SCOURING PROTECTION OF BRIDGE SUB-STRUCTURE

By

MOHAMMED SALEM .M ABOUDINA

Thesis Submitted in Fulfilment of the Requirement for the Degree of Master of Science in the Faculty of Engineering Universiti Putra Malaysia

September 2001

ACKNOWLEDGEMENTS

" In the name of Allah the Compassionate and Most Merciful "

I would like to forward my most thanks to my supervisor Dr: Thamer Ahmed Mohamed , for the entire guide and advises in preparing this project paper. My appreciation also goes to Engineer : Mohd Jan,and my friend Engineer. Mustafa Bin Zakta in assisting me on the use, handling and preparing the equipment for my project.

Lastly I also wish to express my appreciation to all friends and to those who have contributed in giving me the moral support and being with me for these two years May the blessing of Allah be with them. And for those I've over looked - Thank You Very Much.

Mohamed Salem M. Aboudena

ABSTRACT

The substructure element of bridge subjected to flow of water is liable to large effect of scouring development depending on the nature of the water bed , flow velocity and the geometry of the substructure. Due to the scouring effect of flowing water at bridge substructure scour hole formed. If such bridges are allowed to with stand the high flow rate without any form of protection, the damage to the bridge substructure will definitely be severe .

According to the experimentation conducted on the physical model, the maximum scour hole diameter and the maximum scour hole depth were found to be *72 mm* and *28 mm* respectively.

Like wise, those piers which are protected using any one of the four illustrated methods (Collar protection , Slot protection , Riprap protection and piles front of pier protection) have shown some reasonable percentage reduction in the scour hole geometry .

The experimental result from the present study confirmed the effectiveness and efficiency of the studied four mentioned methods to protect bridge substructure. The reduction in the diameter of the scour holes before and after protection were found as follows:

- Using multiple collar with *65%* reduction.
- Using rip rap with 58% reduction.
- Using slot at the top of pier with *34%* reduction.
- Using slot at middle of pier with *45%* reduction.
- Using slot at bottom of pier with *4%* reduction.

- Using collar at top of pier with *50%* reduction.
- Using collar at middle of pier with *43%* reduction.
- Using collar at bottom of pier with *0 %* reduction.
- Using pile front of pier with 16% reduction.

Comparing all the methods, the multiple collar method was found to be the most efficient one among the four tested methods. The advantage of multiple collar is to control the vortices occured at the pier circumference. In Malaysia Public Work Department (JKR) used protection method in which the piles cap is deeper than the scour depth.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

1.1 General

Crossing structures, which are constructed in streams with, erodeable bed, normally are subjected to a serious scouring due to the contraction occurred in the waterway during flood. Scouring is a natural phenomenon caused by the flow of water in rivers and streams. Experience has shown that scouring can progressively undermine the foundation of structure which is constructed across waterway as shown in Figure 1.1. Protection against Scouring is required to minimise the risk of failure. Guidance for protect of the bridge Foundation from failure by controlling scour comes from both controlled studies in laboratory and from field experience. Many bridges failed around the world because of extreme scour around pier and abutment, for example during the spring floods of 1987, 17 bridges in New York and New England were damaged or destroyed by scour. In 1985, floods in Pennsylvania, Virginia destroyed 73 bridges. A total number of 383 bridges failed in USA caused by catastrophic floods and 25 % was failed due to pier damage and 72 % was failed due to abutment damage(Federal Hwy, 1993).

A second more extensive study done in 1978. Indicated that the number of failures in bridge due to Piers scour were almost equal to the number of bridges failed due to abutment scour.

