Effect of Cycling Wetting and Drying on Suction Variation Under Axial Loading an Experimental Approach

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ABSTRACT

Disregarded the unsaturated soil behavior, like changes in volume and soil collapsing has caused a lot of damage to the foundations of the buildings and other structures. These behaviors relate to drying and wetting phenomena. An experimental study was carried out to investigate the variations of suction and stress - settlement relations under axial static loading on fine grain unsaturated soil (CL-ML) after 3 cycles wetting and drying. A prototype foundation model (100×100×35mm) was used in the testing program. Tests were carried out in a specially designed bearing capacity box (900×900×850) mm with soil suction measurements. Results showed an increase in the applied failure stress of about 19%after an application of three wetting-drying cycles. On the other hand, the sense record slight variation in amount of suction about 2 kPa (both recorded sensors S1,S2) during increasing axial load after wetting-drying cycles repetition. While the variation coincide with first applied load increment (before moisturizing drying case), and sense readings showed continue change (from 12 to 15 at S_1,from 7 to 0 kPa at S_2) with increasing load limit till failure happened. This could be attributed to the change in physical soil properties such as soil densification and hysteresis effects, consequently affected its ability on retention water in pore space.

Keyword: wetting dry cyclic, hysteresis, suction variation, unsaturated soil , load increment, fine grain soil.

INTRODUCTION

Soils naturally exposed to a series of drying and wetting cycle due to natural environmental variation. Suction for long time has been recognized an essential variable for interpretation of the mechanical behavior of the unsaturated soil. In reality suction affects the mechanical behavior of the unsaturated soil in two ways (Karube& Kato, 1994[1]; Wheeler &Karube, 1995[2]):

(a)By adjusting the skeleton stress by shifting in the average fluid pressure which effects on the pores of the soil.

(b)Through provision further strength bonding between contact particles, often due to capillary forces that occur in the water meniscus. It is important to understand that the two mechanisms are affected by the suction through the degree saturation of the soil. The proportional area in which the air and water pressure act depends directly on the degree of saturation (percentage of pore spaces occupied by water), but the same parameter also affects the number and severity of capillary induced between inter particle forces.

Shallow foundations, typically exposed to wetting – drying cycles due to the reasons mostly associated with the environmental condition. In this work, a program of experimental research has been carried out of inquiry into variation of the suction and the affected stress- settlement

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relations during axial loading after carry out number of cyclic drying – wetting processes. Special attention has been given to variation of suction behavior during this work.

Background

The influence of drying and wetting repetition on unsaturated soil properties was studied mostly on expansive soils, which addressed on soil reactions after exposure to wetting and drying cycles. Their results focused on the affected swelling and shrinkage behavior. Some of them showed a decrease in swelling with increasing vertical stress, it was detected through studies of Dif & Bluemel (1991)[3] and Al-Homoud et al. (1995)[4], They attributed this behavior to continuity rearrangement of soil particles, lead to decline the microstructure action. While other studies, noted adverse behavior, the swell quantity increased after a number of courses like Obermeier(1973)[5]and Popescu (1980)[6]. In addition, Day (1994)[7] and Basma et al. (1996) [8] concluded that, the accumulated contraction or dilation effort depend on the amount of extended suction during drying process. Low irreversible in volume change has been observed and a certain size can occur during desiccating unsaturated soil by Alonso drying, E.E. and others (1995) [9] and Sharma (1998) [10] through lab tests, which involve wetting-desiccating cycles carried out by decreasing and increasing in suction on soil specimens (prepared artificially mixture of bentonite and kaolin, CH) under fixed net natural stress of 10 kPa, subjected to isotropic and oedometric conditions respectively. Alonso, E.E.et al(2005)[11] predicted through investigation; the amount of change in sample size prepared (mix of sand and bentonite) and exposed to a number of wetting and drying at high suction level. There experimental evidence noted that; moisturizing and desiccating cycles are also able to carrying a ductile strain. The ductile strain regions generated with in underlying microstructure distortion, which can be controlled by applied confining stresses (during odometer test) and compacted soil density. Runi Asmaranto et al (2010)[12]discussed the change in suction caused by repeated moisturizing and desiccating cycles on physical characteristic of inorganic undisturbed residual silt soil have low plasticity. Wetting-drying cycles repetition caused the soil became dense, visible on the fourth and sixth cycles value of void ratio decreases when compared to the first cycle at the same of value water content. However, the void ratio decreased at the sixth cycle was not followed by increasing suction value. They related these phenomena to soil type, where silt soil specimen was more brittle different if the tested soil is expansive soils, which causes an increase in suction value after cycles of wetting-drying.

