Design Parameters Of Klang Clay, Malaysia

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ABSTRACT A series of subsurface investigation including in-situ and laboratory tests has been carefully planned and carried out for the residential and commercial development over soft Silty Clay at Bukit Tinggi, Klang, Malaysia. The approach taken in characterizing and developing a fundamental understanding of the Klang Clay is described in this paper. Some important correlations have been established for key engineering properties from good quality field and laboratory data. A correlation between physical soil properties with undrained shear strength from field vane ($s_{u(fv)}$) and laboratory consolidation tests are established for practical usages in the geotechnical design. In addition, correlations involving the piezocone were also systematically derived from high quality field data.

1 INTRODUCTION

With the rapid economic development in recent years, more and more new developments have shifted away from the congested Kuala Lumpur city, capital of Malaysia. The development in Klang area, which is about 40km towards south west of Kuala Lumpur, increase significantly in this few years. A residential and commercial development was carefully planned at a site of about 1200 acres at Bukit Tinggi, Klang as shown in Figure 1. This development is constructed over soft silty clay, term as Klang Clay in this paper.

This paper presents the characterization of Klang Clay and developed a fundamental understanding of engineering properties of this soft silty clay. In particular, some important correlations have been established for key engineering properties namely undrained shear strength and consolidation parameters of this material. A series of Subsurface Investigation (S.I.) including in-situ and laboratory tests has been properly planned and carried out prior and during design and construction stage. The major field and laboratory tests reported in this paper include 29 boreholes, 8 piezocone (CPTU), 1260 field vane shear tests, 70 oedometer tests and etc.

2 GEOLOGICAL FORMATION

The proposed site is located at the contact boundary of Quarternary Alluvium and Kenny Hill Formation as shown in Figure 2. The alluvial deposits are overlying the Kenny Hill Formation of weathered metasedimentary rock type.

The alluvial deposits generally consist of very soft to firm silty Clay up to a depth of 25m to 30m with presence of intermediate sandy layers. Beneath the silty Clay stratum generally consists of silty Sand. Residual soils (Grade VI) and completely weathered materials (Grade V) derived from the weathering of Quartzite were only encountered at about 40m deep. The presence of quartzite rock-type was further confirmed from the observation of rock outcrop located about 2km from the site.

The behaviour of soft alluvial soils is influenced by the source of the parent material, depositional processes, erosion, redeposition, consolidation and fluctuations in groundwater levels. Alluvial soils is Klang area usually show pronounced stratification and sometimes organic matter, seashell and decayed wood are present in this deposits.

3 CHARACTERIZATION OF KLANG CLAY

3.1 Index Properties

In many engineering situations, preliminary or conceptual design decisions have to be based on inadequate subsoil data particularly during the very initial stage of project development. An attempt has been made to compile numerous geotechnical data in order to establish correlations between some important engineering parameters with the simple Atterberg Limits.

The values of bulk unit weights and Atterberg Limits of Klang Clay are shown in Figure 3. As observed from Figure 3, the subsoil is generally soft, inorganic, possess medium to extremely high plasticity, compressible with high Liquidity Index.

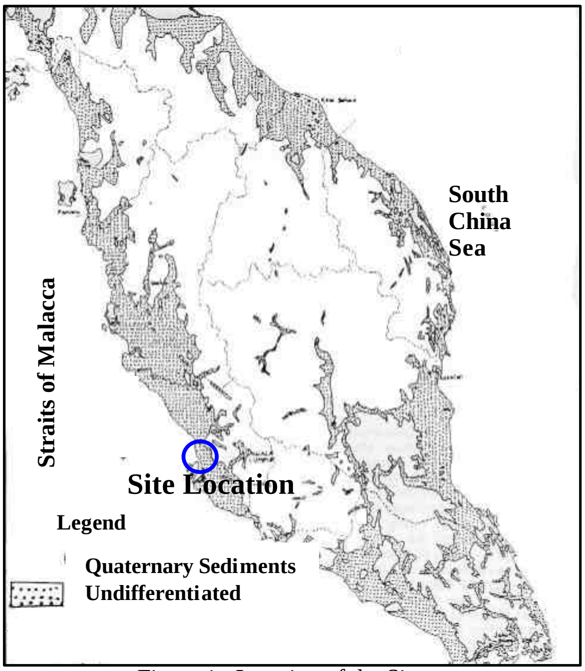

Figure 1 : Location of the Site.