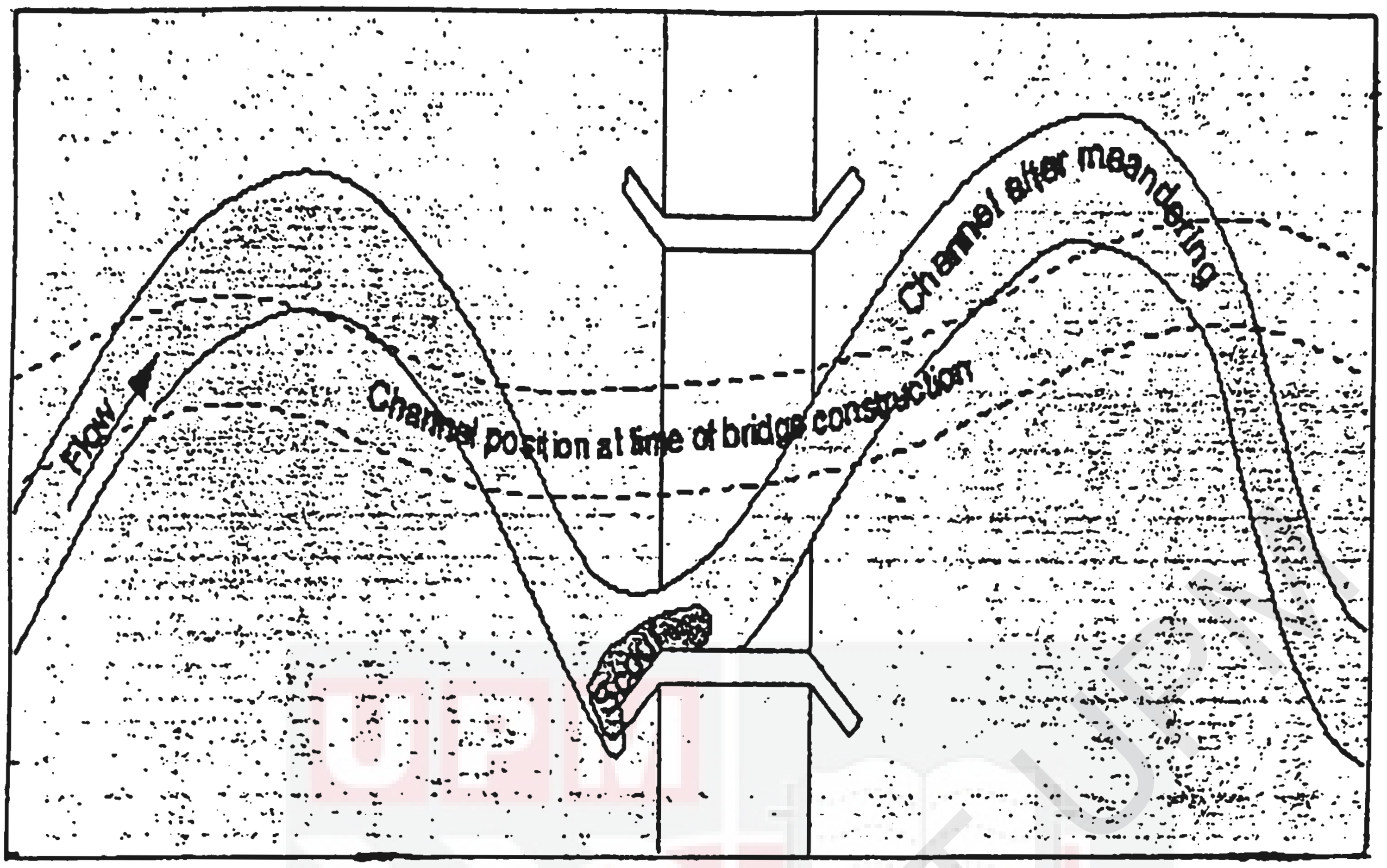


Figure 1. 1: Scour at the bridge abutment

Usually structural engineer checks the safety of the bridge components while an architect designs the bridge shape. The hydraulic engineer predicts the scour depth at the bridge site for design flood before construction and evaluate the need for scour protection at bridge site after construction.

Design of bridge substructure is an important part of the overall design for a bridge and it affects to a considerable extent the aesthetics, safety and the economy of the bridge. The design of bridge substructure demands a detailed knowledge of hydraulics, Geotechnic and structural analysis. Since the soil at any place is not of uniform type, the design of a suitable foundation would involve a soil investigation to get the required data about the soil at the bridge construction site .

In the design of the bridge substructure, the designer must determine the following:

(i) the maximum likely scour depth, at the abutments and pier.

(ii) the minimum grip length required,

(iii) the soil pressures at the base, and

(iv) the stresses in the structure constituting the foundation.

The pattern of scour occurring at a bridge constructed across a river is depends on many factors including river discharge, bed slope, bed material, direction of flow, alignment of piers, their shape and their size. Unless the foundations are rested on rock, adequate grip length below the maximum scour level should be provided. The minimum required grip length is specified as one-third the maximum scour depth for road bridges and one-half of the maximum scour depth for railway bridges. The purpose of the grip length is to ensure stability under heavy flood conditions and to facilitate mobilisation of passive pressure against horizontal forces .