Experimental program

Test Material& suction measurement

Test were performed on compacted siltys and artificial soil have 10% gypsum, the soil physical characteristic are presented in table(1)

Table (1) properties of test soil

Soil Property	
Liquid limit (L.L)	28
Plastic limit (PL)	23
Plasticity index (PI)	5
Soil classification (USCS)	ML
Specific gravity (Gs)	2.69
Max. unit weight (kN/m3)	17.1

A model footing (100×100×35mm) was used to carry out tests in a bearing capacity box (900×900×850) mm was used on saturated- unsaturated fine grained soil as shown in fig.(1), it compacted dynamically in equal layers 4cm in thickness up to 50cm depth with17.1kN/m^{3}dry unite weight at 14% water content, and suitable aggregate layers of 10cm thickness was placed under soil layers as a filter to protect the soil materials. This filter was designed according to Terzaghi &Peak (1948) [13] criteria**.** The matric suction of soil was measured using

WATERMARK sensors of 22 mm in diameter and 83mm length as shown in fig.2 (a) and recorded by Watermark Monitor during testing as shown in fig.2 (b). This device has a capacity of measuring soil water tension ranging from 0 to 239 (kPa) .The sensors S1, S2 were inserted through an opening at a depth of 1B (10cm) and 2B (20cm) respectively beneath footing center (B footing width) within the stress bulb distribution 0.4q and 0.1q (q is contact pressure),as seen in Fig.1 (Note; Sketch without scale). The sensor is a stiff-land electrical resistance notify device that is used to measure soil water tension. Whene verthe stress intensity change the electrical resistance will change, and will be detected through the WATERMARK Sensor.

Drying-wetting cycles process

A set of drying and wetting tests were carried to investigate the variation of the suction and the affected stress - settlement relations state (after drying and wetting cycles) during loading. Three series of drying-wetting cycles were done separately. The model box was placed inside water tank 60cm in depth, feeding of water process has done through openings existed beneath the model box. The soil was saturated slowly by raising water table up to the surface, and then water table was lowered down using drainage valve.17piezometers used to control positive water pressure and 2 suction measurement sensors (watermark) are used to control the distribution of the negative pore water pressure in each of the tests. The locations of piezometers and sensors are fixed through tests, a perforated tip at the end of 100 mm. clear lengths of plastic tubes of 6 mm. diameter have been laterally inserted in locations specified for checking water level during wetting cycle of the positive pore water pressure head. The other ends have been attached to plastic tubes of internal diameter of 3 mm. While, suction sensors locations were placed beneath the model footing within stress bulb. Drying process applied through vapor equilibrium sessions till reached 14 kPa, which represents initial suction condition technique. Through evaporation process water molecules immigrated from the soil surface. This is done as part of the reference application known as a potential of water and soil mass system, even achieving a hydro mechanical equilibrium. The range of suctions applied between (14–0) kPa, which means after moisturizing(0kPa suction) drying process begins and continue till soil (within test space region) suction reach 14kPa for each wetting drying cycle. For noting, through drying process soil surface kept free from vertical confining, wetting process spends 7 days while drying takes 25 days.

