

Comparison of Identification of Soil Stratigraphy between Two Code Methods of CPTU Test and Laboratory Test in Shanghai

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Abstract. This article presents a comparison between two code methods of piezocone penetration test (CPTU) and laboratory test in identifying soil stratigraphy in Shanghai. In China, stratigraphy for soft deposit is mainly obtained through the traditional code method, in which plasticity index and grain size distribution of borehole samples are analyzed in the laboratory. With in-situ tests developed in China, CPTU test is used widely in stratigraphy for soft deposit in railway construction and the Ministry of Railways code based on CPTU test is also established. The analysis is carried out with the field data at test site of Yan'an Road Tunnel in Shanghai. The Ministry of Railways code is applied in identifying soil strata. The results are comparison with two code methods. The results show that The Ministry of Railways code method is more detailed in identifying the stratigraphy of soft deposit of Shanghai. Moreover, the discussion on discrepancies between them is also conducted.

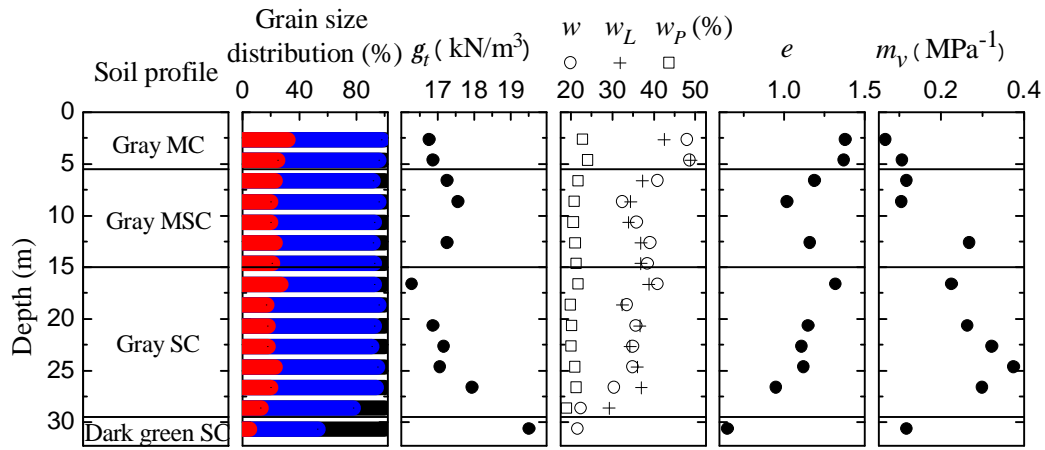
Introduction

The piezocone penetration test (CPTU) is a useful in-situ one and can provide a quantitative measure of soil properties in its natural environment^[1]. With CPTU test developed in China, it is widely used to determine soil stratigraphy in railway construction and the Ministry of Railways code^[2] based on CPTU test is also established. In Shanghai, soil stratigraphy is mainly obtained through laboratory test (also called code method)^[3], in which plasticity index and grain size distribution of borehole samples are analyzed.

In this research, the field data of CPTU test and adjacent borehole data at test site of Yan'an Road Tunnel in Shanghai are collected, the stratigraphy of soft deposit in Shanghai is identified by laboratory test and the Ministry of Railways code respectively. The discrepancies between them are discussed.

Strata Identification and Soil Properties of Yan'an Road Tunnel from laboratory test^[4]

The construction site of Yan'an Road Tunnel is on the alluvial plain of the Yangtze River Delta, Shanghai. The soil profile and properties of soft subsoil obtained by borehole at this location based on the method as established in Shanghai^[3] are depicted in Figure 1. From Fig.1, from up to down, the stratigraphy of soft deposit is in sequence of gray mucky clay (MC) (from 0 to 5.5m deep), gray mucky silty clay (MSC) (from 5.5m to 15m deep), gray silty clay (SC) (from 15m to 29.5m deep) and dark green silty clay (SC) (from 29.5 m to 32.3 m deep).

