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STUDY ON THE INCREASE OF WATER-HOLDING CAPACITY IN SANDY SOILS

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Abstract *Desertification has been one of the major problems that draw global concern. Land degradation occurs with desertification, and from water-resources perspective, the degradation phenomenon is the decrease of water-holding capacity. The objective of the study is in an attempt to improve the water-holding capacity in sandy lands by using irrigation, so that gravity infiltration is introduced to gradually change the distribution structure of soil particles. The concept of lysimeters is applied in this study when water with various clay or silt content is irrigated to sandy lands, and the outflow is observed to better understand the variation of water-holding capacity.*

The lysimeters used in this original set of experiments were designed and made by 4 big plastic buckets with 50 cm in top opening diameter, 40 cm in bottom diameter, and 80 cm in height. Sedimentation from a local reservoir was used as the source of silts to be mixed in the irrigation water with various percentages in weight, along with a reference one in clear water. 30 liters of water was irrigated without disturbing surface soil while water depth not exceeding 1 cm each time, and the curves of accumulated outflow vs. time were observed and recorded.

Basically, the shifting trends of the accumulation outflow curves in each set of experiments could be reasonably explained, i. e., the accumulated outflow curves move towards bottom-right when sedimentation water is irrigated, and move towards top-left when clear water is irrigated. However, irrigations under the silt contents in this study usually cause a clay layer to be formed on the soil surface, which detains water from infiltrating downward. Nonetheless, when these surface clay layers are either broken by simple tools, or left cracking within irrigation periods, the amount of infiltration clearly resumes. Silt contents of 0.2%, 0.4%, and 1% were first tested, and it was later found that 0.1% reached better results.

Keywords: sand, water-retention capacity, lysimeter

1. INTROCDUCTION

There're mostly sandy lands in western Taiwan, and the increase of water-holding capacity in sandy lands has become the major issue of this article. The increase of water-holding capacity can be reached by changing the distribution structure of soil particles. The use of infiltration by gravity through irrigation water is further introduced to gradually alter the soil structure, and the water-holding capacity of sandy soil is hence raised. The concept of lysimeters is applied in this study when water with various clay or silt content is irrigated to sandy lands, and the outflow is observed to better understand the variation of water-holding capacities.

2. EXPERIMENT LAYOUT

2-1 Basic Data

The basic data for the soil characteristics in the experimental site, e.g., specific gravity, bulk specific gravity, void ratio, saturation water content, soil texture, and infiltration coefficients, etc, are shown in Table 1.

Table 1 Physical properties of the soil in Chi-Ting Experimental Station

Sieve Analysis			Soil texture	Organic content(%)	PH value	Remarks
sand(%)	clay(%)	silt(%)				
95.32	2.50	2.18	sand	1.66	5.87	
Specific gravity	Bulk specific gravity	porosity(%)	Void ratio	Saturation water content(%)	Wilting coefficient	
2.63	1.47	44.12	0.79	29.71	1.37	

2-2 Experimental Layout

2.2.1 Design of lysimeters

The experiments were conducted in Chi-Ting Experiment Station. The lysimeters were simulated by four large buckets with 50 cm in inner opening diameter, 40 cm in bottom diameter, and 80 cm in height, A hole was first drilled at the bottom for drainage as well as measurement, followed by installing a drainage pipe, and filling with 2 cm gravels. An layer of un-woven fabric was placed before the sand from experiment area was put on top, as shown in Fig. 1.

