AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
IRRIGATION AND HYDRAULICS DEPARTMENT

PROTECTION MEASURES FOR SCOUR AROUND BRIDGE PIERS

BY

Yasser Khairy Saleh

Thesis

Submitted for partial fulfillment of requirements for the

M.Sc. Degree

Supervised By
Prof. Dr. Ali M. Talaat

Professor, Irrigation and Hydraulics
Dept., Faculty of Engineering
Ain Shams University, Cairo, Egypt

Dr. Mahmoud Sami Abdelsalam
Associate Professor, Irrigation and Hydraulics Dept., Faculty of Engineering
Ain Shams University, Cairo, Egypt

Dr. Mahmoud Sobhi Khalil
Associate Professor, Head of Civil Engineering Dept., The Higher Technological Institute 10th of Ramadan City, Egypt

Cairo, Egypt
2001

M.Sc. Thesis submitted by

Eng. YASSER KHAIRY SALEH

In Civil Engineering (Irrigation & Hydraulics)

Examiners Committee:

Signature

1- Prof. Dr. Moustafa Tawfik Gaweesh ……

Director, Construction Research Institute,
National Water Research Center,
Ministry of Public Works & Water Resources
Cairo, Egypt

2- Prof. Dr. M. Elniazi Hammad ……

Professor, Irrigation and Hydraulics Dept.,
Faculty of Engineering, Ain Shams University
Cairo, Egypt

3- Prof. Dr. Ali M. Talaat ……

Dean, Faculty of Engineering,
6^{th} October University, 6^{th} October city
Cairo, Egypt

4- Dr. Mahmoud Sami Abdel Salam ……

Associate Professor, Irrigation and Hydraulics Dept.,
Faculty of Engineering, Ain Shams University
Cairo, Egypt

Date: 27 / 1 / 2001

STATEMENT

This dissertation is submitted to Ain Shams University for the M.Sc. Degree in Civil Engineering, Irrigation and Hydraulics.

The work included in this thesis was carried out by the author, at Ain Shams University, Faculty of Engineering, Irrigation and Hydraulics Department and The Higher Technological Institute, 10th of Ramadan City, from November 1997 to January 2001.

No part of this thesis has been submitted for a degree or qualification at any other University or Institute.

Date: / /

Signature:

Name: Yasser Khairy Saleh

DEDICATION

It is a great pleasure to dedicate my
M.Sc. Thesis
To the most four persons I love in my life;

My father, my mother,

My wife, and my child

To all of them my deepest gratitude

ACKNOWLEDGMENTS

First of all, thanks to ALLAH without whom nothing could be possible.

I would like to express my deepest gratitude to my advisor Prof. Dr. Ali Mohamed Talaat, Professor of Irrigation and Hydraulics, Irrigation & Hydraulics Department, Faculty of Engineering, Ain Shams University, and The Dean of Faculty of Engineering, 6 October University, for his guidance and wisdom in the direction and scope of the work. His encouragement and support were vital to the success and completion of the thesis.

My special thanks are to Dr. Mahmoud Samy Abdelsalam Mohamed Foda, Assist. Prof. of Irrigation and Hydraulics, Irrigation & Hydraulics Department, Faculty of Engineering, Ain Shams University, for his continuous support and kind assistance.

My great appreciation to Dr. Mahmoud Sobhi Khalil, Head of Civil Engineering Department, The Higher Technological Institute, 10th of Ramadan City, for all he has done in supporting the part of my experimental work at the HTI.

Acknowledgments are greatly extended to the staff of the Higher Technological Institute, 10th of Ramadan City, for their help and cooperation.

My thanks also are to Dr. Osama Khairy Saleh, Associate professor of Irrigation and Hydraulics, Irrigation & Hydraulics Department, Faculty of Engineering, Zagazig University, for his continuous advice throughout the work.

There is no word that can express my deepest gratitude to my wife for her assistance, patience, and understanding. I deeply appreciate her sharing. My warmest thanks are to my child Ammar.

Last, but not least, I owe every thing to my parents for their blessing, sacrifices, encouragement, and for their support, not only these days but since I was born.