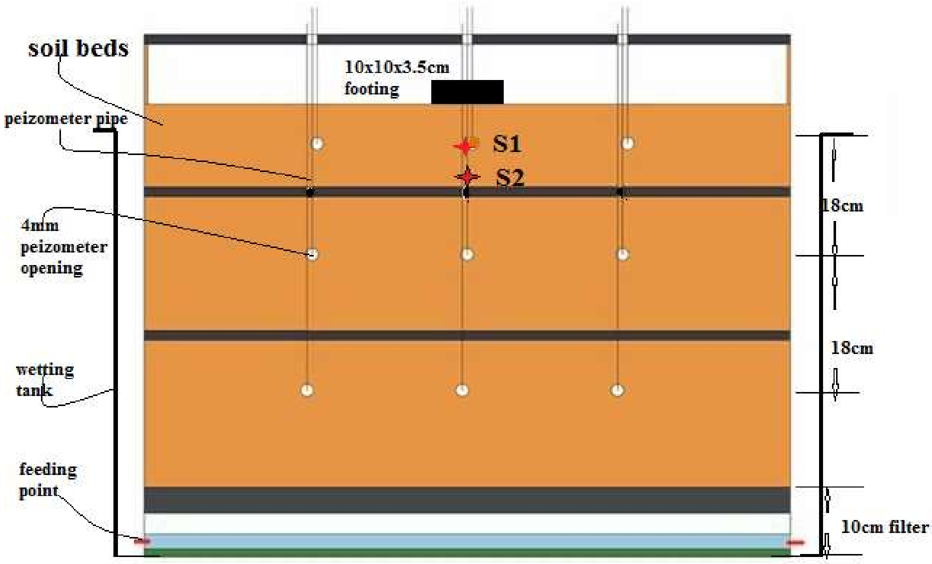


Figure (1) .Schematic the distribution of the piezometers and sensors at a model footing test box.

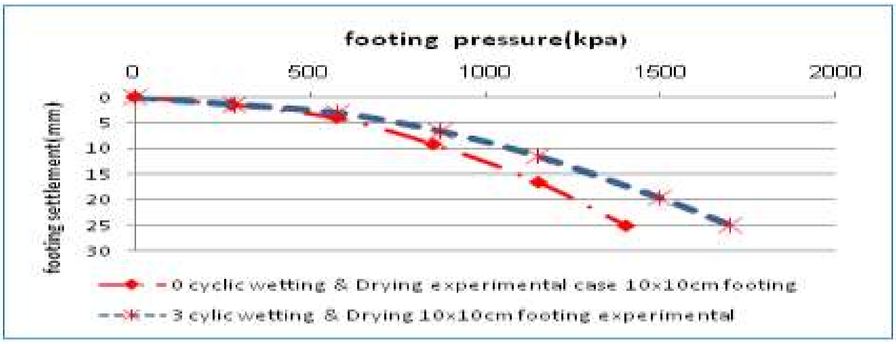
Loading test

The specified loading set depends on the basis of cyclic plate load test. The first load was kept constant until any other settlement or settlement rate becomes negligible [Murthy V.N.S. 2002 [14]. Next highest load placed on the plate and settlement was recorded, notes registered on every increase of load until the settlement rate is less than 0.25 mm per hour measured by 2 LVDT. First applied load taken nearly to five estimated safe carrying capacity of the soil. It is worth noting that the vertical displacement, load increment and suction measurement were recorded with a special data logger of 6 channels and watermark monitor respectively. The test was continued till total settlement of 2.5 cm occurred.

Figure(2).suction measurement: a) watermark sensor, b) watermark monitor.

