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Study on the Mechanical Characteristics of Turfy Soil with Different Decomposition Degree and Organic Content under CUAI Stress Path

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Abstract: Turfy soil is a kind of humus soil characterized by high organic content, high compressibility, high moisture content, low stability, high void ratio and low decomposition degree, which lead to complexities of the mechanical properties of turfy soil. Besides some general characteristics such as nonlinearity, elastic-plastic, anisotropy and rheology, the mechanical properties are also influenced by stress history, stress state, stress level and the stress path. In order to reveal the influences that decomposition degree and organic content impose on strength characteristics and stress-strain behavior of undisturbed turfy soil, stress-strain characteristics and volumetric strain changes of different decomposition degrees and organic contents under CUAI stress path (conventional stress path) were studied and discussed. The results showed that there were more clay particles in turfy soil when it had high decomposition degree but low organic content; the increasing interlocking and friction between soil particles enhanced the ability to resist deformation. But when the soil samples accompanied with high decomposition degree and high organic content, because of strong water absorption ability the organic particles, the void ratio of turfy soil increased, which reduced the ability to resist deformation and it could be inferred that organic particles produced some new relative displacements under the shearing load.

Keywords: *Turfy Soil, Decomposition Degree, Organic Content, Stress Path, Mechanical Characteristics*

1. Introduction

Turfy soil is a special kind of soil which is widely distributed in the Changbai Mountains, Great Khingan Mountains, Lesser Khingan Mountains, Sanjiang Plain, most mountain areas in Xinjiang, Western Sichuan Zoige Plateau, Qinghai-Tibet Plateau, Yunnan plateau, and in the Middle and Lower Reaches of the Yangtze River in China. Due to the unique climate, topography and hydrological conditions, the plant remains (including roots, stems, leaves, fruits, etc.) in the surface swamp environment turn into humus soil under the effects of oxygen and microorganisms (aerobic bacteria)[1]. The material composition, physical properties, chemical properties, water physical properties and mechanical properties is very complex [2]. It forms a class with unique properties different from other soil properties, namely high organic matter, high-compression, high moisture, high permeability, high void ratio, low degree of decomposition because of the special external environment, and it also has the general characteristics of soft soil, namely: nonlinear, press hard, expansion and contraction, plasticity, anisotropy and rheology [3, 4].

With the development of economic construction, carrying out large-scale construction projects in these turfy soil distribution areas has become a development trend. In this way, it will bring many problems in geotechnical engineering design at the region of turfy soil.

The equilibrium conditions, physical conditions and deformation conditions should be considered in numerical computation of soil, of which only the physical condition (constitutive relation) depend on the nature of the intrinsic material, which is the key to numerical calculation. With the continuous development of computer technology and the increasing maturity of numerical calculation method, solving the numerical equations is not a big problem for many scholars. Therefore, the key to solve the problem is to establish the constitutive model that can reasonably describe the soil strength and deformation characteristics.

Experimental researches have shown that the stress history, stress path and physical state of soil composition, structure, etc. have a significant impact on its constitutive model. In many types of soil, turfy soil contains a lot of plant residues and organic matter, and the influence of stress path on the relationship of stress and strain will be more significant due to the complexity of its composition and structure. Based on the above reasons and the case studies, this paper studied further on the deviatoric stress - axial strain or deviatoric strain characteristics, volumetric stress-strain characteristics, strength characteristics and volumetric contraction characteristics after unloading of the undisturbed turfy soil under the CUAI (Confining Pressure is Unchanged and Axial Pressure Increases) stress path in different decomposition degree and the organic matter content of turfy soil in the east of Jilin province.

2. Test for decomposition degree and organic matter content of turfy soil:

2.1. Test for decomposition degree:

The decomposition degree of turfy soil was the relative proportion that animal and plant residues decomposed by soil microbes and lost their original cell structures accounted. Experimental Station that separated the soil and plant residues used the method of running water [5, 6]. The intact turfy soil samples were cut into two parts, then test specimens were took out with 60 cm^3 ring sampler at upper and lower section, which were used for parallel tests. Cut the test specimen into four equal parts, chose two at random then sealed it in a numbered vacuum bag for the determination of organic matter content. NaOH solution was applied in separation test [7], cut the soil specimen into many small pieces and put them in a beaker, then boiling the turfy soil in 3% NaOH solution for 2h to separate plant residues from cementing substance completely. Poured the soil suspensions in a 0.25mm-mesh and washed them with running water to rinse and remove humus and minerals. Collected all the plant residues in ceramic bowls the mesh into and dried them in an oven at 65℃ for 24h, sealed one for testing the organic matter content in plant residues and another was used for measuring the volume of undecomposed plant residues by draining kerosene.

2.1. Test for organic matter content:

The loss on ignition method is used to measure the organic matter content in turfy soil [8]. The soil samples were dried in an oven at 65℃, ground, and sieved to a 0.5mm mesh prior to use. Then the soil samples (m_1g for each depth) were burned at 550℃ for 1 hour, weighed and repeated ignition till there was no further weight loss taking place (less than 0.5 mg) and measured the final weight (m_2g). Repeated the test process above to plant residues, measured the weight loss for m_c g.

