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by Muhamad Yusa

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COVER PHOTO (FRONT) SUNSET AT LOSARI BEACH, MAKASSAR (courtesy of A.Y. Baeda): LAKE OF HASANUDDIN UNIVERSITY, PURA ULUN AT BEDUGUL LAKE (BACK)

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Foreword

In many countries, its capital and major cities have been developed in low-lying area exposing to various stresses from nature and human treats. As a result, natural lowlands are turned into highly vulnerable area in safety, economic and environmental aspect. New record of the highest temperature and precipitation in many region of the world has challenged the knowledge and technology for protecting life, property, and ecological system in lowlands.

To achieve "Sustainability of Lowland to Climate Change and Natural Disaster", not only main themes as for previous ISLT like Geotechnical & Geo-environmental Engineering, Water & Environmental Engineering and City Planning and Management, but also new themes on Coastal Engineering and GIS Application for Lowland Management are concerned in the 8th International Symposium on Lowland Technology (ISLT2012).

In this year, the word "Lowlands" has brought together more than 100 researchers and engineers in related fields from 15 countries to share their great experience on coping with various problems in lowlands. Six outstanding speakers are invited to give one special lectures: Prof. D. T. Bergado (Miura Lecture); two invited lecture: Prof. D. A. Suriamihardja and Prof. W. Wangsadinata; and three keynote lectures: Prof. S. L. Shen, Prof. J. C. Chai and Dr. Olivier Hoes.

This symposium is organized by International Association of Lowland Technology (IALT) and Institute of Lowland and Marine Research (ILMR), Saga University with cooperation of Department of Civil Engineering, Hasanuddin University, Indonesia. I would like to extend my sincere appreciation to Prof. M. Madhav, the President of IALT, Prof. H. Araki the Chairman of the International Advisory Committee and Organizing Committee for their support.

I sincerely wish to express my gratitude to the International and Local organizing committee and all other staff of ILMR for their great contribution. Finally, I would like to thank all the authors for their participation. Without all of you, the symposium will never be successful.

Lawalenna Samang
Local Chairman of ISLT2012

President's Address

Institute of Lowland Technology (ILT) founded in 1991 and renamed as Institute of Lowland and Marine Research has come a long way. Apart from undertaking research and education in the specific areas relevant to problems and issues of lowlands all over the world but especially in the Asian Region, a major activity has been the conduct of International Symposia on Lowland Technology fondly referred to as ISLT. These Symposia offer a great opportunity for researchers, academics, policy makers, etc., who all are interested in studying the various issues of planning, development and management of lowlands to meet once in two years to exchange ideas and developments and to share knowledge for the common benefit of all. The need for interactions is felt continually with natural disasters striking almost all countries of the region. The saddest has been the catastrophic earthquake off the coast of Japan last year. The vulnerability of coastal areas has been once again exposed with the disastrous ten to twelve meter high Tsunami. Similar events in the other regions especially in Indonesia remind us all the need for continued research and study of coastal lowlands.

Following the successful conduct of ISLTs in Saga, Bangkok and Busan, the 8^{th} Symposium in the series is a wonderful opportunity to meet in the picturesque island of Bali thanks to the great efforts of Prof. Samang, Dr Triharianto, Mr Abdurrahman, etc. The five major themes of „Geotechnical/Geo-environmental Engineering", „Water & Environmental Engineering", „City – Urban Planning & Management", „Coastal Environmental Science & Engineering" and „GIS Application for Lowland Management" with twenty seven subthemes would cover all or most of the relevant topics of interest to everyone. Prof. Bergado, the eminent researcher and personality has been invited to present the third Miura lecture. With several keynote and invited lectures the event promises to offer the best occasion to interact and get intellectually stimulated.

ILT and ISLT have been successful because of the foresight of the founders, in particular, Prof. Norihiko Miura. They have been fostered and nurtured by eminent personalities such as Prof. Poorooshasb, Prof. Hayashi, and the members of the Councils all these years. I would like to place on record the help, support and cooperation received from the Executive President Prof. Araki, Secretary General Dr Azizul Moqsud, Prof. Bergado, the conference organizers for the success of the symposium.

