2012 IACSIT Coimbatore Conferences
IPCSIT vol. 28 (2012) © (2012) IACSIT Press, Singapore

Contrast on Static and Dynamic Properties of Taiyuan Loess

Fengxiang Yan and Xianzhi Huang +
Shanxi University Engineering College, Taiyuan Shanxi

Abstract. This paper is mainly to study the static and dynamic properties of Taiyuan loess by large numbers of laboratory tests such as triaxial test, collapse coefficient test and seismic subsidence test under different moisture contents. We discover that the dynamic strength of loess is lower than the static strength at lower moisture content. But with the increasing of moisture content, dynamic strength will be close to static strength. The relationship between coefficients of collapsibility and seismic subsidence can be set up through moisture content.

Keywords: loess, moisture content, dynamic strength, static strength, seismic subsidence, collapse.

1. Introduction

Loess distributing mainly in the Midwest of China where earthquakes frequent occur. Practice demonstrates that loess is sensitive to dynamic load and the seismic damage is tremendous in loess area[1][2]. So we need pay attention to the research of loess's dynamic properties. In this paper, we study the static and dynamic properties of Taiyuan loess by the laboratory tests under different moisture contents [3]. We try to set up the relationship between static and dynamic properties of Taiyuan loess. In this way, we can carry on earthquake resistance design to loess foundation using static force data, which have positive role to economic and social development of loess area.

2. Testing Program

This test adopts DDS-70 system of electromagnetic dynamic triaxial test controlling by microcomputer which is made in China. Based on predecessors [4][5] test methods, we load the dynamic application cascade on the original state loess sample under different moisture contents. First step, the samples consoled when the consolidation stress ratio is equal to 1.73, which simulated the stress state of loess in the general. After the consolidation deformation completed, close the valve of drain and bear the equivalent sine wave load which has regular vibration times and regular frequency on loess sample by degrees until the loess sample destroy. The failure criterion of the test is that stress wave occurs distortion indicate the loess sample destroy.

In order to use the favourite data of static properties to carry on earthquake resistant design, in this experiment we get coefficient of collapsibility by confined compression test and get static strength by consolidated untrained triaxial test.

The loess sample taken from Taiyuan belong to quaternary epipleistocene（Q3）. The yellow-brownish loess sample was taken from the stratum 5.0m deep, whose structure is homogeneous with the macroscopic vertical columns big pore. The various physical mechanics indicates in Table 1.

The loess sample have six kinds moisture contents, as 5%，10%，15%，20%，25%，30% respectively.[1]

Table. 1: Physical parameters of the Taiyuan loess

+ Corresponding author. Tel.: +86-15835113586.
E-mail address: huanxzh1@163.com

e	ρ (g/cm^3)	ω(%)	ω_L(%)	ω_p(%)	I_L(%)	Gs	Grain composition（%）			Soil type
							＞0.05(mm)	0.05～0.005(mm)	＜0.05 (mm)	
1.109	1.42	11.4	29.3	20.5	8.8	2.70	57.9	22.1	20	silt

3. Contrast on Static and Dynamic Strength of Taiyuan Loess

3.1. The relationship between static and dynamic intensity index

The static and dynamic intensity index of Taiyuan loess indicates in Table 2, the relationship between moisture content and intensity index indicates in Fig.1 and Fig.2. From the test result, we can know the static and dynamic intensity friction angle vary little with the change of moisture content. Because the dynamic intensity friction angle is close to static ones, we can consider the dynamic intensity friction angle equals to static ones. The static and dynamic cohesions decrease with the increasing of moisture content，and they all accord exponential function which the constant is different. The curve of dynamic cohesions is gentler, which show the influence of moisture contents to dynamic cohesions is smaller than static cohesions. Analysis further, the dynamic cohesions is smaller than static cohesions when the moisture content is small; and the difference between them dwindle with the increasing of moisture content, at this time the dynamic cohesions even exceed the static cohesions little.

