

THE CORRELATIONS OF ENGINEERING CHARACTERISTICS OF JOHOR
COASTAL CLAY

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ABSTRACT

The characteristics of coastal clay soil are different compared to other soils due to their low strength and high compressibility. It is also difficult to get an undisturbed sample of this type of soil for laboratory testing. Hence, the correlation between engineering characteristics and basic properties or between engineering characteristics itself will be useful to engineers especially for preliminary design purposes. This paper presents some correlations of engineering characteristic of coastal clay in Johor that is the clay taken from Port of Tanjung Pelepas and Pontian. An attempt was made to correlate the Atterberg limits with the shear strength and also the shear strength with depth. In general, the correlations show that the liquid limit and plasticity index increase with moisture content. The plasticity index also tends to increase with liquid limit. For the undrained shear strength it is found to increase with depth, and decreases with moisture content, liquid limit, and plasticity index. An attempt was also made to get correlation between the liquid limit with the clay content. It is found that the liquid limit increases with the increase of clay content, probably due to the clay particles tend to pull or absorb water to the surface of soil particle, making the liquid limit to be much higher. The results give an alternative for engineers to use the basic soil properties to predict the strength of soil. One can also determine the shear strength of the soil at certain depth below ground level. This will allows a quick and economic design for construction on soft clay.

ABSTRAK

Ciri-ciri tanah liat pantai adalah berbeza dibandingkan dengan tanah jenis lain kerana kekuatan yang rendah dan kebolehmampatan yang tinggi. Adalah diketahui bahawa amat sukar untuk mendapatkan sampel tak terganggu bagi tanah jenis ini untuk ujian makmal. Maka, korelasi antara ciri-ciri kejuruteraan dan sifat asas atau antara ciri-ciri kejuruteraan itu sendiri amat berguna untuk para jurutera terutamanya untuk tujuan merekabentuk di peringkat awal. Laporan ini mempersembahkan beberapa korelasi bagi ciri-ciri kejuruteraan tanah liat pantai di Johor, iaitu tanah liat diambil dari Pelabuhan Tanjung Pelepas dan Pontian. Satu percubaan telah dilakukan untuk membuat korelasi antara had Atterberg dengan kekuatan ricih dan kekuaatan ricih dengan kedalaman. Secara amnya, korelasi-korelasi menunjukkan had cecair dan indeks keplastikan meningkat dengan kandungan lembapan asli. Indeks keplastikan juga akan meningkat dengan had cecair. Manakala bagi kekuatan ricih tak tersalir didapati meningkat dengan kedalaman, dan menurun dengan peningkatan kandungan lembapan asli, had cecair, dan indeks keplastikan. Satu percubaan telah dilakukan untuk mendapatkan korelasi antara had cecair dengan kandungan tanah liat. Didapati had cecair meningkat dengan peningkatan kandungan tanah liat, mungkin disebabkan kecenderungan zarah tanah liat lembut untuk menarik atau menyerap air kepada permukaan zarah tanah, menjadikan had cecair menjadi lebih tinggi. Keputusan yang diperolehi memberikan alternatif kepada jurutera untuk menggunakan ciri-ciri asas tanah bagi meramal kekuatan tanah. Kekuatan ricih tanah juga boleh diperolehi pada kedalaman tanah yang tertentu di bawah aras bumi. Ini akan membolehkan proses rekabentuk yang cepat dan ekonomi untuk pembinaan di atas tanah liat lembut.

