Experimental research on the structural characteristics of high organic soft soil in different deposition ages

Fei Liu¹,²* Guo-he Lin³

¹ Fei Liu, Associate Professor, College of Construction and Environmental Engineering, Wuxi City College of Vocational Technology, Wuxi, Jiangsu, China
² Fei Liu, Associate Professor, Wuxi Research Center of Environmental Science and Engineering, Wuxi, Jiangsu, China
³ Guo-he Lin, Engineer, Jiangsu Xinyuan Geotechnical Prospecting Engineering CO.LTD, Wuxi, Jiangsu, China

*Corresponding author e-mail: julia431@126.com

Abstract. High organic soft soil, which is distributed at Ji Lin province in China, has been studied by a lot of scholars. In the paper, structural characteristics with different deposition ages have been researched by experimental tests. Firstly, the characteristics of deposition age, degree of decompositon, high-pressure consolidation and microstructure have been measured by a series of tests. Secondly, structural strengths which were deposited in different ages, have been carried out to test the significant differences of stress-strain relations between remoulded and undisturbed high organic soft soil samples. Results showed that high organic soft soil which is deposited at different ages will influence its structural characteristics.

1. Introduction

Peat soil has been the focus of expert research at home and abroad due to the particularity of its mechanical characteristics.

Many researchers have researched on the deposition age, distribution, edimentary environment, mechanical characteristics of high organic soft soil[1]. And the structural characteristics of Xiashu Soil in Nan-Jing has been tested by Han[2]. Wang has studied the humification degrees of peat in Qinghai-Xizang plateau and palaeoclimate change[3]. And some research has been done to investigate the microstructure of electrokinetically stabilized peat [4], the structure of peat soils and implications for water storage [5], the peat origin and land use effects on microbial activity in drained peat soils [6]. And the hot-water extraction of peat material to determine labile SOM in organic soils has been studied as well [7].

This paper using a series of laboratory tests to investigate the deposition age, degree of decomposition, mechanical characteristics and microstructure of high organic soft soil at Ji Lin province in China. The research results show that the structural strengths changing with the degree of decomposition and microstructure of high organic soft soil changed.
2. Tests of Basic Characteristics
Using Radiocarbon ($^{14}$C) dating method[8], Fiber volume method[9] and high pressure consolidation to test the ages and degree of decompositon of the high organic soft soil, and results shown in table 1.

| SOIL LAYER | AGE /a B.P | BULK DENSITY ρ/(g·cm$^{-3}$) | MOISTURE CONTENT ω/% | DEGREE OF DECOMPOSITION F/% | COMPRESSION COEFFICIENT $a_{1-2}/$(MPa$^{-1}$) | COMPRESSION MODULUS $E_{1-2}$/MPa |
|------------|------------|-------------------------------|----------------------|-----------------------------|------------------------------------|--------------------------|
| Surface    | Modern     | 0.60-0.70                     | 300-350              | 70-85                       | 11-12                              | 0.5-0.6                  |
| Intermediate | 300-2500   | 0.50-1.40                     | 88-360               | 32-50                       | 17-18                              | 0.3-0.4                  |
| Deep       | 4000-5000  | 1.0-1.1                       | 190-200              | 55-60                       | 8-9                                | 0.6-0.7                  |

From table 1, high organic soft soil with the characteristics of high moisture content, high compression coefficient and within 5000 years of formation age.

Moreover, degree of decompositon and coefficient of compressibility varies with the ages where the sample is collected.

3. Structural strength tests
According to the results of compression, an agreement can be reached that the degree of decomposition has great influence on the compression of high organic soft soil. It is the motivation of investigation to structural features of high organic soft soil collected from three typical layers. Specimen 1#, 2# and 3# are corresponding to the undisturbed samples collected from shallow, intermediate and deep layer, respectively.

