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A multilayer soil approach for seepage process analysis in earthen levees

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Earthen levees protect flood-prone areas during severe flood events. In most cases, however, flooding is the result of the collapse of the embankments due to the seepage through and under the levee body. The description of the seepage line is difficult mainly because of the uncertainty on the hydraulic parameters, first of all the soil hydraulic conductivity. Barbetta et al. (2017) proposed a practical method for the seepage analysis based on the Marchi's equation for the estimation of the probability of occurrence of the levee seepage which provides a vulnerability index under the assumption that the groundwater level coincides with the ground. Recently, the method has been tested also considering the groundwater level below the ground pointing out that such a condition has a high impact on the levee vulnerability to seepage. However, it does not consider the interactions between seepage process in the levee body and in the foundation.

In this context, this work proposes a new approach for the analysis of the infiltration line through the body and the foundation, considering a multilayer soil and assuming a different soil hydraulic conductivity for each layer. The new equation is obtained starting from the continuity equation and the flow equation.

The saturation line estimated through the Marchi's equation and the one derived through the new multilayer model equation are compared. The analysis is first addressed to identify a threshold of the ratio between water head and water table beyond which the Marchi's equation is no longer applicable. Indeed, the Marchi's equation is valid when the river water head is lower than the water table. Different values of these two variables are analyzed and a threshold ratio equal to 0.57 is identified.

Furthermore, the levee vulnerability to seepage estimated with the two approaches is compared and the levee is found more vulnerable when the new approach is applied. The results indicate that the difference between the two vulnerability approaches decreases as the distance between the groundwater table and the ground level tends to zero. The proposed approach is an attempt to quantify the seepage probability with more realistic levees characteristics, hydraulic and soil parameters.

Barbetta, S., Camici, S., Bertuccioli, P., Palladino, M. R., & Moramarco, T. 2017. Refinement of seepage vulnerability assessment for different flood magnitude in national levee database of Italy. Hydrology Research, 48(3), 763–775. https://doi.org/10.2166/nh.2017.101.