Selected four groups of undisturbed turfy soil to do consolidated drained triaxial compression tests under CUAI stress path in different degree of decomposition and the organic matter content of turfy soil in the east of Jilin province. The table 1 is the result of the degree of decomposition and the organic matter content.

Table 1: *The results of decomposition degree and organic matter content test*

Sample name	F (%)[a]	S (%)[b]	S_h (%)[c]
1#	38.99	74.23	77.48
2#	53.62	64.55	69.19
3#	68.14	62.03	63.97
4#	88.10	38.96	38.63

[a] *F (%) is the decomposition degree (DEC) of turfy soil*
[b] *The total ignition loss of turfy soil (organic matter content of turfy soil)*
[c] *The ignition loss of humus parts*

3. The mechanical characteristics of undisturbed turfy soil samples under CUAI stress path:

3.1. Deviatoric stress and axial strain characteristics of the turfy soil:

The relation curves of deviatoric stress and axial strain of 1#~4# undisturbed turfy soil samples under CUAI stress path but different consolidation states were plotted in Figure 1. The relation curves of deviatoric stress and axial strain of 1#~4# turfy soil samples.

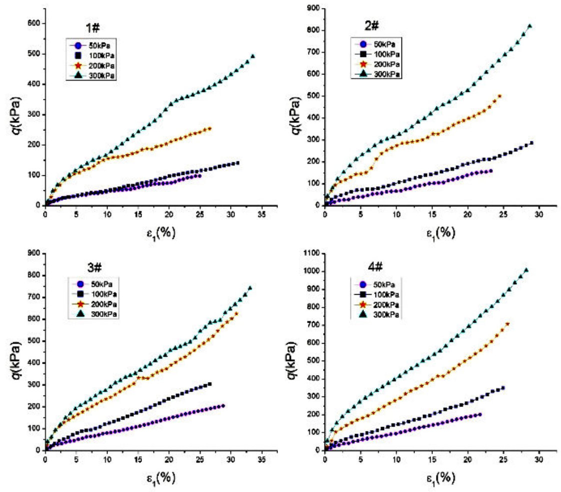

Figure 1*: The relation curves of deviatoric stress and axial strain of 1#~4# turfy soil samples.*

As seen in Figure 1:

All the curves belonged to the hardening type which was not affected by consolidation states. But for the same sample, the greater of the initial consolidation stress, the steeper of the q-ε_1 curve, the more obvious of the degree of hardening, which indicated the obvious pressure-sensitivity of turfy soil.

When the initial consolidation stress is small ($\sigma_{3c} \leq 100$ kPa), the q-ε_1 relationship curve of 1# sample overlapped or crossed in the forepart, Shao[9]and He [10] had also reported this phenomenon in their studies about the stress-strain characteristics of loess. But for turfy soil, the reasons could be interpreted as follows: 1# sample contained lots of plant residual roots and fibers and these residues connected to each other and finally constituted the skeleton structure, which might well resist to deformation when the consolidation stress was at a small level; 1# sample contained large amounts of organic matter, the adsorption ability of organic particles could help maintain the native structure of turfy soil, thus, in the initial stages of shearing action when the consolidation stress was small, the deviatoric stress required to achieve phase axial strain was almost the same level.

When the initial consolidation stresses were in the same level, the q-ε_1 relation curves for different samples were obviously changing and this indicated that the material composition and structural characteristics of turfy soil significantly influenced its stress-strain characteristics, which could be seen that the curve of 4# sample was much steeper than the others in the part before the yield point and the strain developed slowly.

It could be seen in table 1 that the 4# sample contained a smaller number of plant residues and organic content but had much more large-size clayey soil particles, which increased the embedding and interlocking effect between particles and displacements wouldn't easily appear. Thus, when applying axial compression at a certain rate at a constant confining pressure, the soil particles could absorb most of the energy to balance the interlocking and friction force so that it could resist more vertical deformations and produced smaller strains. But the curve of 3# sample was gentler than the others in the part before the yield point and the strain developed rapidly. This was because the 3# sample contained a lot organic particles but less plant residues. From the above we can know that the connection force increased with the decrease of partical size, but the strong water absorption ability of organic matter also made the void ratio increases, compressibility increased, so the ability to resist deformation got weaker and larger axial strain would emerge with the increasing of axial pressure [11].

3.2. Volumetric strain of turfy soil:

The relation curves of volumetric strain- axial strain were plotted in Figure 2. As shown in the figure 2, Under all consolidation states, the volumetric strain increased with the increases of axial strain. But differing from general development laws of soil strain, as the increases of axial strain, the growth rate of volumetric strain didn't show decreasing trend, it might be related to high moisture content and void ratio of turfy soil. Meanwhile, the volume of turfy soil did not decrease with the increase of axial strain which meant the shear dilatancy phenomenon did not happen in the shearing process under the CUAI stress path.