Wishing the Symposium a be great event to be remembered and cherished and looking forward to meet you all,

Madhav Madhira

President, IALT

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PART 1

GEOTECHNICAL/GEOENVIRONMENTAL ENGINEERING

PREDICTION FOR CBR UNSOAKED VALUE TO CBR SOAKED VALUE AND INDEX PROPERTIES OF CLAY-SAND MIXTURE OF PEKANBARU SOILS

S. A. Nugroho [1], Yusa M. [2] and Ningsih, S. R. [3]

ABSTRACT: In design of highway, soil bearing capacity is very affecting the thickness of pavement. One of the methods to determine the soil bearing capacity in Indonesia is CBR (California Bearing Ratio) test. The field soil conditions are soaked (saturated) and un-soaked, considering these conditions, conducted CBR testing in the laboratory on soaked and un-soaked conditions. This research aims to make comparisons between CBR soaked test results for CBR un-soaked in some variation of clay content and make simple comparisons between CBR soaked for CBR un-soaked by considering the soil properties whereas can be predicted the CBR soaked value based on the CBR un-soaked test results. The results showed that there was a linear correlation between the CBR soaked and CBR un-soaked also influenced by the nature of the index (the properties of the soil). The maximum value of CBR ranges of 30-40 percent clay content.

Keywords: California Bearing Ratio, soaked and un-soaked, correlation, clay

INTRODUCTION

Sub-Grade soil bearing capacity plays very important role for the design of highway structure. It determines design thickness of the pavement. High bearing capacity of sub-grade soils reduces the required thickness of pavement. The bearing capacity of sub-grade (base soil) is mostly influenced by the type of soil, water content and its density. Several methods are available to determine base soil bearing capacity such as California Bearing Ratio (CBR) test, Plate Bearing test (to determine modulus of sub-grade reaction and modulus of resilient), Dynamic Cone Penetrometer (DCP) test, Machintosh Probe (Nugroho, 2012) and Hand Cone Penetrometer (HCP) test, which is also known as Proving Ring Penetrometer (Farshad, 2003)

It is common in Indonesia that the base soil bearing capacity for highway pavement design is determined by CBR test measurement. This can be from the laboratory CBR test or directly from field CBR test. However, base soil bearing capacity can also be determined using field tests such as DCP, HCP, and Machintosh Probe. These tests are much simpler and faster to perform. Correlation between the result of DCP test and CBR value, CBR test and HCP (Nugroho, 2012) test are available whereas the prediction between the result of CBR laboratory soaked test and CBR laboratory soaked value is hardly found. Moreover, this prediction should be determined locally based on common local experience.

This research is aimed to obtain a local correlation between the results of CBR laboratory test without soaked and CBR soaked value. The correlation is based on the comparison CBR un-soaked test results and CBR soaked value which has the same fraction of sand and clay in soil

LITERATURE RIVIEW

Proctor Compaction Test

The Proctor compaction test is a laboratory method of experimentally determining the optimal moisture content at which a given soil type will become most dense and achieve its maximum dry density. These laboratory tests generally consist of compacting soil at known moisture content into a cylindrical mould of standard dimensions using a compactive effort of controlled magnitude. The soil is usually compacted into the mould to a certain amount of equal layers, each receiving a number blows from a standard weighted hammer at a specified height. This process is then repeated for various moisture contents and the dry densities are determined for each. The graphical

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relationship of the dry density to moisture content is then plotted to establish the compaction curve. The maximum dry density is finally obtained from the peak point of the compaction curve and its corresponding moisture content, also known as the optimal moisture content (OMC).

The testing described is generally consistent with the American Society for Testing and Materials (ASTM) standards, and are similar to the American Association of State Highway and Transportation Officials (AASHTO) standards. Currently, the procedures and equipment details for the standard Proctor compaction test is designated by ASTM D698 and AASHTO T99. Also, the modified Proctor compaction test is designated by ASTM D1557 and AASHTO T180.

California Bearing Ratio (CBR) Test

The equipment for determining CBR value is a piston having an area of three square-inches. The piston is moved in vertical direction on a soil sample with a speed of 0.05 inch/minute. A Proving ring with dial gauge is attached to the piston to measure the load at certain penetration. The CBR value is the comparison between applied piston loads on a soil sample and the standard loads, which value is expressed in percentage (ASTM D-1883, AASTHO T-193).

Basically, the CBR value describes the strength soil compared to the standard material. Indirectly, it also describes the relative density of the soil. Several correlations between CBR values and the results of other field measurements exist such as to results of Dynamic Cone Penetrometer (DCP) test (Van Vuuren, 1969, Klimochko, 1991, Smith and Pratt, 1983). This has been used in practice.

