Photogrammetric characterization of the scour cavity time evolution around a complex bridge pier

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Abstract

The temporal development of local scour around a complex bridge pier was experimentally studied using a small-scale model embedded in a uniform diameter sand. A set of 15 experiments were conducted at the Hydraulics Laboratory of the Faculty of Engineering of the University of Porto under steady clear-water conditions. Experiments lasted between five minutes and eleven days for a progressive characterization of the scour cavity until the equilibrium stage. Good agreement was achieved by comparing the scour depths directly read in the laboratory with the obtained from application of close-range photogrammetry. The time evolution of the scour cavity is studied. Important empirical relations for the temporal development of the scour cavity and for correlating scour depths with scour cavity volumes were derived. The resultant three-dimensional models can also be usefully used for the calibration and validation phases of a numerical model.

Keywords: complex bridge pier, local scour, scour cavity, close-range photogrammetry

1. Introduction

Local scouring around bridge piers is one of the most significant topics associated with structural stability of bridges. In past decades, the local scour around piers has been extensively investigated, resulting in semi-empirical equations for evaluating the temporal evolution of the maximum scour depth such as in Moreno et al. 2012. Besides the direct applicability of the maximum scour depth in design purposes, the whole geometry of the scour cavity plays a major role in the scouring process such as modifying the income flow characteristics.

Hence, the main goal of this study is to collect a detailed time measurements of the scour cavity geometry development in the near vicinity of a complex bridge pier by close-range photogrammetric means. This technique was successfully applied to measure the scour cavity around single piers in Rapp et al. 2012, among others. The selected methodology will lead to an original experimental dataset as well as a set of empirical relations of the scour patterns to be later used as a useful input for numerical simulations.

2. Materials and Methods

The experiments were conducted on a 32.2 m long and 1 m wide recirculation flume at the Hydraulics Laboratory of FEUP. The adopted flow velocity ($u = 0.327$ ms^{-1}) was set to be 97 % of the critical flow velocity. Therefore, a flow depth of 0.18 m and a flow discharge of 0.059 m^{3}s^{-1} were imposed, guaranteeing clear-water flow conditions. The sand material was characterized by a median diameter, D_{50}, of 0.86 mm, a gradation coefficient of the sediment size distribution, σ_d, of 1.4 and a density, ρ, of 2650 kg m^{-3}. The complex pier model, placed on the channel midplane, is depicted in Figure 1.

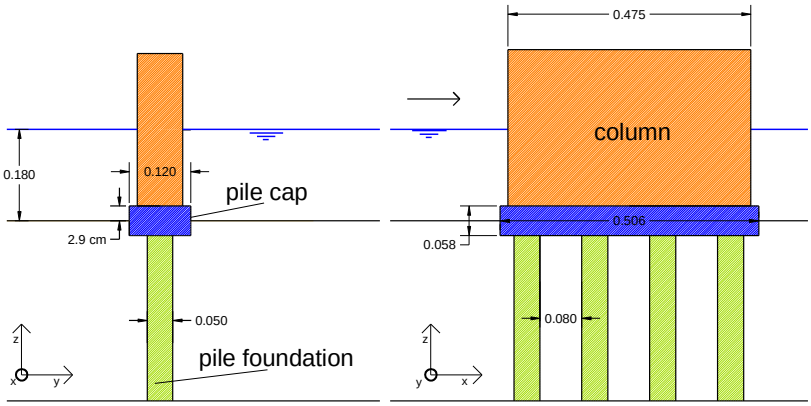

Figure 1: Geometric characteristics of the complex pier (dimensions in m).

3. Results and Discussion

The experimental analysis comprised the measurement of the scour depths at the pile cap front (by a limnimeter), and at each individual foundation pile (reading the attached scale), and the characterization of the scour cavity geometry (by close-range photogrammetry). Its application required a digital camera and a set of ground control points, with controlled light exposure, to enable performing the spatial reference. A comparison between the two experimental approaches is shown in Figure 2. The equilibrium scour stage was reached after 264 hours (11 days) of experiment duration, with a maximum scour depth of 19.8 cm at the base of the upstream foundation pile. Digital elevation models were generated and used to compute volumes and geometric characteristics of the scour cavities. Empirical relations for sediment discharges, scoured volume rates and scour depths were derived for the complex pier model under study.

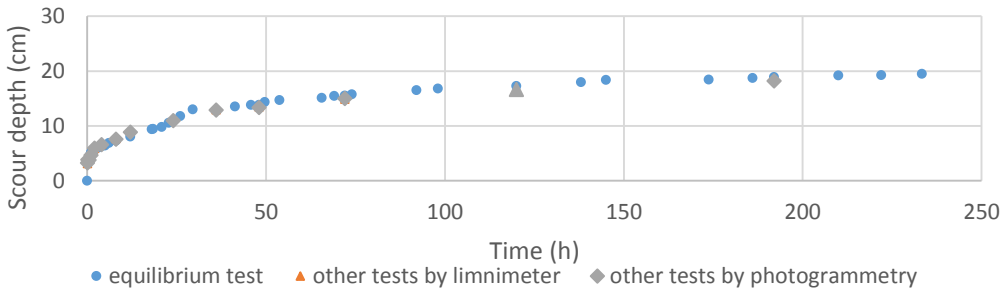

Figure 2: Comparison of the experimental approaches: Scour depths at the pile cap.

4. Conclusions

Scour depth values at the pile cap front were determined by using a limnimeter and close-range photogrammetric means, which are known as intrusive and non-intrusive techniques, respectively; a good agreement was achieved. A wide dataset of the geometrical characteristics of scour cavities around complex bridge piers was constructed, which will be the base for further research works.

References

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