1.2 Types of scour

Scour are categorized into many types and these types are local scour, contraction scour , clean-water scour, and live bed scour .

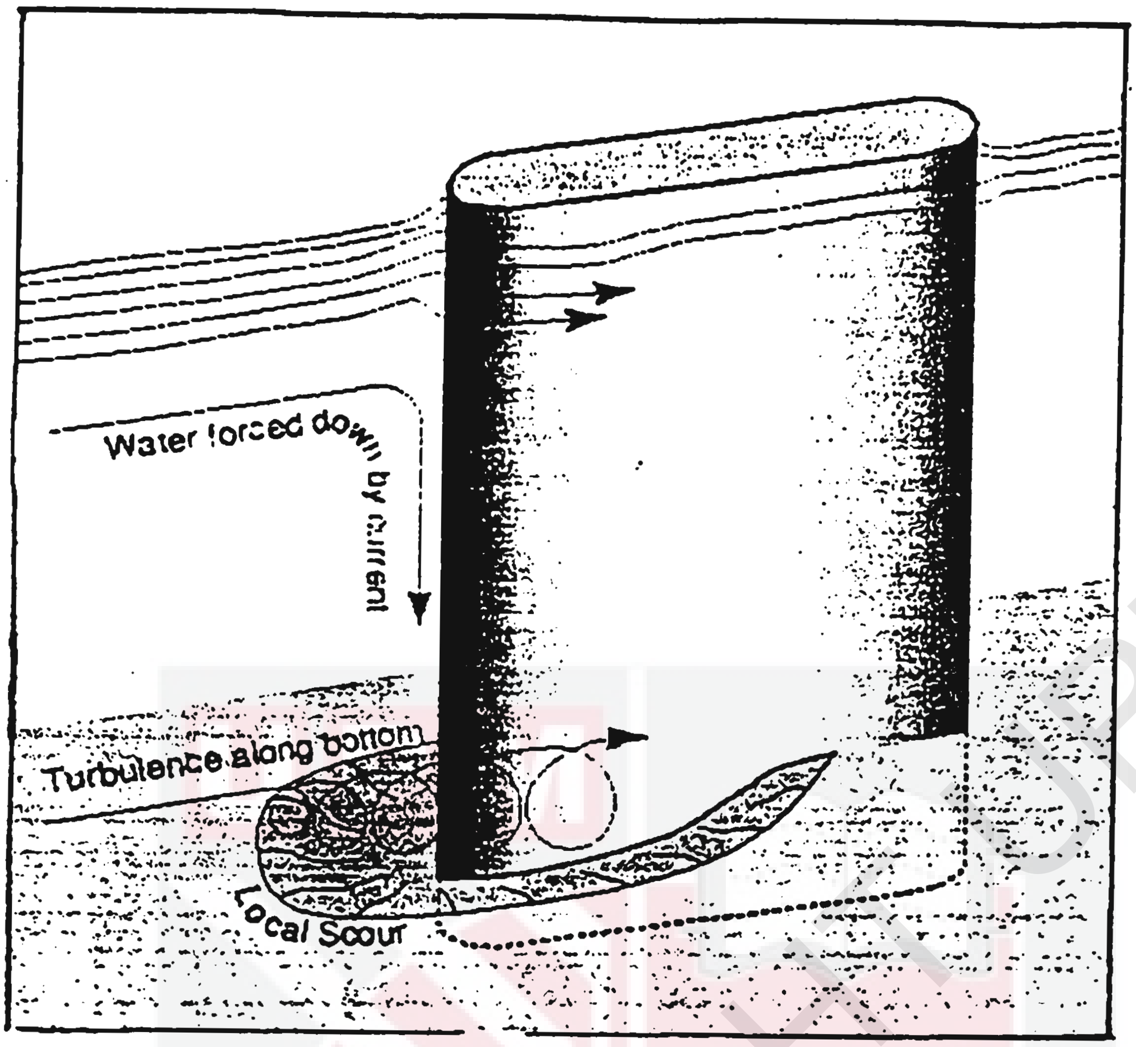
From the literature available, most of the failure case occurred at bridge substructure were related to the local scour . So special concentration will be given to this type of scour in this study.