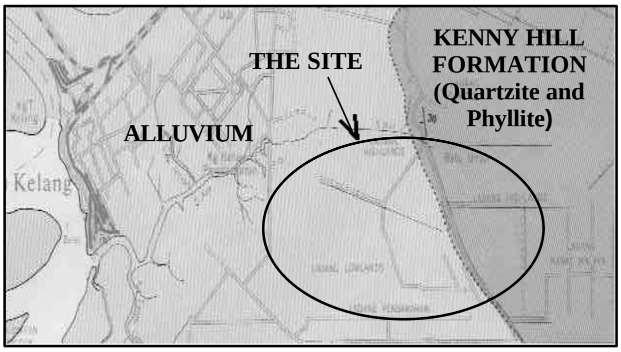

Figure 2 : Geological Map of the Site.

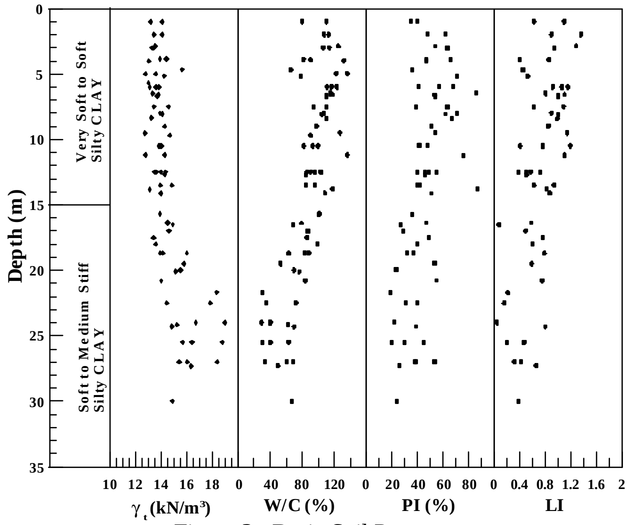

Figure 3 : Basic Soil Parameters.

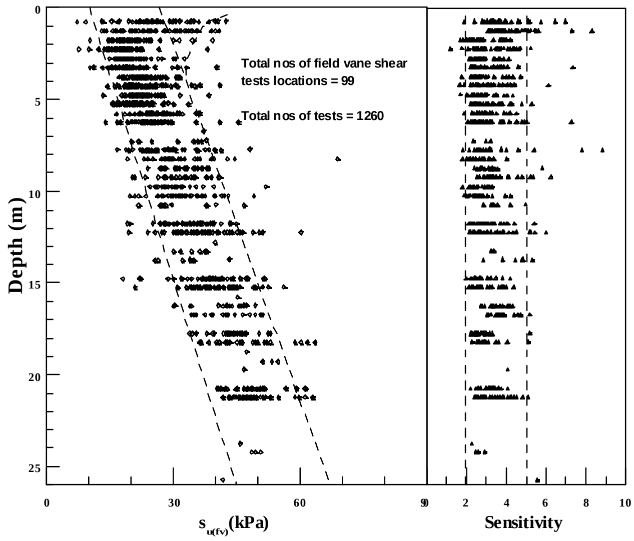

Figure 4 : Undrained Shear Strength and Sensitivity of Klang Clay.

3.2 *Undrained Shear Strength*

Undrained shear strength is essential for the analysis of embankment stability (total stress) and bearing capacity of foundation in saturated clay. Shear strength of soil can be measured directly or indirectly with different apparatus, including laboratory and in-situ tests. However, the results of the laboratory tests are usually subjected to uncertainties due to the inevitable sample disturbance particularly for very soft to soft clay. This is particularly obvious in Malaysia due to the process of sample collection, equipments, skill, etc. In this paper, only the undrained shear strength, s_u obtained from in-situ strength tests such as field vane (FV) and piezocones will be discussed. Figure 4 shows that undrained shear strength of Klang Clay increases almost linearly with depth after the overconsolidated top crust. The sensitivity of Klang Clay from the penetration field vane shear test is about 2 to 5.

