Effect of Hysteresis in Soils on Seepage Flow in Levees Common to the Southeastern United States

Fred T. Tracy*, Lucas A. Walshire† and Maureen K. Corcoran†

* U.S. Army Engineer Research and Development Center
Information Technology Laboratory
3909 Halls Ferry Road, Vicksburg, MS 39180
e-mail: fred.t.tracy@usace.army.mil

† U.S. Army Engineer Research and Development Center
Geotechnical and Structures Laboratory
3909 Halls Ferry Road, Vicksburg, MS 39180
e-mail: lucas.a.walshire@usace.army.mil

† U.S. Army Engineer Research and Development Center
Geotechnical and Structures Laboratory
3909 Halls Ferry Road, Vicksburg, MS 39180
e-mail: maureen.k.corcoran@usace.army.mil

ABSTRACT

Following Hurricane Katrina in New Orleans, LA, USA, a lot of research has been conducted on the levee failures in New Orleans. The finite element programs used in these studies did not incorporate soil water characteristic curve hysteresis. It is important to incorpórate this soil behavior because soils exhibit significant hysteresis during the cycles of rising and falling river eevation, and these effects could greatly affect the modeling results. A 2-D finite element variably saturated transient seepage flow computer program written by the first author was modified as in Kool and Parker, 1987, to allow an option for hysteresis in the moisture content versus pressure head (SWCC) and hydraulic conductivity versus pressure head (HCF) functions used in the unsaturated flow portion of seepage through the levee. A generic levee common to the southeastern United States was then meshed and tested using the modified program to determine the importance of hysteresis in flow through this levee. A homogeneous levee system was modeled in this study.

Three quantities were output to measure the impact of hysteresis as follows: (1) a levee saturation coefficient, S_L, where $0 \leq S_L \leq 1$, (2) the pore pressure at the toe of the levee beneath the confining layer, and (3) flow rate through the downstream portion of the levee. S_L is zero when the river is at initial conditions and one when steady-state has been achieved at the maximum river elevation.

The hydrograph of the river for a 20-ft levee that was used begins at -5 ft, increases at 1 ft/day until it reaches 17.5 ft, remains constant for 10 days, and then descends at 1 ft/day until the river reaches -5 ft again, giving a simulation time of 55 days. Saturated hydraulic conductivity values of 28.3, 2.83, and 0.283 ft/day, which are typical values of sand, silty sand, and clay, respectively, were considered. Typically, researchers use the moisture content and hydraulic conductivity curves for when the soil is drying whether the river is rising, staying constant, or falling. In modeling hysteresis, wetting curves are used when pressure head in a finite element is increasing, and drying curves are used when pressure head in an element is falling. Values of the three output variables for wetting only curves, drying only curves, and hysteresis curves for the 55 days were collected, and a closeness coefficient in terms of percentage was defined and computed from the collected data.

It was found that the closeness coefficient was as high as 24.61% for the levee saturation coefficient, 5.15% for pore pressure, and 119.93% for flow rate. The results clearly show that it is important to consider hysteresis in transient seepage numerical modeling.

REFERENCE

[1] Kool, J.B. and J.C. Parker. 1987. Development and evaluation of closed-form expressions for hysteretic soil hydraulic properties. *Water Resources Research*. Vol. **23**, pp. 105-114.