압밀조건이 지반재료의 공학적 성질에 미치는 영향

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Effects of Consolidation Mode on Engineering Properties of Geomaterials

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요 약

The engineering properties of the geomaterial, an essential material in construction engineering, are significantly influenced by consolidation mode, which is called inherent anisotropy. Speically cohesive soils feature the anisotropy mainly due to their flate-like minerals and chemical interactions. In this research, an experimental study was conducted for the investigation of the anisoropy. Three isotropic and four anisotropic consolidated-undrained triaxial compression tests were performed for the cohesive specimens with various stress ratios of consolidation. The effects of the consolidation mode for cohesive soils were presented and investigated in stress-strain behavior, pore water pressure, and undrained shear strength of the test results.

1. Introduction

Most people do not recognize that construction has been providing us with the foundation for our modern life and comfort until disasters deprive us of our property and lives. It is no wonder that the proper understanding and evaluation of the engineering properties of the construction materials is indispensable for the safe and economical construction. Two types of construction materials are commonly used in practice. They are natural and artificial materials. Such geomaterials as soils and rocks are considered in great weight as the essential natural construction materials, together with river, ocean, wind, rainfall, snow, and so on. Humanbeing is a natural material for which construction works so engineers should understand his endlessly changable characteristics. Concrete and steel are representable artificial materials. The engineering properties of the natural materials are more complicated than those of the artificial materials, or even too complex to fully understand; however, construction engineers should recognize and evaluate the engineering characteristics of all materials for our life and developement.

Anisotropy is one of the significant affecting factors on the engineering properties of geomaterials[1, 2, 3, 4, 5]. Natural soils are commonly anisotropic because of their mode of decomposition. Specially in cohesive soils like clays, the anisotropy with respect to deformation and strength is fundamentally related to the orientation of plate-shaped clay particles during consolidation process. If a clay possesses the anisotropy due to the particles oriented parallel to a plane on which the major principal stress acted during consolidation, then the normal to that plane should be an axis of radial symmetry, and the material can not be considered isotropic. Most previous researches are on the oriental variations of soil properties in a specimen. The research on the soil properties in vertical direction of isotropically and anisotropically consolidated specimens, however, are not common.

An experimental study of stress-strain, pore water pressure, and strength propeties on the specimens consolidated isotropically or anisotropically is presented in this research. Three isotropic and four anisotropic conventional triaxial compression tests were conducted on artificially prepared homogeneous clayey specimens. The effects of consolidation mode are examined from the test results.

2. Experiments

A mixture of 33% kaolin and 67% fine sand by dry weight was used to prepare the triaxial test specimens. The slurry(the mixture at a water content of twice the liquid limit, 40%) was placed inside the small slurry consolidometer for consolidation using dead weight. The small slurry consolidometer is split longitudinally into two stainless steel halves which are held together by a frame to prevent lateral displacement. Since the small slurry consolidometer has the same diameter with the triaxial test specimen and cutting only one side of the specimen after consolidation is needed to prepare the specimen, the disturbance from extrusion and trimming is avoided. Through this slurry consolidometer technique, very homogeneous and undisturbed specimens were prepared with known stress history.

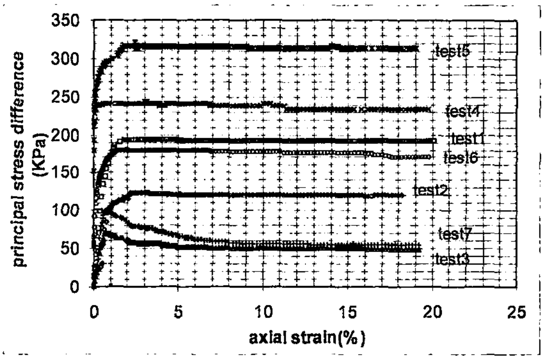
Three isotropic consolidated undrained compression triaxial tests and four anisotropic consolidated undrained compression triaxial tests were conducted with pore water pressure measurements according to the standard test method ASTM D4767. One step was added to the standard procedure to make specimen OC (over-consolidated state), after isotropic or anisotropic consolidation and before undrained compression shearing. Anisotropic consolidation was carried out by applying a vertical stress to the specimen during consolidation, in addition to the all-round cell pressure. The additional vertical stress is applied using dead weight through the yoke system set on and around the triaxial cell. Since bigger lateral stress than vertical stress can not be applied to the specimen in this anisotropic cell, the consolidation at a stress ratio (σ_3'/σ_1') more than 1 could not be done. The strain-control type undrained compression shearing was conducted at the rate of 0.01 %/min. after the isotropic or anisotropic consolidation, actually, after the making specimen OC step. The stress conditions at steps of each test are shown in Table 1. All specimens were consolidated under vertical stress of 206.85 kPa in the small slurry consolidometer before consoildation in triaxial cell.