Table. 2: Static and dynamic strength indexes

Moisture content(w)	c_d(kPa)	φ_d°	c(kPa)	φ°
5%	57.41	22.27	88.89	25.01
10%	23.2	24.6	49.8	23
15%	15.2	23.9	21.6	22.5
20%	8.6	22.6	7.14	22.2
25%	7.2	21.4	3.2	20.4
30%	5.8	20.9	1	19.1

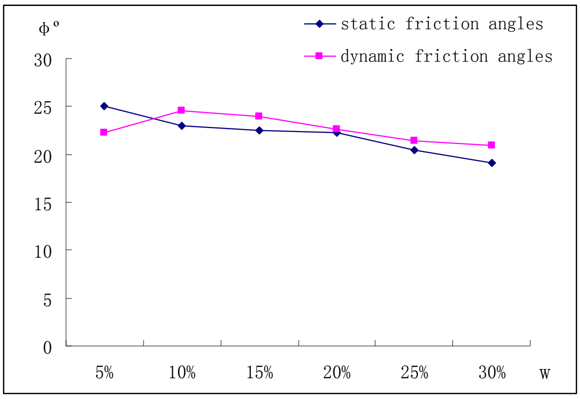

Fig. 1: The relationship of moisture content and static, dynamic friction angles

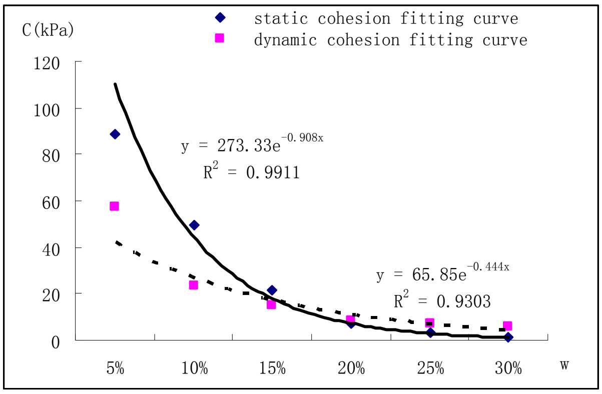

Fig. 2: The relationship of moisture content and static, dynamic cohesions

We try to analyze the reason: the structure of undisturbed loess is unstable, the soil grain connect by joint of point to point or point to side or side to plane. The load will devastate the stability of the connection; the connection is reduced which reinforces the cohesion, thus the dynamic cohesions is smaller than static ones. With the increasing of moisture contents, the function of moisture film wedging and moisture softening will destroy the microstructure of loess, which diminish the aerial pore and impair the joint strength. The stiffening cohesions reduce and the soil become dense by vibration, so the dynamic cohesion is slightly bigger than static ones.

3.2. The relationship between static and dynamic strength

According to coulomb formula, the static shearing strength of Taiyuan loess can express as: $\tau_f = c + \sigma \tan\phi$. The dynamic shearing strength can express as: $\tau_{df} = c_d + \sigma_d \tan\phi_d$. This formula can be express as $\tau_{df} = c_d + \sigma_d \tan\phi$, if we think $\phi \approx \phi_d$. Analyze the formula, the static and dynamic strength decide on cohesions when the direct stress is same. The dynamic strength is less than static strength when the moisture content is low. The dynamic strength approximate to static strength when the moisture content is high. The reason can be generalize two points. The failure criterion of this test is that stress wave occurs distortion, thus the dynamic strain is much less than static strain when the loess sample destroy and the dynamic strength is lower. When the moisture contents is low，loess exhibit powerful structural which is destroyed by vibrating load.

4. Contrast on Static and Dynamic Deformation of Taiyuan Loess

4.1. Collapse under different moisture contents of Taiyuan loess

From the collapse curves under different moisture contents of Taiyuan loess (Fig.3), we can draw the conclusions. The coefficient of collapsibility of Taiyuan loess will decrease obviously with increasing of moisture contents. The coefficients of collapsibility change with increasing of pressure, until they get to peak value. The pressures correspond the peak value are different. The pressures approach to 200kPa when the moisture contents are less than plastic limit moisture contents. The pressures approach to 300kPa when the moisture contents are greater than plastic limit moisture contents. The peak value of coefficients of collapsibility decreases with increasing of moisture contents. The relationship between coefficients of collapsibility and moisture content indicate Fig.4, and the relationship can be expressed by equation as: $\delta_{s\max} = ke^{-lw}$. In this equation: k, l are test constants.