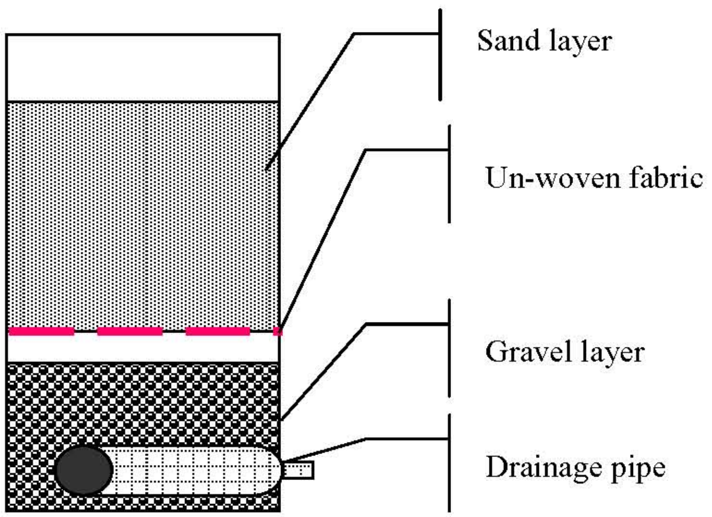


Fig. 1 Design of lysimeter

2.2.2 Sludge content in the irrigation water

The sludge from A-Kung-Tien Reservoir was used as the source for mixing in irrigation water, and it was dried, pounded, then sieved. It was then found that when sludge content was over 1%, a sludge layer would form at the surface, and the infiltration of irrigation was blocked. As a result, the sludge contents of 0.2%, 0.4%, and 1% were selected in the experiment to be uniformly mixed in the irrigation water, and a control experiment of plain water was also prepared.

2.2.3 Irrigation plan

It was expected that the voids could be filled with irrigation water, thus a volume of 30 liters was needed for each irrigation practice. Basic principles for the irrigation practice were that the surface soil was un-interrupted, the depth for surface water was under 1 cm, and the sprayer was used for irrigation. The irrigation frequency is based on the water content in the soil, especially the field capacity. And after real operation, one-week was determined as the irrigation period in the beginning, and in the following stage, irrigation was applied according to the degree of cracking after the soil surface was dried.

2.2.4 Observation and Recording

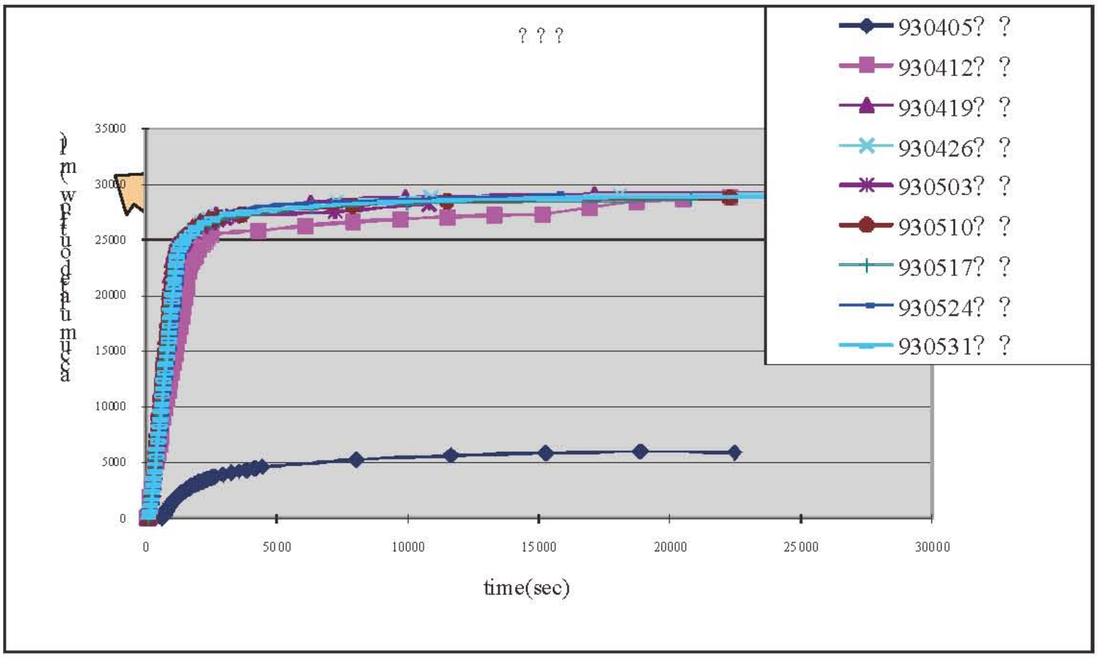
A stop watch was used to record the discharge time in each irrigation practice, the measurement of record interval as well as the amount of water were adjusted according to discharge condition, and the discharge-time curve was plotted.

