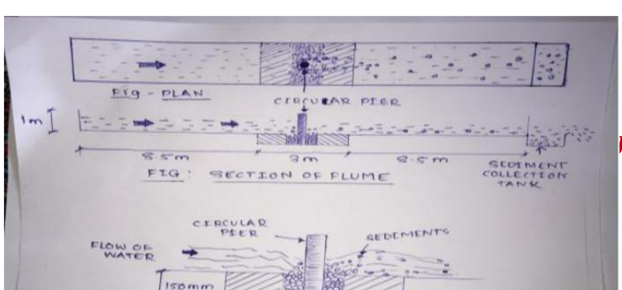

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*Figure2. Arrangement of flume*

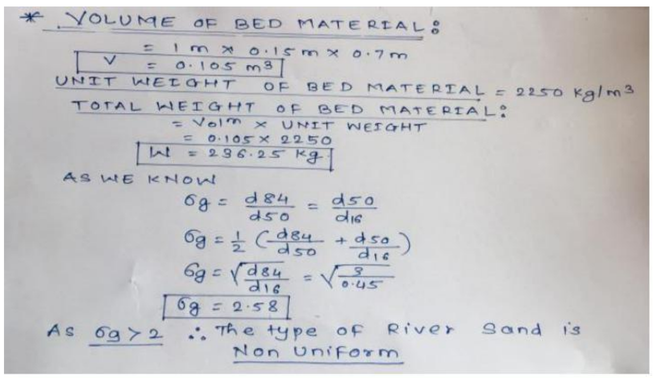
- **Experimental setup:-**

The experiment was performed in tilting flume of dimensions 20m length, 0.7m wide and 1m in depth. The flume is provided with baffle walls at inlet and outlet chamber which were used to keep flow of water steady and calm. A section of 3m length and 150mm depth was prepared by using acrylic sheet. The pier was fixed at center of section and then bed material (sieved sand) was placed around it. The flume was kept horizontal while performing the experiment and flume was provided with gate to handle discharge of flow and maintain the uniformity. The depth of scour was measured with point gauge.

- **Description of bed material** :-

The bed slope material of non-uniform sediments was used for the experiment. Having $\sigma_g$ =2.58, specific gravity 2.7 and size which ranges from pan to 20 mm. Bed materials was washed thoroughly with clean water to remove silt and organic material. After that the sieve analysis is done for the specific sample of sand and we get following curve (graph).

*Figure3, Sieve analysis*


* VOLUME OF BED MATERIAL:
= 1 m × 0.15 m × 0.7 m
V = 0.105 $m^3$
UNIT WEIGHT OF BED MATERIAL = 2250 kg/$m^3$
TOTAL WEIGHT OF BED MATERIAL:
= Vol$^m$ × UNIT WEIGHT
= 0.105 × 2250
W = 236.25 kg
AS WE KNOW
$\sigma_g = \frac{d_{84}}{d_{50}} = \frac{d_{50}}{d_{16}}$
$\sigma_g = \frac{1}{2}\left(\frac{d_{84}}{d_{50}} + \frac{d_{50}}{d_{16}}\right)$
$\sigma_g = \sqrt{\frac{d_{84}}{d_{16}}} = \sqrt{\frac{3}{0.45}}$
$\sigma_g = 2.58$
As $\sigma_g > 2$ ∴ The type of River Sand is Non Uniform

| Passing from | Retained on | Percentage Req. | Weight Of Sand |
|---|---|---|---|
| 20mm | 10mm | 4% | 9.45 kg |
| 10mm | 4.75mm | 5% | 11.8125 kg |
| 4.75mm | 3.28mm | 7% | 16.5375 kg |
| 3.28mm | 2.28mm | 13% | 30.7125g |
| 2.28mm | 1.20mm | 33% | 77.9625kg |
| 1.20mm | 0.600mm | 18% | 42.625kg |
| 0.600mm | 0.300mm | 9% | 21.2625kg |
| 0.300mm | Pan | 11% | 25.9875kg |
| | Total= | 100% | 236.25kg |

*Figure4. Quantity of sand as per standard deviation graph*

- **Experimental procedure**:-

a. Preliminary runs were carried out to calculate the Velocity of water through flume by velocity meter.
b. Section was prepared and bed material (sieved sand) was placed around pier.
c. Bed material was compacted and levelled.
d. Then the flume section was filled with water slowly, so that entrapped air was removed.
e. After that the frame is prepared with thread arrangement on it. This arrangement is used to take reading at various angles and at different positions.
f. This frame was placed over top of the flume to take angular readings of scouring.

g. Valve was fixed at position to keep steady flow condition for a run.
h. Steady flow was maintained for few minutes and velocity was measured.
i. Scouring effect occurs and the scour hole depth was measured using point gauge.
j. Same procedure was repeated for numerous run for an interval of few times for a single set keeping the same velocity.
k. Four sets of four different velocities were taken to measure scouring at different velocities.
l. Same procedure was adopted to carry out numerous run.
m. Readings were noted down and analysed for developing relation between velocities, scour depth, pier dimensions.

- **Analogy**

To determine shear stresses we used formula given by Peggy A. Johnson and J. Sterling Jones.

$$\tau = \frac{\rho V^2}{[5.75\log(12.27\frac{d}{Ks})]^2}$$

Where,
τ = Shear stress around pier
V = Velocity of flow
d = Depth of flow
Ks = Mean diameter of sediment

- **Reduction of scour :-**

Reduction of scour depth around foundation of hydraulic structure is important part in tackling the problems associated with scour. Controlling measures of scour at pier or piles can be divided into two group armor and flow alteration techniques.

## IX. CONCLUSION

This analysis is done for to know the variable affecting local scour depth around bridge pier. Estimation of scour around bridge piers is a main purpose of this analysis, and to know the critical shear stress near bridge pier.

Several mathematical models have been developed over the years for precise estimation of general scour, constriction scour and local scour. The total scour depths estimated by the different mathematical models are nearly the same. It is, however, difficult to conclude which mathematical model gives the best result unless the results are compared with actual scour measurement in prototype at different bridge sites. Measurement of scour at site during the passage of high floods is extremely important for validation of mathematical models most of which have been developed on the basis of scour data obtained in laboratory flumes.

Another thing is that the changes along the time and particles will determine in this study through real-time measurement, using various particles and the image method. The changes in the local scour along the time and the hydraulic condition of the generation of the initial scour in accordance with the size difference of the diameters of riverbed materials, and their results, will compare to the results of the past studies. Based on the data that will obtain, the changes in shear stress around the pier along the scour depth also can examine. Experimental analysis will carried out for the reduction model of the shear stress along each particle and along the influence of time on scour depth.

In this study, the particles and flood phase should be analysed via the scour reduction and the reduction rate.

## X. ACKNOWLEDGMENT

This research is guiding by our Guide Prof. Uday S. Patil (Project Name: Estimation of Scouring and its pattern around Bridge Pier for Non-uniform sediment.)

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