Level set based modeling of local scouring in the vicinity of a submerged arch bridge

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Abstract

The performance of the level set method based numerical solver REEF3D was tested for the simulation of the complex hydro- and morphodynamics in the vicinity of a submerged arch bridge. The complexity of the flow problem comes from pressurized conditions under the bridge deck, which is also the main initiator of the scouring. The level set method is used to simulate both the free surface and the mobile sediment bed. The numerical model results are compared with physical model results. The reasonable agreement with the experimental and numerical results underlines the relevance of level set method based CFD modeling in hydraulic engineering.

Keywords: CFD, level set method, free surface, local scour, submerged bridge

Numerical model

- Employed CFD code: level set method (*Sussman 1994*) based morphodynamic model REEF3D (*Bihs et al., 2016*)
- Level set method is used for:
  - Free surface treatment
  - Solid structure representation
  - Sediment bed representation
- The numerical model setup is constructed to mimic the geometrical configuration of the lab experiments performed by *Martin-Víde (2005)* (**Fig. 1**)

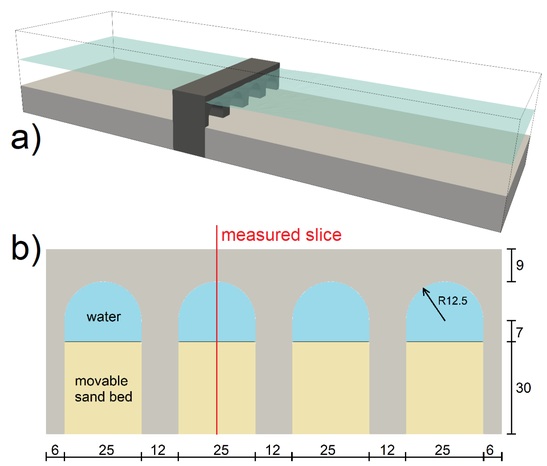

Figure 1. Computational domain (a); bridge geometry in cm (b).

Boundary conditions

- Inflow discharge (Q_{in}) = 0.1243 m^3s^{-1}
- Outflow water level (h_{out}) = 0.252 m
- Bed material: sand (d_{50} = 0.86 mm)

Results

- The pressurized jets between the bridge piers are the main initiators of the local scouring (**Fig. 2**)
- The numerical treatment of this hybrid flow problem (pressure + free surface flow) calls for advanced free surface treatment → LSM
- After the morphodynamic simulations (scouring stops after ~48 h):
  - Flow velocities decrease significantly
  - Backwater effect of the bridge is notably reduced

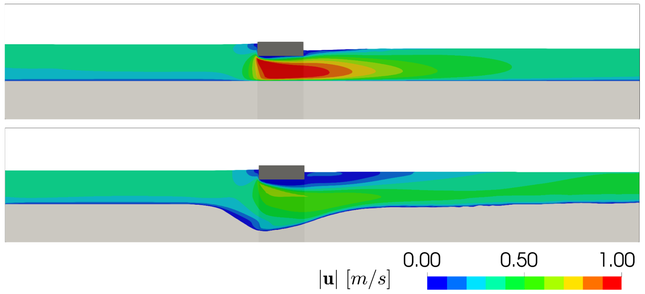

Figure 2. Velocity distribution in the middle of the arc, before and after scouring.

- Scour profile is reasonably reproduced
- Downstream deposition is underestimated

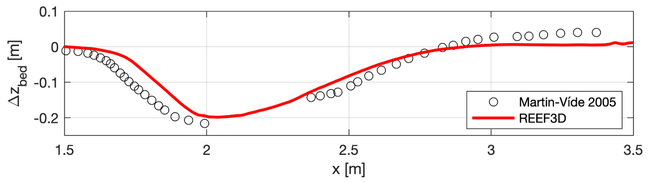

Figure 3. Comparison of predicted scour profile with experimental data.

Conclusions

- The numerical model REEF3D is capable of reproducing the complex morphodynamic problem in the vicinity of a partially submerged arch bridge
- Although the relevance of classical, time consuming and costly physical model experiments is still recognized, it is noted the latest CFD tools are getting better and better in predicting complex hydro- and morphodynamic conditions
- CFD models may soon replace costly physical experiments in hydraulic engineering, but for now, their hybrid use is recommended

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