A comparative study of HCP and CBR field tests has been performed by Nugroho et al. (2011) on peat, sand, clayey sand and clays soil. The study was aimed to indirectly relate the value of CBR un-soaked to CBR soaked value through the comparison of the results of HCP to CBR field tests. From the point of view of testing mechanism, CBR field test and CBR laboratory test procedures are the same. CBR field test uses static penetration whereas HCP is also uses quasi-static penetration test. Compared to CBR un-soaked test, which is also a quasi-static penetration test, CBR laboratory is a closer method. Hence, direct correlation between CBR un-soaked tests results to CBR soaked value seems to be more relevant. This correlation can be based on the same soil mixture. This study aims to obtain direct local correlation between the two latest two tests.

MATERIALS AND METHODS

In order to obtain the correlation between CBR soaked test and CBR un-soaked test results, comparison of two kind CBR test condition of several mixture soil samples from Pekanbaru were performed. The CBR tests of two condition tests were performed for each mix-soil sample from each variation. Thus, the density before and after soaked of the soil for both tests is the same for each soil from each condition. There were 45 CBR soaked tests and 45 CBR un-soaked tests performed at nine conditions of sand and clay mixture soil within the city of Pekanbaru, Indonesia. The result of index properties can be seen in Table 1. For index properties, soil can be classification for sand poorly graded (SP) to clay with low plasticity (CL)

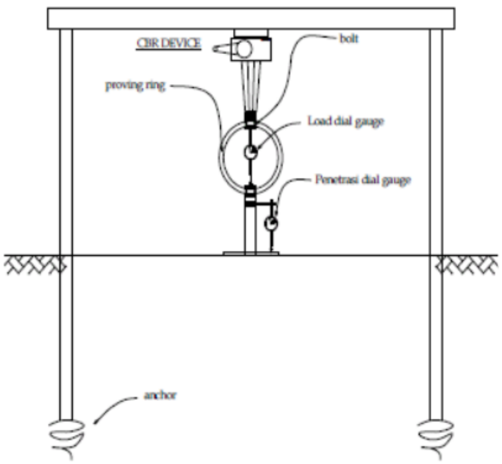
Table 1 Properties of Materials

Clays	LL (%)	PL (%)	Gs	USCS
0	NP	NP	2,671	SP
30	13,58	2,43	2,677	SM
40	16,87	5,56	2,679	SM-SC
45	19,16	6,86	2,681	SM-SC
50	20,36	7,84	2,684	SC
55	20,54	7,96	2,688	CL
60	23,81	9,86	2,704	CL
70	25,63	8,32	2,699	CL
100	37,73	16,19	2,75	CL

Materials

Materials required for field tests are a set field CBR tools and a CBR mould. The CBR mould was used to obtain undisturbed sample for determination of physical and mechanical properties of the soil in laboratory and CBR mould uses to determine CBR value after soaked in the Laboratory for 7 (seven) days. Along mould containing specimen soaked, swelling of the specimen should be noted to know swelling potential of the soil from different location. Figure 1 shows the layout of CBR test in the field (un-soaked) and in the Laboratory (soaked)

a. CBR Laboratory



b. Field CBR equipment

Fig. 1 Testing Equipment

Methods

Surcharge weights of 2.5kg are placed on top surface of soil. The penetration plunger is brought in contact with the soil and a load of 4kg (seating load) is applied so that contact between soil and plunger is established. Then dial readings are adjusted to zero. Load is applied such that penetration rate is approximately 1.25mm per minute. Load at penetration of 0.5, 1, 1.5, 2, 2.5, 3, 4, 5, 7.5, 10 and 12.5mm are noted.

The CBR soaked (CBR tested in laboratory) tests were performed simply. After mould containing specimen soaked about 7 days, mould containing specimen is placed in position on the testing machine, by pressing the piston into the mould containing specimen from different locations. After that, load is applied such that penetration rate is 1.25mm per minute and then the tests were performed. For the determination of the physical and mechanical properties of the soils, undisturbed samples were taken from each location and the tests were done in laboratory.

RESULTS AND DISCUSSION

The results of this research are presented in three parts. First, the results of the all performed tests are described. After that regression analysis between CBR test results and filed CBR values as well as regression of fraction clay with Gs, Atterberg limits, unit weight density of the soils are shown. In the final part, the correlation between CBR soaked tests results and CBR un-soaked test results are put forward

Physical and Mechanical Properties of Test Samples

The test results of physical and mechanical properties of the samples can be divided into four categories based on the type of soils as seen in Table 2 and Table 3.