ABSTRACT

The study presented deals with the problems caused by the scouring process around the bridge piers in alluvial channels. It is motivated by the need to decrease the scour depth around the bridge piers. An experimental study has been conducted to investigate the local scour depth at the bridge pier nose. Five different groups of protective piles at different pile-pier spacing upstream the pier were utilized. The pier has a rectangular shape with cylindrical ends and the piles are circular in cross section. The bed material is uniform fine sand of (D_{50}=0.355 mm), (D_{84}=0.64 mm). Froude number upstream the bridge site ranges from 0.155 to 0.212.

The experimental work included 90 runs conducted at the Higher Technological Institute (HTI), 10^{th} of Ramadan City. The scour depth was measured under clear water scour condition. The aim of this study is to decrease the scour depth around bridge piers to safe guard the bridge foundation.

The experimental results showed that using a group of piles is more effective than using one pile in front of the pier. The arrangement, which gives the maximum reduction in scour depth, is when the piles are arranged in two rows such that the projected width of the piles group is larger than the pier width. The pile-pier spacing, which gives the minimum scour depth equals to two to three times the pier width.

The use of the described group decreases the scour depth from 30% to 95% depending upon the flow conditions.

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

b	Pier width for rectangular piers or pier diameter for circular piers
b_p	Projected pier width
B	Spacing between piers (span)
d	Pile diameter
D_{50}	Mean diameter of sediment
D_{50a}	Mean sediment size of the coarsest armor layer
D_{84}	Particle size for which 84% are finer
d_i	Scour depth at any time
d_s	Maximum scour depth
d_{se}	Equilibrium scour depth
F_c	Threshold Froude number
F_n	Froude number
F_p	Pier Froude number
g	Gravity acceleration
h	Water depth
K_d	Sediment size factor
K_h	Flow depth adjustment factor
K_i	Flow intensity factor

K_s Pier shape factor

K_α Pier alignment factor

K_σ Sediment gradation factor

L Pier length

l_1 Spacing between the protective piles in the flow direction

l_2 Spacing between piles perpendicular to the flow direction

N Number of piles

n Manning coeffecient

Q Discharge passing

R_n Reynolds number

R_{ng} Grain Reynolds number

R_p Pier Reynolds number

S Shield's parameter

t Time

t_{max} Time for equilibrium scour depth to develop

U_* Bed shear velocity of approach flow

U_{*c} Critical shear velocity (threshold condition)

U Mean velocity of the approach flow

U_a Mean approach flow velocity at the armor peak $=0.80U_{ca}$

U_c Cirtical velocity (threshold velocity)

U_{ca} Mean approach flow velocity beyond which armoring of channel bed is impossible

X Distance from the upstream pier nose to the edge of the pile group

Δ Relative submerged density

ρ Fluid density

ρ_s Sediment density

σ_g Geometric standard deviation of the particle size distribution

τ The avarage bed shear stress

τ_c The critical bed shear stress

υ Fluid kinematic viscosity

CHAPTER 1

INTRODUCTION

1.1 GENERAL

Scour is a natural phenomenon caused by the erosive action of the flowing water on the bed and the banks of alluvial channels. Bridges are one of the most common waterway structures. Bridge piers in alluvial rivers and streams cause a type of scour called “Local Scour”. Local scour is defined as the abrupt decrease in bed elevation in the vicinity of an obstruction as a consequence of the influence of the obstruction on the flow. Local scour at obstructions such as bridge piers may occur in two cases; when there is a general movement of sediment along a river channel, called live-bed scour and when there is no such general movement, called clear-water scour.

Scour induced bridge failures occur during flood flows. It is very important for the designer to find out a convenient method to prevent or minimize the scour depth to keep the foundation of the bridge piers and abutments in safe conditions. Scour depth depends upon the properties of the flow, the bed material in the stream, and the bridge foundation geometry at the bridge site. The problem is often further complicated by the large variety of the piers shape, alignment, and flow approach. So, it is not surprising that the various existing scour depth formulae give widely different results.

Various studies of the scouring process and the flow structure at the bridge piers have been investigated. Some of these studies were concentrated on the prediction of the scour depth around the bridge piers for different flow condition and bed material, other studies introduced empirical equations estimating the local scour depth for different shapes of bridge