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Interactive comment on "Behavior analysis by model slope experiment of artificial rainfall" *by* M. C. Park

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Anonymous Referee #1

The paper presents a laboratory experiment and a seepage numerical model of a shallow failure obtained under controlled condition in the lab. I appreciate the paper, and I believe that the research is worth to be published on NHESS. Moreover, the paper is well written, with good English and correct terminology. And the quality of the presentation is high. However, I believe that the paper is still not rich enough to be accepted in the present form.

Question : The main problem is that a single experiment is not enough, also considering the fact that the experiment is cheap and can be repeated many times. With a single experiment, in fact, the research is affected by potential errors and singularities that other experiments could correct. On the other side, interesting behavior are not confirmed by other experiments and should be taken with a big caution. Hence, in my point of view, the research can be accepted for publication only if the author add several other experiments. The fact that the experiment is single makes also difficult to evaluate the results and, lastly, to make a review.

- Answer : All referees presented problems such as the verification of the model test and potential errors from a single test results. However, the purpose of this study is to reproduce rainfall-induced failure of the model slope and to compare the unsaturated slope stability analysis and verify it. In connection with the study, I performed five cases of model experiment in total, one case with inclination of 70 degrees and rainfall intensity of 30 mm/hr, four cases with inclination of 50 degrees and different rainfall condition. The contents published in this article will cover the results of the comparison with unsaturated slope stability analysis, in relation to the slope of 70 degrees that model slope failure caused by the rainfall is induced. In the four result of the model slope that is not described in this paper, model slope experiment with inclination of 50 degrees is a study on rainfall conditions, hysteresis phenomenon appeared in the process of the seepage and drainage, and initial conditions. The slope failure did not occur in all experimental results. Also, the analytical model was verified by repeatedly reproducing the seepage and drainage process of the rainfall and comparing the measurement results of the matric suction and volumetric water content to the seepage analysis results. However, seepage analysis results were similarly shown, but slope failure did not occur in the experiment. Also, Factor of safety is not reduced to less than 1 even in the unsaturated slope stability analysis. Thus, it was not appropriate results for the purpose of this paper, so it was not described in this paper. Much thoughtful considerations were required in order to understand rainfall-induced slope failure process and to perform the comparison and verification with numerical analysis method. If these processes are not described in this paper well and engineering conclusions are not drawn, I will modify these later, of course. If the reliability of the experiment as a single model test becomes a problem, I will add experimental results on the model slope of the 50 degrees and to draw the verification of comparison with experimental results presented in this paper and the conclusions.

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Question : For instance, the anomalous behavior of tensiometer B in the experiment is due to a pipe? Why this pipe appear? Maybe a problem in the compaction of the material? Other experiments will allow to understand what is ultimately generalizable (that's the interest of scientist) and what not.

- Answer : Tensiometer consists of a pipe that ceramic cup is attached and a sensor which measures tensile stress. Tensiometer pipe is penetrated after being drilled up to installation depth with a steel pipe of the same diameter after forming the model slope and the influx of surface water is prevented by filling the gap between slope surface and a tensiometer pipe with clay. However, B sensor is installed in the central portion of an inclined plane with model slope and the gap between slope surface and tensiometer pipe was occurred due to the activities of the model slope caused by rainfall seepage, which had an impact on the measurement results of matric suction.

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Question : Another issue that is critical is the fact that the soil never reach saturation, although the conductivity is relatively low (10-4). In fact, the seepage model reach saturation. Why this saturation does not happen? Is it due to compaction, preferential flow, cracks, pipes? Again, a single experiment does not say anything that is actually certain. According to the experimental results, I suspect that the conceptual model (homogeneous unsaturated flow) based on which the stability analysis is performed, is not correct, and it is clearly violated by the experiment. The experiment shows some heterogeneous behavior, which is not accounted for in the numerical model. Hence, also the numerical model needs to be improved to be more consistent with the actual behavior. Of course (again), this could be done only observing other experiments, when finally it will be possible to generalize the experimental behavior.

- Answer : Permeability of 10-4 m/sec = 0.013 cm/sec can be relatively large even though the range of the permeability in general sandy soil is considered. This is because relative compaction is formed under the 85% condition. In addition, even though heterogeneous behavior was appeared, crushed stone layer whose permeability is very large was installed at the bottom in order to eliminate the heterogeneous behavior in the seepage process as described in the paper. Also, since there was no evidence that heterogeneous behavior was presented even in experimental result, I cannot understand exactly what the engineering meaning of the heterogeneous behavior that referee mentioned is. The verification of the comparison with the model experiment can be possible only if an analysis on all of the unsaturated characteristics of the soil applied to the numerical analysis model, initial condition, and boundary condition should be performed under the same condition as an model slope experiment. It represents rather non-engineering results that the parameters of the seepage analysis model is just manipulated in order to make the results of the experiment and seepage analysis be similar. In general, rainfall-induced slope failure is mostly dominated by saturated permeability of the slope and rainfall intensity. Thus, since the model slope in this study had relatively low compaction and this made into the slope with a relatively high permeability which was larger than rainfall intensity, the saturation of the slope did not occur.

Question : The last point regards the interpretation of the soil parameters. The authors assign an air-entry value of 0.452, which is quite suspect. As far as I know, the air-entry value should be the point where air enters in the pore, i.e., the point where the curve deviates from the saturation. In the fitting of the data, this point is very close to the origin, which means that the material practically does not have any capillarity fringe (that is normal, indeed). Therefore, the air entry value should be low, almost 0, in my opinion.

