Volume change of sandy soil during saturation process under isotropic stress state

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1. Introduction

The seasonal changes produce variations in the water content of any soil. These variations affect some characteristics of soil, such as degree of saturation, void ratio, which have an effect on physical and mechanical properties of soil. For instance, when rainy season comes after dry period, soil may suffer increment of settlement. This phenomenon is known as collapse.

In terms of microscopic scale, the collapse phenomenon is a local shear failure between soil grains which are initially contacted by suction (or another bonding agent); and when water enters, the effective stress is reduced because the suction partially or totally disappears and the initial volume of soil decreases.

In order to understand the collapse phenomenon and analyze suffered changes due to wetting, a series of laboratory tests were carried out where small strain stiffness and volumetric strain were measured during a saturation process.

2. Test material

The material used for these tests was Edosaki sand. Fig. 1 shows grain size distribution and Table 1 summarizes the main properties of this soil.

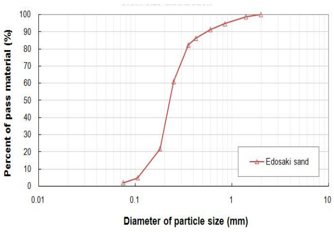

Fig. 1 – Grain size distribution

Properties	
Specific gravity – G_s	2.69
Main grain size – D_{50} (mm)	0.17
Fines content (%)	1.94
Max. dry unit weight –$\gamma_{d\ max}$ (g/cm^3)	1.74
Optimum moisture content – W_{opt} (%)	17
Permeability (cm/s) – at 15°C of water temperature	0.00154

Table 1 – Physical properties

3. Description of apparatus and used devices

In order to determine the collapsible characteristics of Edosaki sand, four triaxial tests were conducted. Three clip gauges at different heights (see Fig. 2) and two Local Displacement Transducers (LDT) were used for measuring radial and axial strains locally. Two small accelerometers were attached on the side of specimen for catching the shear wave produced by actuators placed on top cap (Trigger Accelerometer; TA). Additionally, Bender Elements (BE) were installed in the top cap and pedestal of triaxial apparatus.

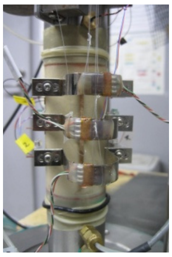

Fig. 2 – Clip gauges

4. Characteristics of tests

Specimens were prepared by rod tamping method, considering four different relative densities; two for looser conditions (Test A3 Dr=44.8% and Test A2 Dr=43.4%) and two for denser conditions (Test A1 Dr=56.5% and Test A5 Dr=67.7%). Dry sand samples were subjected to an isotropic stress (σ_1=σ_3) of 50 kPa where dynamic measurements using BE and TA were conducted. Carbon dioxide (CO_2) was applied inside every specimen for two hours and then water started to flow from bottom to top. At that time, dynamic measurements were executed again. Two hours later, dynamic measurements were carried out once more. These three measurements define dry, wetting process and totally wet stages (See Fig.3). Once saturation process started, water never stopped to flow and all tests were performed under drained conditions.

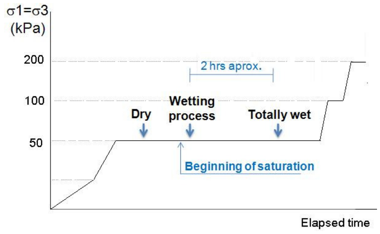

Fig. 3 Testing stage

5. Information analyzes

Small strain stiffness (G) is calculated for every stage (Dry, wetting process and totally wet. Eq. (1) defines the small strain stiffness obtained from shear wave where ρ and V_s are density and velocity of shear wave respectively.

$$G = \rho * V_s^2 \quad (1)$$

The volumetric strain (ε_{vol}) is calculated by using logarithmic strain (Eq. (2)), considering the average of diameter (ϕ_{aver}), obtained by clip gauges, current height of specimen ($h_{current}$) and initial volume ($V_{initial}$).

$$\varepsilon_{vol} = -ln\left(\frac{\phi_{aver}{}^2 * \pi * h_{current}}{V_{initial}}\right) * 100 \quad (2)$$

6. Results and discussion

Fig. 4 exhibits results of volumetric strain obtained for all conducted tests. The general trend shows that, once the saturation process takes place, volumetric strain suffers a large increment or collapse until reaching certain value. Test A1 and Test A5 which have denser condition, exhibit less collapse than Test A2 and Test A3. Additionally, for denser conditions the time to get the limit value is shorter than looser conditions.

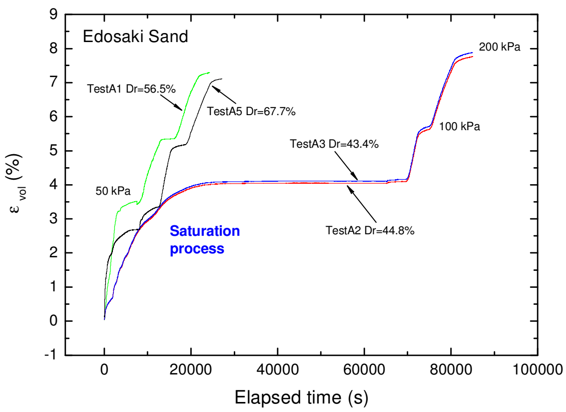

Fig. 4 – ε_{vol} against elapsed time

Fig. 5 summarizes results of collapse for all tests. The tendency indicates that the collapse increase under looser conditions.

