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Wetting behaviour of an unsaturated compacted clayey-silty-sand under anisotropic stress states

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ABSTRACT

Very few experimental results on the wetting and collapse behavior of sand-fine mixtures under anisotropic stress state exist, because of technical difficulties and time-consuming nature of measuring suction and deformation. This paper presents and discusses the results of a set of suction-controlled triaxial test performed on unsaturated compacted clayey silty sand under different level of anisotropic stress states and initial suctions. Axis translation technique and double-walled triaxial cell have been used to measure the soil matric suction and variation of pore air volume. Every one of the specimens was firstly subjected to the specific initial suction and total anisotropic constant stress. Afterward, the suction was decreased incrementally and the engendered deformations were measured during the time. According to the obtained results it was found that for a given anisotropic stress state wetting behaviour of soil depend remarkably on the level of initial suction, so for high level of initial suction, wetting process lead to collapse of specimen. Besides, for a given initial suction, the level of applied anisotropic stress state play an important role in engendering deformations during wetting. Based on results of tests, for a given constant total stress state, the intensity of deformation and the situation of collapse depend on time. On the other hand, stress-strain behaviour of studied unsaturated soil has viscous nature.

1. Introduction

In the majority of earth structures problems such as earth and rock fill dams and slopes, construction is generally down under unsaturated conditions. According to the experimental results existing in literature there are a significant differences between the shearing behaviour of unsaturated soils and the shearing behaviour of fully saturated or completely dry soils. For unsaturated soils, a change in the degree of saturation can cause significant changes in volume, shear strength and hydraulic properties. The unsaturated compacted fills, due to wetting, may experiment a large domain of deformation or in certain cases collapse can be occurred ((Leonard and

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Narain 1963), (Leonard and Davidson 1984), (Miranda 1988)). Wetting effect on unsaturated soil depend on divers factors such as soil type, initial matric suction, density, initial degree of saturation and confining stress. There are a numerous studies in the literature concerning the influence of wetting on stress-strain behaviour of unsaturated soils. In this regard we can cite the works of (Kato et al. 2000), (Ferber et al. 2008), (Airo Farulla et al. 2010), (Lim et al. 2004), (Sun et al. 2004 and 2007), (Meilani 2005), (Fredlund et al. 1991), (Cerata et al. 2009), Escario et al. 1973) and (Bishop 1961). The majority of these works have been executed through oedomertic apparatus. However application of this apparatus presents a certain limitations concerning stress and strain boundary conditions and matric suction measurement. For removing the above limitations, triaxial apparatus has been used by certain authors such as Sun et al, and Meilani et al. With this apparatus, the effect of different factors affecting the wetting and collapse behaviour of soils such as stress path, density, drainage conditions can be studied.

An important path corresponding to the majority of practical geotechnical problems is, wetting of unsaturated compacted soil under a constant anisotropic stress state and measurement of engendered deformation during the time. This aspect that is previously fewer studied, was the aim of the present work. For this, using developed triaxial apparatus, wetting behaviour of one compacted unsaturated clayey-silty-sand in different initial matric suction and in different level of constant anisotropic stress state was studied.

2. Soil physical properties and samples preparation

The used soil in this work is sand mixed with silt and clay. Its physical properties are listed in Table 1. The grain size distribution of soil is shown in Fig. 1 and based on Unified Soil Classification System (USCS), it is classified as silty sand (SM). Wet tamping technique was used for the specimens construction.

