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Discussion of "Influence Factors Involving Rainfall-Induced Shallow Slope Failure Numerical Study" by Somjai Yubonchit, Avirut Chinkulkijniwat, Suksun Horpibulsuk, Chatchai Jothityangkoon, Arul Arulrajah, and Apichat Suddeepong

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The authors have conducted a noteworthy numerical study investigating the influence factors for rainfall-induced shallow slope failure. Specifically, the authors evaluated the influence of soil saturated hydraulic conductivity, slope angle, and antecedent rainfall on the stability of a shallow slope. The rainfall intensity-duration (ID) thresholds were established from the numerical results, and they were comparable to those based on the historical slope failure data in the existing literature. In this discussion paper, the discussers would like to comment on the *Undrained* function selected for modeling the mechanical behavior of soil layers in the finite-element (FE) analyses in the discussed paper (as indicated in Table 3 in the original paper).

The discussers argue that it is most common to specify that soil has drained behavior instead of undrained behavior, except in earthquake problems (Nogueira et al. 2009, 2011; Oh and Lu 2015; Qi and Vanapalli 2015; Matsumaru and Uzuoka 2016; Yang et al. 2017). With respect to the dissipation of excess pore-water pressure over time, the drained and undrained responses of soil can be automatically simulated in coupled hydromechanical analysis. The soil has a drained response (excess pore-water pressure dissipates over time) if the loading rate is slow relative to the soil hydraulic conductivity or if the simulated case occurs over a sufficiently long duration relative to the time required for the drained response. Otherwise, the soil is considered undrained. Thus, specifying undrained soil behavior in the coupled hydromechanical analysis could adversely limit the dissipation of the excess pore-water pressure over time. In addition, when the *Undrained-A* function is selected in the analysis, the undrained calculation is performed according to the effective stress analysis by inputting the effective soil modulus and the assumed water bulk modulus. As noted in the *PLAXIS* manual (Brinkgreve et al. 2016), this approach of modeling undrained soil behavior requires the utmost care because the predicted excess pore-water pressure may be inaccurate, depending on the selected soil model and parameters.

Furthermore, specifying the soil undrained behavior may prevent the proper consideration of the effect of soil dilatancy in the FE analyses. Generally, the soil dilation angle (ψ) defines the flow rule, thus affecting the FE results, such as the deformation and stability [or factor of safety (FS)] of the slopes. Many studies have demonstrated the significance of considering soil dilatancy in FE analyses of slope stability (Manzari and Nour 2000; Cheng et al. 2007; Cascini et al. 2010; Tschuchnigg et al. 2015). For soil under drained conditions, the slope deformation decreases and stability increases as the dilation angle increases. Consequently, ignorance of soil dilatancy ($\psi = 0°$) leads to conservative results in FE analyses. In contrast, for soil under undrained conditions (as adopted in the discussed paper), negative excess pore-water pressure would develop during shearing if $\psi > 0°$ is input for soil. Unless a