1.2.1 Local scour

Local scour involves removal of material from the area around piers, abutments, spurs, and embankments. It is caused by an acceleration of the flow and resulting vortices induced by the flow obstructions. Local scour occurred at bridge piers is caused by the interference of the piers with flowing water. This interference will result in a considerable increase in the mean velocity of the flowing water in the channel section. Scouring vortex will be developed when the fast moving flow near the water surface (at the location of the maximum velocity in the channel section) strikes the blunt nose of the pier and deflected towards the bed where the flow velocity is low. Portion of the deflected surface flow will dive downwards and outwards. This will act as a vacuum cleaner and suck the soil particles at the pier site and result in considerable increase in the scouring depth at this location, Figure 1.2 shows the mechanism local scour around the pier.

Local scour can occur as either 'clear-water scour' or' live-bed scour'. In clear water scour bed materials is removed from the scour hole, but not replenished by the approach flow while in live-bed scour the scour hole is continually supplied with sediment by the approach flow and an equilibrium is attained when, over a period of time, the average amount of sediment transport into the scour hole by the approach flow is equal to the average amount of sediment removed from the scour hole. Under this conditions the local scour depth fluctuates periodically about a mean value. The interaction between the flow around a bridge pier and the erodible sediment bed surrounding it is consider very complex phenomenon (Cheremisinoff 1988).

In fact, the phenomenon is so involved that only very limited success has been enjoyed by the attempts to model scour computational ly, and physical model remains the principal tool employed for estimating expected depths of scour.



Figurel.2: local scour around the pier

Equations for estimating local scour are based on three methods of analysis, these methods are:

1 -Dimensional analysis of the basic variables causing local scour.

2-The use of transport relations in the approaching flow and in the scour hole.

3-Regression analysis of available data.

1.3 Objective of Study

The objective of this study is to investigate the effectivity of the available type to protect the foundation of the bridge piers and abutments from, failure due to local scour. A physical model will be implied to simulation these various methods. The best effective method will be recommended for protecting the bridge substructure.

REFERENCES

Breusers, N.H.C. and Raudkivi, A.J. (1991). " Scouring " A.A. Balkema Publishiry Company.

Chiew, Y.M. (1996). " Mechanics of riprap failure at Bridge piers" Journal of Hydraulic Engineering, ASCE, 121(9),635-641.

Chiew, Y.M. and Lim, F.H (2001) . " Failure Behavior Riprap Layer at Bridge Piers Under Live-Bed condition " Journal of Hydraulic Engineering, ASCE, 126(1),43-55.

Chiew, Y.M. and Lim, F.H (2001) . " Failure Behavior Riprap Layer at Bridge Piers Under Live-Bed condition " Journal of Hydraulic Engineering, ASCE, 126(1),43-55.

Chiew, Y.M. (1993) . " Scour Protection at Bridge Piers " Journal of Hydraulic Engineering, ASCE,118(2) 1260-1265 .

Coleman, S.E. and Melville B.W. (2001)."New ZEALAND BRIDGE SCOUR EXPERIENCES" . Journal of hydraulic engineering, ASCE, 127 (7), 535-546.

Jones, J.S. Kilgore, R.T. and Mistichelli, M.p.(1992)."Effects of footing location on Bridge pier scour" Journal of hydraulic engineering. ASCE,118(2) 280-281.

Johuson, P.A. (1996). " Comparison of pier-scour Equations Using field Data "Journal of hydraulic engineering, ASCE, 121 (8) , 626-642.

Lauchlan, C.S. and Melville B.W.(2001)."Riprap protection at Bridge pier." Journal of hydraulic engineering , ASCE,127(5),412-418.

Li, F. and Cheng .L. (1999)." Numerical Model for local Scour under offshore pipelines " Journal of hydraulic engineering. ASCE, 125(4),400-406.

Melville, B.W. (1996)."Bridge Abutment Scour in Compound Channels" journal of hydraulic engineering. ASCE, 121(12),863 .

Melville, B.W.and Raudkivi, A.J. (1996). " Effects of foundation Geometry on Bridge pier Scour" journal of hydraulic engineering. ASCE, 122(4),203-209.

Melville, B.W.and Raudkivi, A.J. (1999). " Time Scale for local scour at Bridge piers" journal of hydraulic engineering. ASCE, 125(1),59-67.

Mohamed, Thamer.A, Ghazali,A.H., (2001) Yusuf.B, Jaafar,M.S. "Physical Modeling the Effect of Variables governing Local scour around Bridge piers in Erodable Bed," ~~University Putra Malaysia faculty of engineering.~~ Conference on Hydraulic Structures, Kerman, IRAN