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Interactive Comment

- Answer : For seepage analysis, these are required the residual water content θ_r, the air entry pressure u_b, and the pore size distribution parameter n. The SWRCs were obtained from the pressure plate tests and fit to the van Genuchten model using the RETC code (Van Genuchten, 1980). Also, the air-entry value is also very similar compared to the figure below from the reference. It is a different value depending on the state of the soil, an air-entry value of 0.452 will not be a problem.

D.G. Fredlund, H. Rahardjo, and M.D. Fredlund, Unsaturated Soil Mechanics in Engineering Practice, John Wiley & Sons, Inc., pp.203∼204, 2012.

Question : In addition, the residual water content to 0 is impossible.

- Answer : Residual saturation is 0.09. Since it is a typing error, I'll correct it.

Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., 3, 4159, 2015.

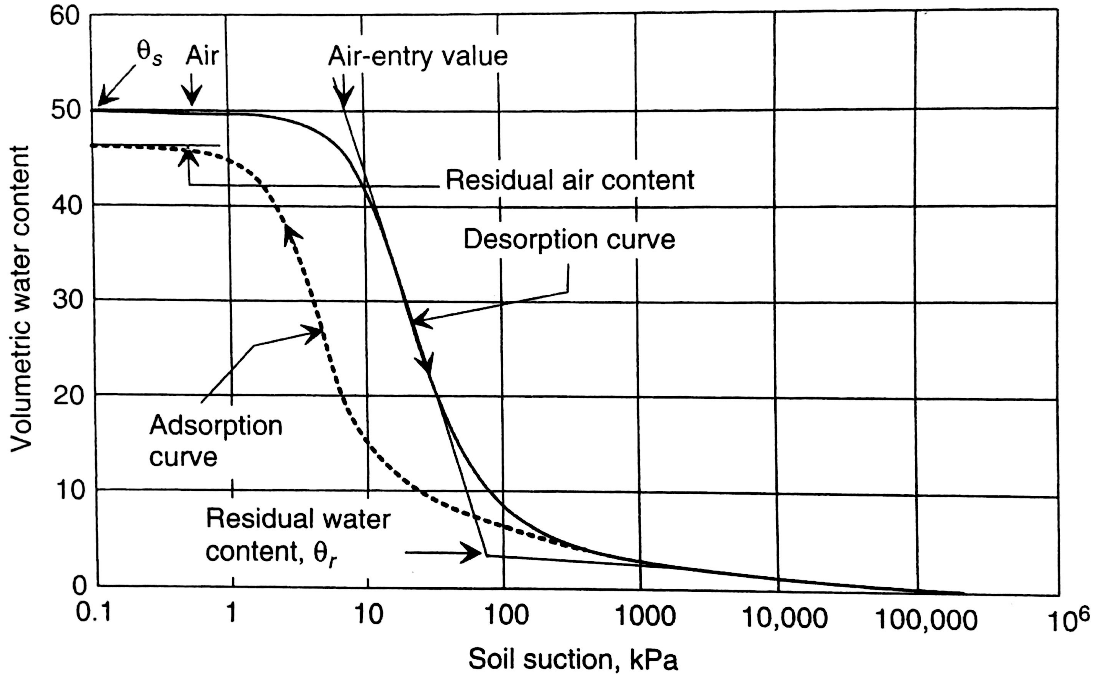

Figure 5.19 Typical SWCC for silt soil.

Fig. 1.

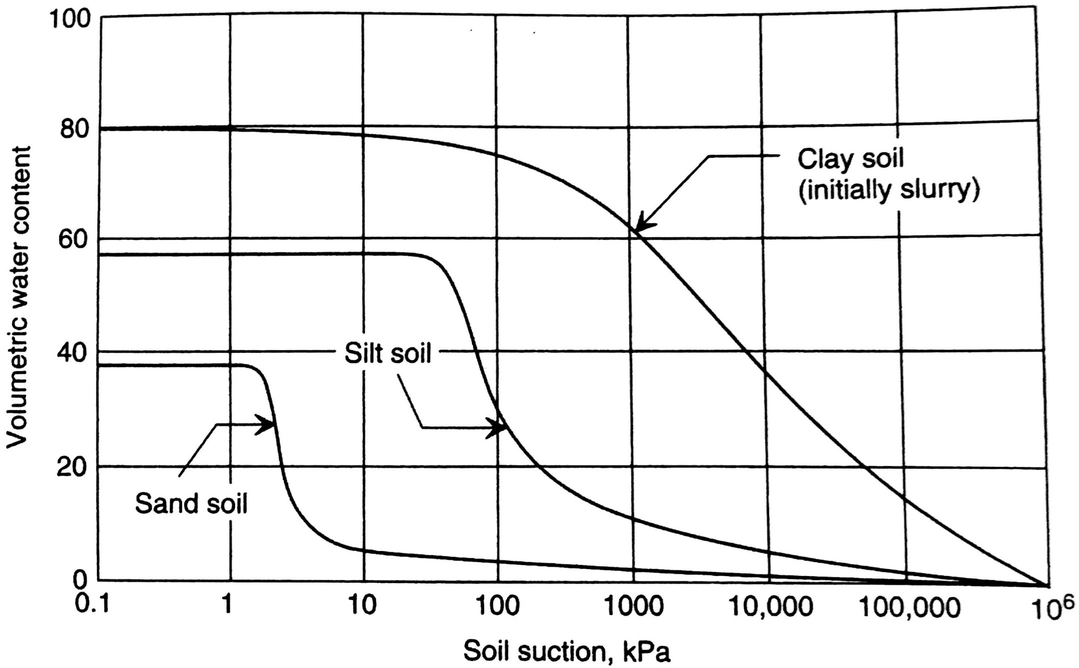

Figure 5.20 Comparative desorption SWCCs for sand, silt, and clay soils.

Fig. 2.