Influence of top layer thickness on the actual evaporation and water storage through coarse overlying fine sand profiles

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1. INTRODUCTION

Evaluation of evaporation from soil surface is essential for many geotechnical problems such as design of soil cover systems for waste sites and so on (3). A key element is to minimize the net evaporation and maximize water storage in the designed covers. The evaporation process occurs in two distinct stages as shown in Fig.1: 1) Constant rate stage (stage I), when the soil surface is saturated or nearly saturated. 2) Falling rate stage, divided into two sub-stages: Stage II and Stage III, negligible (1).

Most of the existing studies focus on the evaporation from layered soil systems without considering the effect of individual layer properties. This study aims to evaluate the effect of the top layer thickness on the actual evaporation rate and water storage through double layered soil system without water table.

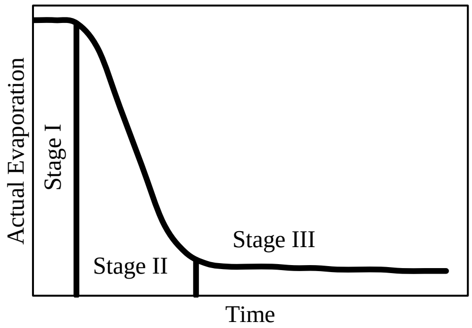

Fig.1. Actual evaporation stages. (Schematic).

2. MATERIALS AND EXPERIMENTAL SETUP

Tests were conducted using silica sand provided by KUMAMOTO –Silica Mining co.,Ltd, Japan. Two texturally distinct soils were used K-7 (fine silica sand) and K-4 (coarse silica sand). Summary of soil properties and the particle size distribution curves are shown in table.1 and Fig.2.

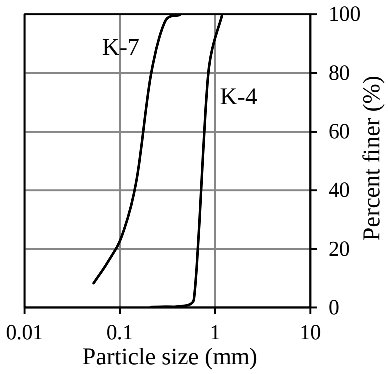

Fig.2. Particle size distribution

Table.1. Soil properties

Soil	Specific gravity (g/cm^3)	Dry bulk density (g/cm^3) (ρ_b)	Saturated hydraulic conductivity (ms^{-1}) (Ks)	Initial volumetric water content (Θ)	Median diameter (mm) (D50)	Uniformity coefficient (Uc)	Initial condition
K-7	2.657	1.618	1.140*10^{-5}	0.389	0.161	3.061	Saturated
K-4	2.655	1.552	2.069*10^{-3}	0.414	0.740	1.222	Saturated

The columns were constructed using a 10 cm in diameter Acrylic material. A valve was installed to the base for saturation purposes. Each column was instrumented with moisture sensors installed through drilled ports as shown in Fig. 3. The actual evaporation rate from each column was continuously obtained by independently measuring the mass of each column using a balance with 31kg capacity and ±1 g resolution. The potential evaporation rate was measured using an evaporation pan placed adjacent to the soil columns and subjected to the same testing conditions. The pan was frequently replenished in order to keep the water surface at the same elevation. In order to increase the evaporation rate a heater lamp in addition to a fan were installed above the soil surface of each column as shown in Fig. 4. A hygrometer was installed 15 cm above the experimental setup which allows continuous recording of relative humidity and temperature of the experimental zone. Soil was filled in separated layers where all the layers were placed using identical placement techniques. The columns were filled in lifts of 3-6 cm and tapped with rubber hammer to disturb the soil in order to obtain consistent and uniform densities. A constant water head was applied to the columns through the water inlet valve in the base. The water supply was kept till the columns achieved fully saturation through the whole soil profile. Then the water valves were closed and the water head was removed.

Through the whole testing period the evaporation rate, saturation profile, relative humidity and temperature were continuously measured with a constant interval of 15 minutes. The evaporation tests were shut down when the evaporation rate of all columns achieved the residual stage where the evaporation rate becomes low and stable.

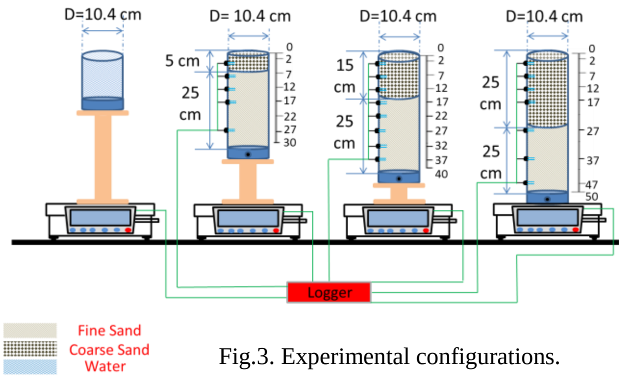

Fig.3. Experimental configurations.

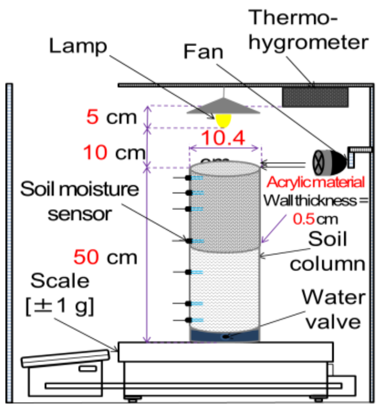

Fig.4. Experimental setup.

3. RESULTS AND DISCUSSION

Fig.5 shows the actual evaporation rates for the three column configurations, where increasing the thickness of the top layer has the effect of increasing the time needed to achieve the residual evaporation stage.

