International Journal of GEOMATE, May, 2020, Vol.18, Issue 69, pp. 118 - 123
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2020.69.9311
Geotechnique, Construction Materials and Environment

THE INCREASING OF UNDRAINED SHEAR STRENGTH AND SHEAR MODULUS OF SOFT BANGKOK CLAY BY SILICA POWDER USING UNCONFINED COMPRESSION TEST WITH BENDER ELEMENT

*Pithan Pairojn[1]

[1] Civil Engineering Technology, Faculty of Science, Chandrakasem Rajabhat University, Thailand

*Corresponding Author, Received: 15 June 2019, Revised: 29 Nov. 2019, Accepted: 30 Jan. 2020

ABSTRACT: The present study aims to increase the undrained shear strength and shear modulus of soft Bangkok Clay soil by silica powder when they were subject to unconfined compression test with the bender element. The shear wave velocity was measured using a pair of bender elements installed at the top cap and pedestal of the unconfined cell. The undrained shear strength was conducted step by step so that the variation of shear modulus could be determined. The undrained shear strength was carried out at the strain rate of 1% per minute during which the shear modulus was continuously recorded. The result found that when the soil was mixed with silica powder an increased rate, the undrained shear strength and shear modulus were increased but the strain was decreased. Therefore, the improvement of soil quality using silica powder can be increased the efficiency of the construction such as embankment and road construction.

Keywords: Undrained shear strength, Shear modulus, Bangkok Clay, Silica powder, Bender element

1. INTRODUCTION

At present, the construction in the central region of Thailand, such as road construction, slope construction, etc., has been damaged due to soil foundations that are soft clay (Bangkok soil), especially roads along the canal (Fig. 1). Therefore, requires the design and construction of roads to be appropriate according to the engineering principles which cause the collapse of roads along the irrigation canal caused by

Fig. 1 Damage of roads along the canal

1. Infrastructure construction and buildings in soft clay areas where soft clay layers are characterized by varying depth.

2. The rapid drop of water level in the irrigation canal (Sudden drawdown) from normal use with water supplying into the canal or during the extreme drought that farmers will accelerate pumping water into the garden or farmland area (Fig. 2) or in the late rainy season, early in the winter, the water in the canal will be drained faster, which will give the opportunity to the collapse of the riverbank slope in this regard. The behavior of river bank collapse due to the rapid decrease of water level, especially the clay bank soil slopes so that water and pressure caused water to flow out. If the water pressure is high enough, it will cause the river bank slopes and roads along the canal to collapse.

Fig. 2 Rapid drop of water level in the irrigation canal

3. Longer summer months as a result of global climate change directly affect the collapse of river bank slopes and roads along the irrigated canal due to lack of water in the canal that will help push or

support the bank slopes to stabilize.

This research focuses on improving soft soils by using additional mixtures, which the researcher uses silica powder because it is cheap, easily available, can fill the gap between soil mass and can increase the undrained shear strength and shear modulus of soft soil. The silica powder is not very expensive compared to other additive mixtures. Therefore, the construction of roads or roads along the canal can use clay mixed with silica powder for the efficiency, the investment value and the reduction of soil collapse [1]-[4].

2. METHODOLOGY

2.1 Unconfined Compression Test with Bender Element

The researcher developed the unconfined compression test with bender element (UCTwBE) by using the unconfined compression test of ELE International to install the axial force transducer and axial displacement transducer of Kyowa (Fig. 3).

Fig. 3 UCTwBE

2.2 Bender Element

Install the bender element to measure small strain modulus. The Bender element converts the Eletro-mechanical system by converting mechanical energy (Vibration) into electrical energy. On the other hand, it converts electrical energy into mechanical energy. The bender element is characterized by two piezo ceramic plates attached together, can be both a transmitter and receiver (Fig. 4). Since the bender element is a material that resists electricity, therefore, the use must be careful about short-circuiting, the need to have electrical insulation because of moisture by using epoxy coating around the bender element (Fig. 5).

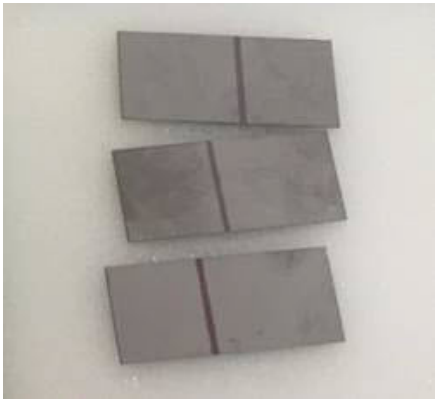

Fig. 4 Sample of bender element T226

Fig. 5 Connecting the cable to the bender element

2.3 Signaling and Recording Equipment

Install the equipment for wave signal transmission using NI CompactDAQ Set (Fig. 6), which is installed with NI9237, NI9215, NI9263, NI9915, Function generator, Amplified voltage and DC supply 24V 5A for control and recording with CRU-Bender Recorder from LabView program (Fig. 7).

