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Evaluation on the Structural Strength of the Clay Soil Distributed in Chongjin Area

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Abstract Distribution of the Quaternary deposits and some physical and mechanical properties of the area have been studied in the previous research. In this paper, the structural strength of the clay soil was evaluated and relationships between natural pressure and structural strength, natural pressure and the ratio of consolidation were estimated on the basis of the data from engineering geological survey to the study area.

Key words clay soil, structural strength

Introduction

Structural strength is one of the important mechanical properties of clay soil. Because we have to use this parameter when we design the basement formed with clay soil and estimate its stability. If the sum of the natural pressure and additional pressure is smaller than the structural strength of the soil in designing of basement composed of clay soil, subsidence of building may be ignored in fact. Therefore, only when the structural strength of clay soil is determined, experiment modes for consolidation and shearing strength can be established, experiments suitable for the practical conditions and designing of the basement can be carried out. In addition, mechanical properties will be evaluated rightly on the basis of estimating correctly consolidated degree of clay soil.

Thus, we evaluated the structural strength of the clay soil distributed in this area for the first time.

This area is covered thickly with the New Tertiary layers and the Quaternary layers of different origin types. This stratum consists of continental layers, continental-oceanic layers and oceanic layers. In this area continental layers are generally distributed with the thick of 10m and it consists of alluvium, diluvium and swamp layers. The alluvium is mainly formed with sandy clay, fine sand, medium-sand, coarse sand and gravelly sand. The diluvium is laid above the New Tertiary bedrocks or the alluvium, and it consists of sandy clay and clay soil. Swamp layers are usually laid above the alluvium and it consists of sandy clay and clay.

The continental-oceanic layers are distributed with the thick of 5-6m below the alluvium and it generally consists of medium-sand and coarse sand.

There is oceanic layer distributed with the thick of 30－40m under this layer and it is formed with the stratums. The top stratum which consists of coarse sand, medium-sand, fine sand, silty sand and sandy clay downward from above is formed under the environment of regression. The button stratum is formed under the environment of transgression, which generally consists of sandy

clay, silty sand, fine sand, medium-sand and downward from above.

In this area, the clay soil the clay soils that have different origins and grading composition are distributed widely. Among them, some physical and mechanical properties of the clay soil that are being widely used as the foundation of building are same as table 1.

Table 1. The value of the physical and mechanical property indices of the clay soil

Soils	Property indices									
	ρ /(g·cm^{-3})	ρ_d /(g·cm^{-3})	ρ_s /(g·cm^{-3})	I_p /%	I_L	e	Q /%	E /MPa	φ /(°)	c /MPa
Alluvium sandy clay	1.82	1.44	2.69	11.8	0.4	0.85		11	21	0.020
Deluvium sandy clay	1.80	1.42	2.68	10.5	0.4	0.88		3	16	0.015
Deluvium clay	1.91	1.45	2.72	24.2	0.5	0.9		15	10	0.030
Swamp layers organic sandy clay	1.68	1.30	2.63	13.6	0.6	1.0	9.0	7	12	0.012
Swamp layers organic clay	1.85	1.35	2.70	26.3	0.6	1.0	9.3	9	7	0.028
Alluvium-swamp layers organic clay	1.87	1.37	2.71	25.1	0.6	1.0	9.1	2	8	0.029

ρ—density, ρ_d—dry density, ρ_s—particle density, I_p—plasticity index, I_L—consistency index, e—pore ratio, Q—content of the organic material, E—modulus of deformation, φ—internal friction angle, c—cohesion

1. The Structural Strength Character of the Clay Soil

The structural strength(σ_s) and the ratio of the consolidation(λ_c) were different determined from the compression test data using 230 samples of the sandy clay and clay with the different origins shown in table 1 in order to evaluate the structural strength of the clay soil in this area, and then the structural strength was estimated from the standard values of those calculated by M—C method. The structural strength was determined by analytical method reported by us [1] and the ratio of the consolidation was calculated by the following equation;

$$\lambda_c = \sigma_s / \sigma$$

Where σ is the natural pressure.

The clay soils are sorted by the size of λ_c [2]

$\lambda_c < 1$ Unconsolidated soil

$\lambda_c = 1$ Normal consolidated soil

$\lambda_c > 1$ Ultra-consolidated soil

The values of the structural strength and the ratio of the consolidation dependent on the natural pressure are as follows (table 2).

