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Physical modelling of flow and geomorphological conditions along an arched bridge with a scoured abutment

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ABSTRACT

This study presents results from turbulent flow measurements conducted in a laboratory flume with a physical model of an arched bridge over a gravel bed stream. The aim of this research is to investigate flow conditions at the bridge abutment that initiated scour development in non-uniform gravel bed river

1 INTRODUCTION

Scour process around underwater structural elements is considered one of the main complications in the design and operation of river and offshore infrastructure [1, 2, 3]. Development of scour around bridge piers and abutments positioned in river channel is an ongoing process driven by turbulent flow in vicinity of bridge elements [4]. Size of scour holes depends on flow parameters and is proportional to flow depth and velocity. Therefore, greatest scour hole depth is expected to occur during high flows.

Investigation of flow characteristics and associated sediment transport and scouring processes are conducted mainly in straight river or flume reaches [5]. A minor portion of studies focuses on investigations of the complex turbulent field at abutments due to constraints imposed by complex flow pattern [6]. Flow from the bridge approach section is deflected towards the foundation in the bridge profile, forming large-scale vortices near the riverbed. Energy dissipation in the vortices along the foundation initiates scour hole development and controls their size.

2 HYDRAULIC ENVIRONMENT

Complex flow field impose restrictions on analysis and distinction of contribution for each of the scour controlling variables. Detailed flow field surveys are influenced by high flow conditions, making acquisition of reliable results uncertain and measurement procedure dangerous. For this reason, surveys are mostly conducted during low and mean flows, when water depth is shallow and flow velocities slower. Surveys conducted in this way may not be representative of flood-induced hazards for bridge safety. On smaller streams long-term recordings of water levels and discharge are rarely readily available, so probability of occurrence for significant high flow events can be challenging to calculate. In such cases physical models can be used to replicate the hydraulic environment and acquire hydraulic data relevant for scour estimation under high flow conditions.

Sediment transport processes associated with scour are especially complicated to describe in riverbeds consisting of sand/gravel mixture where grains of different sizes are entrained by different flow conditions.

3 EXPERIMENTAL SETUP

Research has been conducted on a 1:7 scaled model of a single span masonry arch bridge in south Ireland. The analyzed river reach is a mountainous river characterized with steep slope and drops over submerged weirs, causing constant deflections of flow and altering flow field under different discharges. Riverbed material is sand-gravel mixture.

Experiments are conducted on a physical model placed in a 12 m long, 1.8 m wide and 0.4 m deep laboratory flume located at the University of Glasgow. Physical model geometry is created from detailed bathymetry data surveyed along a rectangular grid of 50 cm spacing at the bridge site.

Figure 1. Flume model setup, looking downstream.

4 RESULTS

Flow field was investigated for different flow conditions using acoustic Doppler velocimetry high data rate measurements. Flow velocity components have been measured on 6 ensembles for each of the different flow rates. Four ensembles were located in the bridge profile and two upstream at the bridge approach section. Each ensemble consisted of 8 velocity measurement points. Flow rates corresponded to the range of conditions expected to occur in the analyzed river reach, from mean flow up to 100-year flood.

Collected data were filtered to remove turbulent fluctuations that exceed natural random fluctuation of the velocity for all velocity components; streamwise, spanwise and vertical. This approach was required because flow in the flume reflected natural conditions characterized with abrupt flow intensity and direction changes that affected measurement procedure.

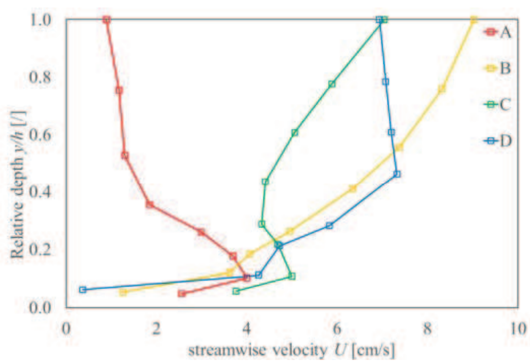

Figure 2. Flow velocity profile on 4 verticals upstream of the bridge.

5 CONCLUSION

The aim of this research is to investigate flow conditions at the bridge abutment that initiated scour development in non-uniform gravel bed river. From the measured data variables representing turbulence characteristics were calculated: Reynolds and boundary shear stresses and turbulent intensities. To define conditions under which the bed substrate is entrained into the flow flume model is used to replicate high flow conditions. Of greatest interest is the interface between submerged weir and abutment face that is most prone to scouring due to high values of the streamwise and vertical turbulent intensities. Specific hydraulic conditions on this river reach are a consequence of high velocity shallow flow over a locally steep bed surface slope.

6 ACKNOWLEDGMENT

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