ENGINEERING PROPERTIES OF OLDER ALLUVIUM

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Dedicated to beloved parents, my lovely wife, my son Elyas, my daughter Taraneem, my grandfathers, my grandmothers, my brothers, my sisters, my sister in law and my family. Thanks for all your love and supports.

Badee Alshameri

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ABSTRACT

Moisture content is one of the most crucial factors influencing soil and rock strength. This paper deals with the effect of moisture content on strength of older alluvium under dry, wet and saturated conditions. Older alluvium is semi cemented eroded deposited and reshaped by water to make non-marine setting. Specimens were tested in for shear strength, hardness and point load index. According to these results, the petrophysical properties of older alluvium decrease with increasing moisture. The strength was extremely reduced after the moisture content increased over the range of natural moisture content i.e. at saturated condition. For soil mechanics and soil engineering projects the shear strength, friction angle and cohesion assess at dry condition in order to give classification for soil strength. While the design parameters (shear strength, friction angle and cohesion) were taken at weak condition i.e. saturated and wet condition. However the difficulties and non reliable preparing regular samples at laboratory, most of samples destroyed during the sample preparation. Point load apparatus and Schmidt (rebound) hammer test did not able to record any reading during test the samples for both wet and dry condition. Older alluvium shows equilibrium between distribution of the clay/silt and gravel with percent finer approximately 38% and 38.5% respectively, and lower presence of sand with percent finer approximately 23.4%. The range of natural moisture content was within range of 17.98 to 19.65%. The results revealed that moisture content have great influence in the reduction of the shear strength τ, friction angle $\emptyset$ and cohesion c. When the moisture content on older alluvium deposits increased the shear strength reduced to 22.3% and to 75.3% at wet and saturated condition respectively (the shear strength equal to 57.4kPa and 18.3kPa for wet and saturated condition respectively) in comparison to the magnitude of shear strength at dry condition (shear strength at dry condition equal to 74.1kPa). The same as for friction angle, when the moisture content increased the friction angle reduced to 18.6% and 66.9% at wet condition and saturated condition respectively (friction angle equal to 55.19^{o} and 22.45^{o} for wet and saturated condition respectively) in comparison to the magnitude at dry condition (at dry condition friction angle equal to 67.83^{o}). Otherwise the effective of increase the moisture content at cohesion is different i. e. the magnitude of cohesion at dry condition was equal to 21.044 kPa. At wet condition the cohesion increased to 12.7% (cohesion equal to 23.71kPa) in comparison to the magnitude at dry condition. At saturated condition the cohesion value will decreased to 54.6% (cohesion equal to 9.54 kPa) in comparison to the magnitude at dry condition.

