CHAPTER 1

INTRODUCTION

1.1. General

Bridges are considered as a necessary means of vehicle transport for fast-growing cities, especially those having waterways crossing it. Therefore, design for hydraulic and structural considerations is important to maintain safety. While structural analysis and design of bridges are well understood, the uncertainties of hydraulic predictions often lead to over-design resulting in additional costs, or under-design and possibly failure (M. W. Horst, 2004). According to Richardson et al. (2001), the local scour around bridge piers is one of the most common causes of bridge failures.

Local scour is the removal of sediment from stream beds around or near structures located in flowing water. It 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 (Richardson et al., 2001). This means that it will increase the tendency to expose bridges foundations which may lead to bridge failure and loss of life and property.

The initiation of local scour around bridge piers and abutments is developed by the diversion of flow around them and scour hole is developed by a complex three-dimensional vortex. The down flow and horseshoe vortex develop local scour holes around bridge piers foundations (Millville, 1975).

Local scour around bridge piers or abutment pile foundations can be classified to three categories. The first category is the local scour, which occurs locally at the area around a bridge pier or abutment foundation. The second category is the contraction scour, this type occurs where the flow is contracted by the presence of a bridge pier and abutment foundations. The third is the general scour, which occurs due to the increase velocities across the channel.

Local scour can be either clear-water or live-bed. When the bed shear stress of approach flow does not exceed the critical shear stress for the bed materials and no sediment supply to the scour hole a clear water scour occurs, while the live bed scour occurs when sediment forming the channel bed in the approach flow is in motion Sharafaddin, (2003).

1.2. Problem Description

Local scour, especially during flood events, is considered one of the major causes of bridge failure, as it is directly disturbing the soil around bridge pier or abutment foundations.

Richardson et al. (1993) quoted a study produced in 1973 for the U.S. Federal Highway Administration that concluded of 383 bridge failures exist, 25% bridge pier damage and 72% abutment damage. Further, in an extensive study of bridge failure in United States, Brice et al. (1978) reported that the damage of highways bridges from major regional floods in 1964 and 1972 amounted to about 100 million Dollars per event. Sutherland (1986) compiled a record of all major bridge failure that occurred in New Zealand during the period of 1960-1984, of the 180 bridge failure, 19 abutment and 97 pier failures.

Melville et al. (2002) quoted that, in New Zealand, at least one serious bridge failure each year (on average) can be attributed to scour of the bridge foundations. A survey of road authorities showed that scour caused by rivers results in road expenditure of NZ$36 million per year. The survey also shows that expenditure on scour-related bridge damage amounted to about NZ$18 million per year, with more than 70% of this expenditure being related to bridge repairs.

Therefore, the understanding of the local scour phenomena is important to the engineer responsible for the design of bridge foundations. It is very important aspect to know the maximum possible scour around bridge piers and abutments in order to get safe and economic design. Underestimating the scour depth may leads to design too shallow foundations, which may become exposed to the flow reducing the safety of the bridge. Overestimating the scour depth leads to deep foundations, this is not an economical design. Generally, it is important to predict the maximum scour to minimize the risk of bridge failure and to minimize the cost of the bridge construction.

During the last decades river engineers were tried to calculate the maximum scour depth at bridge piers and abutments foundations, an extensive work have been done using physical models under different conditions. However, a few of them study the scour using numerical models. Nowadays many mathematical models have been developed to simulate the flow field in the vicinity of vertical obstructions. Fewer models were developed to simulate the sediment transport through waterways and around structures. These models have enabled researchers to predict the effects of changing the flow variables, which could not be accomplished easily during laboratory experiments.

1.3. Objectives

The general goal of the present research is to utilize accurate numerical simulations for predicting local scour around bridge piers. The objectives of this research are to validate a 3-D computational fluid dynamics model (SSIIM) for local scour around a bridge pier by comparison with complied laboratory data; to use SSIIM, to predict the maximum scour depth around pile groups with different pile arrangements. These objectives are achieved through:

A. Checking the validity of SSIIM numerical model in predicting the local scour around a bridge pier.

B. Studying the effect of pile groups, while changing the pile numbers and spacing in both longitudinal and transversal directions.

1.4. Methodology

In order to accomplish research objectives, the boundary conditions from the experimental work have been assigned through SSIIM Control file, using the experimental data presented by Sharafaddin, (2003). Three single piles with different sizes were used in model calibration. The used piles are 50 mm, 100 mm and 150 mm square piles. The validation was based on a low Froude number of 0.21. the following program have been used.

A. Validating the used numerical model using a 50 mm square pile. In this case the time step and roughness have been changed in order to meet the experimental results.

B. After fully calibration of the used model using the 50 mm pile, two runs have been conducted using 100 mm and 150 mm square pile to check if the maximum scour for those piles are predictable or not.

C. Different arrangement of square piles groups have been studied, number of piles ranging from 2 piles to 9 piles, separated by a clear spacing ranging from 50 mm to 200 mm.

1.5. Thesis Layout

In order to accomplish this research objectives, mathematical model was done, this mathematical model have been verified by the experimental work by Sharafaddin, (2003).

Chapter 2: This chapter represents a literature review on scour phenomena; it is also include scour definitions and classifications. The mechanism of developing scour hole around bridge pier and abutment foundations is also presented. Previous studies which focus on scour around bridge piers or pile, and pile group in non cohesive soil are also presented.

Chapter 3: describes the used mathematical model theoretical bases for both water flow calculations and sediment flow calculations. A brief description for model input and output files are also presented in this chapter.

Chapter 4: This chapter introduces the 3-D mathematical model geometry description and model inputs like boundary conditions, and sediment properties. Moreover, this chapter presents model verifications and research program.

Chapter 5: This chapter describes the parametric study which was carried out to investigate the effect of pile group and arrangement on the scour around bridge piers.

Chapter 6: contains a summary, conclusions, and recommendations.