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Stiffness characteristics of cemented granular by ultrasonic waves

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Natural cementation may significantly affect geotechnical properties of soils under low confining pressure. The goal of this study is to evaluate the stiffness characteristics of cemented particulate media according to the depth. Piezo disk elements are installed along the cemented specimen cell to monitor ultrasonic waves during the cementation process. The ultrasonic wave velocities show different values according to the depth and the change of velocities can be classified by three separated stages. The ultrasonic wave velocity is influenced by cementation, effective stress, and coordinate number. This study also shows that cementation by salt is affected by the depth on the granular media.

1. Introduction

Natural cementation, such as that by salt mineral, a popular natural mineral, has an enermous effect on laboratory and insitu properties and parameters, espcially for the offshore soils. The cementation improves small strain stiffness and resistance to liquefaction, increases soil strength and decreases soil settlement (Asghari el al. 2003).

In this research, the cementation phenomena are investigated by evaporating salt water from a model granuler media, glass bead. Salt is used as a cementation agent to investigate the cementation effect. Piezo disk elements are used to conduct the ultrasonic waves through the specimen. The stiffness characteristic of salt cementation according to the depth of the specimens of granular media are monitored during cementation process.

2. Experimental Setup

Experiments were carried out in rectangular cells with the piezo disk elements housed along the wall in layers.

In this study, glass beads with the perfect sphericity and roundness were used to minimize the influence of particle shape. The mean particle size is 0.50mm (D_{50}) (see Fig. 1). The glass beads consist of SiO_2, CaO and Na_2O, and have the specific gravity of 2.52. Table salt with the specific gravity of 2.16 was used as a cemented agent.

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The specimens were prepared by water pluviation in the electrolyte of NaCl 0.5M. The water pluviation was used due to the advantage of minimizing the effect of relative density influencing cementation. The 1000g glass bead specimen was prepared in an acrylic cell with the dimensions of 94mm × 94mm × 135mm (width × length × height) and the thickness of the bottom plate is 5mm. The piezo disk elements are installed at the depth of 20mm, 85mm and 115mm along the wall to monitor the effect of cementation according to the depth of the specimens.

The cementation by salt was conducted by drying the specimen cell in the oven. The changes of the specimen weight were measured during the drying process. The variation of the degree of saturation S_r, can then also be evaluated. The stiffness characteristics of cementation were investigated by measuring the ultrasonic waves at each saturation degree. Experimental studies were carried out until the water was dried perfectly in the specimen. The temperature of the oven was kept at 70℃. Also, particle rearrangement and void ratio change by external impact was not generated during the experiment

The piezo disk elements, which can create and capture ultrasonic waves, were installed on the opposite walls of the cell as shown in Fig. 2. The piezo disk elements are circular metal plates covered with piezo electric ceramic elements. The diameter of the piezo electric ceramic elements is 11mm, the diameter of the metal plates is 15mm and the thickness is 0.45mm. A system of electrical peripherals including a signal generator, a filter-amplifier, and an oscilloscope were used to generate and capture the ultrasonic waves transferring through the specimens (see Fig. 3). The signals were averaged 1024 times to remove noise. Note that silicon was used to prevent a direct wave through the cell due to the high damping property. The ultrasonic wave velocity was calculated with an acquired signal, $V_p=L_p/t_p$, where L_p is the distance from the source piezo disk elements to the receiver piezo disk elements, and t_p is the first arrival time of the ultrasonic waves.

3. Results and Discussions

The evolutions of the ultrasonic waves are plotted in Fig. 4. The change of the ultrasonic waves can be divided in three stages: (1) the ultrasonic wave velocities decrease according to a reduction in the degree of saturation from 100% to 90%; (2) the velocities become stable at a degree of saturation from 90% to 10%; and (3) the velocities increase a significant amount at a degree of saturation from 10% to 0%.

In the 2nd stage, the ultrasonic wave velocities are about 200m/s, 250m/s and 300m/s at each depth of 20mm, 85mm and 115mm, respectively. Thus, the velocity increases with depth. The effective stress prevails in the stage. For the depths of 20mm and 85mm, the velocities at the saturation degrees of 10% to 1% were identical. However, the velocity difference is 46m/s, represented at the perfectly dried condition between these two depths. The high concentration of salt cementation in the 20mm depth influenced the wave velocities.

The difference between the ultrasonic wave velocity at the depths of 85mm and 115mm is much greater than that between the 20mm and 85mm depths. The cementation considerably affects the stiffness behavior of the specimen at the depth of 115mm. Thus, the ultrasonic wave velocity at the bottom of the cell was the fastest velocity with a complex process between effective stress and cementation effects.

4. Conclusion

The effects of cementation and effective stress on the small strain stiffness of the cemented specimens according to the depth have been considered. The changes of the ultrasonic wave velocities can be divided into three different stages depending on the degree of saturation (S: 100-90%, 90-10%, and 10-0% stages). While the effective stress prevails in the second stage, the cementation may control the stiffness behavior at the third stage.

Acknowledgements

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References

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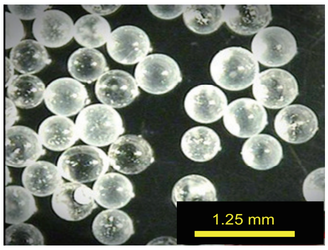

Fig. 1 Particle shape of glass beads (D_{50}=0.5mm)

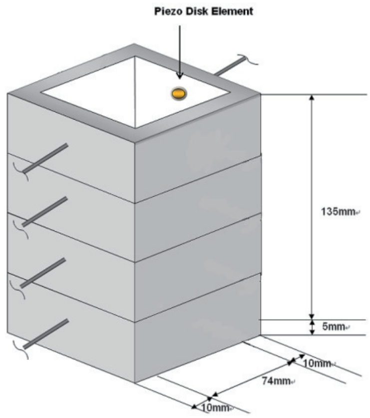

Fig. 2 Acrylic cell

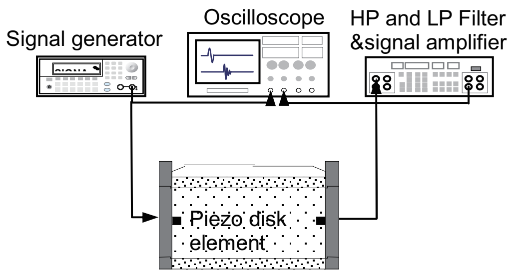

Fig. 3 Measurement system

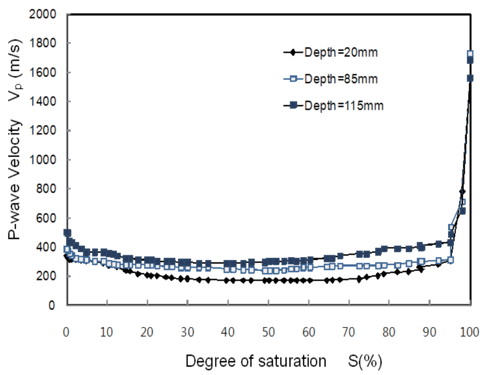

Fig. 4 Evolution of the ultrasonic wave velocity