Strategy for numerical modelling of bank erosion due to river traffic

1) Study context

In France, river transport is in full renewal (a new trans-European project for Seine-Nord-Europe large gauge railways) as it fully meets the objectives of sustainable development: it reduces the saturation of roads and motorways (reduction of greenhouse gas, Kyoto Protocol); it offers a cost per tonne transported very attractive; Finally, investments in inland waterways offer advantages for spatial planning (electricity production, disposal of waste from major industrial and urban centres, creation of sites suitable for industry, housing or tourism).

However, the development of this mode of transportation requires the study of the economic and ecological impact of the passage of boats on waterways and the maintenance of the network of waterways. This maintenance consists of carrying out dredging operations to maintain navigation channel depths (estimated at 2Meuro in 2001 for the Nord-Pas-de-Calais navigation service, NPC-NS) and to ensure flow conditions in the flood period or for the banks restorations. These operations are generally expensive because the volumes of material to extract are important.

The intensification of river traffic on some waterways (and in particular the Oise river which will feed the Seine North-Europe Canal) is accompanied today by the will to limit the recourse to artificial and expensive solutions of bank protection. (installation of sheet piles or rockfill, ...). This raises the question of the prediction of the long-term holding of the banks. To our knowledge, few investigations concern the study of riverbank erosion induced by river traffic [**1**]. At the present time, "pragmatic" approaches based on simplified analytical formulations that do not make it possible to give a satisfactory account of the complexity of the physical phenomena involved are privileged. This phenomenon is the conjugation of several processes. multi-physics involving the fluid flow and its evolution under the effect of the passage of a boat but also its interaction with the porous medium that constitutes the bank and whose saturation level depends on the hydrodynamic flow.

In this context, we propose to implement numerical modelling strategy of the behaviour of the banks under hydrodynamic flow. The bank can be seen as a porous medium subject to variable loading corresponding to the hydrodynamic flow induced by the passage of boats. Under the effect of the passage of a boat, the level of loading and the level of saturation in the bank evolve possibly inducing local overloads of the solid skeleton of the bank leading to the gradual degradation of the bank. The objective of the thesis is to propose a numerical tool allowing to predict the evolution of the state of the bank and its possible rupture under the effect of the fluctuating fluvial flow associated with the passages of the boats.

2) Details of the proposal

In order to give an account of these phenomena, the thesis work will aim at extending, the tools of description of the damage and the rupture developed within the team " Mécanique

numérique " of the University of Compiègne [**2,3**] in the case of saturated and unsaturated porous media. A strategy to couple these description tools with the river flow calculation tools developed within the team "Laboratoire d-Hydraulique Numérique LHN" will be developed. In particular, will be studied the effect of the establishment of natural protection (planting for example) or artificial protection of the banks. These protections have the effect of damping the weak waves induced by the passage of a boat. The numerical tool developed will allow a parametric study to be carried out on the effect of this damping on bank behavior.

The second objective of the thesis is to study the morphodynamic changes of navigable waterways. In fact, the quantities of eroded materials are transported by the fluvial stream. These quantities must be localized in order to optimize the dredging operations necessary to maintain navigation channels (for example, an experimental study in the Netherlands, conducted on a canal in the city of Delft, has shown that river traffic impacts sediment transport by importing the amount of 520 t / year in the presence of boats against 85 t / year without traffic). To answer this problematic, the numerical tool developed in the first part of the thesis will then be coupled with a numerical model of eroded substrate management to feed a sedimentary transport model (morphodynamic).

3) References

[1] H. Smaoui, A. Ouahsine, D. P ham Van Bang, P. Sergent, F. Hissel: Numerical modelling of the sediment re-suspension induced by boat traffic. In Sediment Transport. Edited by Silvia Susana Ginsberg, Chapter 3, pp 55-70, InTech, Vienna, Austria. 2011.

[2] T. Saksala, D. Brancherie, and A. Ibrahimbegovic. Numerical modeling of dynamic rock fracture with a combined 3d continuum viscodamage-embedded discontinuity model. International Journal for Numerical and Analytical Methods in Geomechanics, 40 :1339–1357, 2016.

[3] D. Brancherie and A. Ibrahimbegovic. Novel anisotropic continuum-discrete damage model capable of representing localized failure of massive structures. part I: theoretical formulation and numerical implementation. Engineering Computations, 26(1-2):100–127, 2009.

4) Profile of the applicant

The applicant should hold an M2 in Mechanics engineering (solid or fluid) or Applied Mathematics and skilled in the following area:
- Numerical modelling;
- Finite Element (or Volume) Method;
- Environmental flows;
- Code programming (Fortran90, C, C++).

5) Contacts

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