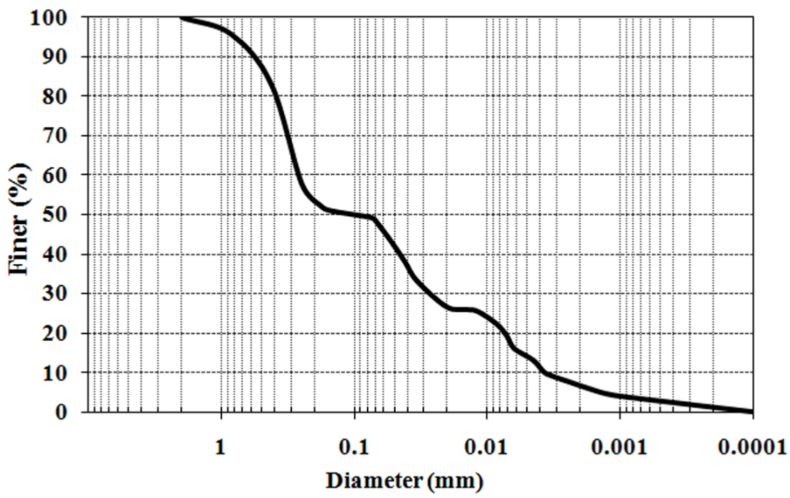


Fig. 1 Grain size distribution curve

3. Testing apparatus

The load controlled triaxial test apparatus developed at Bu-Ali Sina University, used to achieve the aim of this work. The matric suction in this apparatus is generally controlled using the axis translation technique. The pore-water pressure was controlled through a satu-rated ceramic disc with an air entry value of 500 kPa. The apparatus has ability to control and measure the pore air and pore-water pressure in the soil specimen independently by using axis translation technique.

Table 1. Physical properties of soil

Soil Type	Clay Content (%)	Silt Content (%)	Specific Gravity	LL (%)	PL (%)	eo
SM	29	20.29	2.68	16	-	0.46

4. Testing procedure

The anisotropic initial stress states for specimens were selected as a percentage of their maximum deviatoric stresses. For this, a set of classical drained triaxial tests with different value of initial suction (50,100 and 162 kPa) and under net confining stress equal to 100 kPa were firstly performed. The stress-strain curves for different tests are shown in the figure 2. It's obvious from figure 2 that increasing in initial matric suction led to increase in shear strength of soil. Different values of anisotropic stress states for wetting tests are listed in Table 2. The unsaturated specimens were prepared in the second step and were subjected to selected initial anisotropic stress states and initial suction. In the experiment program pore-air pressure were constant equal to 250 kPa. After achieving the equilibrium state between pore-air and pore-water pressures the wetting phase were started. Figure 3 shows the tests results for equilibrium phase after applying the stress states. We observe an instantaneous behaviour due to applying external stresses and a delayed behaviour under constant loading for achieving equilibrium state. In the wetting phase the specimens were subjected to decrease in matric suction incrementally and engendered deformations were recorded during the time.

Table 2. Definition of different types of tests

Test	q_{max}(kPa)	$0.5q_{max}$(kPa)	$0.7q_{max}$(kPa)
S_0=162-CD-100	658	329	460.6
S_0=100-CD-100	603	301.5	422.1
S_0=50-CD-100	540	270	378

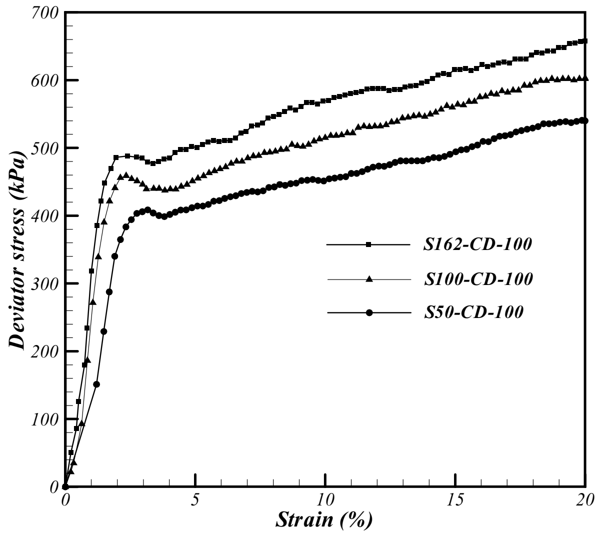


Fig. 2 Stress- strain curves of triaxial tests for different initial matric suctions