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LIST OF SYMBOLS

$^{\circ}\text{C}$	-	Degree Celcius
A	-	Activity
c	-	Cohesion
c_u	-	Undrained shear strength
c'	-	Effective cohesion
CID	-	Isotropically consolidated drained
CIU	-	Isotropically consolidated undrained
I_L	-	Liquidity index
I_p	-	Plasticity index
UU	-	Undrained unconsolidated
w	-	Natural moisture content
w_L	-	Liquid limit
w_p	-	Plastic limit
w_s	-	Shrinkage limit
σ	-	Stress
ϕ	-	Internal angle of friction
ϕ'	-	Effective internal angle of friction
R^2	-	Correlation of determination
s_u/σ'_{vo}	-	Soil strength ratio
σ'_{vc}	-	Preconsolidation pressure
σ'_{vo}	-	Overburden pressure

CHAPTER 1

INTRODUCTION

1.1 General

The emergence of development in construction industry has minimized the preferred site of geotechnical quality for construction although these sites are known to reduce technical problems and thus the cost associated with their construction. By that, socio-economic and political considerations have forced the use of sites of lower quality and in particular, the sites covered by compressible soils. In developed country such as Malaysia, the chances to have good quality construction sites become rarer and it is necessary to choose sites that include compressible soils, especially for industrial structures and transportation projects. Therefore, the tasks to do constructions on these compressible soils have become a challenge for geotechnical engineers all over the world.

This study presents the characterization of coastal clay in Johor and developed a fundamental understanding of engineering properties of this type of

clay. In particular, some important correlations have been established for key engineering properties.

Soils with characteristics of low strength and compressible exist all over the world. One of the most significant problem arises because of its characteristics that is difficulties in supporting loads on such foundation. The problem arises with low strength is that it leads to difficulties in guaranteeing the stability of the structure on this type of soil. On the other hand, this type of soil also associated with high compressibility which leads to large settlements and deformations of the structure.

Clays, referring to the United Soil Classification System, are fine-grained soils with more than 50% by weight passing No.200 US Standard sieve (0.075 mm). Soft clay is defined as clay with shear strength below 25 kPa (Brand & Brenner, 1989). Soft soils have weak compressibility and known to engineers as very complex, problematic, and treacherous materials. That is why many structures constructed on soft clay experiencing failure.

Because of this, it is important to continue research effort on this problem in order to resolve the problems posed by construction on soft clay.

1.2 Background of Problem

The construction on soft cohesive soil is increasing lately because there are not too many suitable sites for construction of infrastructures and other development. The problems that related to this type of soil are stability and settlement. Due to that, the understanding and knowledge of engineering characteristics of soft clay soil are critical and should be understand by people

related in this field. The selection of construction method on this formation is restricted by costs, duration of completion, and benefits.

The development in South East Asia had been so rapid that studying the soft clay soil is very important. However, the studies that been done mostly concentrated on major cities, such as Bangkok, Kuala Lumpur, Jakarta, Singapore, and others. Because of that, the coastal areas in Johor are chosen in this study in order to develop correlations that hopefully will be used in the design of structure on soft clay.

It is difficult to get samples from soft clay for laboratory testing, such as shear strength. Some of the tests take a long time to complete and also need a careful analysis. So correlations with basic properties play an important role to overcome this problem. Besides that, the correlation of shear strength with depth could also help the engineer to make prediction of the shear strength soil at certain depth below ground level.

1.3 Objectives

The objectives of this study are:

- a) To determine the engineering properties and design parameters for soft clay soil.
- b) To produce correlations between engineering characteristics and basic properties of soft clay soil for design purposes.
- c) To produce correlations between engineering characteristic and basic properties with depth of soft clay soil for design purposes.

1.4 Scope

This study was conducted on Johor coastal clay. The samples were taken from the construction project sites at the coastal area of Port of Tanjung Pelepas and Pontian. The soil samples were tested by Geolab (M) Sdn. Bhd. and the analysis carried out in this study was from the results obtained from this company. Figure 1.1 shows the location of the sites, while Figure 1.2 and 1.3 show the location map of Port of Tanjung Pelepas and Pontian, respectively.