3. EXPERIMENT RESULTS AND ANALYSIS

3-1 Plain Water Control Group

The plain water was irrigated in the lysimeter filled with sand from the experimental site. Irrigation was applied in the period of one-week, or when the amount of discharge was small enough, and was continued until the accumulated discharge vs. time curves had reached stable, as shown in Fig. 2.

Overall speaking, except in the first application of irrigation in which there was detention effect due to the considerable void volume in the soil particles, the lag time before discharge was nearly 10 minutes (592 sec), and the discharge volume had reached stable ar 6 liters after 3 hours, in later experiments, the lag time for discharge water was less than 1 min, the discharge decreased drastically, and the accumulated discharge volume had reached stabilization at 30 liters after about 1-hour.

Fig. 

2

Accumulated discharge curves for the control group

There is significant difference in the accumulated discharge curves between the first application of irrigation and later observations. In the first application, the irrigation water is retained to fill the voids between soil particles. Theoretically, the amount of retained water should be close to the field water content of the experimental soil.

Observations on the later accumulated discharge curves, it is found that there is a moving trend to the left-upper direction, as shown by the arrow in Fig. 2. The possible explanation could be to add-up the field water content, or the electric-flow phenomenon when the newly irrigation water has forced the bottom water to flow out. The other observation is on the turbidity of the discharged water. The discharge rate increases because the micro particles are washed out by the irrigated water, and the area for water flow through soil particles increases.

3-2 Group of 0.2% Sludge Content

The irrigation water with 0.2% of sludge content was applied under the period of one week, and was adjusted according to the discharge curves and actual conditions, and the daily accumulated discharge curves were shown in Fig. 3.

Basically, the shapes for the discharges curves of this group are consistent with the control group, however, the variations among experiments could be discussed separately.

From 2nd test (930420) until 6th (930525), the variation trend was gradually to the bottom right direction, the lag time increases, and the discharge rate decreases, which were opposite to that of control group. The effect of sludge was obviously observed. However, the accumulated discharges turned at the 25 liter were rather consistent, which implies that field water content was related.