Fig. 6 NI CompactDAQ Set

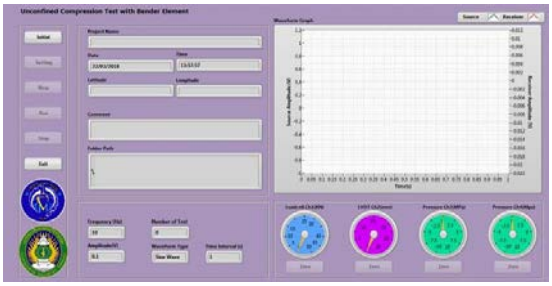

Fig. 7 CRU-Bender Recorder program

2.4 Soil Properties Testing

Collect soil samples for testing as clay at Bang Khen in Bangkok, Thailand at a depth of 0-5 meters (13° 53’ 03" N, 100° 36’ 19" E) with engineering Properties as shown in Table 1.

Table 1 Engineering properties of clay samples

Property	Standard	Value
Water content (%)	ASTM D4959-00	20-21
Unit weight, (t/m^3)	ASTM D4253-00	1.95
Liquid limit (%)	ASTM D4318	53
Plastic limit (%)	ASTM D4318	28
Plasticity index (%)	ASTM D4318	25
Specific gravity	ASTM D854-00	2.56

2.5 Mixing Clay with Silica

Compaction of clay as standard ASTM D698-12e2 standard test methods for soil using standard effort [5] by mixing normal water and mixing silica powder by 5% to 50% of water weight, respectively. Silica powder in Thailand is easy to find because Thailand has a lot of paddies so it can be synthesized into silica powder. Mix together (Figs. 8 and 9) and cut samples according to ASTM D2166-00 standard test method for unconfined compressive strength of cohesive soil [7] as shown in Fig. 10, installed with the UCTwBE to find undrained shear strength and shear modulus values.

Fig. 8 Mixing silica powder

Fig. 9 Standard compaction test

Fig. 10 Soil sample cutting

2.6 Determination of Undrained Shear Strength

When cutting samples obtained from soil compaction tests Installed with the unconfined compression test with bender element (Fig. 11). The undrained shear strength can be obtained from Eq. (1) according to the standard ASTM D2166-00 Standard Test Method for Unconfined Compressive Strength of Cohesive Soil [6].

$$S_u = q_u / 2 \quad (1)$$

Where S_u = Undrained shear strength (kPa), q_u = Unconfined compressive strength (kPa).

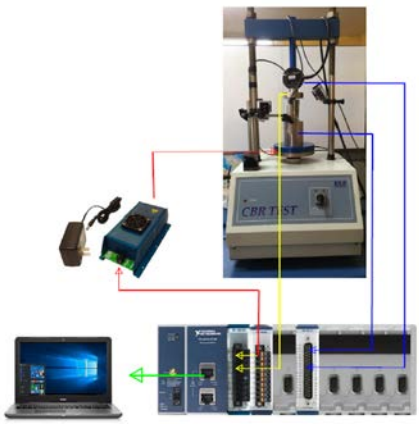

Fig. 11 The system of UCTwBE

2.7 Determination of Shear Wave Velocity and Shear Modulus

2.7.1 Shear Wave Velocity

During the testing of soil compression (Fig. 12), the sine waveform is generated and transmitted by a 20V pp 1 kHz frequency signal from the function generator and sent via the transmitter at the base through the soil sample to the receiver at the top cap when the shear wave travels through the soil sample. The shear wave velocity can calculate as Eq. (2) [7]-[11].

$$V_s = L / t \tag{2}$$

Where V_s = Shear wave velocity (m/s), L = Distance between transmitter and receiver (m), t = The travels time of wave between transmitter and receiver peak-peak (s).

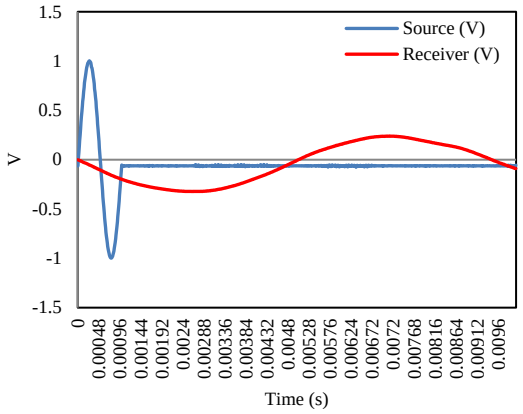

Fig. 12 Shear wave of 30% silica powder mixing

2.7.2 Shear Modulus

When the shear wave velocity is obtained, then the small-strain shear modulus can be obtained from Eq. (3) [12]-[17].

$$G_{max} = \rho V_s^2 \tag{3}$$

Where G_{max} = Shear modulus (MPa), ρ = Soil density (kN/m^3), V_s = Shear wave velocity (m/s).