[Table 1.] Triaxial Test Program

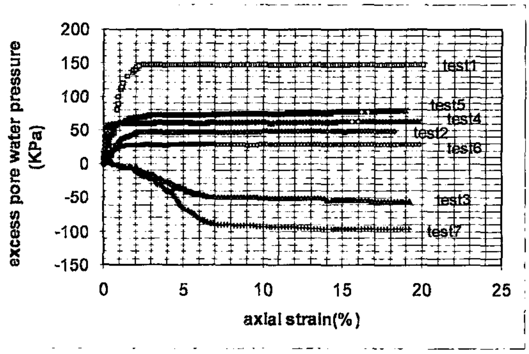
test no.	consolidation		
	σ_1'(kPa)	σ_3'(kPa)	σ_1'/σ_3'
1	262.01	262.01	1
2	262.01	262.01	1
3	262.01	262.01	1
4	262.01	110.04	0.42
5	330.96	139.00	0.42
6	262.01	110.04	0.42
7	262.01	110.04	0.42
test no.	making specimen OC before undrained shearing		
	σ_1'(kPa)	σ_3'(kPa)	σ_1'/σ_3'
1	262.01	262.01	1
2	131.01	131.01	2
3	26.20	26.20	10
4	262.01	110.04	1
5	330.96	139.00	1
6	131.01	77.29	2
7	43.67	43.67	6

3. Results and Discussion

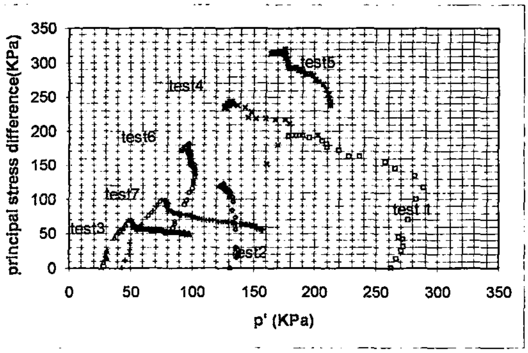
Figs. 1 to 3 show the relationships between principal stress difference and axial strain, between excess pore water pressure and axial strain, and between principal stress difference and effective mean normal stress, respectively. It is shown in Figs. 1 and 2, as expected, that the undrained shear strength and the generated excess pore water pressure at a higher confining stress are higher (in the isotropic tests 1 to 3, and in the anisotropic tests 4 to 7), but the undrained shear strength of anisotropic specimen is higher than that of isotropic specimen at a same vertical stress from comparing test 1 with 4, and test 2 with 6). The stress ratio was chosen to simulate Ko condition and obtained from the a well-calibrated large experimental chamber system, not from a theoretical formula.



[Fig. 1.] Principal Stress Difference-Axial Strain Relation



[Fig. 2.] Excess Pore Water Pressure-Axial Strain Relation



[Fig. 3.] Principal Stress Difference-Effective Mean Normal Stress Relation

The principal stress difference and excess pore water pressure of heavily over consolidated specimens(tests 3, 7) show the sharp peaks in Fig.1 and the negative values occurred immediately after the small positive values in Fig.2. In Fig.3, the data of normally consolidated specimens(tests 1, 3, 5) bend to left side, the data of lightly over consolidated specimens(tests 2, 6) slightly bend to left side, and the data of heavily over consolidated specimens(tests 3, 7) bend to right side.

4. Conclusions

The test results have indicated that anisotropy due to consolidation mode influences stress-strain, pore water pressure, and undrained shear strength of clayey specimens. The relationships between principal stress difference and axial strain, and between excess pore water pressure and axial strain for heavily over-consolidated specimens show the sharp peaks. The undrained shear strength and excess pore water pressure of the specimens consolidated under Ko condition are higher than those of the specimens consolidated under isotropic condition at a same axial stress.

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