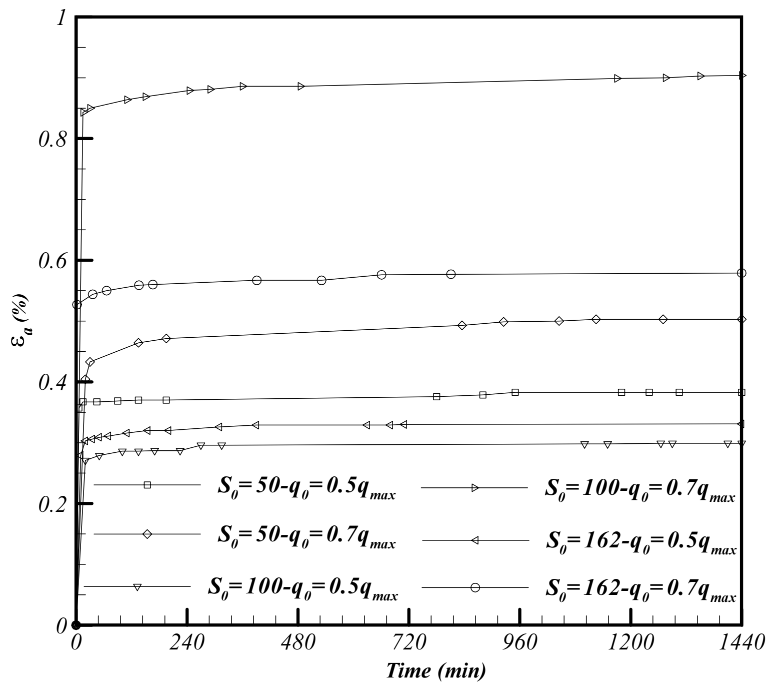
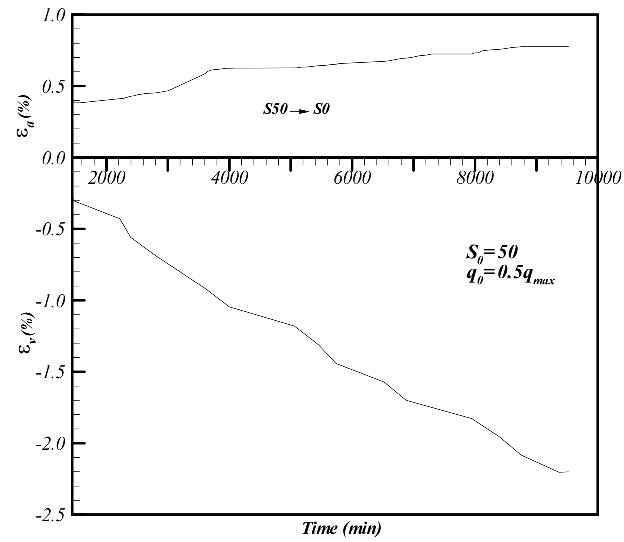


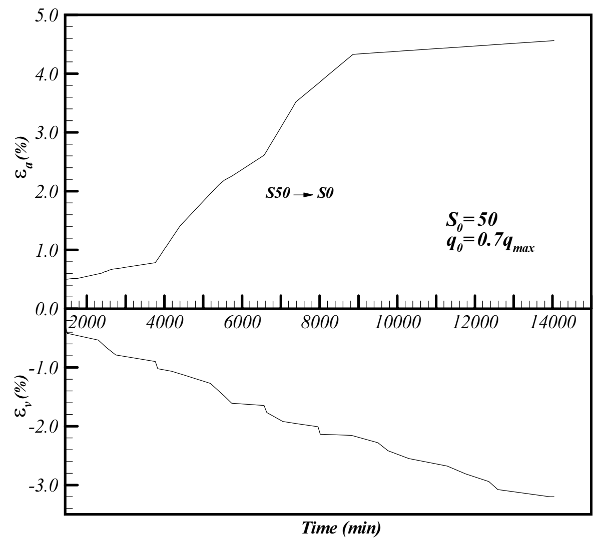
Fig. 3 Instantaneous and delayed axial strains of specimens before wetting phase.