Results and Discussion

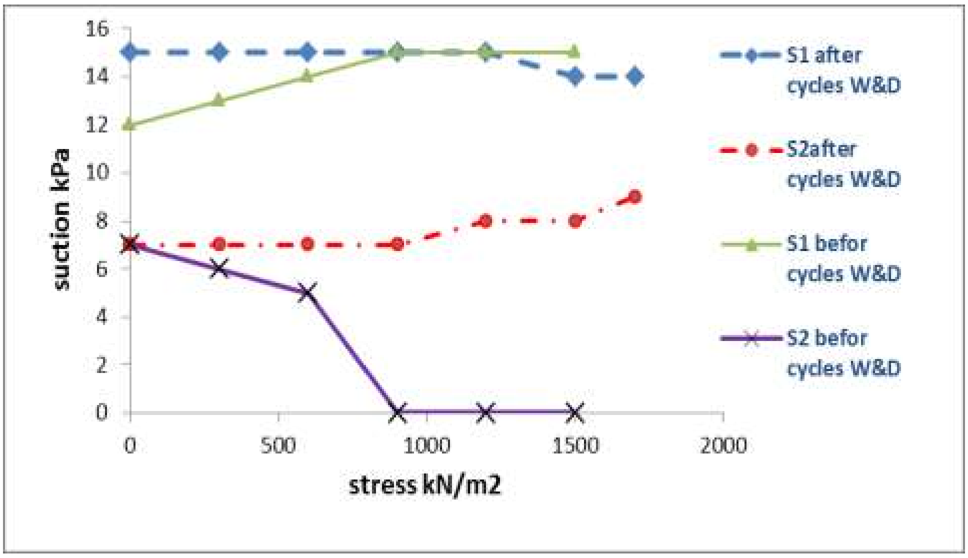
The laboratory results indicated an increasing in applied failure stress(according to settlement failure criteria) after wetting drying repetition up to 1700kN/m^2 in comparison with applied failure stress before cycling wetting drying ranged about 1400kN/m^2 as shown in fig. (3)**,**it is worth to note that soil had the same suction of 14kPa within test range (for the two cases before and after imposing to wetting drying repetition). Increasing in the applied failure stress could be attributed to the soil densification through the rearrangement of particles, accompanied with wetting drying repetition. Where increase in density was found up to 5% at the lower layers and plastic strain occur due to micro structural distortion. In addition; the effect of hysteresis, generally It tends to retain a larger amount of water during the drying of the same suction stress during moisturizing as discussed by Lu, N. and Likos, W.J., (2007)[15]. Where approaching the grains to each other had increased the ability of unsaturated soil to retention the water inside the pores, and hence, reducing the possibility of water leakage, this works increase suction stress under the effect of applied stresses within this limit. Where, this result coincide with other experimental evidence already mentioned in the review on the effect of wetting drying repetition on durability of residual silty soil; induced a plastic strain generated after exposing to wetting and drying sessions. Runi et al (2010)[16] showed that wetting-drying cycles repetition increases the soil density. This was visible on the fourth and sixth cycle's void ratio value. Where the void ratio shows reduction when compared with the first cycle have same value of water content. This might be attributed to the brittleness behavior of silty soil specimen as reported previously.



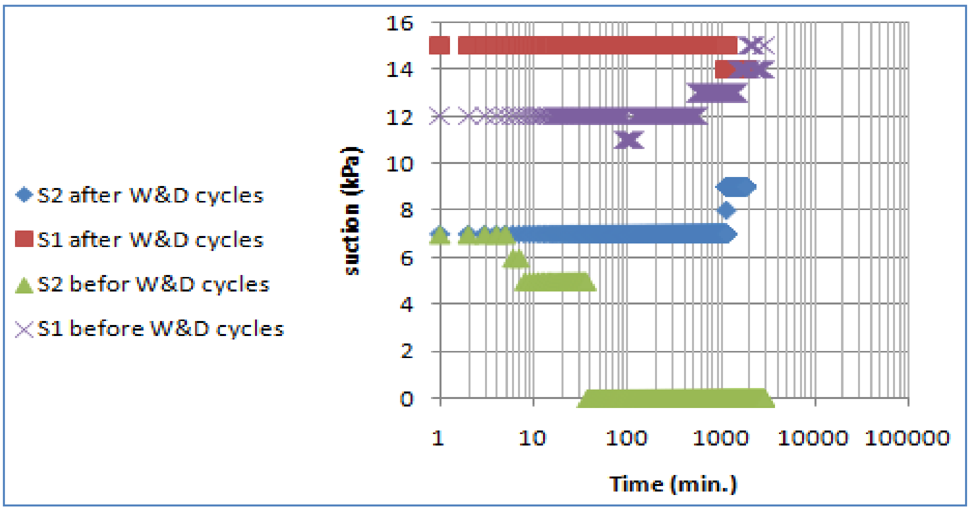
Figure(3) Stress-settlement relation (before and after wetting-drying cycles).