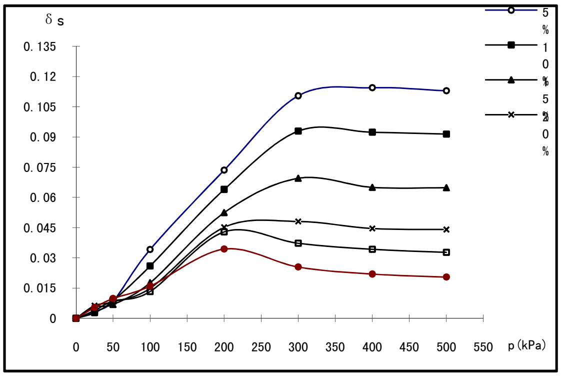

Fig.3: Collapse curves of different moisture content

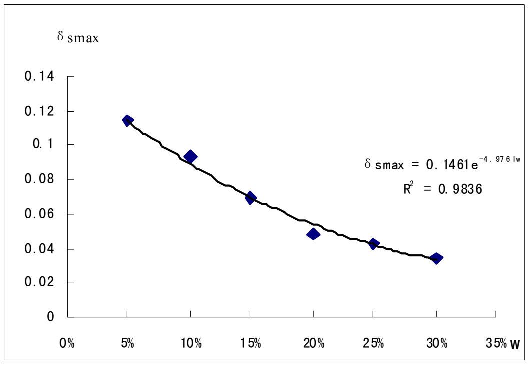

Fig.4: Relationship between δ_{smax} and moisture content

4.2. Under different moisture contents of taiyuan loess

When the dynamic stress and consolidation same, the seismic subsidence increase with the increasing of moisture contents; the seismic subsidence decrease with the increasing of moisture contents when the dynamic stress and moisture contents same.

The curve fitting of seismic subsidence coefficient indicate in Fig.5. The relationship between coefficient and moisture contents can be expressed by parabolic line law as: $\varepsilon_p = E \cdot \sigma_d^2 \quad (0 \le \sigma_d \le \sigma_{df})$.

The test constant "E" in this formula is the function of moisture contents when the confining pressure is same, the relationship can be expressed by the formula as: $E = Fw^G$

In this formula, the test constants "F" and "G" are relevant to properties of loess.

Then we can get the formula: $\varepsilon_p = Fw^G \cdot \sigma_d^2$, $(0 \le \sigma_d \le \sigma_{df})$.

4.3. The relationship between seismic subsidence and collapse of taiyuan loess

From the analysis above, we can see the collapse coefficient and seismic subsidence coefficient are all the function of moisture contents. We can set up the relationship between $\varepsilon_{s\max}$ and ε_p by moisture contents as:

$$\varepsilon_p = A\left(\ln\frac{\delta_s}{B}\right)^c \cdot \sigma_d^2 , \ (0 \le \sigma_d \le \sigma_{df})$$

In this formula, the test constants "A" and "B" and "C" are relevant to properties of loess and stress condition. In this test "A" equal to about 10^{-6}/kPa^2, "B" equal to about 0.1416, "C" equal to about 2.

