Institut Pprime
Recherche en physique et ingénierie

PhD thesis
Local analysis of erosion modes of real cohesive sediments subjected to turbulent flow

Context

Cohesive sediments are present in most river and marine environments. They play a key role in the functioning of these ecosystems. Their erosion not only has repercussions on the morphology of the environment (erosion of the bed and banks), but also has a major impact on the habitats of benthic communities and can lead to a sharp increase in turbidity and the release of pollution. The problems associated with their characterisation and analysis of their transport are therefore of prime importance, particularly in terms of preserving coastal and river environments.

In this context, the PhD thesis work will focus on a laboratory study of the links between the rheological properties of cohesive sediments and their erosion in the presence of turbulent flow. As cohesive sediments have complex rheological properties (shear thinning properties, yield stress, thixotropy), the interaction between these sediments and a flow will depend on both the rheological characteristics of the material and the properties of the flow.


(left) Silted banks of Arcins Island, Gironde estuary (right) Erosion of sediment in a hydrosedimentary channel in the Gironde estuary

In this PhD thesis, we propose a laboratory study to analyse the erosion process. This study will be based on the use of real sediments from different sites (Gironde estuary, Charente estuary, Saône river) and on the study of their interaction with a flow using non-intrusive measurements (optical and/or ultrasonic). Previous work on transparent model sediments (PhD thesis by Pierre Lecostey) has highlighted the existing relationships between the rheological properties of the sediment and the hydrodynamic stresses in the erosion process. It is now important to verify these initial results with real materials and under hydrodynamic conditions closer to the field.

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Proposed work

In the first phase, real sediments from different geographical locations will be analysed using the SPI platform: measurements of the rheological properties of the materials (https://www.univ-poitiers.fr/accompagner-les-entreprises/innover/plateformes-technologiques/systemes-et-produits-industriels-proprietes-rheologiques-des-materiaux/). Previous work has modelled some of the rheological properties of these materials for different solid concentrations, including yield stress. In the proposed work, an additional study of the rheological properties of real sediments based on dynamic (oscillating) rheometry measurements will be carried out. A relationship between complex modulus and yield stress has been demonstrated for transparent model sediments. It will be necessary to check whether this relationship is maintained with real sediments or whether new modelling is required. The properties of these real sediments could be modified by adjusting the concentration and density of the suspension, or even by taking into account the effects of consolidation. The results of this first phase will then be linked to the dynamics of the sedimentary bed under hydrodynamic stress.

In a second phase, the hydrodynamic flow generated in a hydro-sedimentary channel will be qualified using the Environmental Hydrodynamics platform (https://www.univ-poitiers.fr/accompagner-les-entreprises/innover/plateformes-technologiques/plateforme-hydrodynamique-environnementale-phe/). Optical measurement methods such as PIV will be used to study the flow generated. Particular attention will be paid to the characteristics of the boundary layer generating the frictional stresses on the bed. These characteristics (height, mean shear stress, unsteadiness) can be modified by various means, such as introducing roughness into the channel.

Finally, these flows will be applied to a real sediment bed with the aim of relating the rheological properties of the sediment to the hydrodynamic constraints during the erosion process. Thus, for given hydrodynamic conditions, the properties of cohesive sediments will be modified on the basis of the first phase of the project. Similarly, for a given sediment, the hydrodynamic conditions can be modified. Ultrasonic velocimetry measurements in the water/sediment interface should then enable a local analysis of the erosion phenomenon to be proposed (local velocity gradients, pressure gradient, local sediment concentration). Measurements of the surface of the sedimentary bed using optical methods could also be proposed to understand the dynamics of bed deformation as a function of the rheological properties of the sediment and the characteristics of the flow.

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