3. RESULTS AND DISCUSSION

3.1 Results of Undrained Shear Strength

Figure 13 showed that the undrained shear strength of the soil mixed with silica 50% of water weight was the highest at about 69.25 kPa. Which is greater than the soil mixed with water about 30.34 kPa, which is about 2 times at optimum moisture content (OMC).

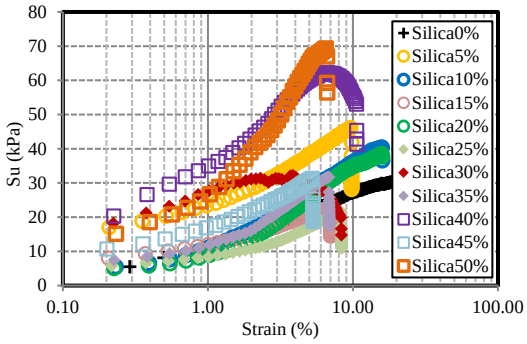

Fig. 13 Undrained shear strength of soil

3.2 Results of Shear Wave Velocity

Figure 14 showed that the shear wave velocity of the soil mixed with silica 5% of water weight was the highest at about 436.58 m/s. Which is greater than the soil mixed with water about 211.39 m/s, which is about 2 times at optimum moisture content (OMC).

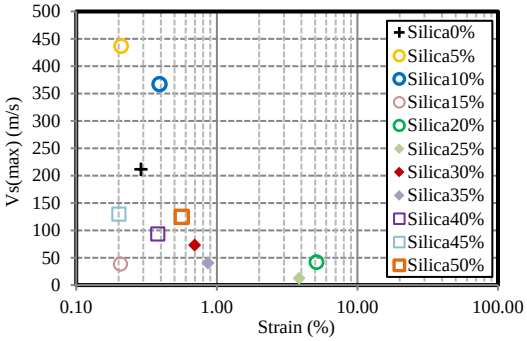

Fig. 14 Shear wave velocity of soil

3.3 Results of Shear Modulus

Figure 15 showed that the shear modulus of the soil mixed with silica 5% of water weight was the highest about 4,117.09 MPa. Which is greater than the soil mixed with water about 933.91 MPa, which is about 4 times at optimum moisture content (OMC).

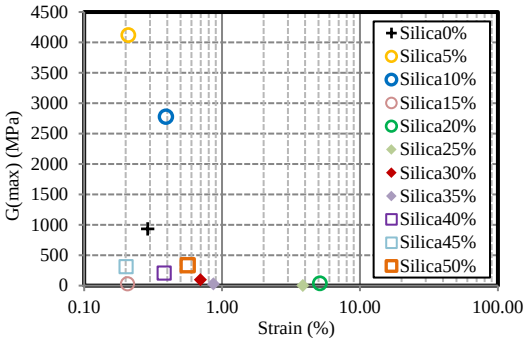

Fig. 15 Shear modulus of soil

3.4 The Relationship between Shear Modulus and Unconfined Compressive Strength

Figure 16 showed that the empirical model of soil mixed with silica has the performance to predict the shear modulus when the unconfined compressive strength is received from the unconfined compressive test by Eq. (4). After that, shear modulus can be calculated in the finite element limit analysis design program.

$$G_{max} = 0.00005 q_u^{3.5947} \quad (4)$$

Where G_{max} = Shear modulus (MPa), q_u = Unconfined compressive strength (kPa).

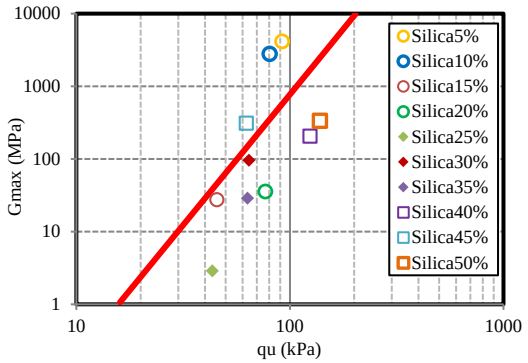

Fig. 16 The relationship between shear modulus and unconfined compressive strength of soil mixed with silica