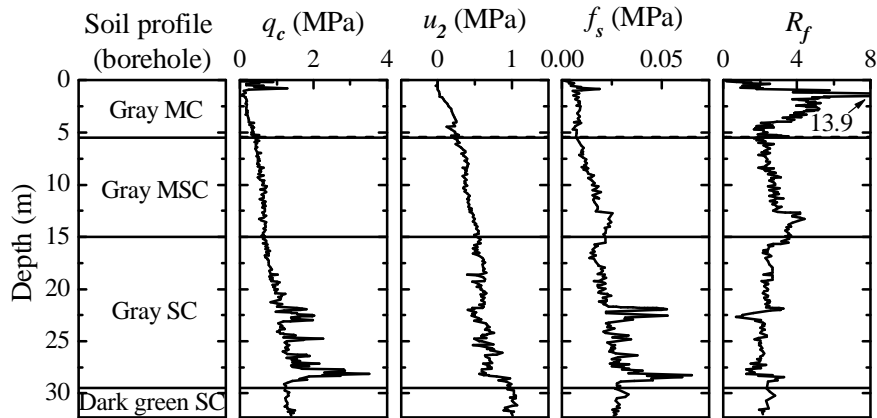


Note: MC = mucky clay, MSC = mucky silty clay, SC = silty clay, g_t = unit weight, w_p = plastic limit, w = natural water content, w_L = liquid limit, e = void ratio, m_v = coefficient of volume compressibility, ■ clay ■ silt ■ sand

Fig. 1. Soil profile and geotechnical properties of borehole samples in laboratory test.

CPTU Test Results^[4]

The CPTU with controlled rate (2cm/s) of penetration has been carried out in Yan'an Road Tunnel of Shanghai. The depth of the site was 32.3m. The continuous CPTU profile of soft deposit in Shanghai is shown in Fig. 2. From Fig. 2, it shows that there is a general increase in q_c , u_2 , and f_s along with depth while no obvious tendency is noticed in R_f along with depth. There is a sudden decrease in u_2 while a significant increase exists in q_c at the location, which suggests the presence of a thin sandy layer.



Note: MC = mucky clay, MSC = mucky silty clay, SC = silty clay, q_c = cone resistance, u_2 = pore pressure, f_s = sleeve friction, R_f = friction ratio

Fig. 2. Geotechnical profile based on borehole and soil properties from CPTU test.

Soil Identification from the Ministry of Railways code in China^[2]

CPTU test was used in railway construction very early in China. Soil classification charts were adapted and improved based on an expanded CPTU database. In 2003, a soil classification chart was proposed by the Ministry of Railways in China for railway construction, in which soil classification is divided into five zones: soft soil, clay, silty clay, silt and sand, as shown in Fig. 3.

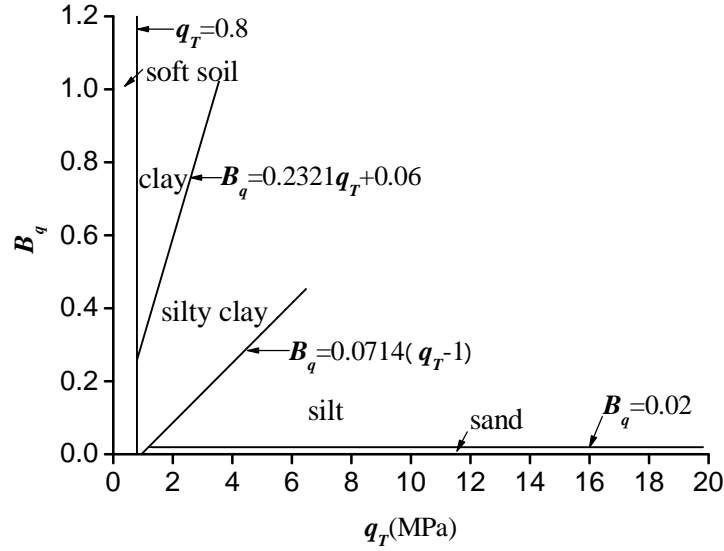


Fig.3. Soil classification chart from the Ministry of Railways code^[2]

where q_T is the total cone tip resistance, $q_T = q_c + (1-a)u_2$, a is the correction factor, B_q is the pore water pressure ratio, defined as^[5]

$$B_q = \frac{u_2 - u_0}{q_T - s_{v0}} \quad (1)$$

s_{v0} is the initial total vertical stress, u_0 is the initial static pore water, s'_{v0} is the initial vertical effective stress.