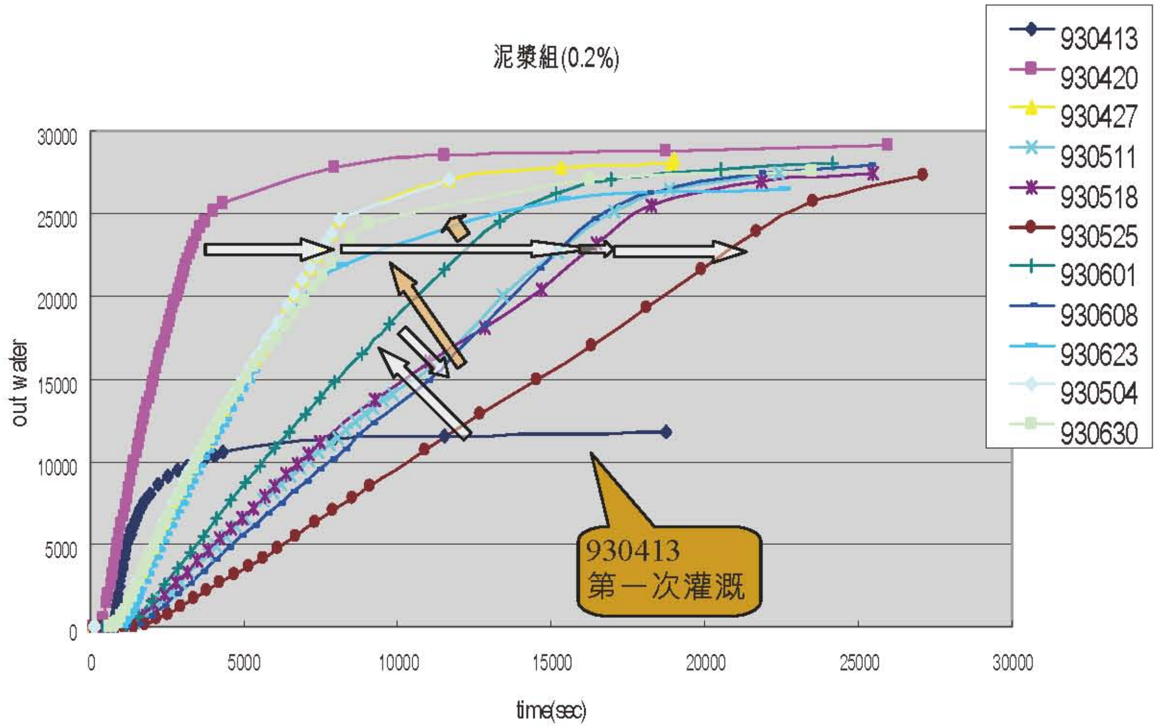


Fig. 3 Accumulative discharge curves for group with 0.2% sludge content

Although the 0.2% was the lowest sludge content in the series of experiments, and was expected to meet the experiment goal, nonetheless, due to the thin clay layer which formed at the surface to block the infiltration water, had caused the infiltration rate to decrease. As a result, in order to simulate the actual situation in field to increase the infiltration rate, the surface layer in the lysimeter was interrupted by using sticks to punch holes before next irrigation was applied. And the result showed that the curve did resume, although not completely. And when irrigation was further applied, the curves moved to the bottom-right direction again.

For the surface clay layers, cracking occurs easily due to their thinness. The cracking in the lysimeters occurs in about one week, and reach considerable cracking as shown in Figs. 4(a) to (d). If irrigation is further applied, then the accumulated discharge curves move to the upper left as expected.

However, there maintained only once for the re-application of irrigation, the span of the moving of accumulated discharge curve decreases drastically, and seems to reach stable. The reasons could be either related to the condition of re-application of irrigation after cracking (Fig. 5), or is believed to have reached the water-holding effect as expected in this study.

(a) 930610

(b) 930615

(c) 930618

(d) 930623

Fig. 4 Cracking of surface clay layers for the 0.2% sludge content group 930610-930623

(a1) 930630 (before)

(a2) 930701 (after)

(b1) 930727 (before)

(b2) 930728 (after)

Fig. 5 Cracking of surface clay layers before and after irrigation for the 0.2% sludge content group

3-3 Group of 0.4% sludge content

The irrigation water with 0.4% of sludge content was applied under the period of one week, and was adjusted according to the discharge curves and actual conditions, and the daily accumulated discharge curves were shown in Fig. 6.
Basically, the moving trends of the discharges curves for the first few experiments in this group are consistent with the 0.2% group. In other words, from the second (930428) to sixth (930526), the curves were moving to the bottom right direction, lag time gradually increases, and the discharge rate gradually decreased, and the effect of sludge content. In addition, the bending or turning of all curves at the accumulated discharge of 25 liters is pretty consistent, which again shows the correlation with field water content.