4. CONCLUSION

The results of the research concluded that improvement of soil quality by using silica powder approximately 5-10% of water weight as an additive during soil compaction in construction can increase the efficiency of the pavement to have undrained shear strength and shear modulus rather than soil mixed with water. Therefore, silica powder can be used to improve soil quality by mixing it as an additive during soil compaction. The unconfined compression test with bender element developed by the researcher can be used to determine the undrained shear strength and shear modulus. Thus, reducing time and cost savings in soil testing. It can be used to solve problems during construction, so it is an innovation that is suitable for engineers, designers, field engineers, and supervisors. In future research, the researcher will conduct the modification of soil chemical structure by mixing silica powder and use the finite element limit analysis design program to calculate the safety ratio of the canal when soil improvement using silica powder.

5. ACKNOWLEDGMENTS

The author would like to acknowledge the Chandrakasem Rajabhat University Research Grant, which collectively funded this project.

6. REFERENCES

[1] Barnes G., Workability of Clay Mixtures. Applied Clay Science, Vol. 153, 2018, pp. 107-112.

[2] Goodarzia A., Akbari H.R., and Salimi M., Enhanced Stabilization of Highly Expansive Clays by Mixing Cement and Silica Fume. Applied Clay Science, Vol. 132, Issue 133, 2016, pp. 678-684.

[3] Istratea O., and Chen B., Structure and Properties of Clay/Recycled Plastic Composites. Applied Clay Science, Vol. 156, 2018, pp. 144-151

[4] Mousavi S.E., and Karamvand A., Assessment of Strength Development in Stabilized Soil with CBR Plus and Silica Sand. Journal of Traffic and Transportation Engineering, Vol. 4, Issue 4, 2017, pp. 412-421.

[5] ASTM International, ASTM D 698-12e2 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort, 2019, pp. 1-13.

[6] ASTM International, ASTM D 2166-00 Standard Test Method for Unconfined Compressive Strength of Cohesive Soil, 2000, pp. 1-6.

[7] Pairojn P., The Simple Method of Shear Wave Velocity Profile from Explosion Source in Surin, Thailand. International Journal of GEOMATE, Vol. 16, Issue 58, 2019, pp.184-189.

[8] Pairojn P., and Pedrung S., An Identification of Shear Wave Velocity of Soft Bangkok Clay using Unconfined Compression Test with Bender Element, in Proc. 23rd National Conf. on Civil Engineering, 2018, pp. 1-10.

[9] Teachavorasinskun S., and Lukkunaprasit P., Stress Induced and Inherent Anisotropy on Elastic Stiffness of Soft Clays. Soils and Foundations, Vol. 48, Issue 1, 2008, pp. 127-132.

[10] Teachavorasinskun S., and Lukkunaprasit P., A Simple Correlation for Shear Wave Velocity of Soft Bangkok Clays. Geotechnique, Vol. 54, 2004, pp.1-4.

[11] Pairojn P., and Teachavorasinskun S., An Identification of Shear Wave Velocity Profile in Northeastern Thailand by Downhole Test.

International Journal of Applied Engineering Research, Vol. 9, Issue 22, 2014, pp. 13503-13510.

[12] Hardin B.O., and Drnevich V.P., Shear Modulus and Damping in Soils: Measurement and Parameter Effect. Journal of Soil Mechanics and Foundations Engineering ASCE, Vol. 98, Issue 6, 1972, pp. 603-624.

[13] Iwasaki T., Tatsuoka F., and Takagi Y., Shear Moduli of Sands under Cyclic Torsional Shear Loading. Soils and Foundations, Vol. 18, Issue 1, 1978, pp. 39-56.

[14] Roesler S.K., Anisotropic Shear Modulus due to Stress Anisotropy. Journal of the Geotechnical Engineering ASCE, Vol. 105, Issue 7, 1979, pp. 871-880.

[15] Yu P., and Richart F.E., Stress Ratio Effects on Shear Modulus of Dry Sands. Journal of Geotechnical Engineering ASCE, Vol. 110, Issue 3, 1984, pp. 331-345.

[16] Teachavorasinskun S., Thongchim P., and Lukkunaprasit P., Shear Modulus and Damping of Soft Bangkok Clays. Canadian Geotechnical Journal, Vol. 39, Issue 5, 2002a, pp. 1201-1208.

[17] Teachavorasinskun S., and Amornwithayalax T., Elastic Shear Modulus of Bangkok Clay during Undrained Triaxial Compression. Geotechnique, Vol. 52, Issue 7, 2002, pp. 537-540.

Copyright © Int. J. of GEOMATE. All rights reserved, including the making of copies unless permission is obtained from the copyright proprietors.