3.1. Detection of microstructural features
Micrographs of the microstructure of specimen (1# ~3#) are recorded by the same resolution and shown in Figure 1 (a)-(c), with the help of Scanning Electron Microscopy. As seen respectively in Figure1 (a) and (c), specimen 1# and 3# possess compact structure containing small pores of up to 0.005 mm. A small amount of undecomposed tubular plant residues can be found in the micrograph of specimen 3#. In the micrograph of specimen 2#, shown in Figure 1 (b), reveals the loose structure containing rich large-diametered pores of up to 0.025mm, composed of massive tubular and flaked undecomposed plant residues.

3.2. Measurements of structural strength
In this test, the structural strenght is measured by a comparison of stress-strain curve between undisturbed and remoulded specimens. In order to guarantee the same moisture content as the undisturbed, an air-dried and re-diluted treatment is required in the processing of remoulded specimens. First of all, make natural samples air-dried, and then dilute them using pure water to the same moisture content as that of the undisturbed, stirring well. Finally, crush the specimens into the saturator and ensure that they have the same bulk density as that of the undisturbed. Thus, the remoulded specimens are ready for the conventional triaxial test. The tests are carried out in the same conditions for both undisturbed and remoulded specimens (The physical characteristics of undisturbed and remoulded specimens are listed in table 2).

The structural strength curves in Figure 2 (c), determined by the difference of strain-stress curves between undisturbed and remoulded specimens, can intuitively indicate the development and disappearing process of structural features of high organic soft soil. The stress value at the inflection point in structural strength curve represents the structural strength of high organic soft soil. it is carried out under confining pressure of 300 kPa in order to give full play to structural strength of high organic soft soil, considering the linear growth relationship of structural strength with confining pressure.
In Figure 2(a), it shows that there occur several marked inflection points in the early stage of stress-strain curves for undisturbed specimen 2#. It is hinting that non-linear stress-strain relations are established in the early stage of dedeposition which agrees well with the relations for specimen 1# and 3# (despite a slight inflection point occurs in specimen 3#). Nevertheless, in Figure 2(b), it shows that the stress-strain relations are linear in the early stage of dedeposition for all the remoulded specimen C1#, C2# and C3#. In addition, as the dedeposition develops, all the stress-strain curves for three remoulded specimens show a significant work-hardening effect. Apparently, specimen C2# has the highest work-hardening effect in all of the three, followed by C3# with C1# the lowest. In Figure2(c), it shows that there is a big change of stress difference at the inflection point in the curve.
for specimen 2#. In front of the point, the stress raises as strain increases, and reverses after that. It is hinting that the structural strength drops after the inflection point. Meanwhile, a slight change at inflection point occurs for specimen 1# and 3#, subsequently, the stress flattens as strain increases. The exact values of structural strength for all the specimens are shown in Table 3.

4. Discussion

According to the results of tests above, one can find that the degree of decomposition and microstructure are building a bridge between the climate and microbiological environment in deposition stage, and mechanical characteristics of high organic soft soil from different soils.

![Fig.2 Stress-strain curves of undisturbed samples(a), remoulded samples(b) and stress difference-strain curves(c). C represents the remoulded sample.](image)

Table 3

| SAMPLE NO. | STRUCTURAL STRENGTH/kPa |
|------------|--------------------------|
| 1#         | 45.4                     |
| 2#         | 78.6                     |
| 3#         | 56.3                     |

The mechanical characteristics of high organic soft soil collected from different layers greatly depend on its microstructure. As the micrograph shown in Figure 2 (b), a large amount of undecomposed plant residues which results in the loose structure and good connectivity, is clearly found in specimen 2#. Only a small amount of undecomposed plant residues is found in the micrograph of specimen 3#. In specimen 1# and 3#, the considerable reduction in amount of undecomposed plant residues and the clot structure formed by humate spherical particles wrapping non-cohesive soil particles in acidic condition, PH value of 5.5, give them small void volume and compact structure. The structural features of high organic soft soil can be verified by its compression, shear strengths and developments of stress-strain curve. Due to low resistance to compression and shear, the loose structure may suddenly collapse in the early stage of deposition and then rapidly becomes compact as a reslut of void volume contraction in specimen 2#, which is presented by the inflection point in stress-strain curve. There exists the slight inflection point in the early stage of depedosition for specimen 3# due to the loose structure locally existing. Because of compact structure of specimen C2# after remoulding process, the stress is gradually exceeding that for specimen 2# as the strain increases in the late stage. According to the developments of stress-strain curve for high organic soft soil collected from different layers, one can find that there are high growth rate for specimen 2#, meanwhile, low ones for specimen 1# and 3# in the late stage. In particular, for specimen 1# the stress tends to be constant, which means that work-hardening is weakening.