Table 2: Physical and Mechanical Properties of CBR unsoaked Test Samples

Sand (%)	Clay (%)	w (%)	γd (kN/m^3)	CBR (%)
100	0	7.5	16.24	12.710
70	30	10.70	20.50	34.005
60	40	11.75	20.09	14.433
55	45	12.60	19.75	14.738
50	50	12.80	19.65	13.927
45	55	12.85	19.18	13.509
40	60	14.00	19.12	13.411
30	70	14.75	18.68	13.786
0	0	14.85	16.31	4.739

Table 3: Physical and Mechanical Properties of CBR soaked Test Samples

Sand (%)	Clay (%)	w (%)	γd (kN/m^3)	CBR (%)
100	0	9.379	16.05	9.573
70	30	10.276	19.13	21.286
60	40	12.648	18.18	8.910
55	45	13.726	18.25	4.976
50	50	13.889	18.61	4.979
45	55	14.223	18.16	3.862
40	60	15.510	17.98	3.507
30	70	19.153	17.05	1.625
0	0	24.805	15.71	2.795

For the soils which are considered as in-organic soils (Sand, Clay, Sand-Clay mixture), in general, they have water content, w_n between 7.50–14.85%, dry unit weight, γd between 16.24–20.50 kN./m^3.in field (un-soaked) and have water content between 9.379-24.805%, dry unit weight between 15.71-19.13kN/m^3 (after soaked in laboratory). Furthermore, It was recorded that the values of CBR un-soaked tests on those soils are between 4.739-34.005% and CBR soaked values between 2.795-21.286% (see Table 2 and Table 3). It is shown that the range of the physical and mechanical properties the soils varies considerably.

As also can be seen in Table 2 and Table 3, for sand soil (sand poorly graded, SP), its properties (water content, dry unit weight, CBR value) are not different compared between soaked and un-soaked condition showing that it has a significant characteristic compared to the other samples. The soils with clay fraction 70% and sand fraction 30% of sample CBR value is far above the maximum CBR value of all soils. The values of its dry unit weight, CBR soaked, and CBR un-soaked are far below the values of the other soils.

Regression Analysis of CBR, Index Properties and Unit Weight Density

Figure 2 to Figure 4 show the results of regression analyses between clay fraction, index properties and unit weigh density tests results as well as regression results between CBR un-soaked and CBR soaked test results. The regression analyses are made for each clay fraction of soils which are 0% clay, 0% sand, clay and sand and clay mixture.

It can be seen that regression using linier function suits the relation between water content and clay fraction relatively accurately whereas for the relation between Atterberg limits and clay fraction, second order polynomial function shows relatively accurate approximation. The two regression analyses will be combined later using Pearson's correlation method to find the correlation between CBR test results and Atterberg limit with unit weight density.

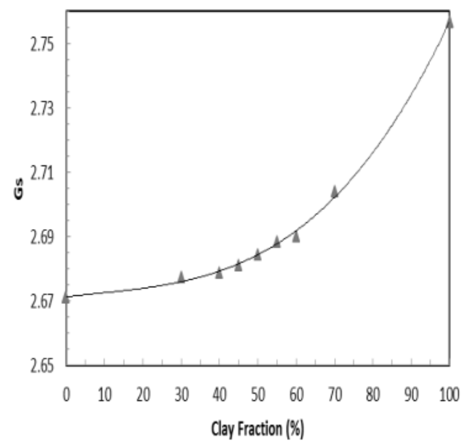


Fig. 2 Regression results for Spesific Gravity

Figure 3 shows that the value of liquid limit and plastic limit of soils increased with increasing clay fraction in the soil. Gradient increasing of liquid limit higher than plastic limit of soil. So, plasticity index of soils increases in proportion to the increase in soil clay fraction. Figure 3 also shows that optimum moisture content, determined from compaction test, same as with value of plastic limit at clay fraction between 30% and 70%. It means that for sand clay soils with for 30% to 70% clay fraction, water content for CBR test can be approximated by the value of the soil plastic limit.