Concerning to suction variation of unsaturated soil during loading; changes were noted during loading increments before moisturizing and drying cycles as shown in fig.4. The result showed; that suction remains constant during steady loading period and change with every loading increment, as given in fig.5. This action could be related to the mechanical characteristic of unsaturated soils, which relies on two stress state variables (suction and net normal stress).The sensors S1 and S2 recorded different suction variations during the applied load as given in the fig. 4. Where increase stresses cause changes in pore space and led to leaks water in between, this action increase suction from one location and reduces in another.

Suction decreasing in S2 to zero kPa (as shown in fig.4) related to reducing it volume and hence was increasing its degree of saturation; this followed the transient regime from dry to wet face state. While, after exposing the unsaturated soils to cycling wetting drying process the suction was not expose to any variation, the sensors did not recorded any change in the amount of suction values during loading increments fig. 5. It is worth noting that, recorded a little changes in sensors reading at the last increment. Where S_1recorded increase in suction for a while to 16kPa then return to start suction value 14kPa, while S_2 sensor recorded increase in suction from 7to 9kPa as shown at fig. (4) .This behavior is attributed to the effect of both hysteresis and soil densification; where repetition of moisturizing and drying process of making the soil exposed to pre-stress, so a change in the suction happened when it became the overhead hanging higher (at the last load increment) than the stress which involved already. In addition; monitoring soil suction through sensors S1, S2(during the press implications imbalance due to air and water exchange operations as described in suction- stress relation fig.4. This is consistent with Peng et al. (2004)[17] explanation about suction variation under static compression at different initial suction condition and aggregate fractions. It was indicated that loading distorts the pores,t herefore, deformity the large pores, and a decrease in the size and creation of new small pores. If the degree of saturation is lower (the case of a small percentage of the water and suction high), and the smallest pore size is sufficiently established to achieve a balance in the water caused by the destruction of other pore flow, and thus the soil suction tends to increase or remain constant.



Figure(4) - Suction- loading stress relation at sensors S1, S2before &after wetting drying repetition.



Figure(5) Suction- time relation for sensors S1,S2before and after cycling wetting drying.

CONCLUSION

Variation of suction values and stress-settlement relation (under shallow prototype footing) during axial loading discussed herein on unsaturated soil case before and after exposing to wetting drying repetition, using especially bearing capacity tank with suction measurement device. The results showed;

1-increase in applied failure stress of the unsaturated soil in comparing with applied failure stress at initial condition, after exposure to cyclic wetting-drying process. Where suction stresses ranged between 0 to 14kPa through wetting–drying process.

2-Variation in the amount of suction stresses observed during increasing axial load in both cases before and after wetting and drying processes but unevenly. Where before moisturizing drying process the variation coincide with first applied load increment, and sense readings showed continue change with increasing load limit till failure happened, while after wetting drying cycles case noted change in sense reading during the last applied load increment only, in another meaning the variation accrued during failure applied stress. This behavior is attributed to a change that has happened in the physical properties of the unsaturated soil after wetting-drying cycles; it's both densification and accompanied hysteresis effects.

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