5. **Results and discussions**

The wetting tests were performed for three values of initial suction (50,100 and 162 kPa) in two levels of initial anisotropic stress states (50 and 70% of maximum deviatoric stress (q_{max}), according to Table 2). Figure 4a shows the test results of wetting phase for specimen with S_0=50 kPa, and initial stress state of $0.5q_{max}$. As it can be seen in this figure, axial and lateral deformations have been produced during the wetting step, however contracting volumetric deformation is considerable due to lateral expansion of specimen. Variation of axial and volumetric strains during the wetting for specimen with S_0=50 kPa, and initial stress state of $0.7q_{max}$ is presented in figure 4b. In comparison with the figure 3a we can deduce that, increase in initial deviatoric stress state led to the considerable axial strain however the specimen took a stationary state at the end of wetting. This comparison show also that volumetric strain increases with increasing in the in initial deviatoric stress state. The tests results for the other values of initial suction and initial deviatoric stress states are presented in figures 5 and 6. We can conclude that during the wetting, deformation of specimen increases with increasing in the initial suction. The engendered deformation strongly depend on the level of initial deviatoric stress state, so, for great value of initial stress states collapse wetting will be occurred. The other important conclusion is that the produced deformation depends also on the time. On the other hand soil behaviour during wetting process under a constant stress state is a viscous behaviour. For example the comparison between figures 6a and 6b indicates that for the same initial suction, collapse of soil under $q_0 = 0.7q_{max}$ occurs faster than the case of $q_0 = 0.5q_{max}$.

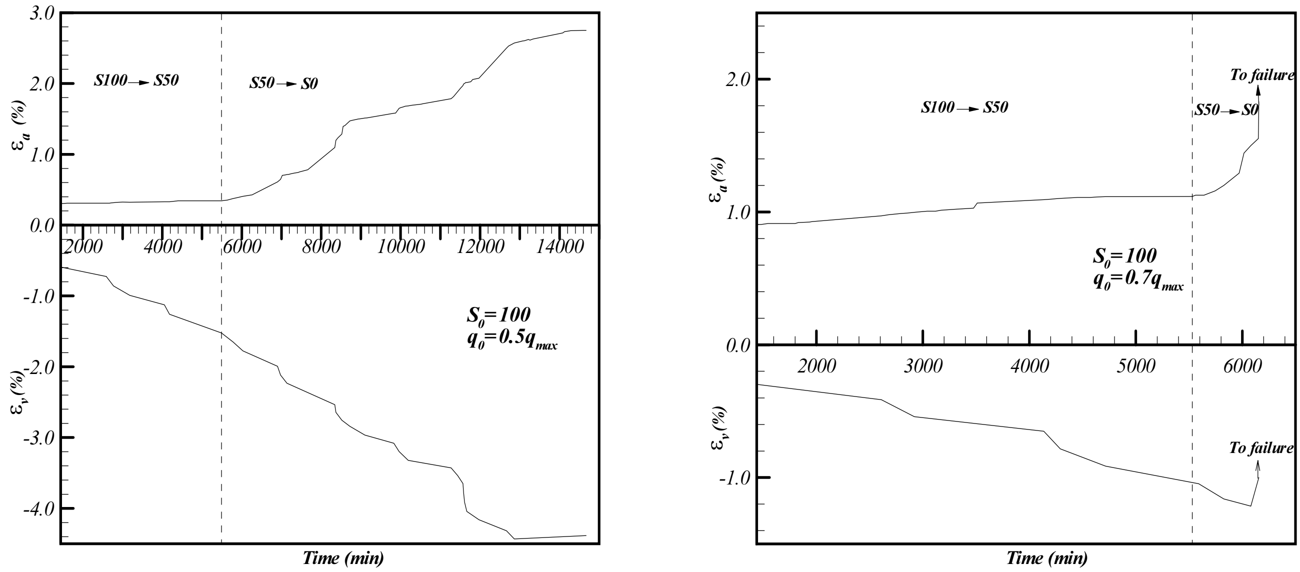


(a)



