Modeling Internal Erosion Processes In Soil Pipes

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Abstract

The erosion of the interior of soil pipes is an important process in the fields of geomechanics and geomorphology. Soil pipes can form in water holding structures like dams and levees, and water flow through these structures becomes concentrated into the soil pipes as they evolve by the process of internal erosion. With time the erosion process will lead to a soil pipe spanning the entire structure, leading to catastrophic structural failure. The emergency at the Oroville Dam in California during winter 2017 is an example of this erosion process. Fortunately in that case emergency measures were taken to prevent complete collapse of the dam. Soil pipes also form in hillslopes of the landscape, and water entering into those pipes will erode pipe wall surfaces and thereby enlarge. Soil pipes that become large enough can then collapse, leading to the formation of surface gullies. Soil pipes in hillslopes can also be the cause for the initiation of hillslope failure (landslides). We are currently examining the process of internal erosion in soil pipes using laboratory models of soil pipes, with the objective to evaluate the effects of flow rate, pipe size, soil particle size, and sediment concentration in the flowing water. The modeling of the internal erosion of a soil pipe is being conducted using the COMSOL CFD module to solve the Navier-Stokes equation to determine the velocity field in the soil pipe and the shear stress on the pipe wall, and the convection-dispersion equation to solve for the transport of sediment eroded from the pipe wall. The erosion rate from the pipe wall is modeled using an empirical equation known as the excess shear stress equation. This mass loading rate is given as ρ_d k (μ ∂v/∂r - τ_crit), where ρ_d is the dry bulk density of the soil, k is the empirical erosion rate coefficient, μ is the dynamic viscosity of the fluid, v is the velocity along the pipe axis, and τ_crit is the critical shear stress required to initiate erosion. This erosion rate provides the source term (at the pipe wall) for suspended sediment generation in the convection-dispersion equation. In our presentation we will show the simulation of soil pipe wall erosion, examining the effect of flow rate, soil pipe diameter, and shear strength properties of the soil material along the soil pipe wall. The solutions will be compared to the analytical expressions for piping erosion derived by Bonelli et al. (2006). Reference will also be given to the results of the ongoing laboratory experiments, and comparisons between the modeling simulations and laboratory results will be presented.

Reference

Bonelli, S., O. Brivois, R. Borghi, and N. Benahmed. 2006. On the modelling of piping erosion. Comptes Rendu Mécanique, 334(8-9): 555-559.

Figures used in the abstract

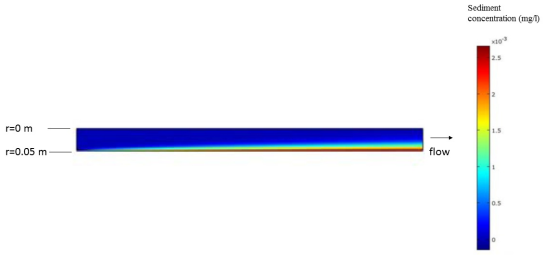

Figure 1 : Sediment concentration in a soil pipe section. The pipe section is 1 meter long and the radius of the pipe is 0.05 m. The velocity was specified as 1 m/s on the left boundary and pressure (p=0) specified on the right boundary. The dynamic viscosity for water was specified as 0.001 Pa-s. The suspended sediment concentration is given in mg/l. The pipe wall is at r=0.05 m. The result given for the case where turbulence is absent.