Three (3) empirical approaches for interpretation of undrained shear strength from the piezocone results are presented in this paper. They are:

$$s_{u(fv)} = \frac{q_c - s_{vo}}{N_k} \qquad s_{u(fv)} = \frac{q_t - s_{vo}}{N_{kt}}$$

$$s_{u(fv)} = \frac{q_t - u_2}{N_{ke}} \qquad s_{u(fv)} = \frac{u_2 - u_o}{N_{\Delta u}}$$

Figures 5 to 8 show the correlations obtained from the interpretation of the piezocone results. The undrained shear strength values ($s_{u(fv)}$) used in the correlations were obtained from the field penetration vane shear tests without any correction for plasticity index. The correlation factors for different type of empirical approaches are tabulated in Table 1.

Table 1: Correlation Factor to Determine $s_{u(fv)}$ from Piezocone

Empirical Approaches	Obtained Correlation Factor
Total cone resistance	N_k= 5 to 15, N_{kt}=10 to 20
Effective cone resistance	N_{ke}= 5 to 11
Excess pore pressure	$N_{\Delta u}$= 2 to 7

Generally, the most frequent used empirical approach to estimate undrained shear strength is the corrected total cone resistance (q_t). Gue and Tan (2000) recommended to use an N_{kt} value of 15 to estimate a lower bound for the undrained shear strength at new site. The results show that it is reasonable to use average value of N_{kt} = 15 to estimate the undrained shear strength for Klang Clay.

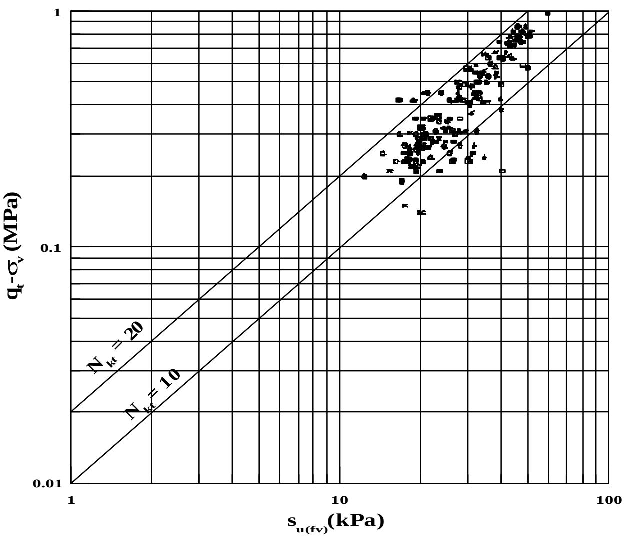

Figure 5: Relationship Between Uncorrected Total Cone Resistance And Uncorrected Field Vane Shear Strength

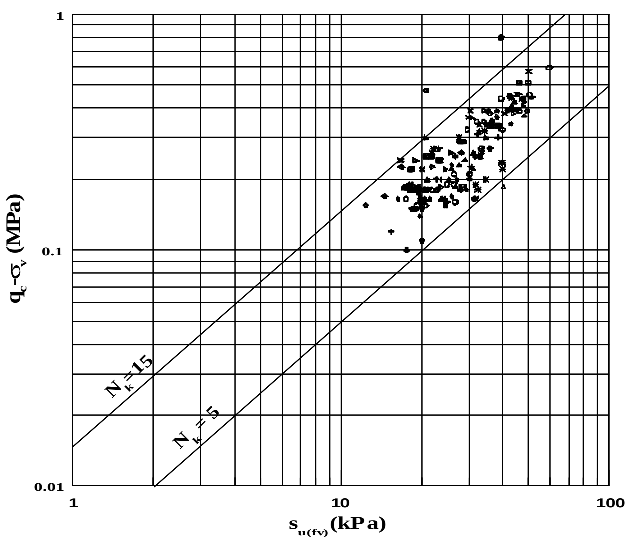

Figure 6 : Relationship Between Corrected Total Cone Resistance And Uncorrected Field Vane Shear Strength