Key words: Collapse, Bender Element, Trigger Accelerometer , Volumetric strain.
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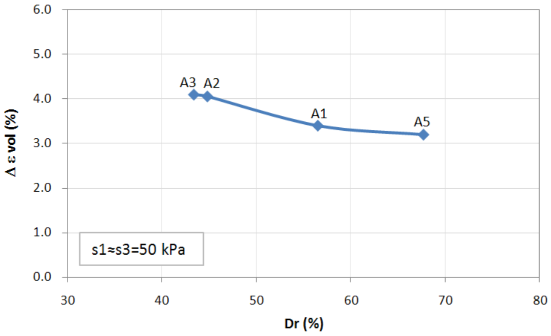

Fig. 5 –Collapse of Edosaki sand

Local radial strain for Test A1 and A2 are shown in Figs. 6 and 7 respectively. For denser specimens, the collapse occurs at the same time, while for looser specimens, the collapse gradually takes place. In addition, the lower part of every specimen suffers bigger deformation (ε_{r3}) than other parts (ε_{r1} and ε_{r2}), regardless the initial condition of relative density.

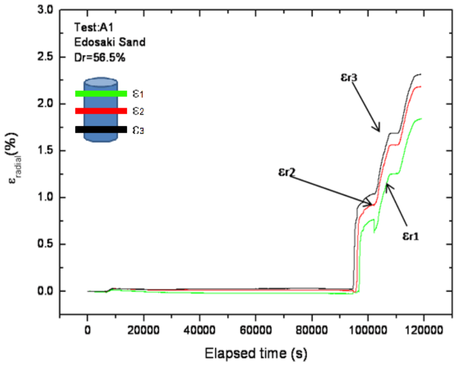

Fig. 6 – ε_{radial} Test A1

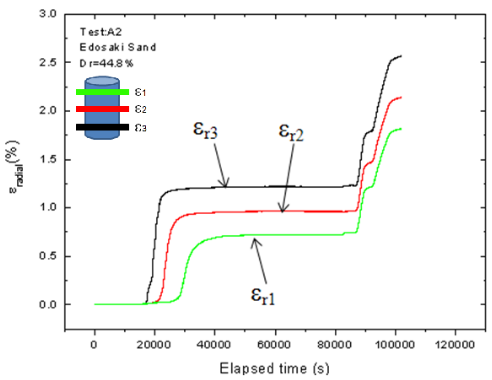

Fig. 7 – ε_{radial} Test A2

Fig. 8 exhibits results of dynamic measurements of Edosaki sand obtained by BE and TA. These results have been normalized by using the void ratio function f(e), proposed by Hardin and Richart (1963), in order to avoid the effect of density.

In general terms, small strain stiffness undergoes a slight increment during wetting process and then when specimens are totally wet, no additional variation is detected. Even though results present certain scatter, in case of BE the increment of G/f(e) for looser conditions is larger than the increment for denser conditions. In case of TA, although results are less clear, they show the same trend, except for Test A1.

Fig. 9 shows a plot of ε_{radial} against ε_{axial}. During wetting process, soil shows an anisotropic strain response, where ε_{axial} is greater than ε_{radial} even though the stress state is completely isotropic (σ_1=σ_3=50 kPa). In addition, this effect is more noticeable for looser cases than denser cases.

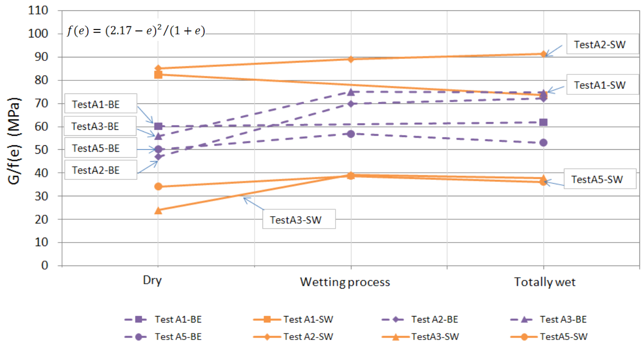

Fig. 8 – Small strain stiffness

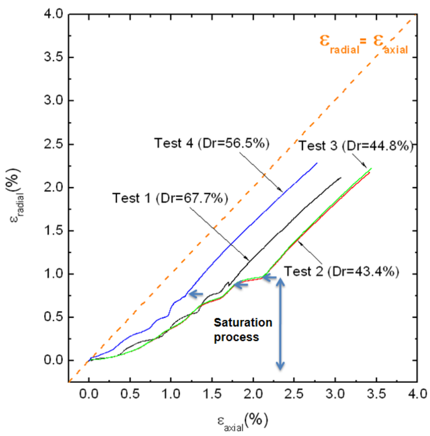

Fig. 9 – Radial strain against axial strain

7. Conclusions

Following conclusions are drawn in this study:

- After saturation process, the collapse reaches a limit value.
- The collapse depends on the relative density.
- Apparently, collapsing time is faster for denser soils than looser conditions.
- The collapse is detected at radial and axial direction, under isotropic state (σ_1=σ_3=50 kPa). ε_{axial} seems to be greater than ε_{radial}.
- It seems that small strain stiffness undergoes a slight variation when wetting process takes place, however this phenomena is more evident for looser cases than denser ones.

8. Acknowledgment

The authors would like to acknowledge to Public Works Research Institute which provided the material used for these tests.

9. References

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