C106

# Modelling of bank erosion using a 3D numerical model

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## 1 Introduction

Bank erosion is an important river morphodynamic process, resulting in channel migration, loss of agricultural lands, damaging hydraulic structures and infrastructure, which can also create a variety of habits contributing to ecological diversity. Reliable and practical numerical models are required to model bank erosion and channel migration assessing the outcome of the bank protection or restoration works.

The objective of this research work is to present a simple bank failure operator which is incorporated into a 3D flow and sediment transport model built on the OpenFOAM framework, to be capable of investigating bank erosion and channel migration.

## 2 Numerical model

The hydrodynamic model by Ota et al. (2020) is adopted. The model consists of NS equations for the incompressible flow that considers seepage flow and profile evolution in sediment. The VOF method is used to capture the water surface. The scale adaptive version of *k*-*ω* SST model is used to compute the effect of turbulence. An Eulerian-Lagrangian coupled model by Ota et al. (2017) is employed to calculate sediment transport, in which the Lagrangian method integrating the grain trajectory and momentum equation is employed to introduce the effect of non-equilibrium sediment transport around bank protection structures and the effect of large bed slope.

The bank failure operator is based on triangular prism mesh. The slope of each bed cell is calculated by surrounding adjacent cells to be suitable for the cell-centered finite-volume method of OpenFOAM. The operator guarantees that when the local slope exceeds the critical stability angles, the unstable areas are rotated to the stable state in a reasonable manner around an appropriate horizontal axis, ensuring mass balance.

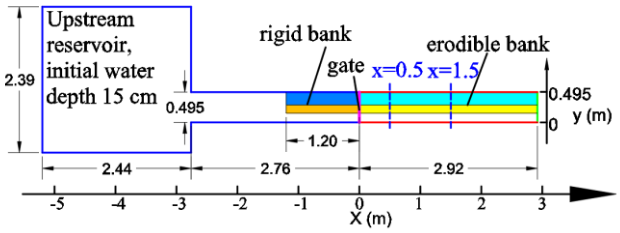
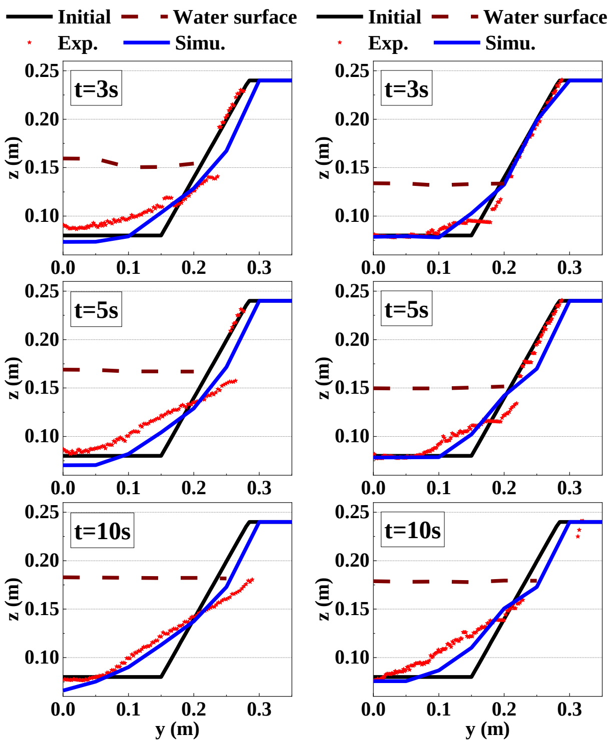



Fig. 1. Experimental set-up of test 1




(a) x = 0.5 m (b) x = 1.5 m

Fig. 2. Bed cross-section of test 1 at x = 0.5, 1.5 m, and t = 3, 5, 10 s

Tab. 1. Root mean squared error (RMSE)

| | t = 3 s | t = 5 s | t = 10 s |
|---|---|---|---|
| x = 0.5 m | 0.015 | 0.017 | 0.007 |
| x = 1.5 m | 0.009 | 0.010 | 0.008 |

## 3 Results and discussions

The model performance is tested against two laboratory flume experiments: 1) dam-break flow in a straight channel by Soares-Frazão et al. (2007); 2) meandering channel migration by Karki (2019).