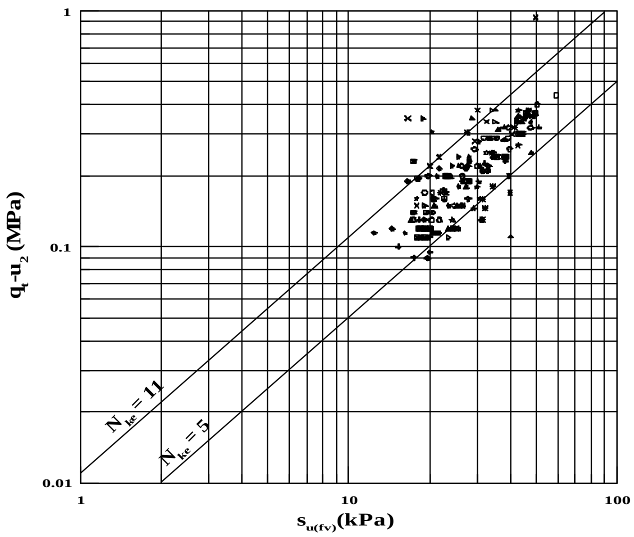

Figure 7 : Relationship Between Effective Cone Resistance And Uncorrected Field Vane Shear Strength

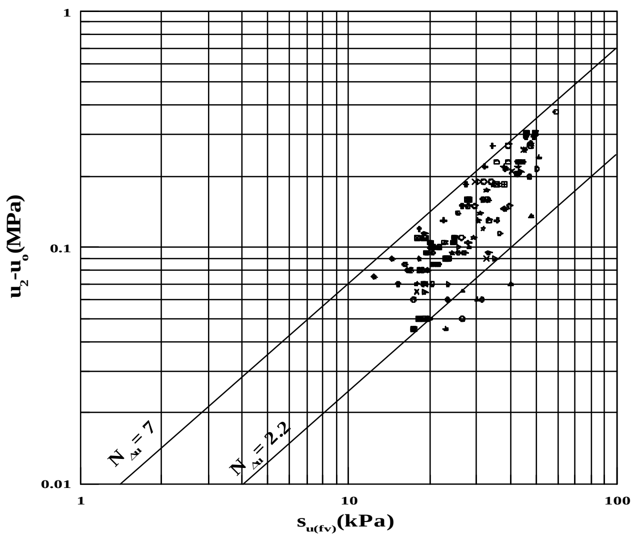

Figure 8 : Relationship Between Excess Pore Pressure And Uncorrected Field Vane Shear Strength

Many literatures had reported that the undrained shear strength can be correlated to the preconsolidation pressure. Figure 9 shows the $s_{u(fv)}/P_c'$ ratio of Klang Clay. Klang Clay shows a relatively higher ratio of $s_{u(fv)}/P_c' = 0.4$ compared to other type of clays in Southeast Asia that ranges from 0.19 – 0.33 (Tanaka, 2000). In addition, Figure 10 shows that the s_u/P_c' ratio is independent of the plasticity index.

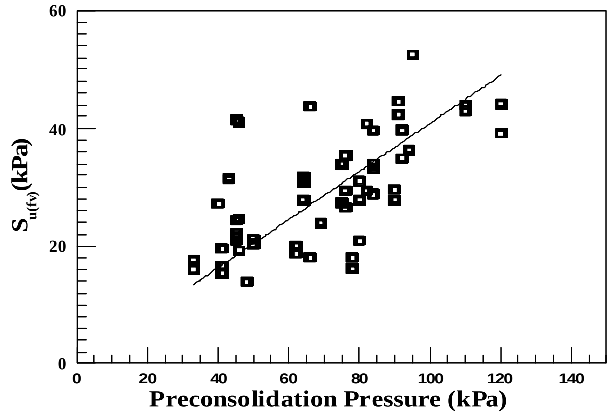

Figure 9 : $s_{u(fv)}/P_c'$ ratio of Klang Clay.