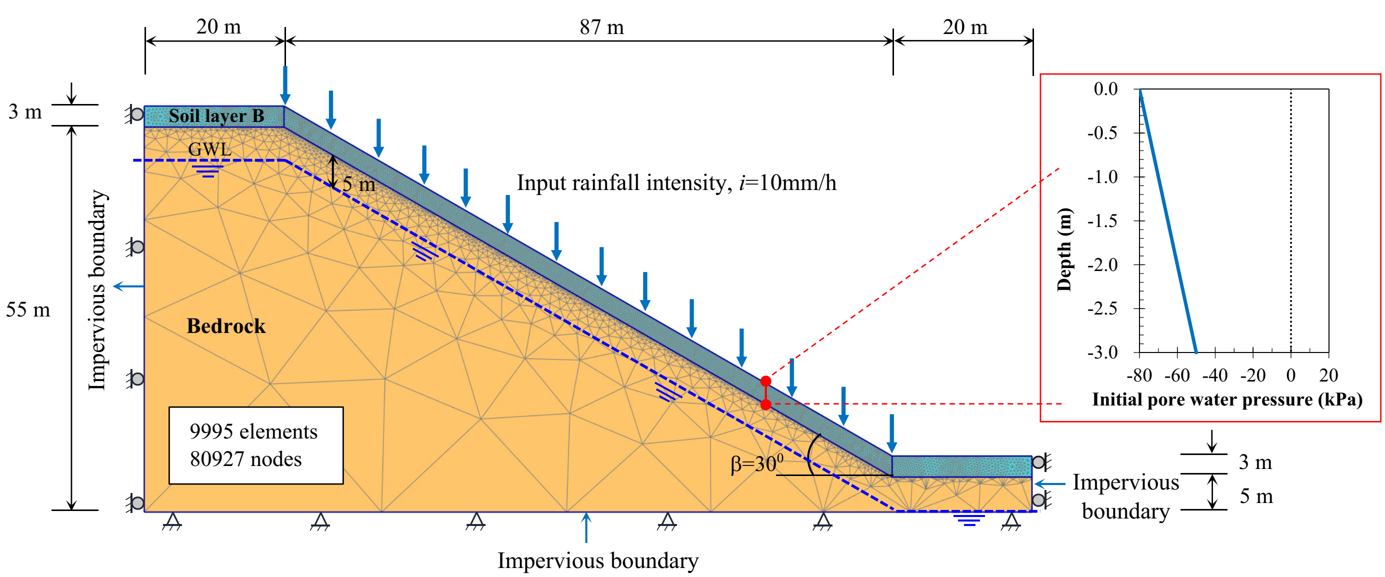

Fig. 1. Slope model for the coupled hydromechanical analyses

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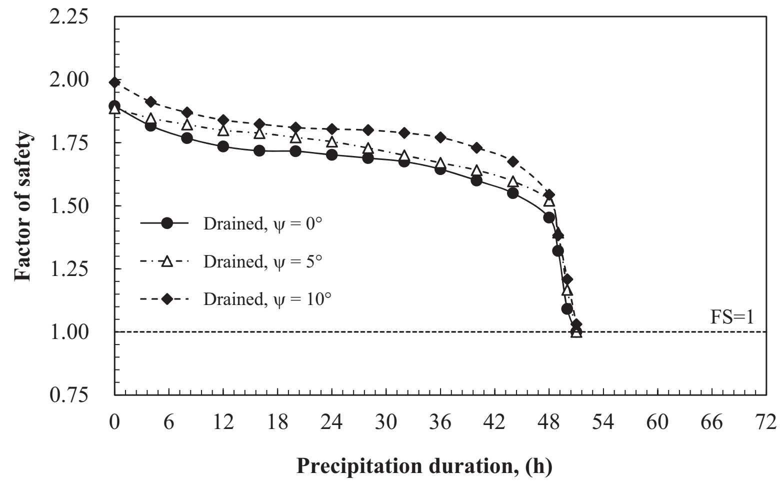

Fig. 2. Effect of dilation angle on the FS of the slope under drained analysis

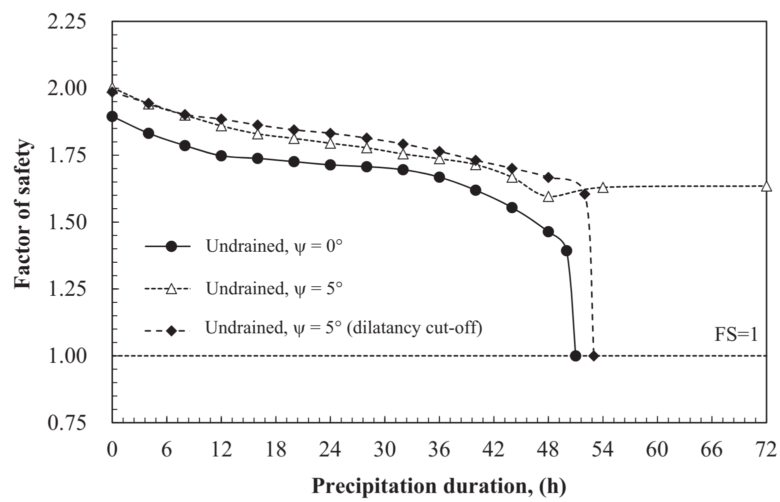

Fig. 3. Effect of dilation angle on the FS of the slopes under undrained analysis

dilatancy cutoff is imposed on the soil, the soil shear strength and slope stability continue to increase with the development of negative excess pore-water pressure, yielding an unrealistically high FS value (Brinkgreve et al. 2016).

A series of coupled hydromechanical analyses was performed to demonstrate the preceding discussion. The FE slope model (Fig. 1) was established in *PLAXIS* following the numerical model reported by the authors (Fig. 3 in the original paper). The case involving soil Type B, a slope angle of 30°, and a continuous uniform rainfall intensity of 10 mm/h was analyzed. The soil was modeled using the Mohr-Coulomb model, and the soil hydraulic and mechanical input properties were adopted directly from the values reported in the discussed paper (Table 2 in the original paper). In the numerical analyses, the effects of soil drainage type (i.e., drained and undrained) and dilation angle were evaluated. Figs. 2 and 3 present the numerical results for drained and undrained conditions, respectively. The numerical results for the undrained case with $\psi = 0°$ in Fig. 3 is similar to the results obtained by the authors [for the curve of Soil B (10 mm/h) shown in Fig. 4 in the original paper].

Fig. 2 shows the variation in FS over time for soil with different dilation angles under drained conditions. Fig. 2 indicates that the soil dilation angle has a clear influence on the calculated FS. The slope with a higher soil dilation angle has a greater FS value. Interestingly, all drained cases reach to slope failure (FS = 1) at approximately the same time ($t \approx 52$ h). The numerical results suggest that the soil dilation angle does not seem to affect the timing of slope failure because the same soil shear strength value (effective cohesion $c' = 6.74$ kPa and effective friction angle $\phi' = 33.62°$ in Table 2 in the original paper), which governs the slope stability at the limit state, was input for all cases.