ABSTRAK

Kandungan lembapan ialah salah satu faktor penting yang mempengaruhi kekuatan tanah dan batu. Kajian ini dibuat bagi mengkaji kesan kandungan lembapan terhadap kekuatan Alluvium tua dalam keadaan kering, basah dan tepu. Alluvium tua ialah separa tersimen. Spesimen diuji untuk kekuatan ricih, ketahanan dan indeks beban titik. Keputusan uji kaji menunjukkan sifat petrofizikal alluvium yang berkurangan apabila kelembapan meningkat. Kekuatannya menurun dengan mendadak selepas kandungan lembapan meningkat melebihi daripada kadar yang sepatutnya, sebagai contoh ketika dalam keadaan tepu. Kebiasaannya, rekabentuk mekanik tanah dan kejuruteraan tanah, kekuatan ricih, sudut geseran dan kejelikitan dibuat ketika keadaan kering dengan tujuan untuk mengklasifikasikan kekuatan tanah. Walaubagaimanapun, parameter reka bentuk (kekuatan ricih, sudut geseran dan kejelikitan) sangat terubah ketika keadaan tepu dan basah. Kesukaran dan cara pengambilan sampel yang tidak betul menyebabkan kebanyakan sampel musnah. Alat Beban Tumpu dan Ujian Hentakan Schmidt tidak dapat mencatatkan sebarang bacaan ketika uji kaji sampel dilakukan dalam keadaan basah dan kering. Alluvium tua menunjukkan persamaan di antara agihan untuk tanah liat dan batu kerikil, peratus halus di antara 38% dan 38.5%, manakala untuk pasir, peratus lulus ialah 23.4%. Kebiasaannya, bacaan untuk kandungan lembapan yang asal ialah di antara 17.98% ke 19.65%. Keputusan menunjukkan kandungan lembapan memberi kesan kepada pengurangan kekuatan ricih τ, sudut geseran $\emptyset$ dan kejelikitan c. Apabila kandungan lembapan untuk mendapan alluvium tua ditingkatkan, kekuatan ricih berkurangan kepada 22.3% dan 75.3% dalam keadaan basah dan tepu (kekuatan ricih bersamaan dengan 57.4kPa dan 18.3kPa untuk keadaan basah dan tepu) dengan membandingkan dengan kekuatan ricih dalam keadaan kering (kekuatan ricih ketika kering bersamaan dengan 74.1kPa). Begitu juga dengan sudut geseran, apabila kandungan lembapan meningkat, sudut geseran juga berkurangan kepada 18.6% dan 66.9% dalam keadaan basah dan tepu) dengan membandingkan dengan magnitud dalam keadaan kering (sudut geseran bersamaan dengan 67.83% dalam keadaan kering). Walaubagaimanapun, kandungan lembapan efektif dalam keadaan jelekit adalah berbeza. Sebagai contoh, magnitud kejelikitan dalam keadaan kering adalah bersamaan dengan 21.044kPa. Dalam keadaan basah, kejelikitan telah meningkat kepada 12.7% (kejelikitan bersamaan dengan 23.71kPa) dengan membandingkan magnitud dalam keadaan kering. Dalam keadan tepu, nilai kejelikitan akan berkurangan kepada 54.6% (kejelikitan bersamaan dengan 9.54kPa) dengan membandingkan dengan magnitud ketika keadaan kering.

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SYMBOL		DEFINITION
A	-	Initial area of the specimen
c	-	Cohesion
C_u	-	Uniformity coefficient for soil particles
C_c	-	Coefficient of gradation (curvature) for soil particles
D_{10}	-	Diameter of soil particles at percent finer 10%
D_{30}	-	Diameter of soil particles at percent finer 30%
D_{60}	-	Diameter of soil particles at percent finer 60%
d_f	-	Estimated horizontal displacement at failure, mm (in this study it assumed as = 5 mm)
d_r	-	Displacement rate, mm/min
F	-	Shear force
I.D.	-	Iron deposits leaching into the relict structure and file it
Is	-	Point load index (index of strength)
M_1	-	Mass of container + wet soil
M_2	-	Mass of container + dry soil
M_c	-	Mass of container
M_s	-	Mass of dry soil
M_w	-	Mass of water
N	-	Normal vertical force acting on the specimen
n	-	Normal stress
O.A.	-	Older alluvium
PLT	-	Point-load test

SYMBOL		DEFINITION
R	-	Rebound number
R.S.	-	Relict structure
RH	-	Schmidt (rebound) hammer test
S	-	Degree of saturation
SDI	-	Slake durability index
SDT	-	Slake durability test
SHI	-	Shore hardness index
t_{50}	-	Time required for the specimen to achieve 50 percent consolidation under the specified normal stress (or increments thereof), min
t_{90}	-	Time required for the specimen to achieve 90 percent Consolidation under the specified normal stress (or increment thereof), min
t_f	-	Total estimated elapsed time to failure, min
UCS	-	Uniaxial compression strength
w	-	Moisture content
W.G.	-	Weathering granite
μ	-	A susceptibility coefficient
σ	-	Total normal stress
σ'	-	Effective normal stress
σ_{c0}	-	Dry uniaxial compression strength
σ_{csat}	-	Fully saturated uniaxial compressive strength
τ	-	Shear strength
θ	-	Volumetric water content of soil
ϕ	-	Friction angle
γ	-	Unit weight of rock