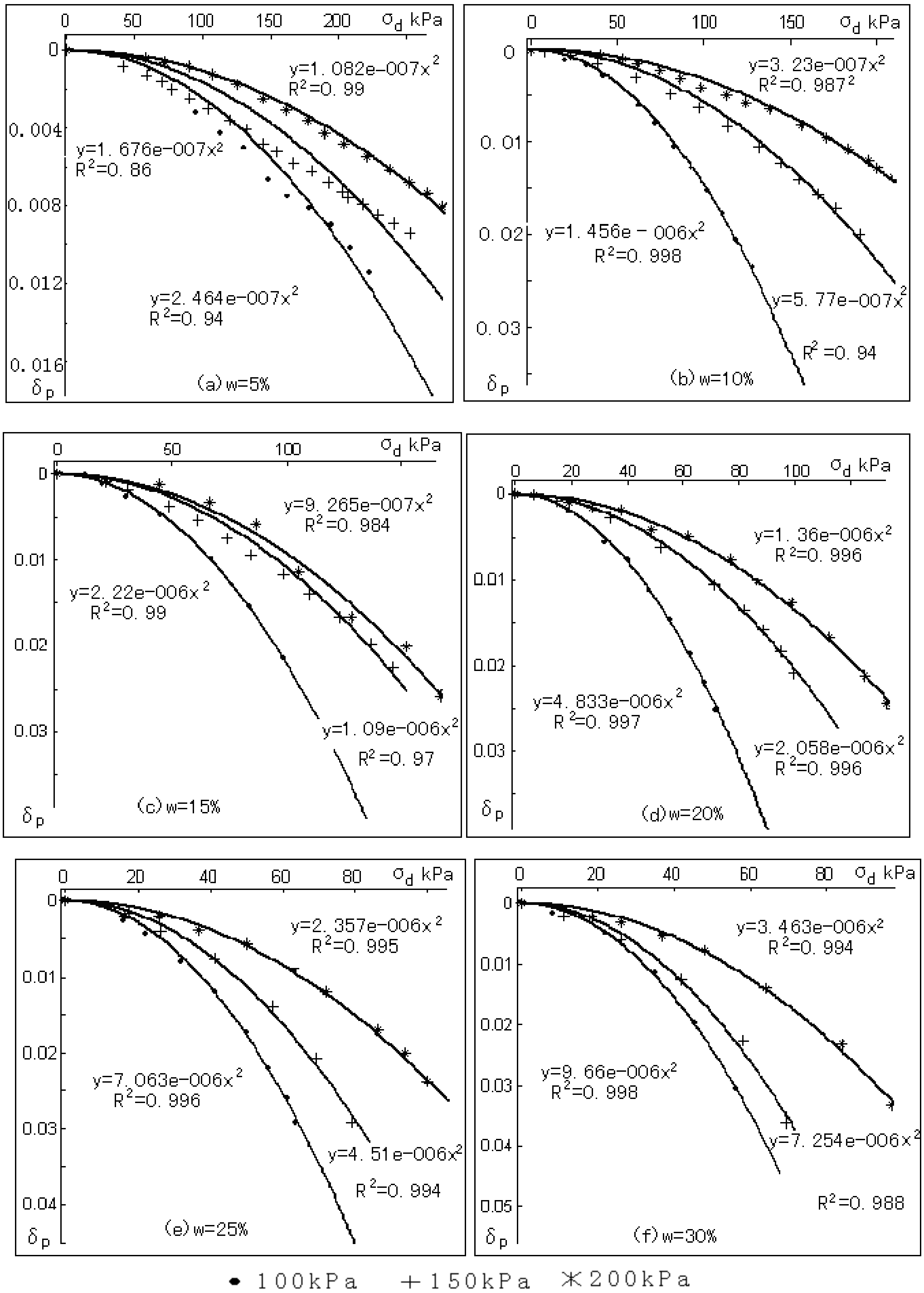

Fig. 5: The nonlinear fitting of the seismic subsidence curves

5. Conclusion

Study the static and dynamic properties of Taiyuan loess by the laboratory tests; we can draw the conclusions as follows:

(1) The static and dynamic friction angles vary little with the change of moisture content, and they are very adjacent. The friction angle of loess is a constant parameter. The static and dynamic cohesions decrease with the increasing of moisture content, and they accord exponential function.

(2)At lower moisture content, the dynamic cohesion is smaller than the static ones, in turn, the dynamic strength of Taiyuan loess is lower than the static strength. But with the increasing of moisture content, dynamic strength will be close to static strength even exceed.

(3)The collapse settlement of Taiyuan loess decreases and the seismic subsidence according to the same dynamic stress increases with the increasing of moisture content when the consolidation pressure is same.

The relationship between coefficients of collapsibility and seismic subsidence can be set up through moisture content.

(4) The dynamic properties of loess are more sensitive than the static properties because the unstable microstructure of dry loess is destroyed by vibration easily.

6. Acknowledgements

The authors gratefully acknowledge the financial support through the research funds from Shanxi Scholarship Council of China Project No 2011-089.

7. References

[1] Xie Dingyi. Exploration of Some New Tendencies in Research of Loess Soil Mechanics. *Chinese Journal of Geotechnical Engineering*. 2001,23(1):3-13.

[2] He Guang, Zhu Hongbo. Study of Loess Seismic Subsidence. *Chinese Journal of Geotechnical Engineering*. 1990,12(6):99-103.

[3] Yan Fengxiang, Liang Renwang, Bai Xiaohong. The Research of Static Deformation Properties of Taiyuan Loess. *Shanxi Architecture*. 2010,36(22):103-104.

[4] Wang Lanmin. Dynamic behaviors of loess under irregular seismic loading. *Proc of 2 Intern Conf on Earthquake Construction and Design*. Berlin Germany, 1994,pp. 398～401.

[5] Yan Fengxiang. Study on Static and Dynamic Properties of Taiyuan Loess. *Master's Thesis*. *Taiyuan University of technology.* Taiyuan, 2004.

[6] Luo Yasheng. Test Analysis on Dynamic Characteristics and Parameters of Typical Loess in China. *Doctor's* Thesis. *Xian University of technology.* Xian, 2004.

[7] BAI Xiao-hong. Peter Smar. Engineering Properties of LuCheng Loess in ShanXi. *Chinese Journal of* Geotechnical *Engineering*. 2002, 24（4）: 516～518.