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ORIGINAL ARTICLE

Experimental and numerical simulation of scour at bridge abutment provided with different arrangements of collars

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Abstract In this paper, the effects of different widths and lengths of collar around bridge abutment on local scour depth are studied numerically and experimentally. Numerical simulation of scour hole evolution at bridge abutment is more convenient than the experimental modeling, because the computational cost and time have significantly decreased. The numerical model solves 3-D Navier–Stokes equations and bed load conservation equation. The k–ε turbulence model is used to solve the Reynolds-stress term. The simulated results are verified using the laboratory experiments. In addition, the multiple linear regressions are applied to correlate the maximum local scour depth with the other independent parameters. It was found that the relative length of collar 0.73 around bridge abutment reduces the maximum scour depth by 69% compared to no-collar case. Moreover, the results of 3-D numerical model and regression models agree well with the experimental data.

1. Introduction

Scour around bridge piers and abutments is considered one of the most important fields of hydraulic researches. The scour phenomenon may endanger the whole structure after long or short run depending upon the extent of scouring processes. Richardson and Abed [1] quoted a study produced in 1973 for the U.S. Federal Highway Administration, that concluded of 383 bridge failures, 25% involved pier damage and 72% involved abutment damage; so many researchers investigated the scour phenomenon at bridge foundations, i.e. bridge piers and abutments. The local scour depth around spur dikes and bridge abutments was estimated in alluvial rivers [2]. Static reliability model was developed for the assessment of local scouring reliability around bridge abutments [3]. Overview of scour types and scour-estimation difficulties faced at bridge abutments was investigated [4], and clear-water scour development at bridge abutments was presented [5]. Numerical simulation of scour depth evolution around bridge piers was investigated [6–8].

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Nomenclature

D_{50}	the median sand size	K	von Karmen constant
σ_g	the geometric standard deviation	U_*	shear velocity
U	mean flow velocity	z	height above the bed
U_c	mean approach velocity at the threshold condition	y_t	tail water depth
d	sediment particle diameter	F_t	tail Froude number
τ	bed shear stress	d_s	maximum local scour depth
τ_c	critical bed shear stress	L_1	collar width
ρ_w	density of water	b	abutment width in lateral direction
ρ_s	density of sediment	L_c	length of collar in longitudinal direction
v	kinematic viscosity	L	length of bridge abutment
g	gravitational acceleration		
q_b	bed load discharge		

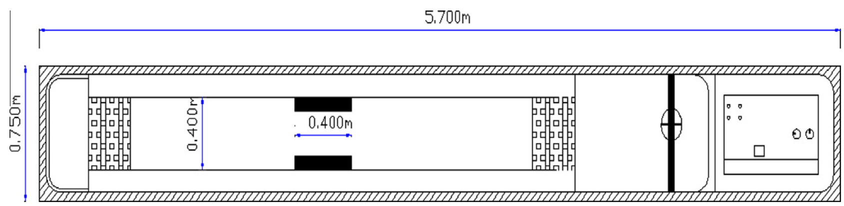

Figure 1 Definition sketch of a re-circulating flume.

Scour around bridge abutment was studied experimentally [9–14]. Time-wise variation of scouring at bridge abutments was studied [15]. Numerical models were also presented to simulate the scour depth around bridge abutment [16,17]. Group method of data handling (GMDH) network was used to predict abutments scour depth of the bridges [18]. Gene expression programming and artificial neural networks were used to predict the time variation of scour depth at a short abutment [19]. In this study, the local scour around bridge abutment was studied experimentally and numerically. The effect of different widths and lengths of collar at abutment edge, on local scour depth were investigated. These collars were considered as a tool that maximize the reduction of maximum local scour around bridge foundation and hence ensure greater safety of the structure against the harmful scour around bridge foundation, and hence longer life of the hydraulic structure is expected. The numerical models were created by using sediment simulation in water intakes with multiblock option (SSIIM) program. This 3D CFD model was

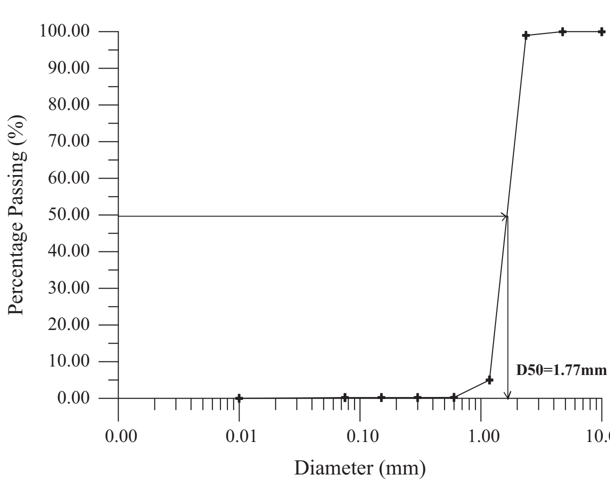

Figure 2 Sieve analysis of movable bed soil.

Table 1 Details of experimental conditions.

Discharge (l/s)	3.5	Median sand size (mm)	1.77
Abutment width (b) cm	3.75, 5.0, and 7.5	Flow depth (cm)	3–7
Collar width ($L1$) cm	4.5, 6 and 7.5	Froude number	0.20–0.55
Collar length (Lc) cm	12, 13.5, 15, 20.5, 29, 37.5, 46 and 52		

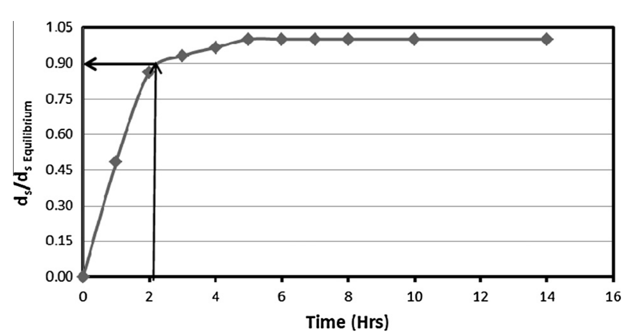

Figure 3 Ratio of maximum to equilibrium scour depths ($d_s/d_{s\ \mathrm{Equilibrium}}$) versus time.