For the same soil sample, the greater of the initial consolidation stress, the smaller of the volumetric strain for the same axis, i.e. volumetric strain decreased with the increase of consolidation stress. This was because the greater of the consolidation stress, the closer of the contact between soil particles, then the combined water film around the particles got thinner, the moving space for the particle got smaller so that the volumetric strain gradually decreased.

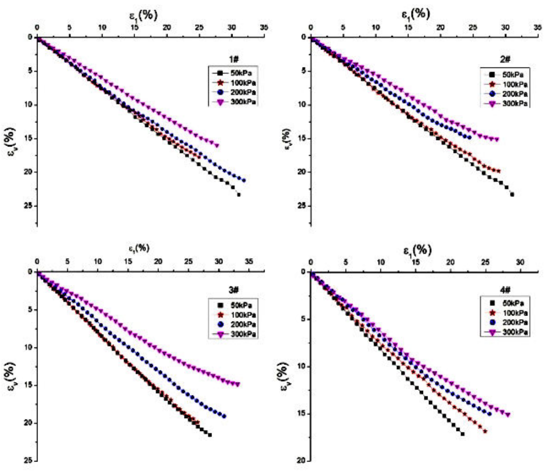

***Figure 2**: The relation curves of vo1ume strain and axial strain of #1~4# samples.*

The growth rates of volumetric strain, i.e. the slope of line portion in   relation curve of 1#~4# samples were listed in table 2. At the same consolidation stress, when the stress was small, 3# sample had the maximum growth rate. And the former test indicated that 3# contained highest organic content and decomposition degree than the other samples, that is, 3# sample contained large amounts of organic particles but few plant residues and fibers, small isotropic consolidation stress was not enough to fully filled micro pores inside soil. But when there was a shear load, the initial consolidation state was changed, small-sized organic particles produced new relative displacements, thereby filling the micro pores and the volume strain began to increase rapidly with the increase of axial strain [12].

***Table 2.** The growth rate of volume strain of 1#~4# samples*

Consolidation stress	Sample name			
	1#	2#	3#	4#
50kPa	0.743	0.827	0.839	0.785
100kPa	0.704	0.762	0.775	0.628
200kPa	0.651	0.630	0.671	0.669
300kPa	0.595	0.597	0.530	0.614

However, when the initial consolidation stress became larger (σ_{3c} >300 kPa), the volume strain growth rate was the lowest for 3# sample but the highest for 4#. This was because large consolidation stress greatly damaged the native structure of 3# turfy soil samples, the micro pores were fully filled. But 1# and 2# samples contained lots of plant residues and fibers besides organic particles, 300 kPa was insufficient to make internal micro pores fully filled. The 4# sample had less organic particles and plant residues than the others but was more occupied by large-sized clay particles which made up the micro skeleton structure. Isotropic consolidation process was not powerful enough to fill the micro pores inside soil particles completely while the shearing process could destroy the skeleton structure so that those micro pores were filly by damaged clay particles and organic particles and that was why large volume strain appeared [13].

When the consolidation stress was small ($\sigma_{3c} \leq 100$ kPa), with the increase of axial strain, the volumetric strains (ε_v) of 2# and 3# samples were almost the same in the initial stages of shear ($\varepsilon_1 \leq 11\%$). This might be because the 3# and 2# samples contained large amounts of organic particles which could protect the native structures of turfy soil free of being destroyed when the shearing force was small but when we kept increasing the axial force under CUAI stress path till axial strain exceeded 11%, then the native structures were severely destroyed so the volume strains of 2# and 3# started to differ.

4. Conclusion:

All the curves belonged to the hardening type which was not affected by consolidation states. When the initial consolidation stress is small, the relationship curve of high organic matter content and low degree of decomposition sample overlapped or crossed in the forepart. It contained large amounts of organic matter, the adsorption ability of organic particles could help maintain the native structure of turfy soil.

Under the same consolidation state, the strain of the turfy soil that has the larger degree of decomposition and lower organic matter content develops slowly. It is because this kind of soil contains more clayey soil particles, which has stronger resistance to deformation ability due to the interlocking and the friction effect between particles. However, the strain of the turfy soil that has the larger degree of decomposition and the higher organic matter content develops rapidly. This is mainly because it contains a lot of organic matter content. The strong absorption capacity can make void ratio increase, which has the weak ability to resist deformation.

Under all consolidation states, the volumetric strain increased with the increases of axial strain. But the shear dilatancy phenomenon did not happen in the shearing process. For the same soil sample, volumetric strain decreased with the increase of consolidation stress. This was because the greater of the consolidation stress, the closer of the contact between soil particles, then the combined water film around the particles got thinner, the moving space for the particle got smaller.

The volumetric strain rate of the turfy soil that has the larger degree of decomposition and the higher organic matter content is the biggest under the smaller consolidation stress, which can't make the internal micro-pores be fully tamped. The organic particles may therefore have the relative displacement under the action of shear loads. However, the volumetric strain rate of the turfy soil that has the larger degree of decomposition and the lower organic matter content is the biggest under the larger consolidation stress. 'Skeleton' structure formed by clayey soil particles is destroyed by the shear loads while the original micro pores are filling by the clayey soil particles that were cut into pieces and organic matter particles.

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