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CHAPTER 1

INTRODUCTION

1.1 General Concept

A geotechnical engineer must take precautions when the materials at hand cannot be classified as rock or as soils in terms of their behaviour in slopes or in civil engineering works in general. In their in situ form, the geologic formations may have appearances that imply rocklike behaviour but behave very much different when it is subjected to saturated condition. Older alluvium or semi cemented sediment which was eroded, deposited and reshaped by water in a non-marine setting has this characteristics. Once disturbed, this formation may degrade to soil-size particles in a time frame and their engineering properties will deteriorate drastically, that is relevant to the long term performance of slopes built in or in other civil engineering work. The wide distribution for older alluvium in Malaysia creates problems in many field of construction such as excavation, slope stability and foundation in understanding their engineering characteristics especially the changes in dry and wet condition. The water content is known as one of the most important factors lowering the strength of rocks. A small increase in the water content may lead to a marked reduction in strength and deformability (Erguler and Ulusay, 2009).

Study in basic engineering properties such as the grain size distributions, hardness, strength, durability and shear strength parameters (cohesion c, friction angle ϕ) is important to understand the behaviour for the older alluvium and avoid the inherence problems (David, 2007). Many previous researchers, Abdul Shakoor and Barefild, 2009; Engin et al., 1998; Vásárhelyi and Ván, 2006; Romana and Vásárhelyi, 2007; Edward and Abdulshakoor, 2006; Namdar, 2010; Joseph et. al., 2009 studied the changes of engineering properties for igneous and sedimentary rocks but very minimal works has been carried out for older alluvium. Thus, this research is carried out to study the effect of water content to the shear strength, durability and strength parameters c, ϕ of the older alluvium. Determining the characteristics of this material is essential for effective evaluation of the behaviour of subsurface as a whole for many civil engineering applications (Torok and Vásárhelyi, 2010; Mohd For, 2008).

In general, the point load index I_s and uniaxial compressive strength UCS will decrease by increase of moisture content (Vásárhelyi and Ván, 2006; Adnan, 2008; Margaret Kasim and Abdul Shakoor, 1996). In addition, Edy Tonnizam et al. (2008) noted the increase of water absorption with weathering grade. Neyde Fabiola et al. (2003) found that micro-morphological features in kaolinitic soils were related to compaction, increased tensile strength, penetrometer resistance, bulk density and hard setting behaviour. Fine particles of silt and clay form structural connections between sand particles and as the material dried out the strength of these connections increased (Mathieu Lamotte et al., 1997). Namdar (2010) compared between several types of mixed soil from the mineralogy, optimum moisture content OMC, cohesion of soil, friction angle of soil and soil bearing capacity, and he found that the soil cohesion decreases continuously with reduction of clay minerals in the soil.

In rock engineering projects, the effect of moisture content is important for the safety and stability of slopes and underground openings. In addition, for conservation and reclamation of ancient buildings and monuments, determination of the effect of the moisture content on rock strength has a prime importance. This behaviour is more pronounced in fine-grained sedimentary rocks, particularly in

clay-bearing rocks. Engineering properties of the rocks (i.e. the grain size distributions, hardness, strength, durability and shear strength parameters) are very important parameters for rock classification and design of structures either upon or inside rock. In addition, they are essential for judgment about their suitability for various construction purposes. Some rock is weakened by the addition of water, the effect being a chemical deterioration of the cement or clay binder.

1.2 Importance Of The Study

This material have become notorious as a result of the numerous foundation, slope stability, excavation and embankment failure problems with which they are often associated. Most of these problems resulted from the change of moisture content. By increasing the water content, the older alluvium exhibit significant reductions in strength and deformability. Thus, by understanding the behaviour of this material will certainly help in the designing stage with the actual performance of this material.