Table 2. The value of σ_s and λ_c dependent on σ

Soils	σ/kPa	σ_s/kPa	λ_c
Alluvium sandy clay	20～120	125～170	1.4～6.7
Deluvium sandy clay	20～100	130～184	1.8～6.7
Deluvium clay	10～90	123～173	2.0～10.6
Swamp layers organic sandy clay	30～110	109～223	2.0～3.8
Swamp layers organic clay	30～60	131～173	2.8～4.4
Alluvium-swamp layers organic clay	30～60	124～142	2.4～4.1

Table 2 shows that the structural strength values range from 109 to 223 and the ratio of consolidation range from 1.4 to 10.6. These values vary with the conditions, such as the natural pressure, origin, the sort of soils. We can see the structural strength of the clay soil distributed in this area depends on the natural pressure, origins and its grading composition.

2. The Relation between the Natural Pressure and the Structural Strength

As shown in Fig. 1, the structural strength value increases from 125kPa to 170kPa as the natural pressure changes from 20kPa to 120kPa in the alluvium sandy clay. It shows that the structural strength increases 0.47kPa on an average with the increasing 1kPa of the natural pressure. By the way, the structural strength decreases from 147kPa to 125kPa when the natural pressure changes from 50kPa to 60kPa. It shows not only that the view which is reported by the several researchers [3] that the structural strength is related with the only one pre-natural pressure is not right but also that the structural strength is related to material composition and the structure of the soil, various kinds of physicochemical action during process of the formation of the soil and after that, with the pre-natural pressure.

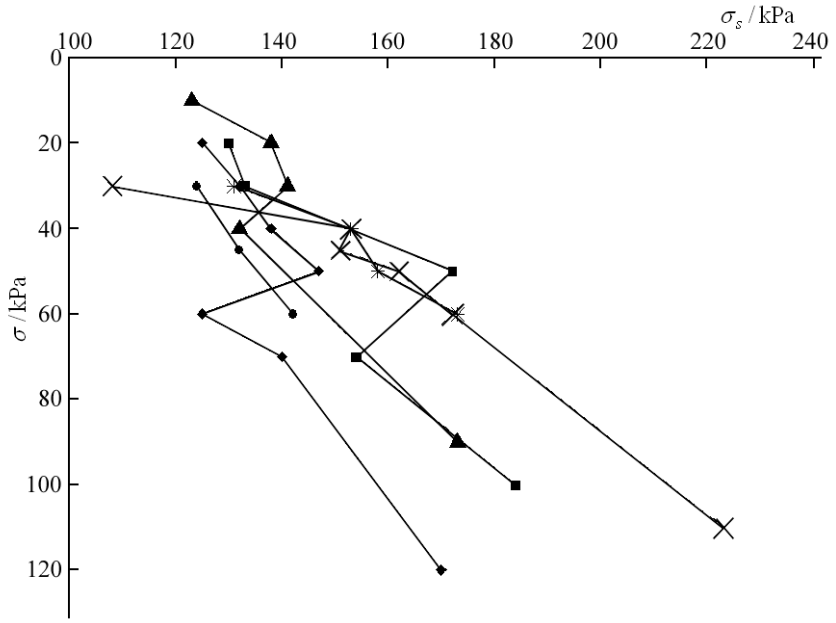

Fig. 1. The relation between the natural pressure and the structural strength
◆ Alluvium sandy clay, ■ Deluvium sandy clay, ▲ Deluvium clay, × Swamp layers organic sandy clay, ✳ Swamp layers organic clay, ● Alluvium-swamp layers organic clay

As the natural pressure changes from 20kPa to 100kPa, the structural strength value increases from 130kPa to 184kPa in the deluvium clay. We can see the structural strength increases 0.67kPa on an average with the increasing 1kPa of the natural pressure. But the structural strength decreases from 172kPa to 154kPa when the natural pressure changes from 50kPa to 70kPa. It is also caused like the alluvium sandy clay.

It also shows that the structural strength value increases from 123kPa to 173kPa in the diluvium clay as the natural pressure changes from 10kPa to 90kPa. And the structural strength increases 0.67Kpa on average with the increasing 1kPa of the natural pressure. Only when the natural pressure changes from 30kPa to 40kPa, the structural strength decreases from 141kPa to 132kPa. This can be also explained by above-mentioned cause.

In the organic sandy clay of swamp layers the structural strength value increases from the 109kPa to 223kPa as the natural pressure changes from 30kPa to 110kPa, and the structural strength increases 0.42kPa on average with the increasing 1kPa of the natural pressure. It decreases from 153kPa to 151kPa when the natural pressure changes from 40kPa to 45kPa. This can be also explained by above-mentioned causes.

The structural strength value increases from 131kPa to 173kPa in the organic clay of swamp layers and it increases from 124kPa to 142kPa in the organic clay of alluvium-swamp layers as the natural pressure changes from 30kPa to 60kPa. We can see the structural strength increases 1.4 and 0.6kPa respectively on average with the increasing 1kPa of the natural pressure.

Like this, in the study area the structural strength of the clay soil increases with the increasing of the natural pressure, which differs according to origins, variety of the soil.

