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Research Paper

Numerical evaluation of reinforced slopes with various backfill-reinforcement-drainage systems subject to rainfall infiltration

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ABSTRACT

This paper presents a numerical study investigating the hydraulic response and stability of geosynthetic-reinforced soil slopes subject to rainfall. A series of numerical simulations of unsaturated slopes with various backfill–reinforcement–drainage systems subject to rainfall infiltration was performed by comprehensively considering the combined effect of backfill (i.e., sand, silt, and silty clay), reinforcement type (i.e., geogrid or nonwoven geotextile), and rainfall intensity (350 and 500 mm/day). The backfills were modeled using three soil–water characteristic curves (SWCCs) representing the general suction range associated with sand, silt, and clay. The influence of sand cushions in improving the stability of reinforced clay slopes was also assessed. The numerical results reveal that the loss of matric suction and development of a capillary barrier effect within clay backfills could have adverse impacts on both the global and local stabilities of the reinforced clay slopes. The contribution of matric suction in enhancing slope stability was initially high for reinforced clay slopes; however, the global stability of the reinforced clay slope substantially decreased due to the loss of matric suction as the rainfall infiltration proceeded. The local instability of the geotextile-reinforced clay slope occurred due to the capillary barrier effect at the geotextile–clay interface. The reinforced marginal soil slopes cannot effectively drain the infiltrating water under torrential rainfall. Free drainage conditions may not be assumed for these slopes if the drainage is not properly considered. Both the global and local factors of safety (FS) of the reinforced sand slope were minimally influenced by the loss of matric suction induced by rainfall infiltration. The required reinforcement tensile strengths for the reinforced silt and clay slopes to maintain $FS = 1.3$ were, respectively, approximately 3 and 4 times larger than that for reinforced sand slopes. Numerical results also indicated that the inclusion of sand cushions, which provide both strength and drainage functions, can effectively enhance the slope stability. An optimal sand cushion thickness of 15 cm (replacing 20% of marginal backfill with sand) was determined in this study.