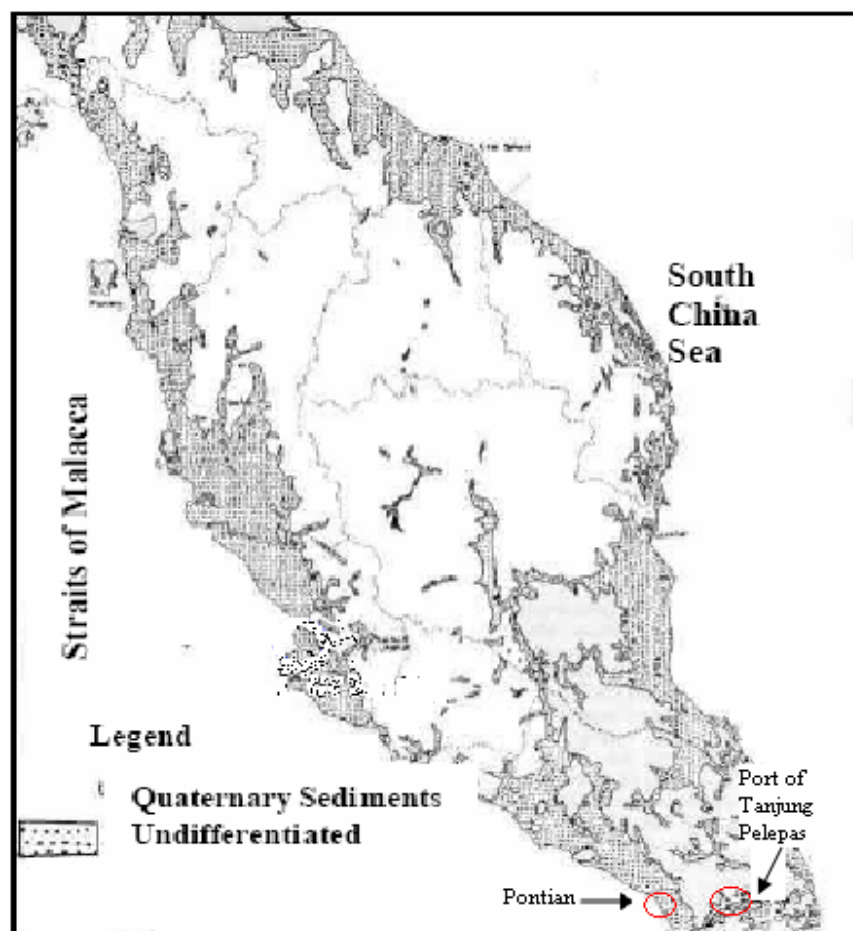


Figure 1.1: Location of the sites (After Brand and Brenner, 1981)



Figure 1.2: Location map for Port of Tanjung Pelepas (PTP)

