Characterization of Marine Clay for Road Embankment Design in Coastal Area

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ABSTRACT

The sub-soils in Northwestern Peninsular Malaysia consist of sedimentary soil deposits which form alternate layers of clay and sand. In this paper, the characteristics of marine clay in Northwestern Peninsular Malaysia are investigated based on field and laboratory test data gathered from the ground investigations. Empirical relations between the index properties and compressibility properties are presented. Regression analyses are conducted to propose new empirical relationships to predict the compressibility behaviors of marine clay. Furthermore, the role of soil properties, geological conditions and other aspects are discussed. This paper will also highlight some regional marine clay parameters with the aim for enhancing geotechnical design of road embankment in coastal area.

KEY WORDS: Marine clay; compressibility; index properties.

INTRODUCTION

The occurrence of thick deposits of marine clay in the Northwestern part of Peninsular Malaysia, is due to the result of quaternary deposition. The presence of these poor ground condition has posed numerous technical challenges in the implementation of development projects. The information gathered in this paper, were derived from ground investigation conducted for the North South Expressway between Jawi and Alor Pongsu.

The study area is mainly covered by coastal alluvium deposited since the Quaternary age. The soft ground is typically flat with only slight variations in ground level. The occurrence of widespread and thick deposit of soft marine clay is due to the Quaternary deposition. These normally consolidated deposits were mainly deposited near the coastal area of Peninsular Malaysia when there were several changes of sea level during the deposition period. The segments of the Quaternary age are found throughout Peninsular Malaysia particularly in its coastal areas where they give rise to broad stretches of flat to gently undulating curtain (Bosch, 1988).

The thickness of these deposits varies from 4 m to 23.9m. Ground investigations showed that, the study area mainly comprisal of light to

dork grey silly clay with varying consistency from very soft to soft with traces of organic matter, decayed wood and occasional occurrence of dark grey clay packets. Traces of fine sand in the form of send pockets are also encountered in small amounts during the borehole logging.

The natural moisture content of the marine clay is extremely variable, and range from 39% to 129%, further, the specific gravity (Gs) of the samples range from 2.55 to 2.65. From the Atterberg test, marine clay samples taken from the study area are silty clay of high to extremely high plasticity. Most of the soil samples lied above the A-line in the Casagrande Plasticity Chart which indicates the clay behavior dominates (as shown in Fig. 1). The typical range of plastic limit (PL) varies from 18% to 51%, liquid limit (LL) ranges from 50% to 127%, whereby plastic index (PI) varies from 19% to 77%. The clay percentages measured from the soil samples varies from 22% to 66%, with most of the samples containing more than 40% of clay.



The compressibility parameters considered are the compression index (Cc), and compression ratio (Cr). The typical initial void ratio taken from the study ranges from 0.43 to 3.36, while the compression index varies from 0.21 to 2.6, and is depending on location. The study also indicates that the coefficient of consolidation at the study area ranges from 0.15 to 3.7 m^2 /year, while the compression ratio varies from 0.15 to 0.61. Some standard relationships for these parameters are presented in Figs 2 and 3. The plastics index of soil is used in the derivation of activity and liquidity index. Activity is defined as the ratio of the plastic index to the percentage of clay sized minerals. Fig. 4 shows the relationship between plasticity index, percentage of clay fraction and the activity of the clay. The figure indicates that the clay samples have activities ranging form 0.5 to 2.0. The liquidity index falls into high to very high expansion category. Figs. 5 to 7 showed the relationships of compression index and various soil properties. Fig. 8 showed the relationship of compression ratio and liquid limit, and Fig. 9 showed the compression ratio (Cr) at various depths.





Fig. 3 Compression index (Cc) versus depth

COMPARISON OF COMPRESSIBILIYT PARAMETERS

This section of the paper evaluates the applicability of a number of relationships between soil index properties and compressibility for the marine clay. The published relationships are considered in comparing measured data from the study area to predicted data. The multiple correlation coefficient (R^2) is used to illustrate the adequacy regression model (Walpole et al., 2006). The value of R^2 indicates what proportion of the total variation in the response of (dependent variable) is explained by the fitted model. The value of R^2 is reported in percentage variation explained by the model. The higher R^2 value obtained indicates a better relationship between the dependent variables and independent variables. The relationships between measured compressibility index and natural moisture content were established for marine clay samples taken from the study area. A typical plot showing the data is presented in Fig. 10. Fig. 11 shows the relationship between measured compression ratio (Cr) and moisture content (w).