1.3 Problem Statement

This case study is represent of one of this statement, an older alluvium at Desa Tebrau, south of Johor state in Malaysia showing different engineering properties for the same material within different conditions (dry, wet and saturated). The older alluvium behaviour at dry condition as rock, otherwise, at saturated condition it become week. In rock and soil engineering projects, the effect of moisture content is important for the safety and stability of slopes and underground openings. In addition, for conservation and reclamation of ancient buildings and

monuments, determination of the effect of the moisture content on rock and soil strength has a prime importance.

1.4 Objectives

The objectives of this research are:

1 - To investigate the occurrences and basic engineering properties of the older alluvium (i.e. the grain size distributions, hardness, durability and moisture content)

2 - To determine the shear strength and shear strength parameters (friction angle ∅ and cohesion c) of the older alluvium under dry, wet and saturated condition.

1.5 Scope And Limitations

This case study should focused on study some engineering properties of older alluvium:

-Collect the sample from the site location and description the older alluvium at field.

-Field test applies by the Schmidt hammer test.

-Laboratory tests should be include point-load test PLT, slakes durability test SDT, moisture content and direct shear strength test for the samples at different conditions.

-Laboratory tests also should be include wet sieve analysis.

-Determine the rebound number R, point load index (index of strength) I_s and slake durability index SDI for different condition than compare between its.

-Determine the shear strength τ and shear strength parameters (friction angle ∅, cohesion c) for the samples at both conditions from the laboratory tests.

REFERENCES

Abdul Shakoor and Barefild, E.H. (2009). Relationship between Unconfined Compressive Strength and Degree of Saturation for Selected Sandstones. *Environmental and Engineering Geoscience*15 (1), 29-40. The Geological Society Of America.

Adeniran, K.A. and Babatunde, O.O. (2010). Investigation of Wetland Soil Properties affecting Optimum Soil Cultivation. *Journal of Engineering Science and Technology Review.* 3 (1), 23-26. Kavala Institute of Technology.

Adnan Aydin (2008). ISRM Suggested Method for Determination of the Schmidt Hammer Rebound Hardness. *International Journal of Rock Mechanics and Mining Sciences*. 46, 627– 634. Elsevier Ltd.

Ajalloian, R. and Karimzadeh, L. (2003). Geotechnical rock mass evaluation of Givi dam site (case study, Ardabil-Iran). *International Society for Rock Mechanics.* 10th Int. Cong. On Rock Mech. (Technology road-map for Rock Mech.). Johannesburg. SAIMM Vol 1, 7-10.

Alkhafaji, Amir (1992). *Geotechnical Engineering and Soil Testing*. Bradley University, Orland, Florida, USA. Saunders College Publishing. ISBN 0-03-004377-8.

American Society for Testing and Materials (2009). *ASTM D2488*. Pennsylvania, United States. ASTM International.

American Society for Testing and Materials (2010). *ASTM D2487*. Pennsylvania, United States. ASTM International.

American Society for Testing and Materials (2005). *ASTM 5873*. Pennsylvania, United States. ASTM International.

American Society for Testing and Materials (2008). *ASTM D5731*. Pennsylvania, United States. ASTM International.

American Society for Testing and Materials (2000). ASTM D4959, 07. Pennsylvania, United States. ASTM International.

American Society for Testing and Materials (2004). *ASTM D3080*. Pennsylvania, United States. ASTM International.

American Society for Testing and Materials (2008). *ASTM D 4644*. Pennsylvania, United States. ASTM International.

Biscontin, Giovanna (2007). *Introduction to Geotechnical Engineering Laboratory Manual*. USA. Texas A and M University.

British Standards (1990). *BS 1377-2*. London. British Standards Institution.

Budhu, Muni (2007). *Soil Mechanics and Foundations*. (2nd ed.) Department of Civil Engineering and Engineering Mechanics, University of Arizona, USA. John Wiley and Sons, Inc.

Burt G. Look (2007). *Handbook of Geotechnical Investigation and Design Tables*. London, UK. Taylor & Francis Group.