3. The Relation between the Natural Pressure and the Ratio of the Consolidation

In all sorts of soils the relation between the natural pressure and the ratio of the consolidation represent similarly, which is the characterized that it decreases with the increasing of the natural pressure (Fig. 2).

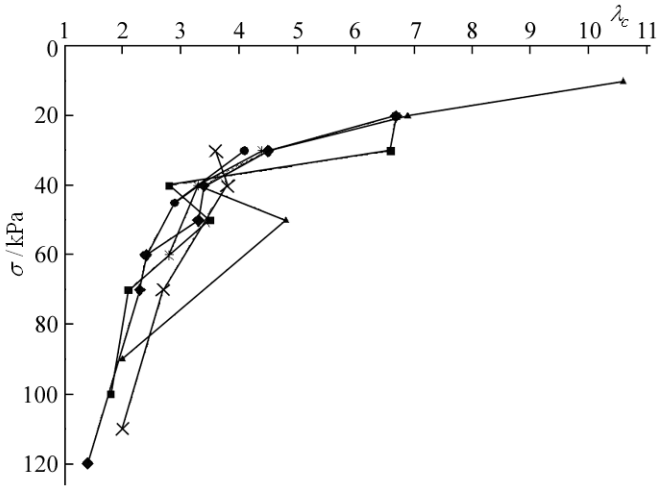

Fig. 2. The relation between the natural pressure and the ratio of the consolidation

◆ Alluvium sandy clay, ■ Deluvium sandy clay, ▲ Deluvium clay, × Swamp layers organic sandy clay, ✳ Swamp layers organic clay, ● Alluvium-swamp layers organic clay

As shown in Fig. 2, in the alluvium sandy clay the ratio of the consolidation decreases from 6.7 to 1.4 and the gradient of the broken line increases as the natural pressure changes from 20kPa to 120kPa. We can see the soil is ultra-consolidated soil and the ultra-consolidated degree decreases with the increasing of the natural pressure, and the ratio of the consolidation decreases 0.05 on average with the increasing 1kPa of the natural pressure.

In the diluvium sandy clay, the ratio of the consolidation decrease from 6.7 to 1.8 and the gradient of the broken line increases as the natural pressure changes from 20kPa to 100kPa. We can see the deluvium sandy clay is ultra-consolidated soil and the ultra-consolidated degree decreases with the increasing of the natural pressure, and the ratio of the

consolidation decreases 0.06 on average with the increasing 1kPa of the natural pressure.

It also shows that the ratio of the consolidation decreases from 10.6 to 2.0 in the diluvium clay and the gradient of the broken line increases as the natural pressure changes from 10kPa to 90kPa. We can see this soil is ultra-consolidated soil and the ultra-consolidated degree usually decreases with the increasing of the natural pressure. We can also see that the ratio of the consolidation decreases 0.10 on average with the increasing 1kPa of the natural pressure. Only when the natural pressure changes from 40kPa to 50kPa, the ratio of the consolidation increases from 3.3 to 4.8. It is also caused like the forward unusual relation between the natural pressure and the structural strength.

In the organic sandy clay of swamp layers, the ratio of the consolidation decreases from 3.8 to 2.0 and the gradient of the broken line increases as the natural pressure changes from 30KPa to 110kPa. We can see this soil is ultra-consolidated soil and the ultra-consolidated degree usually decreases with the increasing of the natural pressure. We can also see that the ratio of the consolidation decrease 0.02 on an average with the increasing 1kPa of the natural pressure. But the ratio of the consolidation increases from 3.6 to 4.0 when the natural pressure changes from 30kPa to 40kPa. It is also explained by the above-mentioned causes.

The ratio of the consolidation decreases from 4.4 to 2.8 in the organic clay of swamp layers and it also decreases from 4.1 to 2.4 in the organic clay of alluvium swamp layers and the gradient of the broken line increases as the natural pressure changes from 30kPa to 60kPa. We can also see this soil is ultra-consolidated soil and the ultra-consolidated degree usually decreases with the increasing of the natural pressure and the ratio of the consolidation decreases 0.05 and 0.06 respectively on average with the increasing 1kPa of the natural pressure.

Like this, in the study area the ratio of the consolidation of the clay soil decreases with increasing of the natural pressure, which differs according to origins, variety of the soil.

Conclusion

The structural strength values range from 109 to 223kPa and the ratio of consolidation ranges from 1.4 to 10.6 when the natural pressure is at the range of 10~20kPa.

In all sorts of clay soils the relation between the natural pressure and the structural strength represent similarly, which is characterized that the structural strength increases with the increasing of the natural pressure and all clay soils are in ultra-consolidated situation and the ultra-consolidated degree decreases with the increasing of the natural pressure.

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