In this research, a set of the data was recorded, as shown in Fig. 2. According to these data, the total cone tip resistance q_T , pore water pressure ratio B_q were calculated respectively and drawn in the soil classification chart from the Ministry of Railways, as shown in Fig. 4. From Fig. 4, most of the CPTU data is located in soft soil, clay, silty clay zones while a few data fall in silt zone. Zones of soil classification from CPTU test are basically consistent with that from laboratory test.

Discussion

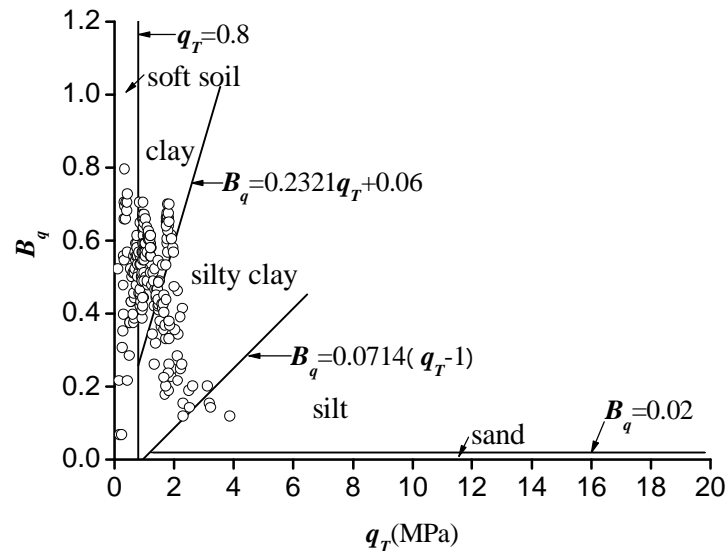


Fig.4. Plot of all data from CPTU at the site in the Ministry of Railways code

In order to investigate the discrepancies on soil identification between the laboratory test and the Ministry of Railways code, the total cone tip resistance q_T and pore water pressure ratio B_q of each soil

layer of the soft deposit identified by laboratory test in Fig. 2 are redrawn in the soil classification charts from the Ministry of Railways, as shown in Figs. 5~8.

Fig. 5 shows the CPTU data of gray mucky clay identified from laboratory test. All CPTU data of MC layer is located in soft soil zone. It is well known that soft soil includes mucky clay, which represents that the soil type identified from two methods is consistent. Fig. 6 plots the CPTU data of gray MSC layer identified from laboratory test. The CPTU data of the MSC layer is located in soft soil, clay zones. Fig. 7 shows the CPTU data of gray SC layer identified from laboratory test. According to Fig. 7, most of the CPTU data of the SC layer are located in clay, silty clay zones while a few data fall in silt zone. Figure 8 shows the CPTU data of dark green SC layer identified from laboratory test. Most of CPTU data of dark green silty clay layer are located in clay zone while a few data fall in silt clay zone.

