MODELLING AND CALIBRATION OF THE LOCAL SCOUR AROUND PIERS IN ERODABLE BED

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Introduction

The construction of bridges in alluvial channels will cause a contraction in the waterway at the bridge site. The contraction in the waterway will cause significant scour at that site. Many bridges failed around the world because of extreme scour around piers. Local scour in the bridge site is caused by the interference of the piers with flowing water. This interference will result in a considerable increase in 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. In the present study, an empirical model was proposed to compute the local scour in the bridge site. The data used in the model calibration was obtained experimentally from a physical model.

Materials and Methods

The physical model used for simulating the local scour around piers consisted of a 20 m glass-sided tilted flume, which has a rectangular cross-section (90 cm width and 60 cm high). Two types of soil were used to simulate bed materials; the first type was a sandy soil with 0.45mm average particle size, the second type was a silty clay soil with 0.06 mm average particle size. A sieve and hydrometer analysis was used to classify these two bed materials respectively. Hard teak wood was used to simulate the piers and three pier shapes were used. These shapes were squared nose, circular cylindrical, and the sharp nose. The physical model has a 1/100 horizontal scale and 1/25 vertical scale. For fixed discharge and bed material, the effect of piers shape and number were investigated using single pier, two piers, three piers, four piers, and five piers from the same shape. The runs to be repeated for other used shapes. The effect of the flow on the local scour depth was studied by using different values of the discharge starting from 10 l/s up to 26 l/s, the discharges were measured using a V-shape weir which was calibrated before use.

Results and Discussion

In the present work a physical model was used to simulate the local scour around piers. The variables governing the local scour were arranged in dimensionless groups and a general formula to estimate the local scour in bride site was formulated. In the proposed model, the combined effect of the studied variables on the local scour was lumped in a coefficient, K. Data gathered from the physical model, together with previous data (Jain, 1981; Qadar 1981), were used to calibrate the proposed model. The value of the coefficient K was found to be 1.36. Based on the limitation of the data used in the calibration process, the proposed model would be applicable to piers of any shape with bed materials ranging from 0.1 mm to 0.6 mm. It is obvious that the local scour is ultimately a field problem, so field data is necessary to be used in the validation process of the proposed model. Recorded data related to bridges in India, Pakistan, and Canada were used in the validation process of the proposed model. The validation process showed that the proposed model was in agreement with the recorded data. The computed local scour depth from the proposed model was found in agreement with those previously computed values (Qadar, 1981). The overall mean and standard deviation obtained from applying the proposed model to the above mentioned bridges were 10% and 0.07 respectively. This confirms that the proposed model was in agreement with the method of Qadar (1991). In the design stage, the effect of local scour can by tackled by selecting the pier shape. Froehlich (1995) and Chiew (1992) proposed different approaches to reduce the score depth at the pier site. According to Chiew (1992), the local scour depth can be reduced by 20% to 30% in case of having a collar or a slot in the pier. Shen (1971) proposed to use a layer of a riprap around the pier site to reduce the local scour depth, the thickness of that layer is the larger of the following values: a) width of the pier, and b) three riprap diameters. But Froehlich (1995) highlighted that if the smallest nontransportable particles in the armor layer around the pier is larger than D_{95} of the underlying bed materials, evidence indicates that the armor layer will be unstable and particles of all sizes will be nearly equally mobile. This findings highlighted the importance of the graduation of nontransportable particles of the armor layer which will be used in the protection of the mobile bed against scour at the pier site, although Shen (1971) did not mention anything regarding the graduation of the protection layer in his presentation.

Conclusions

Local scour around bridge pier located in an erodible bed is a complicated problem and only very limited success has been made to model the local scour computationally. Physical model remains the principal tool employed to estimate local scour depth. The proposed model is simple and can be applied to calculate the local scour in the prototype having bed material ranging between 0.1 mm to 0.6 mm. A mean deviation and standard deviation of 10% and 0.07 was obtained from applying the proposed model using the historical records for several bridges around the world. This application also revealed that the proposed model is in agreement with other approaches.

References

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