Fig.6 shows the saturation profile for the three column configurations, where the results agree with the results of (Huang M. et al., 2012); almost all of the water removed by evaporation came from the coarse sand (top layer). By the end of the experiment, the overlying coarse sand layer had undergone extensive drying while the fine sand layer remained close to saturation. This trend can be justified to be a result of water content discontinuities and preferential fluid transport pathways through the soil profile as a result of the textural contrast configuration. It can be observed that increasing the thickness of the top layer has the effect of decreasing the thickness of the severely desaturated zone through the bottom fine sand layer.

As shown in fig.7, increasing the thickness of the top layer increases the amount of water lost from the whole soil profile, on the other hand it has the effect of dramatically decreasing the amount of water lost from the bottom layer. As fig.7 shows, the amount of water lost by evaporation from the bottom layer is highly related to the thickness of the top layer up to a certain thickness (Optimum thickness). From the three tested configurations, it can be concluded that thicker than 15 cm (top layer), the top layer thickness has weak influence on the amount of water lost from the bottom fine sand layer.

4. CONCLUSIONS

An experimental study aiming to evaluate the influence of the top layer thickness on evaporation and water storage in layered soil profile was carried out. The following were observed:

1. For coarse overlying fine sand soil profiles, increasing the thickness of the top layer:
   A) Increases the time required to achieve the residual stage.
   B) Decreases the thickness of the severely desaturated zone through the bottom fine sand layer.
   C) Increases the amount of water lost from the whole profile, on the other hand decreases the amount of water lost from the bottom fine sand layer.
2. The thickness of the top layer has high effect on the actual evaporation rate and water storage up to an optimum thickness (15 cm).

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REFERENCES

(1) Fisher E.A. (1923): Some factors affecting the evaporation of water from soil. J. Agr.Sci., 13(02): 121-143.

(2) Huang M., Bruch P.G., Barbour S.L. (2013): Evaporation and water redistribution in layered unsaturated soil profiles. Vadose Zone Journal, 12(1).

(3) Yanful E.K., Mousavi S.M., Yang M. (2003): Modeling and measurement of evaporation in moisture-retaining soil covers. Adv. Environ. Res., 7(4): 783-801.

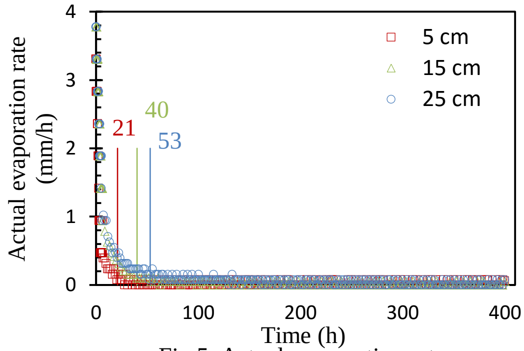

Fig.5. Actual evaporation rate

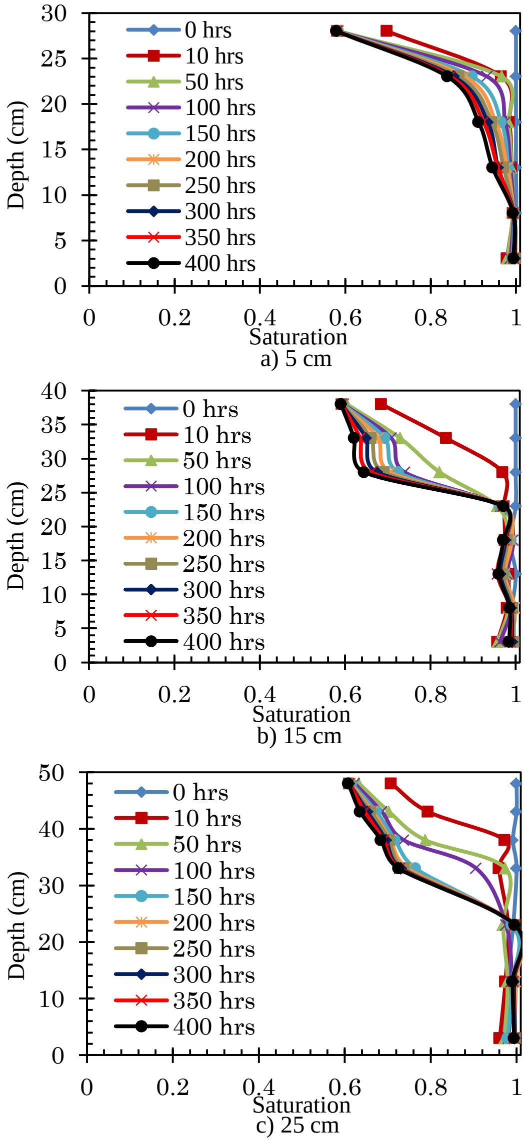

Fig.6. Saturation profile

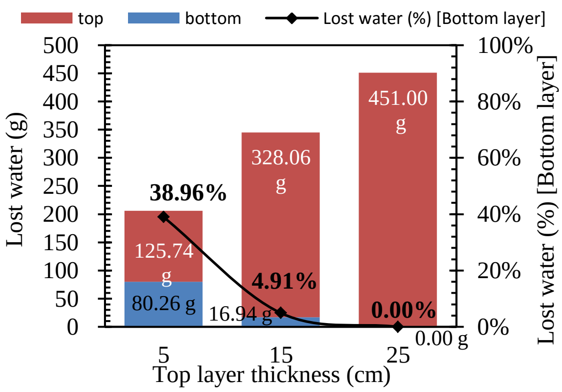

Fig.7. Lost water distribution