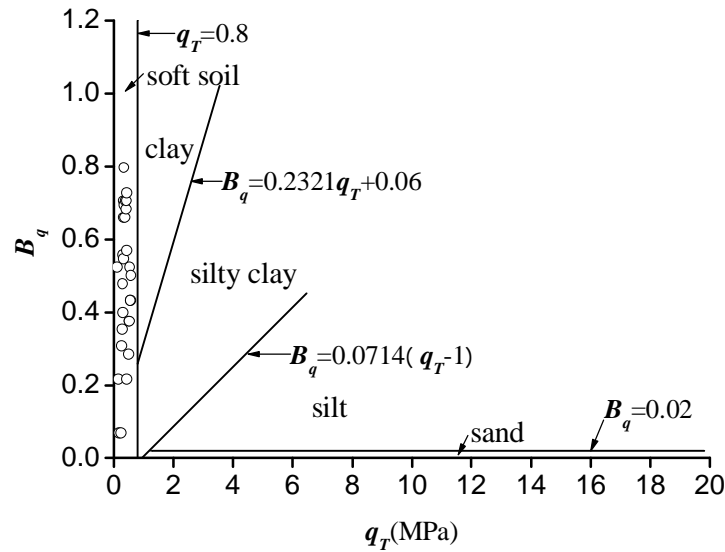


Fig. 5. Plot of CPTU data of gray MC layer from laboratory test in the Ministry of Railways code.

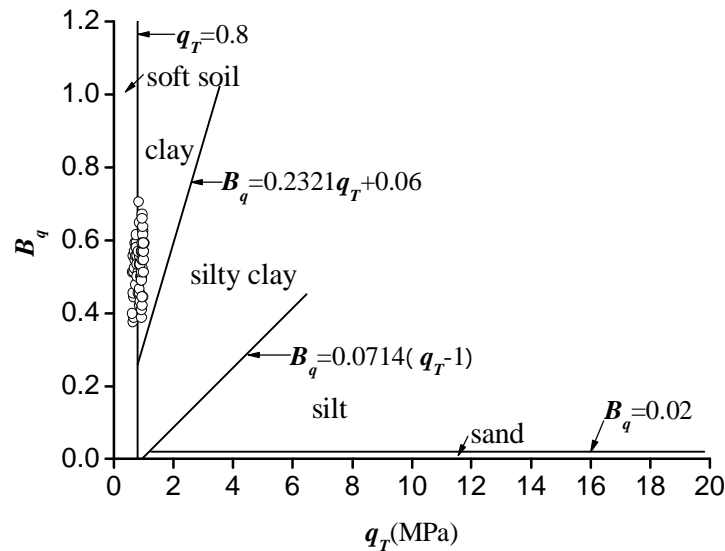


Fig. 6. Plot of CPTU data of gray MSC layer from laboratory test in the Ministry of Railways code.

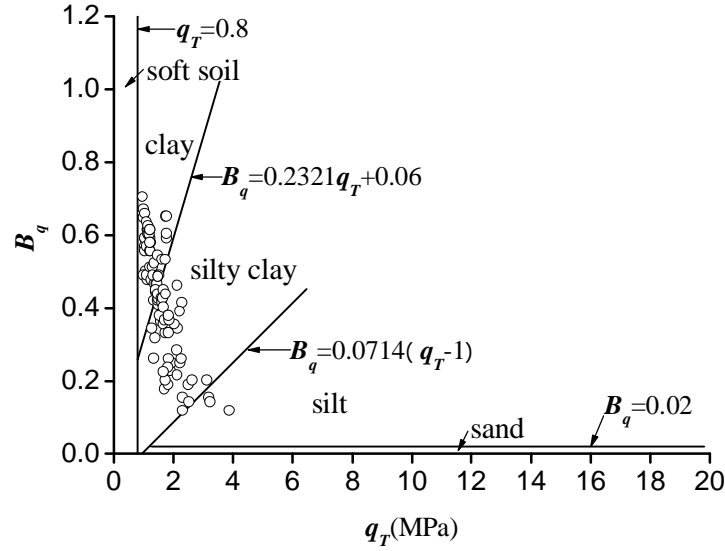


Fig. 7. Plot of CPTU data of gray SC layer from laboratory test in the Ministry of Railways code.