Test 1 is a horizontal halfwidth channel with a single erodible bank (Fig. 1). Fig. 2 compares the simulated results and measured results of bed cross-section profiles at x = 0.5, 1.5 m and t = 3, 5, 10s, the corresponding root mean squared error (RMSE) values are given in Tab. 1. The simulated cross-sections evolution matches the observed results well. Test 2 is a meandering channel with erodible banks (Fig. 3). Fig. 4 shows the temporal variations of bankline shifting. The computed bank retreat near the apexes of inner banks is in agreement with the measurement, while the bankline shifting in the outer banks is not noticeable. After all, the simulation conditions and experimental conditions cannot be exactly the same. For example, in experiments, the bed topography was measured after the bed became dry, but there's no such process in simulation.

## References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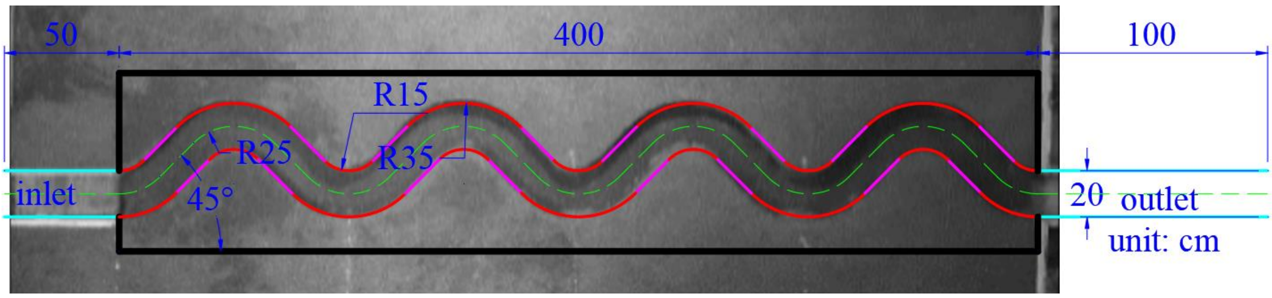


Fig. 3. Channel set-up of test 2

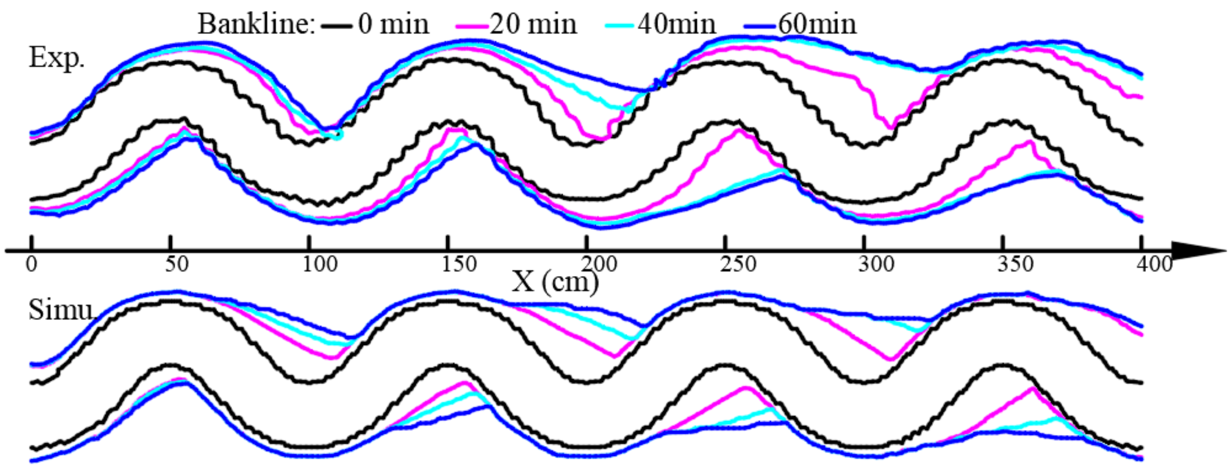


Fig. 4. Comparison of measured and simulated bankline shifting variations with time in test 2