LABORATOIRE DE CONSTRUCTIONS HYDRAULIQUES

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Flow conditions and intense sediment transport in steep mountain rivers considering the large immobile boulders (2011)

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Problem statement

Recent flood events in Switzerland and across Europe have pointed out several deficiencies of the planning and prediction methods used for flood risk mitigation. The goal of APUNCH (Advanced Process UNderstanding and prediction of hydrological extremes and Complex Hazards) is to gain a comprehensive and process chain based insight into the response of Alpine watersheds hit by storm rainfall events (Figure 1). This will be achieved by a multidisciplinary project context. The present study will focus on the sediment transport in mountain rivers.

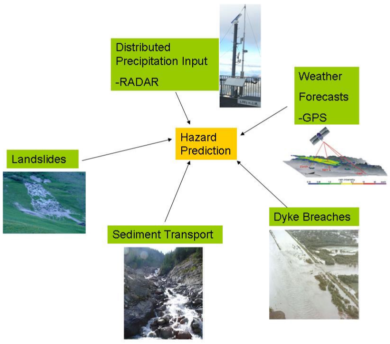

Figure 1 : APUNCH project organisation.

Objectives

When applied to mountain torrents, sediment transport formulae habitually overestimate the bedload by several orders of magnitude. The reason is that the influence of macro-roughness elements, such as large immobile boulders, is not taken into account. Larger roughness elements induce an increased form drag, implying a lower shear stress available for sediment entrainment. The impact of boulders on shear stress should then be taken into account. A shear stress partitioning method is needed. The goal of the present research is to develop an empirical formula to calculate bedload when boulders are present.

Methodology

The influence of multiple parameters is being studied on a tilting flume. The experimental facility is described in Figure 2.

During the experiments the following parameters are measured:

- Velocity (ink injection)
- Water depth (point gauge)
- Boulder protrusion (point gauge)
- Sediment outlet (weight; continuously)

The influence of the following parameters on sediment transport is studied:

- Slope S
- Discharge Q
- Boulder diameter D
- Boulder distance λ

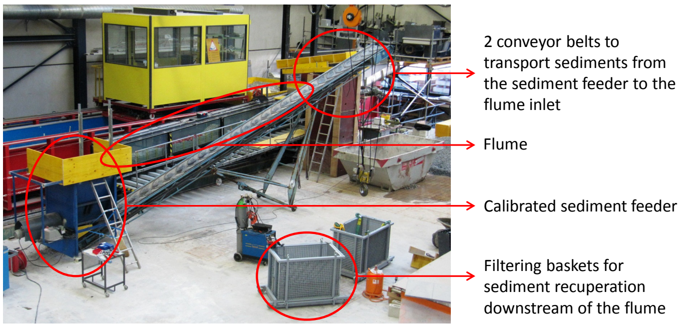

Figure 2 : Experimental facility.

Results

First results (slope of 6.7% and D=7.5 cm) show that when a high number of boulders is present (ratio between average boulder distance λ and average boulder diameter D of 2.4, with a unit water discharge of 0.02 m^2/s), corresponding to 15% of the surface occupied by boulders, the bedload can be reduced by 60% compared to transport rate without boulders (Figure 3, right). Boulder protrusion, distance and diameters are key factors for a good estimation of sediment transport capacity. This amount of reduction is also highly dependent on water discharge. An increasing discharge decreases the impact of boulders, because of the reduced relative roughness.

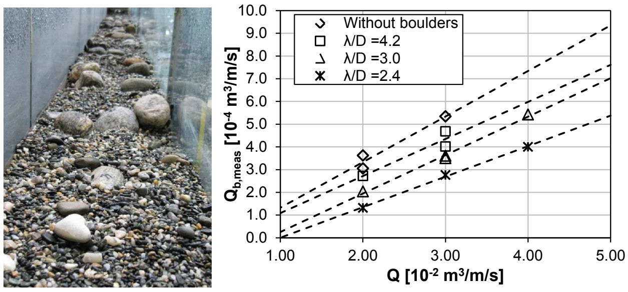

Figure 3: Left: flume after a test; Right: measured sediment transport $Q_{b,meas}$ as a function of the discharge Q for different boulder spacing λ/D.

Different sediment transport formulae, such as Smart and Jäggi formula, are applied to the measured data. These formulae are then modified to take into account the shear stress acting on mobile sediments. Figure 4 shows the improvement in the calculated value.

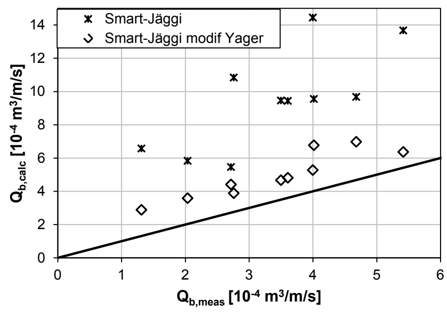

Figure 4: Comparison of measured $Q_{b,meas}$ and calculated $Q_{b,calc}$ sediment discharge for the original and modified (according Yager) Smart and Jäggi equation.

Research financed by the Competence Center Environment and Sustainability (CCES) and the Swiss Federal Office of Energy (SFOE).