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ORIGINAL ARTICLE

Experimental and theoretical investigations of scour at bridge abutment

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Abstract Numerical and experimental studies were carried out to investigate the effect of different contraction ratios and entrance angles of bridge abutment on local scour depth. A 3-D numerical model is developed to simulate the scour at bridge abutment. This model solves 3-D Navier–Stokes equations and a bed load conservation equation. The $k-\varepsilon$ turbulence model is used to solve the Reynolds-stress term. In addition, the model verification is made by comparing the computed results with existing experimental data. The results show the ability of the numerical model to simulate local scouring at bridge abutments for different contraction ratios and entrance angles of abutment with high accuracy. The determination coefficient and mean relative absolute error, in average, are 0.95 and, 0.12, respectively.

1. Introduction

The scour is 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 (Richardson and Davis, 2001). Such scour around pier and pile supported structures and abutments can result in structural collapse and loss of life and property. Richardson and Abed (1993), quoted in 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. The total scour at a river crossing consists of three components: general scour, contraction scour, and local scour (Cheremisinoff et al., 1987). Local scour occurs around piers, abutments, spurs and embankments, which is caused by the acceleration of the flow and the development of vortex systems induced by these obstructions to the flow. Many studies have been carried out to develop the relationships for predicting the maximum scour depth at bridge piers under clear-water scour condition and these relations have been used

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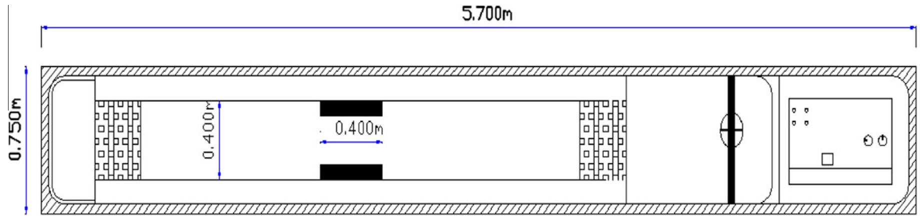

Figure 1 Definition sketch of a re-circulating flume.

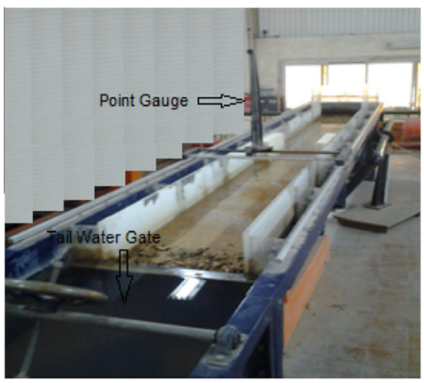

Photo 1 Re-circulating flume.

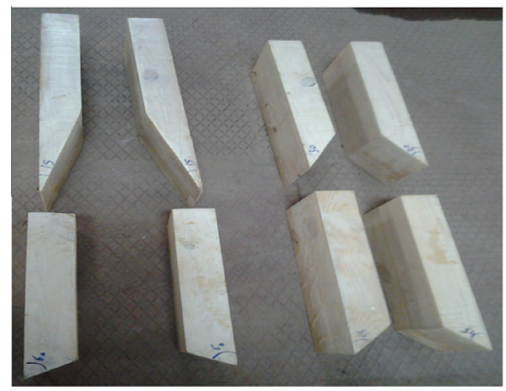

Photo 2 Different shapes of abutment.

extensively for designing purposes (Dehghani et al., 2009). Lots of researches are carried out to minified the scour dimensions by implementing a circular collar around the pier (Zarrati et al., 2004, 2006; Alabi, 2006; Moncada-M et al., 2009; Abdel-Aal and Mohamed, 2010; Abdel-Aal et al., 2008), submerged vanes (Odgaard and Wang, 1987), a slot through the pier (Chiew, 1992; Grilmaldi et al., 2009; Gaudio et al., 2012, Tafarojnoruz et al., 2010, 2012). The guide wall was used to protect the scour depth at bridge abutment (Fathi et al., 2011). Effect of weed accumulation on scour depth around bridge piers was investigated by Mowafy and EI-Saed (2000). The effect of constructing two adjacent bridges on the flow characteristics and local scour around bridge piers was discussed by Mowafy and Fahmy (2001). Melville (1992) and Melville (1997) presented an integrating approach to the estimation of local scour depth at bridge piers and abutments. Scour around bridge abutment is studied experimentally by-Hua (2005), Abou-Seida et al. (2009) and Kose and Yanmaz (2010). Gene expression programming and artificial neural networks were used to predict the time variation of scour depth at a short abutment by Mohammadpour et al. (2013). The scour computation is considered as a complicated process and time consuming, so, many soft-wares were created and applied to compute scour around bridge piers. Several numerical models have been constructed for simulating the 3D flow field and bed

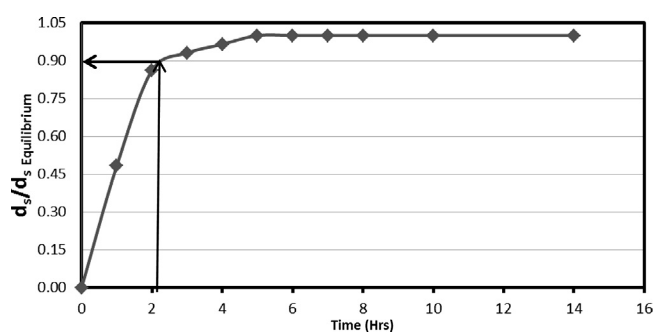

Figure 2 Ratio of maximum to equilibrium scour depths ($d_s/d_{s\ \mathrm{Equilibrium}}$) versus time.

variations around bridge piers. Scour around bridge piers was numerically simulated by Olsen and Melaaen (1993), Dou (1997), Richardson and Panchang (1998)and Tseng et al. (2000). In addition, numerical models are also presented to simulate the scour depth around bridge abutment by Morales and Ettema (2011) and Taymaz et al. (2011). In this study, the local scour around bridge abutment was studied experimentally and numerically. The effects of different contraction

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
Abutment entrance angle	90°, 60°, 45°, 30°, 15°, and 10°	Froude Number	0.20–0.55