Burton, C.K. (1973). *Geology and Mineral Resources*, Johor Bahru, Kulai, South Johor. Department of Geological Survey, West Malaysia.

Daniel A. Vellone and Charles Merguerian (2007). Measuring Engineering Properties of NYC Rocks Using A Schmidt Rebound Hammer–Preliminary Results. Geology Department, 114 Hofstra University. DAVCM.

Das, Braja M. (2006). *Principle of Geotechnical Engineering*. (6th ed. International Student Edition) California State University, Sacramento, USA. Thomson Learning. part of the Thomson Corporation.

Das, Braja M. (2008). *Introduction to Geotechnical Engineering*. (International Student Edition) California State University, Sacramento, USA. Thomson Learning . part of the Thomson Corporation.

David, F. (2007). *Essentials of Soil Mechanics and Foundations Basic Geotechnics*. (6th ed.). USA, Upper Saddle River, New Jersy. Pearson Education, Inc. 07458. ISBN 0-13-114560-6.

Edward and Abdul Shakoor (2006). The Effect of Degree of Saturation on the Unconfined Compressive Strength of Selected Sandstones. *International Association for Engineering Geology and the Environment, IAEG*. 606. The Geological Society of London.

Edy Tonnizam, Ibrahim Komoo, Khairul Anuar Kassim and Nurly Gofar (2008). Influence of Moisture Content on the Strength of Weathering Sandstone, *Malaysian Journal of Civil Engineering* 20 (1), 137 – 144.

Engin, C., Koncagu, È. and Paul Santi, M. (1998). Predicting the Unconfined Compressive Strength of the Breathitt Shale Using Slake Durability, Shore Hardness and Rock Structural Properties. *International Journal of Rock Mechanics and Mining Sciences*. 36, 139-153. Elsevier Science Ltd.

Erguler, Z.A. and Ulusay, R. (2009). Assessment of Physical Disintegration Characteristics of Clay Bearing Rocks: Disintegration Index Test and A new Durability Classification Chart. *Engineering Geology*. 105, 11–19. Elsevier B.V.

Erguler, Z.A. and Ulusay R. (2009). Water-Induced Variations in Mechanical Properties of Clay-Bearing Rocks, *International Journal of Rock Mechanics & Mining Sciences*. 46, 355–370. Elsevier Ltd.

Eugene R. Russell and Renk, Michael (1999). *Soils Sampling and Testing Training Guide for Field and Laboratory Technicians on Roadway*. Manhattan, Kansas Construction , Kansas State University.

Evert Hoek (2000). *Practical Rock Engineering*. Edgemont Boulevard, North Vancouver, B.C Canada. Evert Hoek Consulting Engineer Inc.

Hawkins and McConnell (1992). Sensitivity of Sandstone Strength and Deformability to Changes in Moisture Content. *Quarterly Journal of Engineering Geology and Hydrogeology*. v. 25. 2, 115-130. Geological Society of London

Ibrahim, C. and Sefer, B. C. (2008). Estimation of Uniaxial Compressive Strength from Point Load Strength, Schmidt Hardness and P-wave Velocity. *Bull Eng Geol Environ*. 67,491–498. Springer-Verlag.

International Society of Rock Mechanics ISRM (1981). *Rock Characterisation Testing and Monitoring*, ISRM Suggested Methods, Commission on testing methods. Oxford. Brown E.T., Pergamon Press. 211.

Joseph, M., Serkan, S. and Paul, H. (2009). A Study on the Effect of Moisture Content on Rock Cutting Performance. *Coal Operators' Conference*. Coal 2009. University of Wollongong & the Australasian Institute of Mining and Metallurgy. 340-347.

Kalinski, M. (2006). *Soil Mechanics Laboratory Manual*. United States of America. John Wiley & Sons, Inc.

Kemper, W. D. and Rosenau, R. C. (1984). Soil Cohesion as Affected by Time and Water Content. *Soil Science Society of America Journal.* Volume 48, 5.

