Method on simultaneous measurements of water retention, seepage, and evaporation proprieties in unsaturated soil

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1. Introduction

Rainfall induced slope stability issues are a constant consideration subject in the city planning and disaster prevention. For the understanding and prevention of slope failure issues, hydraulic proprieties such as water retention and seepage are often used to analyze the soil and water interactions through soil-water-characteristic-curve (SWCC) and numerical simulations. Evaporation characteristics, however, are not regularly considered, even though the understanding of upward moisture flux in boundary conditions can be reflected in the analysis of safety factors of slopes stability and disaster warnings. In this study, a method to obtain the parameters of water retention, seepage, and evaporation simultaneously in unsaturated soils, was proposed, analyzed, and verified.

2. Materials and methods

This study had the objective of adapting the HYPROP device (Hydraulic property analyzer, UMS, 2015) based on the evaporation method of Wind (1966), and Schindler (1980), with the surface evaporation method (bulk method) proposed by Kondo et al. (1990).

Operating on the simplified method of evaporation developed by Schindler (1980), the HYPROP equipment operates with 2 tensiometers positioned at the heigh of z_1 = 0.25 h and z_2 = 0.75 h cm, h being the total height of the soil sample ring. The soil sample ring is initially measured with a saturated soil sample that measures the evaporation through the weight difference. The hydraulic conductivity (K) is obtained according to Darcy-Buckingham law, and the seepage results are filtered according to Peters A., and Duner W. (2008) considerations. In this method, the hydraulic conductivity presents an increased consistency in data when the water retention has a low value.

The proposed method consisted of adapting the HYPROP

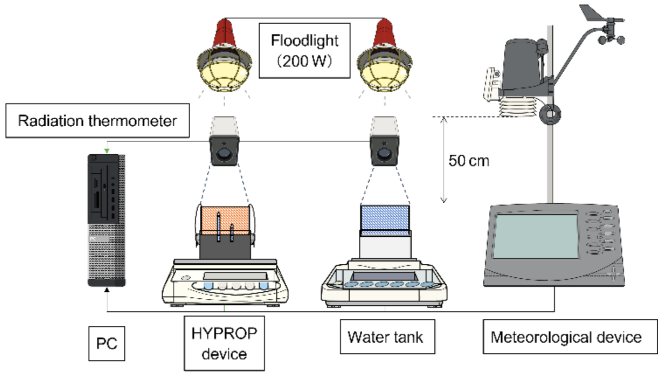

Figure 1. Model of the proposed experiment

device with a structure based on the evaporation method of Kondo (1990) (Figure 1), by preparing a water tank sample with the same material proprieties and volume capacity of the soil sample ring, positioned on an electronical balance to measure the weight, with radiation advent from flood lamps (200 W) at 0.75 m of distance for induced natural convection, and a thermometer for surface temperature measurements. The weather station was positioned at 0.5m of height compared to the samples, gathering data of wind speed, humidity, atmospheric pressure, and temperature. The measurements of the parameters were recorded at a time frame of 5 minutes.

Three base measurements and one measurement with the proposed method were conducted for Toyoura sand at a void ratio of 0.75. For the evaporation analysis 3 sets of data for Toyoura sand at 80%, 50%, and 20% of initial degree of saturation were used. The data sets were compared for the hydraulic conductivity, the water retention and suction proprieties were compared through the soil-water-characteristic-curves, and the evaporation proprieties through the bulk method.

3. Results and discussions

The data obtained from the HYPROP device without the additions from the bulk method (normal method) had an average air entry point or boiling point value of 893 hPa for the bottom tensiometer and an average value of 1035.6 hPa for the top tensiometer, while the pressure for the proposed experiment had a value of 877.7 hPa and 920.7 hPa respectively. The obtained hydraulic conductivity (Figure 2) is concentrated around a saturation of 2,5% to 4,5%, with the seepage of the proposed method showing consistency with the other measurements around 4% of saturation. The proposed method, however, presented a sharp decline in a higher degree of volumetric water. One of the obtained measurements was not possible to be plotted in the graph, due to noise in the results.

The SWCC obtained for the four measurements (figure 3) presented a consistent degree of coherence in the saturated zone and the entry values in the residual zone. The proposed method entered the desaturated zone at a lower degree of saturation, possibly due to the increase in natural convection on the surface stratum due to the radiation.

While the bulk evaporation for the proposed method presented a good concentration of data on low volumetric water content, 2 problems were prominent: the high instability between points, and the evaporation efficiency surpassing the value of 1. The irregularities in the data are estimated to advent from the difference in heat capacity difference between the soil and water. The sample ring of the HYPROP device being 8cm in diameter and 5cm in heigh, and the sample ring of the normal bulk evaporation experiment being 16 cm in diameter and 2 cm heigh, is also a point of consideration.

4.Conclusion

The possibility for simultaneous measurements of water retention, seepage and evaporation in unsaturated soil was analyzed for sandy soil. While no major interference was found in the proposed method for water retention, seepage, and the soil suction and water retention relationship, there is a need to analyze in further detail the evaporation characteristics. Future tasks consists on stabilizing the evaporation data, increasing the number of samples for the sandy soil, and measuring a variety of soil types (clay and silt), to verify the validity and accuracy of the proposed method.

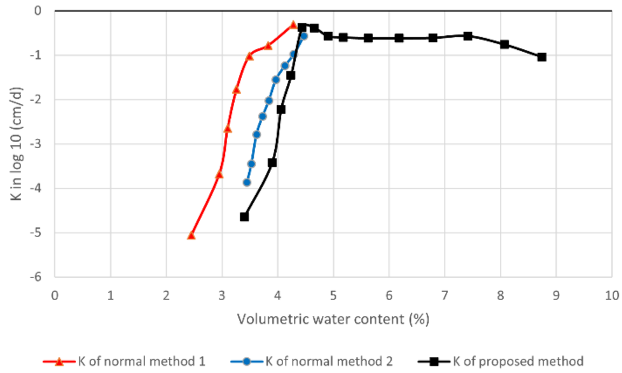

Figure 2. Hydraulic conductivity of the experiments.

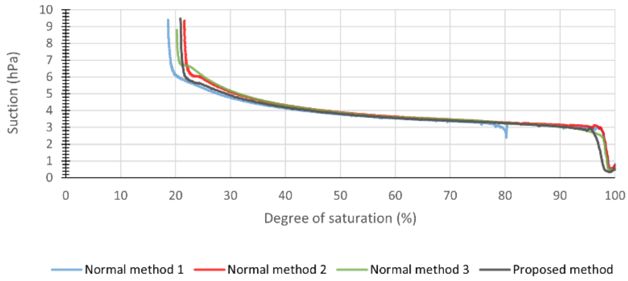

Figure 3. SWCC of the measurements.

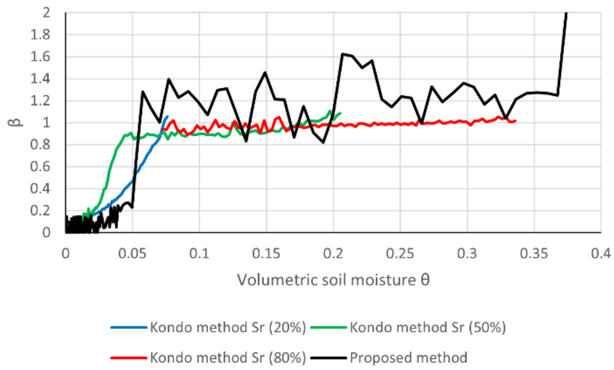

Figure 4. Surface moisture availability of the measurements.

References

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