MORPHEUS – River Bed Morphology and Erosion Studies

Summary

Motivation

The EU Water framework directory stresses the importance of the ecology and economy associated to fluvial systems. From a physical point of view, a river is as an example of a very complex system. In fact, different spatial and time scales coexist.

Spatial scales range from sediment diameter to the hydrographic basin dimensions and time scales can range from a few seconds to millennia. Another layer of complexity is added by the presence of different types of sediments, flow regimes, and biota.

Sediments in particular are a vital part of a fluvial system and fluid-sediment interaction is a key factor to understand how such complex systems, like the river bed, evolve in the different time and spatial scales ranging.

Sediment mechanics is of fundamental importance to other phenomena found in the scope of civil engineering such as mudflows, dam-breaking (hydraulics), landslides (geotechnical), debris transport (mining).

This proposal follows the path of other ongoing projects (SediTrans and HyTech), funded by the European Union, with a combined 3M€ budget. Research team members are active members of those projects. The present project can be seen as the natural step forward of the proponent team that combines senior researchers with recent PhD holders' researchers. This project is also an opportunity to strength the ties between three major universities in Portugal (ULisboa, UPorto and UMinho) and to gain critical mass in an important field of research.

State of the art

Until the 20th century fundamental research and applied science on fluvial hydraulics was based on variables such as the water flow rate, bed slope and bed roughness. This approach is here referred as macro-scale approach. Often founded in empirical grounds, it allowed to solve engineering problems; however little was known about the physics behind such empirical data. With the development of fluid mechanics, namely with the boundary-layer theory proposed by Prandtl, a different approach on fluvial hydraulics problems was made. Shields was probably the first to analyze the beginning of individual sediment grains motion due to the critical shear stress. Hans Albert Einstein innovative studies presented a formulation of sediment transport based on turbulence and boundary-layer theories and introducing concepts of probabilistic approach. These studies made at sediment scale are hereafter referred as micro-scale analysis, as opposed to the macro-scale approach. This analysis is focused on sediments mechanics and often importing concepts from statistical thermodynamics. Despite the originalities of the micro-scale approach, Meyer-Peter remarks about H.A. Einstein's theses, as producing "some intriguing ideas, but not exactly useful for my Alpine Rhine study", still haunts the relation between sediment mechanics (micro-scale) and macro-scale formulations.

Examples do exist that show how the micro-scale approach is of fundamental importance, namely the bridge pier localized erosion pattern. Experiments show that classical formulae derived from macro-scale analysis, do not offer accurate predictions of the erosion patterns induced by a bridge pier, for example.

Problems tackled

Although the many progresses made a large gap still exists between the micro-scale and the macro-scale approaches, namely how to obtain the macro-scale results from upscaling the micro-scale results. Recent studies have shed some light on this subject but the following five major limitations are easily found:

a) the small scale of the tests; b) the experimental techniques limitations (e.g. short measurement periods); c) analysis in very simple 1D case; d) the lack of independent confirmation of such results and e) the existence of different definitions, by different authors, for the same variable (e.g. solid flowrate).

How problems are addressed them and expected Results

A set of experiments using state of the art techniques is proposed (Figure 1), in order to perform a detailed analysis of sediment mechanics under different flow conditions by looking at the sediment scale and to understand the mechanisms behind large scale processes such as scour.

A deeper and accurate vision of granular mechanics from the statistical point of view is expected at the end of this project. This will be achieved by an independent confirmation of existing results, the application of existing mathematical and numerical models to different cases, rather than the 1D flows found in the literature. The partners involved in this project will benefit in first hand from a solid discharge meter (Figure 2); a combined PIV+PTV (Particle Image Velocimetry + Particle Tracking Velocimetry respectively) and an accurate numerical model capable of describing local scour based on sediment dynamics. The obtained results and methodologies will be made available to the scientific community.

Project Reference

PTDC/ECM-HID/6387/2014

Leading Institution

FEUP – Faculdade de Engenharia da Universidade do Porto (Portugal)

Partners

IST-ID – Associação do Instituto Superior Técnico para a Investigação e Desenvolvimento (Portugal), UMinho – University of Minho (Portugal)

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Period

2016-2020

Total

198 501.00€

CERIS

93 009.00€

Project Website

https://morpheusfct.wordpress.com/workshop/

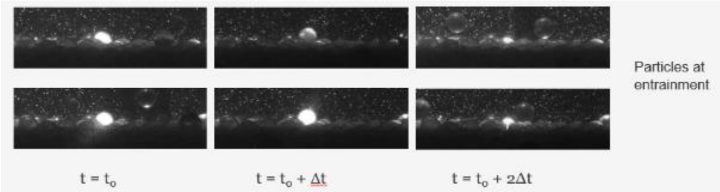

Figure 1. PTV-PIV system to track sediment motion and corresponding velocity field.

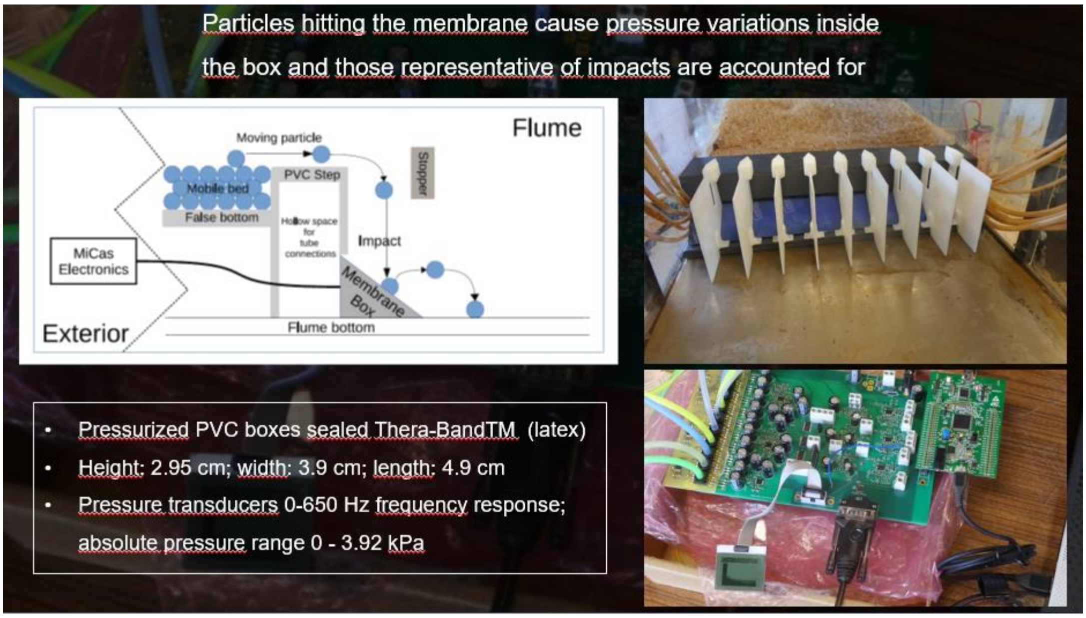

Figure 2. In-house pressure-based bedload discharge meter.