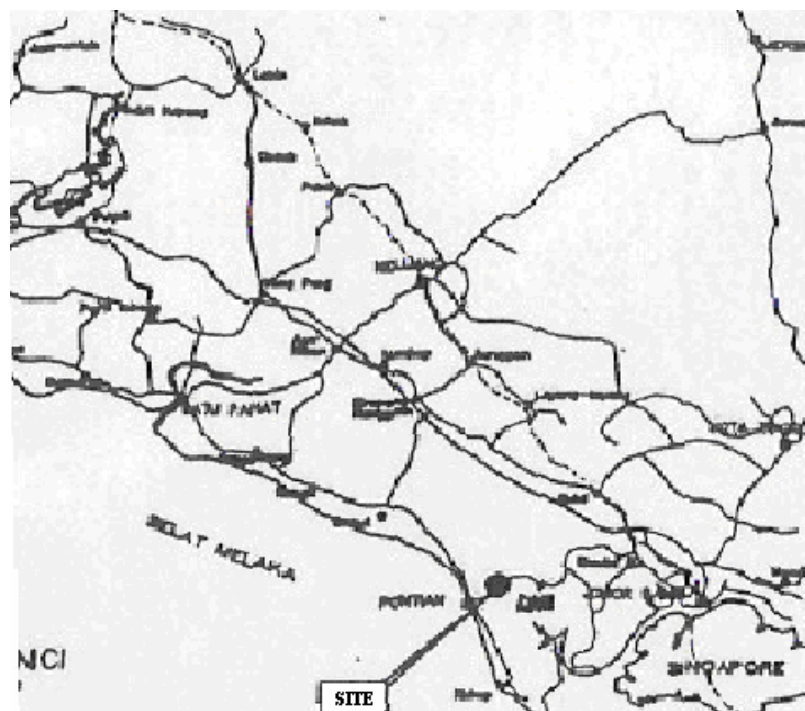


Figure 1.3: Location map for Pontian

1.5 Importance of Study

To overcome the problem encountered in soft clay, knowledge and deep understanding about the engineering characteristics of soft clay are very important. The data that obtained are analyzed will hopefully become a part of soft clay database in Malaysia. This is because there still lack of studies in soft clay properties and engineering characteristics in Malaysia. The result from this study can be referred by engineers as useful guidance for them to apply in construction on soft clay soil. The correlations produced could be used as preliminary design of structure on soft clay soil.

REFERENCES

- Abdullah, A. I. M. B. and Chandra, P. (1987). "Engineering Properties for Coastal Subsoils in Peninsula Malaysia." Proc. of the 9th South East Asia Geotechnical Conference. Vol. 1. Bangkok: Thailand. 127-138.
- Aziz, S. (1993). "Engineering Characteristics of the Coastal Soft Soils of West Peninsula Malaysia." University of Strachlyde, Glasgow: Master Thesis.
- Azmi, J. and Taha, M. R. (1990). "Some Consolidation Characteristics of Soft Muar Clay." Proc. of National Seminar on Current Geotechnical Problems in Tropical Region, Johor, 31 - 46.
- Balasubramaniam, A. S., Bergado, D. T., Sivandran, C., and Ting, W. H. (1985). "Engineering Behavior of Soils in Southeast Asia." Geotechnical Engineering in Southeast Asia. Bangkok, Thailand. 25 – 95.
- Brand, E.W. and Brenner, R. P. (1981). "Soft Clay Engineering." Elsevier Scientific Publishing Company, Amsterdam, 1981.
- British Standard Institution (1990). "British Standard Methods of Test for Soils for Civil Engineering Purpose, Part 2: Classification Test." London: BS 1377.
- Bujang, K. H., Ahmad Jusoh, and Shukri Maail (1991). "Pengenalan Mekanik Tanah." 1st Edition. Kuala Lumpur: Dewan Bahasa dan Pustaka.

- Cernica, J. N. (1995). "Geotechnical Engineering: Soil Mechanics." Canada: John Wiley and Sons, Inc. 256 – 288.
- Coutinho, R.Q. and Lacerda, W.A. (1987). "Characterization and Consolidation of Juturba Organic Clays." Proceeding of the International Symposium on Geotechnical Engineering of Soft Soils, Mexico, Vol. 1, 17-24.
- Cox, J. B. (1968). "A Review of the Engineering Properties of the Recent Marine Clay in Southeast Asia." Research Report No. 6, Asian Institute of Technology, Bangkok, Thailand.
- Craig, R. F. (1993). "Mekanik Tanah." Translation from Soil Mechanics by Aminaton Marto, Fatimah Mohd Nor, and Fauziah Kasim, 4th Edition, Academic Publishing Unit, Universiti Teknologi Malaysia.
- Hussein, A. N. (1995). "The Formation, Properties and Behavior of Coastal Soft Soil Deposits at Perlis and Other Sites in Peninsula Malaysia." University of Strachlyde, PhD Thesis, Vols I and II.
- Kobayashi, Y., Todo, H., Weerasinghe, W.A.Y. and Chandra, P. (1990). "Comparison of Coastal Clay Found in Singapore, Malaysia, and Indonesia." 10th Southeast Asian Geotechnical Conference, 16-20 April, 1990, Taipei, Taiwan.
- Kukal, Z. (1971). "Geology of Recent Sediments." Academic Press, London.
- Lambe, T.W. and Whitman, R.V. (1979). "Soil Mechanics." Massachusetts Institute of Technology, John Wiley and Sons, United States of America.