Fig. 3 shows the variation of FS over time for soil with different dilation angles under undrained conditions. For the undrained case with $\psi = 5°$, the FS decreases over time until $t = 48$ h and then starts to increase due to the influence of soil dilatancy, as discussed previously. The slope instability does not occur during the 72-h rainfall simulation; the FS remains 1.64 at the end of the simulation. The high FS obtained from the undrained case with $\psi = 5°$ is confirmed to be unrealistic because real soil does not continue to dilate after reaching its critical state. To overcome this problem, a dilatancy cutoff function, as coded in *PLAXIS*, was selected by specifying the initial and maximum void ratio of soil ($e_{initial}$ and e_{max}, respectively). When the soil void ratio changes from $e_{initial}$ to e_{max}, the dilatancy cutoff function is activated and soil dilation is no longer permitted. The initial void ratio of soil, $e_{initial} = 0.73$, was calculated from the soil porosity inferred from the saturated volumetric water content in the soil-water characteristics curve in the discussed paper [Fig. 2(a) in the original paper]. The maximum void ratio was assumed to be $e_{max} = 0.83$. Fig. 3 indicates that when the dilatancy cutoff function is considered, the slope failure occurs at $t \approx 54$ h (no unrealistically high FS is obtained in this case). Notably, the timing of slope failure depends on the input e_{max} value in the dilatancy cutoff function.

In conclusion, the soil drainage type in the coupled hydromechanical analysis was examined and discussed in this paper. The discussers suggested specifying drained rather than undrained soil behavior in the coupled hydromechanical analysis because the drained and undrained responses of soil, as a process of the dissipation of excess pore-water pressure over time, can be automatically simulated in the coupled hydromechanical analysis. Specifying undrained soil behavior could adversely limit the dissipation of excess pore-water pressure over time. In addition, specifying undrained soil behavior may prevent the proper consideration of the effect of soil dilatancy in the FE analyses. Negative excess pore-water pressure could develop for soil with $\psi > 0°$ under undrained shearing conditions, which would yield an unrealistically high FS. A dilatancy cutoff should be imposed through the specification of a reasonable maximum void ratio for soil to avoid unrealistic soil dilation during shear deformation.

References

Brinkgreve, R. B. J., Kumarswamy, S., and Swolfs, W. M., eds. (2016). "PLAXIS 2016 manual." PLAXIS bv, Delft, Netherlands.

Cascini, L., Cuomo, S., Pastor, M., and Sorbino, G. (2010). "Modeling of rainfall-induced shallow landslides of the flow-type." *J. Geotech. Geoenviron. Eng.*, 10.1061/(ASCE)GT.1943-5606.0000182, 85–98.

Cheng, Y. M., Lansivaara, T., and Wei, W. B. (2007). "Two-dimensional slope stability analysis by limit equilibrium and strength reduction methods." *Comput. Geotech.*, 34(3), 137–150.

Manzari, M., and Nour, M. (2000). "Significance of soil dilatancy in slope stability analysis." *J. Geotech. Geoenviron. Eng.*, 10.1061/(ASCE)1090-0241(2000)126:1(75), 75–80.

Matsumaru, T., and Uzuoka, R. (2016). "Three-phase seepage-deformation coupled analysis about unsaturated embankment damaged by earthquake." *Int. J. Geomech.*, 10.1061/(ASCE)GM.1943-5622.0000699, C4016006.

Nogueira, C., de Azevedo, R., and Zornberg, J. (2009). "Coupled analyses of excavation in saturated soil." *Int. J. Geomech.*, 10.1061/(ASCE)1532-3641(2009)9:2(73), 73–81.

Nogueira, C., de Azevedo, R., and Zornberg, J. (2011). "Validation of coupled simulation of excavations in saturated clay: Camboinhas case history." *Int. J. Geomech.*, 10.1061/(ASCE)GM.1943-5622.0000077, 202–210.

Oh, S., and Lu, N. (2015). "Slope stability analysis under unsaturated conditions: Case studies of rainfall-induced failure of cut slopes." *Eng. Geol.*, 184(Jan), 96–103.

Qi, S., and Vanapalli, S. K. (2015). "Hydro-mechanical coupling effect on surficial layer stability of unsaturated expansive soil slopes." *Comput. Geomech.*, 70(Oct), 68–82.

Tschuchnigg, F., Schweiger, H. F., and Sloan, S. W. (2015). "Slope stability analysis by means of finite element limit analysis and finite element strength reduction techniques. Part I: Numerical studies considering non-associated plasticity." *Comput. Geotech.*, 70(Oct), 169–177.

Yang, K.-H., Uzuoka, R., Thuo, J. N., Lin, G.-L., and Nakai, T. (2017). "Coupled hydro-mechanical analysis of two unstable unsaturated slopes subject to rainfall infiltration." *Eng. Geol.*, 216(Jan), 13–30.

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