CERIS Civil Engineering Research and Innovation for Sustainability

STEEP STREAMS – Solid Transport Evaluation and Efficiency in Prevention: Sustainable Techniques of Rational Engineering and Advanced Methods

Project Reference

WATERJPI/0006/2014

Leading Institution

University of Trento (Italy)

Partners

Uppsala University (Sweden), IST-ID – Associação do Instituto Superior Técnico para a Investigação e Desenvolvimento (Portugal)

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CERIS

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Project Website

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Summary

The STEEP STREAMS project aimed at producing new rational criteria for the design of protection works against debris flows, which are catastrophic events that usually occur in steep channels and are triggered by intense rainstorms. Recently, such events have been characterized by an increase in their intensity and frequency due to an alteration of small-scale storm events, which are responsible for strong runoffs and solid mobilization. Most conventional defensive strategies that are currently employed in mountainous catchments may not be sufficient to provide adequate levels of protection due to these changes. Additionally, most of these structures have proven to behave poorly in the presence of woody material, which is common in mountainous channels. The project consisted of a collaboration among different Universities dealing with different macro-tasks: i) the analysis of the correlation between climate change and the increasing intensity and frequency of extreme events in small catchments of mountainous areas; ii) the development of a two-dimensional mathematical model able to predict the transport of large woody debris during floods; iii) the development of innovative approaches for the prevention and mitigation related to debris flows in presence of woody material; iv) the assessment of the developed models and tools through physical models and basins at real scale.

The CERIS Research team dealt with tasks related to the assessment of new device(s) capable of intercepting the driftwood without interfering with sediment lamination during a debris flow, through laboratory and numerical experiments. The general objective was structured into different sub-tasks, which can be summarized as follows: a) sub-task 1 - assessment of the closure relations for driftwood dynamics through experiments of wood transport in physical models; b) sub-task 2 - analysis of the performance of retaining structures for driftwood in the absence of sediments, and near a slit check dam; c) sub-task 3 - assessment of the efficiency of the system in the presence of wood and intense sediment transport.

Sub-task 1 was partly carried out at the Laboratory of Hydraulics of IST in Lisbon, and partly developed at the University of Trento (Italy). In Lisbon, fifty drag tests were performed in a flume wide 0.7 m and long 7 m, to assess the variation of the drag force exerted on a single cylindrical log in different hydraulic conditions. The measurements were obtained by developing a hydrodynamic scale (e.g. Figure 1) that allowed for the variation of the log submergence and orientation with respect to the flow. The experimental values, compared to the numerical simulations, provided interesting insights on the evolution of the drag coefficient for single logs, and they were implemented into the two-dimensional numerical model developed by this project, in order to compute the motion of cylindrical floating bodies.

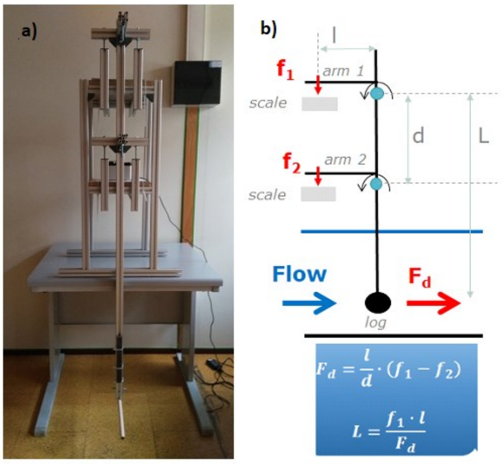

Figure 1. Hydrodynamic scale used to investigate the drag force (Fd) exerted on a log: a) general view of the structure; b) functioning scheme.

Regarding the same sub-task on the driftwood dynamics (sub-task 1), one experimental campaign was designed and carried out at the University of Trento, using a 22 m long and 2 m wide distorted physical model (see Figure 2 (a)), with a double bend and a fixed bottom. In this preliminary phase, one hundred different logs were released from four different points of the same section, and tracked by using three synchronized GoPro cameras across the channel. These tests allowed for a meaningful statistical description of the dynamics of single floating elements, analysing the effect of the morphology and the change of the starting point on the wood transport. Further experiments were carried out to complete the analysis, whose aim was two-fold: from one side the collected data were used to validate the two-dimensional numerical model developed to simulate driftwood in rivers; on the other side, the investigation helped formulate an Eulerian description of the driftwood dynamics, able to provide an estimation of the volumes and concentration of wood accumulation starting from the hydraulic conditions and wood characteristics.

For sub-tasks 2 and 3, a tilting flume present at the laboratory of Hydraulics of IST (see Fig 2 (b)) has been elongated and equipped with a recirculating system both for the solid material and water. The channel was also provided with a section having one glass lateral wall and a transparent bottom, in order to allow for the visual inspection of the flow from these sides. Level sensors were installed to measure the water depth in four different sections across the channel length, while three cameras were placed to observe the flow from the top, the lateral side wall and the bottom. The final section of the flume was provided with a check dam, with changeable apertures and spacing. The retaining device for driftwood was positioned upstream of the check dam and it consisted of a rack whose spacing, inclination and position could be easily varied during the experiments. For sub-tasks 2 and 3 two different experimental campaigns were performed by running tests on the tilting flume, and the results were widened by numerical simulations. More precisely, the efficiency of the rack placed close to the check dam was assessed first in the absence of sediments and then by adding solid material. The performance of the structure was analysed for different hydraulic conditions and driftwood input by changing: a) its distance from the check dam; b) its inclination; c) its distance from the bottom. Specific runs were selected to derive information about the driftwood dynamics close to the retaining device (velocity, orientation a concentration of wood logs) to match the results with the numerical simulations.

At the end of this project, the combination of the laboratory and numerical experiments answered the three aforementioned sub-tasks. First, they helped to define the closure relationships used for driftwood dynamics within the two-dimensional numerical model. Sub-task 1 illustrated the drag force and driftwood dynamics in specific configurations. Then, sub-task 2 gave a thorough evaluation of the efficiency of simple retaining structures for woody material, while sub-task 3 investigated the effect of the wood clogging on the sediment transport and the efficiency of the retaining device placed before the check dam. Design criteria for structures that are able to capture wood material without interfering with the intercepting processes for the sediments of the check dam were derived.

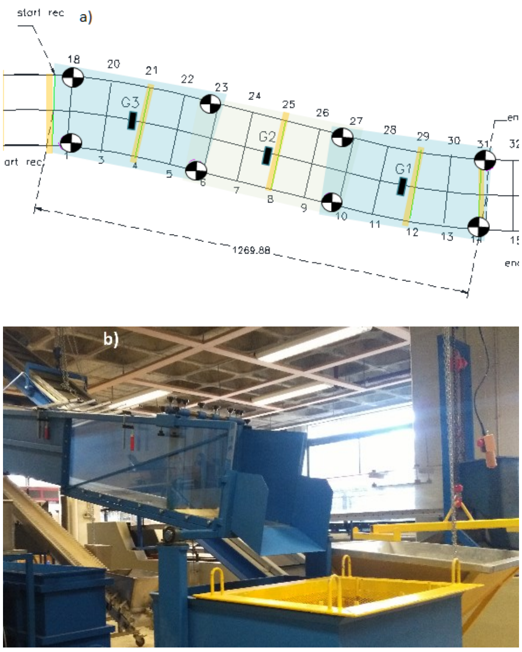

Figure 2. a) Scheme of the channel employed at the University of Trento to analyse the driftwood transport, with the positions of the three cameras and the reference points for the measurements; b) view of the tilting flume at the University of Lisbon.