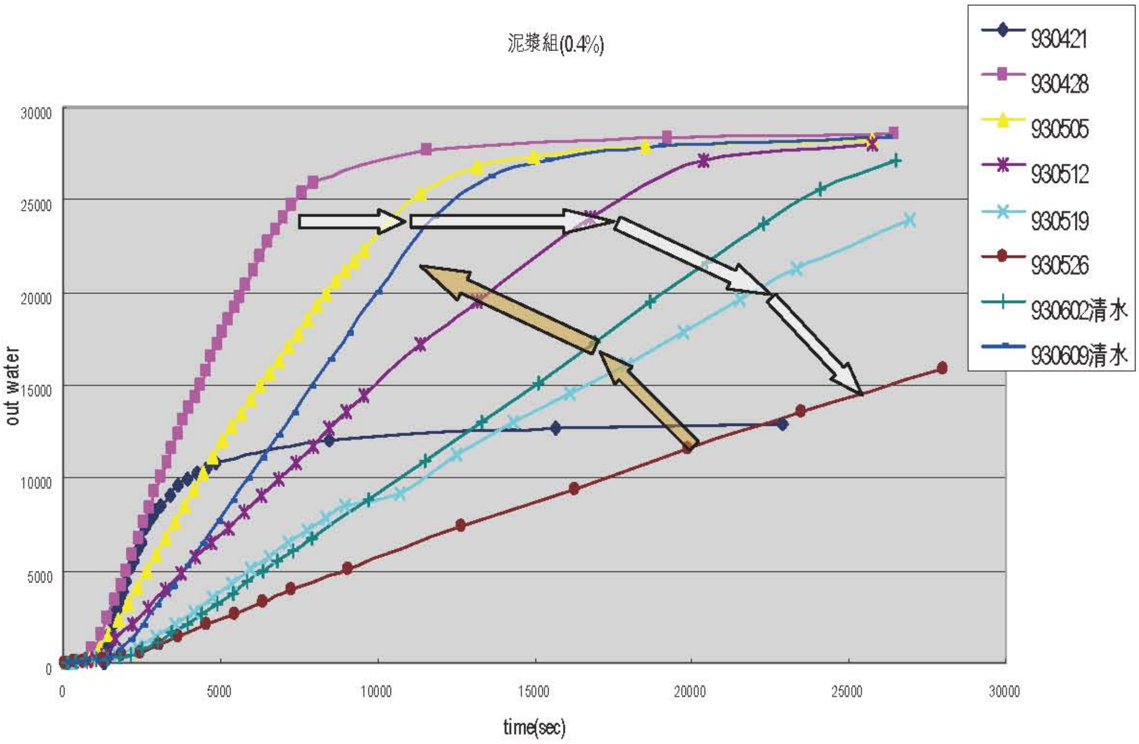


Fig. 6 Accumulative discharge curves for group with 0.4% sludge content

However, when compared with the 0.2% group, the clay layers formed at the surface are thicker, and the effect on the retention of infiltration is more significant. As a result, plain water was used for the following two consecutive weeks, and it can be seen from Fig. 6 that the accumulated discharge curves move to the upper-left promptly, and even over expected. But when inspecting at the surface after irrigation, the sand and clay seemed to be mixing, which indicated that the plain water seemed to have brought the sludge into the voids of the sand.

The drying and cracking process was then conducted, and it was observed that the surface layer remained very minor changes for a certain period of time, as shown in Fig. 7(b), except that there was break off between soil sample and lysimeter wall due to drying. And the expected cracking occurred promptly after three weeks (Fig. 7(c)). But when again irrigated with 0.4% sludge content, the surface was fast covered by clay, and the cracking was filled up, as in Fig. 7(d).

(a) 930610 after irrigated with plain water清水施灌後

(b) 930621 drying of surface clay layer

(c) 930701 cracking before irrigation

(d) 930705 after irrigation

Fig. 7 Cracking of surface clay layers and comparison between before and after irrigation for 0.4% sludge content group

Two identical experiments were conducted afterwards (i.e., irrigation twice with plain water, followed by sludge water after cracking), and consistent results were observed. That is, the surface clay layers remained for a certain time (almost a month), and cracking promptly occurred once started. It could also be observed that some discharge curves, especially those irrigated by plain water, located mostly on the top-left corner, as shown in Fig. 6, were hard to explain. The possible explanation was that gaps occurred between soil sample and lysimeter during the drying process, and caused irrigation water to flow downward, as shown in Figurre 7(b).