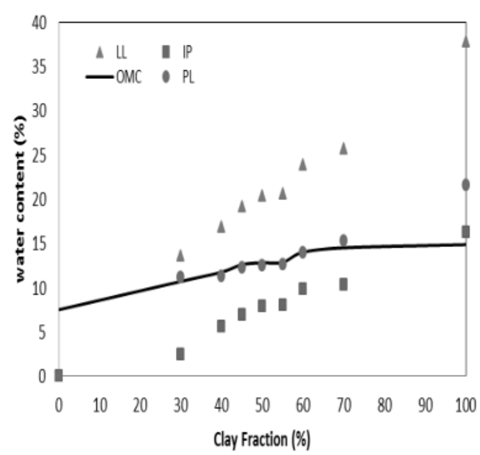


Fig. 3 Relationship between clay fraction and water content

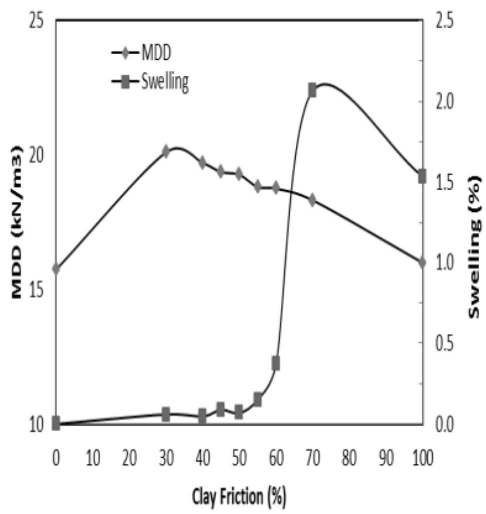


Fig. 4 Regression Results for Clay

It can be seen from Figure 4 that for the clay fraction smaller than 70%, swelling is relatively smaller. Therefore, potential swelling for soil containing fine grain smaller than 70% is relatively small.

Figure 4 shows that maximum density is on a combination of 30% clay and 70% sand. In other words, it is the best composition to obtain the optimal value of CBR is in the range of 30-70% clay fraction. Fraction of clay between 30% and 70%, soil density is more than 90% of the value of density of 30% clay and 70% sand.

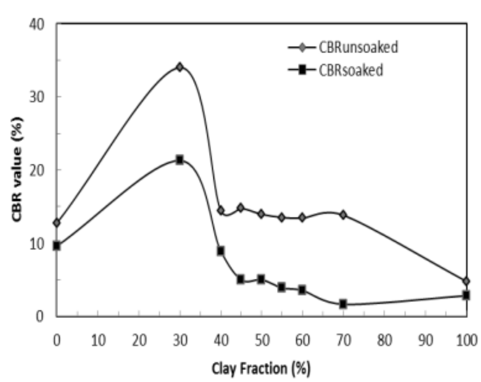


Figure 5 Regression Results for Sand-Clay Mixture

Figure 5 shows that the difference of the results of the CBR un-soaked and the CBR soaked are increase for 0% to 30% fraction of clay and then decreases again up to 45% fraction of clay. For clay fraction more than 45% difference between the CBR un-soaked and CBR soaked tend to a constant.

Correlation CBR Test Results

In the previous section, relations between Clay Fraction and index properties as well as between clay fraction and soil density have been obtained. In order to correlate the CBR un-soaked test results to CBR soaked CBR value, Pearson's correlation method is applied to both obtained power and polynomial functions for each type of soils.

On using soil index properties (liquid limit, index plasticity) and the value of unit weight density (OMC, MDD) test as variables, the following linear equation can be applied to find simple correlation between CBR soaked and CBR un-soaked on the basis of the same clay fraction value of (Nugroho, 2011)

$$\Delta Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 \qquad (1)$$

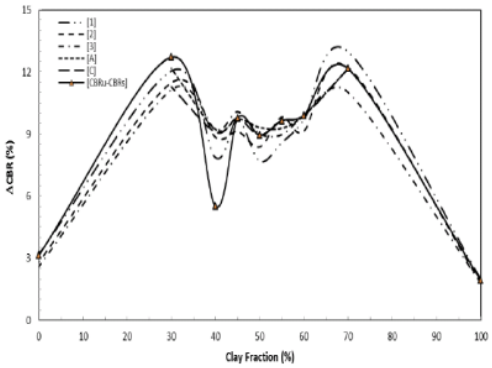
with

b_0, b_1, b_2, b_3, b_4 = constants
ΔY = value of CBR un-soaked – CBR soaked (%)
X_1 = clay fraction (%)
X_2 = value of liquid limit (%)
X_3 = value of plasticity index (%)
X_4 = value of optimum water content (%)