Khan, Athar (2008). *Geotechnical Manual*. USA. Geotechnical Engineering Indiana Department of Transportation.

Lau, J.S.O., Gorski, B. and Jackson, R. (1993). The Effects of Temperature and Water Saturation on Mechanical Properties of Lac du Bonnet Granite. *International Society for Rock Mechanics*. 8th ISRM Congress. Tokyo. 3, 1167-1170

Margaret Kasim and Abdul Shakoor (1996). An investigation of the Relationship Between Uniaxial Compressive Strength and Degradation for Selected Rock Types. *Engineering Geology.* 44, 213-227. Elsevier Science B.V.

Mathieu Lamotte, Ary Bruand and Georges Pedro (1997). Towards the Hardening of Sandy Soils: A natural Evolution in Semi-arid Tropics. *Earth & Planetary Sciences*. 325, 577.584. Elsevie

Matsushi, Y. Matsukura, Y. (2006). Cohesion of Unsaturated Residual Soils as A function of Volumetric Water Content. *Bull Eng Geol Env*. 65, 449–455.

Mohd For (2008). *Short Course on Rock Testing*. Faculty of Civil Engineering, UTM, Johor.

Namdar, A. (2010). Mineralogy in Geotechnical Engineering. Mysore University, India. *Journal of Engineering Science and Technology Review.* 3(1), 108-110. Kavala Institute of Technology.

Neyde Fabiola, Balarezo Giarola, Alvaro Pires da Silva, Silvia Imhoff and Anthony Roger Dexter (2003). Contribution of Natural Soil Compaction on Hardsetting Behaviour, *Geoderma.* 113, 95–108. Elsevier Science B.V.

Paul W. Mayne, Barry R. Christopher and Jason DeJong (2001). *Manual on Subsurface Investigations*. Federal Highway Administration Washington, DC. National Highway Institute Publication No. FHWA NHI-01-031.

Romana, M. and Vásárhelyi, B. (2007). A discussion on the Decrease of Unconfined Compressive Strength between Saturated and Dry Rock Samples. Polytechnic University of Valencia, Spain.

Roots of Peace (2008). *Soil testing*. Afghanistan. Perennial Corp Support . Publication Galabad, No. 2008-001-AFG

Sachpazis C. I. 2004. Monitoring Degree of Metamorphism in A four-stage Alteration Process Passing from Pure Limestone to Pure Marble. *The Electronic Journal of Geotechnical Engineering, EJGE*. 0416, 25

Steiger, R. P. and Leung, P. K. (1990). Predictions of Wellbore Stability in Shale Formations at Great Depth. *International Symposium on Rock at Great Depth*, Pau, 28–31 August 1989. V3, P1209–1218. Elsevier Science Ltd.

Torok, A. and Vásárhelyi, B. (2010). The Influence of Fabric and Water Content on Selected Rock Mechanical Parameters of Travertine, Examples from Hungary. *Engineering Geology*. 03038, 9. Elsevier B.V.

Vásárhelyi, B. (2003). Some Observation Regarding the Strength and Deformability of Sandstones in Case of Dry and Saturated Conditions. *Bull. Eng. Geol. Environ*. 62, 245–249. Springer-Verlag.

Vásárhelyi, B. and Ván, P. (2006). Influence of Water Content on the Strength of Rock. *Engineering Geology*. 84, 70-74. Elsevier B.V.

Verwaal, W. (2004). *Soil Mechanics Laboratory Manual*. Bhutan. Geotechnical Laboratory of DGM in Thimphu.

Whitlow, Roy (2001). *Basic Soil Mechanics.* (4^{th} ed.) Pearson Education Ltd, Edinburgh Gate, Harlow, Esse" CM20 2JE, England © Pearson Education Limited 1983,2001 ISBN 0582-38109-6.

Zhang, Lianyang (2006). *Engineering Properties of Rocks*, Volume 4 (Geo-Engineering Book Series). Lexington, MA ,USA. ICF Consulting.