3-4 Group of 1% Sludge Content

The irrigation water with 1% of sludge content was applied under the period of one week, and was adjusted according to the discharge curves and actual conditions, and the daily accumulated discharge curves were shown in Fig. 8.

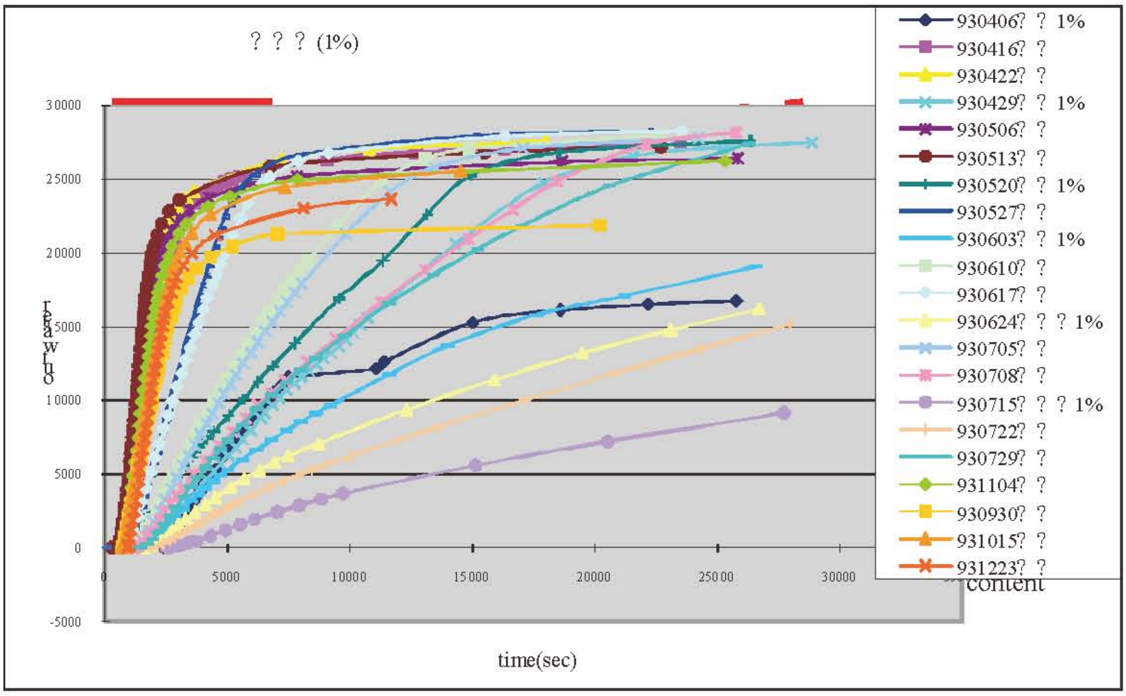


Fig. 8 : Accumulated discharge curves for the group of 1% sludge content

Due to the high clay content in this group, the irrigations with plain water and sludge water were alternately applied. Overall speaking, there is a trend to the bottom-right direction for those discharge curves, as shown by the yellow arrow in Fig. 8. However, when the distribution of these curves were observed closely, it was interesting to find that except the plain water experiment of 930708, those with plain water irrigation seemed to appear on the upper-left corner, while those with sludge content water appeared on the bottom-right corner, as separated by the red-dotted line in Fig. 8.

4. CONCLUDING REMARKS

- In addition to the control group of plain water, the irrigation with sludge contents of 0.2%, 0.4%, and 1% was applied, and corresponding observation as well as records were taken in order to plot the accumulated discharge curves. Basically the moving trends for the obtained curves could be reasonably explained. In other words, the curves form the plain water irrigation moved in the trend of upper-left direction, and the curves by the irrigation water with various sludge-contents moved in the trend of bottom-right direction.

- Under the irrigation conditions of selected sludge content, the clay layers are more or less formed at the surface, and the infiltration of irrigation was interrupted. However, when these layers were broken by simple tools, or let cracking during irrigation periods, then the infiltration resumed profoundly.