- Leroueil, S., Magnan, J. and Tavenas, F. (1990). "Embankments on Soft Clays." Ellis Horwood Limited.
- Marto, A. (1996). "Volumetric Compression of a Silt Under Periodic Loading." University of Bradford: PhD Thesis.
- McGown, A. and Cook, J.R. (1994). "Origin and Nature of Malaysian Weathered Rocks and Soil." Geotropika 94, Universiti Teknologi Malaysia.
- Menzies, B.K. and Simons, N.E. (1977). "Stability of Embankments on Soil Grounds." A Short Course in Foundation Engineering, Newnes-Butterworth, London.
- Millot, G. (1978). "Geology of Clays." Chapman & Hall, London, Chapter 5, pp 102.
- Mitchell, K.J. (1993). "Fundamentals of Soil Behaviour." John Wiley & Sons, Inc., New York, United States of America.
- Mohamad, R., Chin, C.H., Mohd, P.I. and Zaini, M.Z. (1994). "The Engineering Geology and Geotechnics of Soft Deposit in Peninsula Malaysia." Geotropika 94, Universiti Teknologi Malaysia.
- Mohd Fairus, Y. (2003). "Ciri-ciri Kejuruteraan Tanah Baki Granit di Semenanjung Malaysia." Universiti Teknologi Malaysia: Master Thesis.
- Nagaraj, T.S. and Miura, N. (2001). "Soft Clay Behavior Analysis and Assessment." A.A. Balkema, Rotterdam.

- Neoh, C.A. (2000). "Case Histories of Road Construction over Soft Ground - Engineering Problems and Solutions." Seminar on Ground Improvement - Soft Clay (SOGISC), Universiti Teknologi Malaysia, Kuala Lumpur.
- Parry, R.H.G. and Wroth, C.P. (1981). "Soft Clays Engineering." Elsevier Scientific Publishing Company, Amsterdam.
- Saiful Azhar, A.T., (2004). "Ciri-ciri Kejuruteraan Mineralogi dan Mikrostruktur Tanah Liat Lembut di Semenanjung Malaysia." Universiti Teknologi Malaysia: Master Thesis.
- Shaefer, V.R., (1997). "Ground Improvement, Ground Reinforcement, Ground Treatment Developments 1987-1997". Proceedings of sessions sponsored by the Committee on Soil Improvement and Geosynthetics of the Geoinstitute of the American Society of Civil Engineers in conjunction with Geo-Logan '97 . July 17-19,1997. Logan, Utah: ASCE, 253-255.
- Smith, M.J. (1984). "Soil Mechanics." 4th Edition, George Godwin ELBS.
- Terzaghi, K, Peck, R.B. and Mesri, G. (1996). "Soil Mechanics in Engineering Practice." 3rd Edition, Wiley-Interscience Publication, John Wiley & Sons, Inc., New York.
- Tija, H.D. (1987). "Geomorfologi." Dewan Bahasa dan Pustaka, Kuala Lumpur.
- Ting, W.H., and Ooi, T.A. (1977). "Some Properties of the Coastal Alluvia of Peninsula Malaysia." Proceeding of the International Symposium on Soft Clay. Bangkok, 89-101.
- Tuma, J.J (1973). "Engineering Soil Mechanics." Prentice-Hall, Inc.

Wright, L.D. (1978). "River Deltas in Coastal Sedimentary Environment." Ed
Davis, R.A., Springer-Verlag, New York.

Wycherley, P.R. (1967). "Rainfall Probability Tables for Malaysia." Rubber
Research Institute.