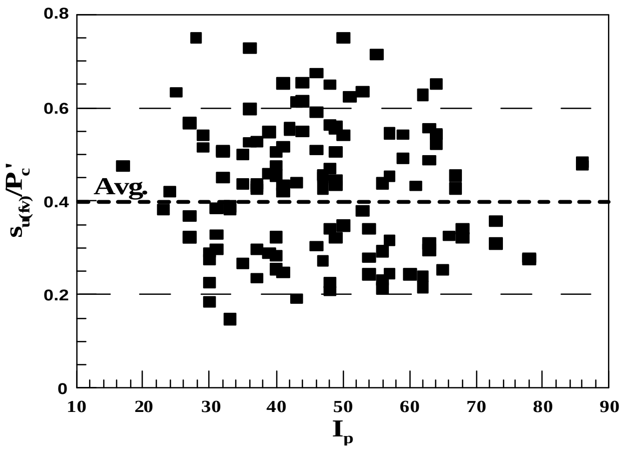

Figure 10 : $s_{u(fv)}/P_c'$ ratio Klang Clay is independent on its Plasticity Index

3.3 Compressibility

There are always two main problems in soft clay, namely stability and settlement. However, many practising engineers always forget about the importance of settlement problem. Therefore, more effort should be emphasized in the process of interpretating soil parameters for settlement analysis. Some of the compressibility parameters of Klang Clay such as natural void ratio (e_o), preconsolidation pressure (P'_c), overconsolidation ratio (OCR), compression ratio (CR) and recompression ratio (RR) are presented in Figure 11. All the abovementioned parameters always play major role in the settlement analyses. Many researches have been carried out in order to have more understanding in these parameters. However, the reported literature is different for all type of clay all over the world. Hence, the authors will discuss the compression index of Klang Clay with some empirical correlations in the following section.

Compression index, C_c is the slope of the linear portion of the e – log σ′ plot and is dimensionless. Many attempts have been carried out to correlate C_c with the basic index properties of soil, especially with the liquid limit, LL. Figure 12 shows the relationship between the compression index of Klang Clay and its liquid limit and the equation is as below:-

$$C_c = 0.02LL – 0.87$$

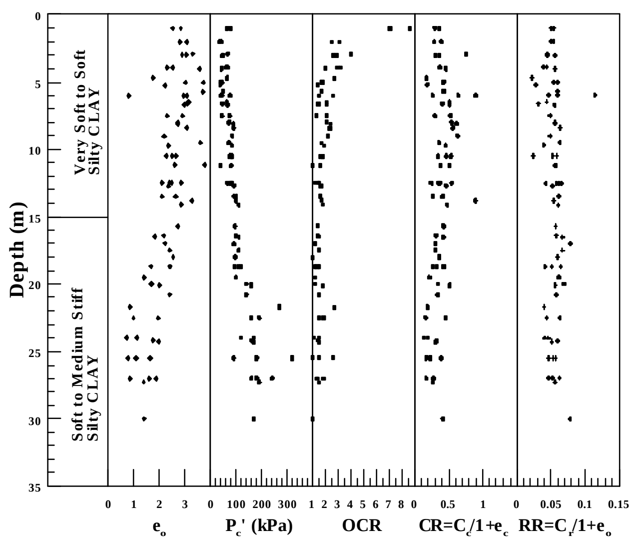

Figure 11 : Compressibility Parameters for Klang Clay

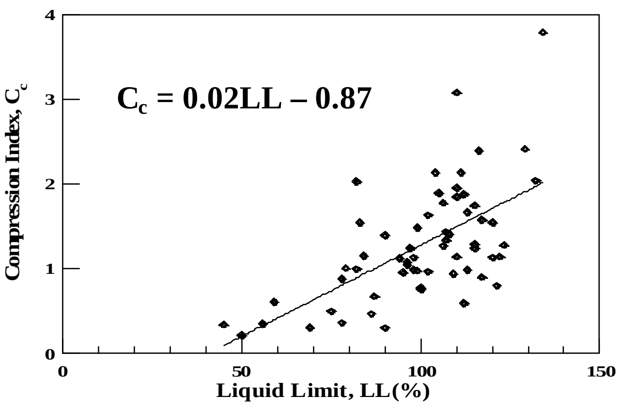

Figure 12 : Relationship between C_c and liquid limit of Klang Clay

As compression index, C_c is influenced by the sensitivity of natural clays, it can generally be related to void ratio and sensitivity (Leroueil et al., 1983). Figure 13 shows the relationship between C_c and natural void ratio by equation below:-