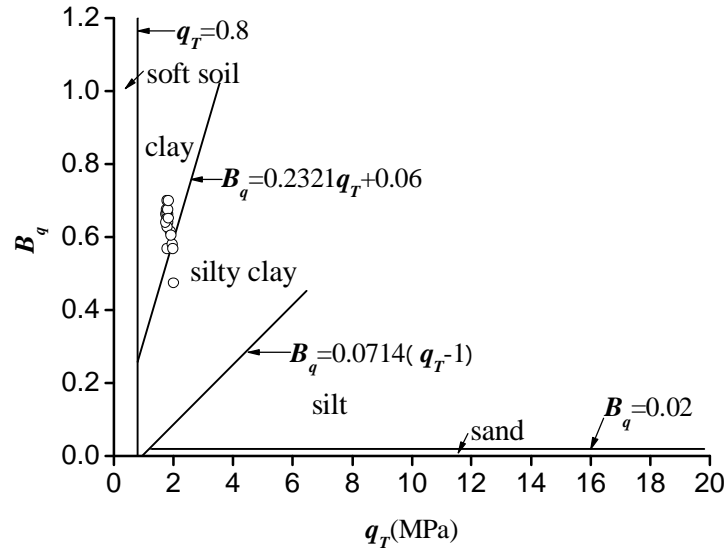


Fig. 8. Plot of CPTU data of dark green SC layer from laboratory test in the Ministry of Railways code.

From Fig. 2 and Figs. 5~8, it can be found that both of laboratory test results and the Ministry of Railways code ones are similar in identification of soil stratigraphy while the accuracies of two methods are different. Especially, there are some discrepancies at the depth from 12.5 m to 14.9 m, where a thin clay lens exists, and from 1.1 m to 2.1 m, 22 m to 23.5 m and 26.4 m to 28.3 m, where three thin layers of sand lens exist. For these thin lens layers identified by CPTU test, the laboratory test can not identify. This is because in CPTU test data is measured continuously with a very small time interval or vertical distance, e.g. one data within 20 mm. However, the data interval was at least 500 mm for laboratory test method and the borehole data in laboratory test was obtained with the depth interval of 1m in this field case. As shown in Fig. 2, obvious changes occur in the curves of CPTU data when the cone passes through these thin layers: cone resistance q_c and friction ratio R_f suddenly increase compared with that at other depths. Therefore, these thin layers can be identified from CPTU test. In this sense, the Ministry of Railways code based on CPTU test becomes more detailed and suitable for geotechnical investigation in railway construction.

Conclusions

- 1) Based on the CPTU data and combined with the Ministry of Railways code method, the stratigraphy of soft deposit in Shanghai was identified. The Ministry of Railways code method is more detailed to identify the stratigraphy of the soft deposit in Shanghai.
- 2) By use of CPTU test, thin layers of clay lens and sand lens can be identified through cone resistance, pore pressure and sleeve friction. However, this trait is very difficult to be found by the borehole sample in laboratory test.
- 3) The Ministry of Railways code method based on CPTU test is more suitable in soil stratigraphy of railway construction. More detailed researches on the CPTU method in different locations and soil types must to be carried out further to establish the relationship between the CPTU method and The Ministry of Railways code method.

References

- [1] T. Lunne, P. K. Robertson and J. M Powell. Cone Penetration Testing in Geotechnical Practice. Spon Press, Taylor & Francis Group, London and New York (2002).
- [2] Ministry of Railways of the People's Republic of China. Code for In-situ Test of railway engineering geology (TB10041-2003, J261-2003), China Railway Publishing House, Beijing (2003).
- [3] Committee of Civil Engineering and Management in Shanghai (CCEMS). *Code for Investigation of Geotechnical Engineering* (DGJ08-37-2002), Shanghai (2002).
- [4] S.L. Shen, J.P. Wang and L. Ma. Identification of soil stratigraphy of soft deposit in Shanghai from CPTU test. In: Meier, R., Abbo, A., Wang, L.B. (Eds.), *Soil Behavior and Geo-Micromechanics, Proceedings of Sessions of Geoshanghai 2010*, ASCE, pp. 384-391 (2010).
- [5] C.P. Wroth. The interpretation of in situ soil tests. *Géotechnique* 34, No. 4, 449–89 (1984).