Fig. 10 shows the measured Cc versus w, which gives a R^2 value of 68.52%, and indicates that Cc has a good linear relationship with the moisture content parameter. Fig. 11 shows measured Cr versus w, and gives a reasonable relationship. Study conducted by Huat et al. (1995) gave the relationship between Cc and w for the area as Cc = 0.0019(w-11.95), which is shown in Fig. 12. The regression analysis gave different R^2 values for each of the equations. Similar analyses were conducted for compression ratio, where previous study (Huat et al., 1995) gave an expression as Cr = 0.0037(LL-1.19). Fig. 13 shows relationship between measured Cr and liquid limit adopted from

the field and laboratory investigation. Fig. 13 gives a R^2 value of 32.53%, and indicates that the linear relationship is not significant. Fig. 14 showed the comparison between the expression recommended by Huat et al (1995) and the measured values of compression ratio (Cr).



Fig. 7 Compression index versus clay percentages



Fig. 8 Compression ratio (Cr) versus liquid limit (LL).



Fig. 9 Compression ratio (Cr) versus depth

New relationships are established for Cc and Cr of the marine clay using measured index properties in the study area. Regression analysis was adopted in deriving the new empirical relationships. The R^2 values for Cr (41.642%) are much lower than Cc (78.995%). This indicated that, the relationship between Cr and the variables used are not significant. For the compression index, the regression analysis gave an empirical equation as:

$$Cc = -0.1248 - 0.0074PI + 0.5393e_0 + 0.0049LL$$
(1)

Where, Cc is the compression index, PI is the plastic index, e0 is the initial void ratio, and LL is the liquid limit.

For 95% confident level, the following empirical equations can be obtained:

Upper limit,
$$Cc = 0.0481 + 0.0047PI + 0.6217e_0 + 0.0125LL$$
 (2)
Lower limit, $Cc = -0.2977 - 0.0195PI + 0.4568e_0 - 0.0026LL$ (3)

For 99% confident level, the following empirical equations can be obtained:

Upper limit,
$$Cc = 0.1052 + 0.0087PI + 0.6489e_0 + 0.015LL$$
 (4)

Lower limit, $Cc = -0.3548 - 0.0235PI + 0.4296e_0 - 0.0051LL$ (5)



Fig. 10 Compression index (Cc) versus moisture content (measured)



Fig. 11 Compression ratio (Cr) versus moisture content (measured)

For the compression ratio, the empirical relations can be established as: $Cr = 0.1173 - 0.0043PI + 0.0946e_0 + 0.0028LL$ (6) Where Cr is the compression weight PI is the electric index of i is the

Where, Cr is the compression ratio, PI is the plastic index, e0 is the initial void ratio, and LL is the liquid limit.

For 95% confident level, the following empirical equations can be obtained:

Upper limit,	$Cr = 0.1881 + 0.0007PI + 0.1284e_0 + 0.0059LL$	(7)
Lower limit,	$Cr = 0.0465 - 0.0092PI + 0.0609e_0 - 0.0002LL$	(8)

For 99% confident level, the following empirical equations can be obtained:

Upper limit,	$Cr = 0.2114 + 0.0023PI + 0.1395e_0 - 0.0069LL$	(9)
Lower limit,	$Cr = 0.0232 - 0.0108PI + 0.0498e_0 - 0.0012LL$	(10)

The coefficient of correlation between the predicted values of Cc using moisture content (w) is 68.52%. The empirical relations between Cc

and moisture content can be established as: Cc = -0.0484 + 0.0134w (11) Where, Cc is the compression index, and w is the moisture content.



Fig. 12 Measured Cc versus predicted Cc (Huat et al., 1995)

For 95% confident level, the following empirical equations can be obtained:

Upper limit,	Cc = 0.1538 + 0.0157 w	(12)
Lower limit,	Cc = -0.2506 + 0.0111w	(13)

For 99% confident level, the following empirical equations can be obtained:

Upper limit,	Cc = 0.2204 + 0.1648w	(14)
Lower limit,	Cc = -0.3172 + 0.0103w	(15)

CONCLUSIONS AND RECOMMENDATIONS

The stepwise variable selection analysis conducted for Cc and Cr showed significant differences in the R^2 values. The variables adopted are initial void ratio, liquid limits and plastic index. The R^2 value obtained for Cc is 78.99%, and indicated a good relationship. Cr has a R^2 value of 41.64%, which indicated a poor linear relationship.

The new empirical relationships shown in this paper can be used in preliminary analysis and feasibility studies, prior to detail laboratory tests. In addition, the results presented here can be used to verify laboratory results. The relationship between Cc and w gives a quick and easy estimation of Cc, if no other index properties are available. Most of the data falls into the 95% confidence levels. It is recommended, for design purposes, the upper limit from 95% confident intervals are used, instead of the best fit coefficients, which give conservative settlement estimation for initial design purposes.





Fig. 14 Measured Cr versus predicted Cr (Huat et al., 1995)

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