$$C_c = 0.61e_o - 0.17$$

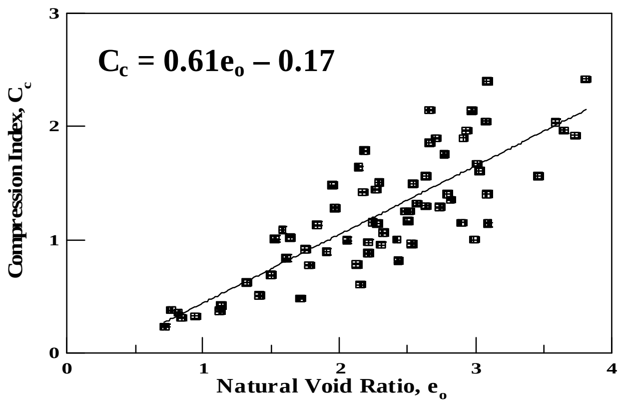

Figure 13 : Relationship between C_c and natural void ratio of Klang Clay

On the other hand, some researchers such as Woo et al. (1990) also indicated that the relationship of the C_c and the natural water content and for Klang Clay, this relationship is shown in Figure 14 and represented by the equation below:-

$$C_c = 0.02Wn - 0.37$$

The recompression index, C_r is also an importance parameter for soft compressible ground settlement analysis. C_r is defined in the same way as C_c except that it applies to the unloading-reloading phase of the oedometer test. Figure 15 shows that the ratio of C_c/C_r of Klang Clay is in the range of 5 to 10 for the first 15m and ranges from 3 to 7.5 for the subsequent depth.

4 DISCUSSIONS AND CONCLUSIONS

The undrained shear strength of Klang Clay increases almost linearly with depth and shows relatively high value for the first 3m for the overconsolidated crust. The relationships between undrained shear strength and parameters from piezocone show an acceptable scatter. Generally, it is reasonable to use average correlation factor of N_{kt} = 15 to estimate the undrained shear strength for Klang Clay. The $s_{u(fv)}/P_c'$ ratio of Klang Clay is about 0.4. The $s_{u(fv)}/P_c'$ ratio is also clearly independent of plasticity index.

A series of correlation of compressibility index have also been presented in this paper. The results show that the compressibility index can be correlated well with the liquid limit, natural void ratio and natural water content.

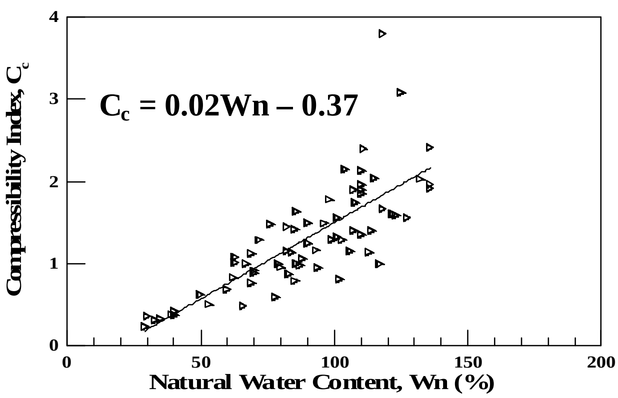

Figure 14 : Relationship between C_c and natural water content, Wn of Klang Clay

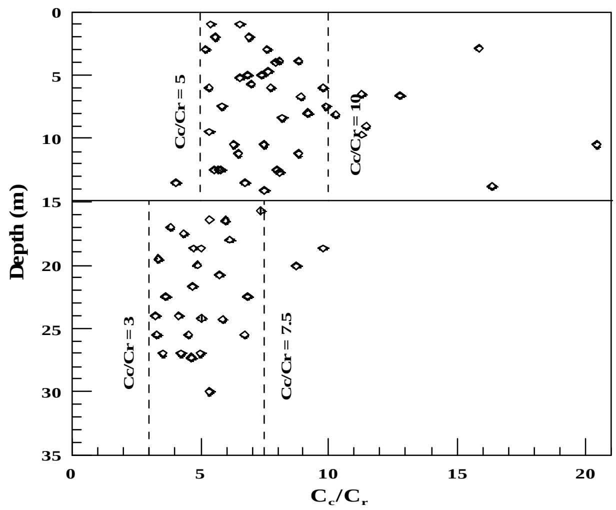

Figure 15 : Ratio C_c and C_r of Klang Clay

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