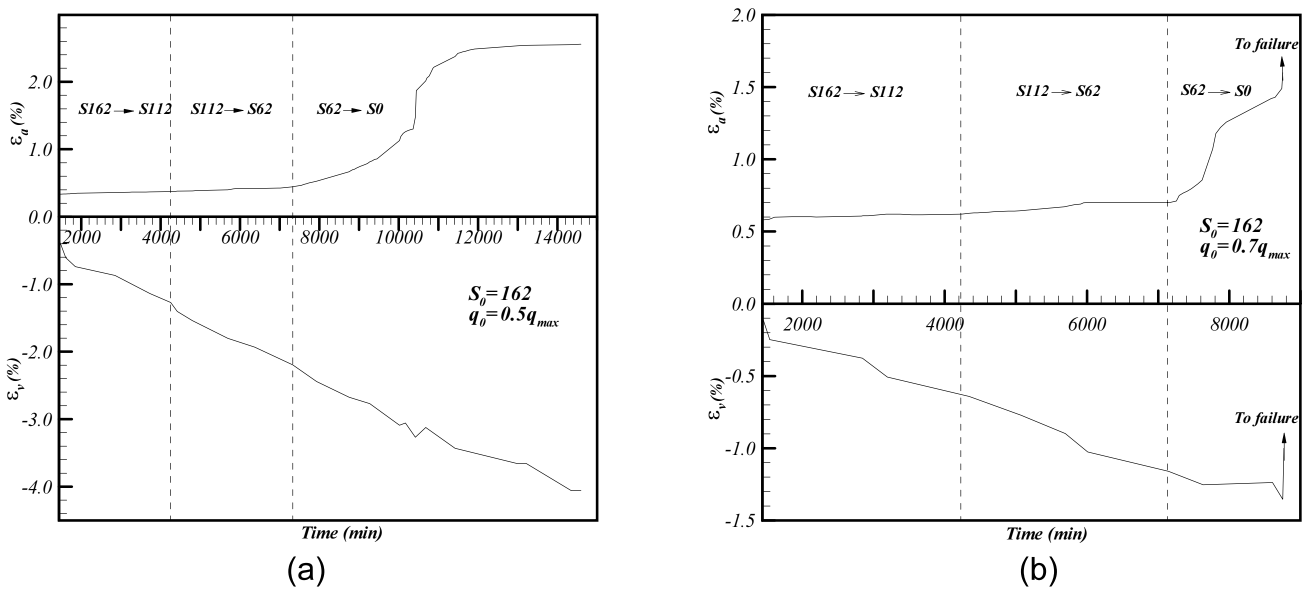
(b)

Fig. 4 Axial and volumetric strains of specimen during wetting phase with initial suction of 50 kPa.



(a) (b)

Fig. 5 Axial and volumetric strains of specimen during wetting phase with initial suction of 100 kPa.



(a) (b)

Fig. 6 Axial and volumetric strains of specimen during wetting phase with initial suction of 162 kPa.

Conclusions

An experimental program has been carried out to investigate the effect of initial anisotropic stress and initial suction on wetting behaviour of a sand fine mixture. The following conclusions can be drawn from this study:

1. The engendered deformation due to wetting of an unsaturated soil, for a given density depends mainly on initial suction and stress state under which wetting is occurred.
2. for un unsaturated soil, for a given stress state, for great values of initial suction, decrease in suction due to wetting, lead to failure of specimen.
3. For a given initial suction, great value of stress state under which wetting process occurs lead to the large strain or failure of soil.
4. Deformation due to wetting depends on time. On the other hand behaviour of unsaturated soil during wetting is viscous.
5. Volumetric strains during wetting, in comparison with deviatoric strains, are less dependent on initial suction.

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