On the other hand, the mechanical characteristics of high organic soft soil collected from different layers are closely related to its degree of decomposition. Firstly, big quantities of modern organic carbon compounds exists in shallow-layered high organic soft soil. In relatively high temperature and freeze-thaw condition, frequent microbial activity is deemed to reduce the amount of undecomposed
plant residues. As a result, compact microstructure exhibits high resistance to compression and shear. In addition, slight influence of remoulding process on the microstructure gives low structural strength to high organic soft soil. Secondly, due to low mean annual temperature and mean annual precipitation in Northeast China around 400 years ago, the limited microbial activity gave low degree of decomposition and loose microstructure to the intermediate-layered soil which exhibits low resistance to compression and shear. After remoulding process in laboratory, the microstructure is changed from loose to compact, thus, the specimen C2# obtains high structural strength. Likewise, the deep-layered high organic soft soil formed in Sub-north period of North Atlantic phase, approximately 3000–5000 years ago [15]. Frequent microbial activity in relatively high temperature resulted in high degree of decomposition, in turn, compact structure with high resistance to compression and shear. And the structural strength is small because of slight change in microstructure in response to remoulding process.

5. Conclusions
1) Compression, structural characteristics and structural strength will vary with deposition age.
2) In terms of the structural strength, it increases as the microstructure gets loose and degree of decomposition becomes low. It is proved that the intermediated layered soil has the highest structural strength, twice as those for other layers, thanks to its massive void volume and rich organic content.

References
[1] Jiang, Z.X. DianChi Peat Soil. Southwest JiaoTong University Publishing House, Chengdu, 1994. In Chinese.
[2] Han, A.M., Qiao, C.Y. and Ding, C.Y. (2009). Study on the Structural Strength of Xiashu Soil in Nan-Jing. Journal of Engineering Geology 17, No. 3, 371-376. In Chinese.
[3] Wang, H., Hong, Y.T. and Zhu, Y.X. (2004). Humification degrees of peat in Qinghai-Xizang Plateau and palaeoclimate change. Chinese Science Bulletin 49, No. 5, 514-519.
[4] Moayedi H., Nazir R., Kazemian S., Huat B. K.(2014) Microstructure analysis of electrokinetically stabilized peat. Measurement 48, 187-194.
[5] Fereidoun, R. (2016) Structure of peat soils and implications for water storage, flow and solute transport: A review update for geochemists. Chemical Geology 429, 75-84.
[6] Keuskamp J. A., Potkamp G., Verhoeven J.T.A., Hefling M.M.(2016). Peat origin and land use effects on microbial activity, respiration dynamics and exo-enzyme activities in drained peat soils in the Netherlands. Soil Biology and Biochemistry 95, 144-155.
[7] Heller C.(2015). Approaching a Standardized Method for the Hot-Water Extraction of Peat Material to Determine Labile SOM in Organic Soils. Communications in Soil Science and Plant Analysis 46, 171-178.
[8] Jiao, W.Q., Zhang, J.W. and Li, G.Y. The Symposium of Quaternary Glaciation and Geology. Geological Publishing House, Beijing, 1990, pp. 43-57. In Chinese.
[9] Korol, H.T. The Basic Characteristics and Determination Methods of Peat Soil. Science press, Beijing, 1989.
[10] Xia, Y.M. and Wang, P.F. (2001). Peat record of climate change for the last 3000 years in Yangmu, Mishan region of Sanjiang Plain. Journal of Geographical Sciences 11, No. 4, 454-460.