The values of the constants b_0, b_1, b_2, b_3, b_4 can be solved using SPSS software which is based on the solution of the following matrix

$$\begin{bmatrix} 9 & \sum X_1 & \sum X_2 & \sum X_3 & \sum X_4 \\ \sum X_1 & \sum X_1X_1 & \sum X_1X_2 & \sum X_1X_3 & \sum X_1X_4 \\ \sum X_2 & \sum X_2X_1 & \sum X_2X_2 & \sum X_2X_3 & \sum X_2X_4 \\ \sum X_3 & \sum X_3X_1 & \sum X_3X_2 & \sum X_3X_3 & \sum X_3X_4 \\ \sum X_4 & \sum X_4X_1 & \sum X_4X_2 & \sum X_4X_3 & \sum X_4X_4 \end{bmatrix} \begin{Bmatrix} b_0 \\ b_1 \\ b_2 \\ b_3 \\ b_4 \end{Bmatrix} = \begin{bmatrix} \sum \Delta Y \\ \sum X_1Y \\ \sum X_2Y \\ \sum X_3Y \\ \sum X_4Y \end{bmatrix} \qquad (2)$$

It was found that value for b_0 b_1, b_2, b_3 and b_4 are –25.28, 0.168, -0.064, -2.356 and 3.562 respectively for all soils. However, for the value of a_3, there is no unique solution for all soils



The correlation formula obtained from the correlation analyses can be written as follow:

$$\Delta CBR_{[1]}=10.78+0.01C+0.01LL-4.41IP+6.37OMC-2.15MDD \quad (3)$$

$$\Delta CBR_{[2]}=-25.75+0.34C-0.53LL-2.63IP+3.81OMC \quad (4)$$

$$\Delta CBR_{[3]}=-25.91+0.09LL-0.98IP+3.80OMC \quad (5)$$

$$\Delta CBR_{[A]}=-2.25+2.19LL-2.98IP-0.76OMC \quad (6)$$

$$\Delta CBR_{[C]}=-25.28+0.17C-0.06LL-2.35IP+3.56)MC \quad (7)$$

It is found that the value of b_0 of -25, suits for equation (4), (5) and (7), clay and sand-clay mixture (in-organic soils) whereas for the solution of b_0 is for minus 25 to minus 26.
The final correlation formula can be written as follow:

$$\Delta CBR=-25+C_1 C+C_2 LL+C_3 IP+3.5\ OMC \quad (8)$$

Where C_1, C_2 and C_3 is 0.34; -0.53 and -2.63 for sand, clay and sand-clay mixture (in-organic soils). ΔCBR is the value of CBR un-soaked-CBR soaked.
For soils containing clay between 30 and 70%, the value of C_2 need to be further tested and the C_3 value is 2.35. The formula can be rewritten below.

$$\Delta CBR=-25+0.168\ C-0.064\ LL - 2.356\ IP +3.5\ OMC \quad (9)$$

Validation of the Correlation Formula

For the validation of Equation (9), several prediction tests have been performed. Figure 7a to figure 7b show the comparison between predicted values of field CBR and measured field CBR values for different soil types and soil densities.

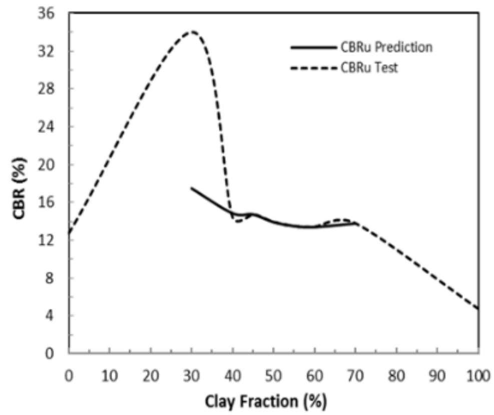


Fig. 6 Predicted and Tested CBR un-soaked (30-70%)

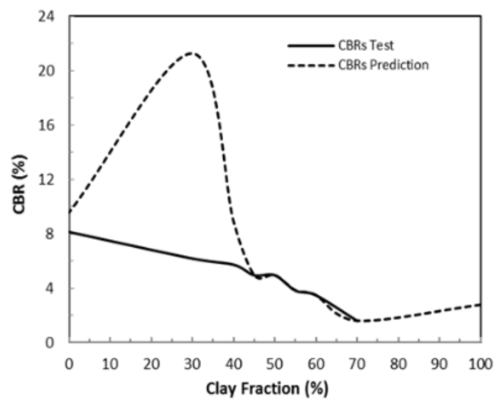


Fig. 7 Predicted and Tested CBR soaked (0-70%)

It can be seen from Figure 6 to figure 7; the predicted field CBR values give significant agreements with the measured field CBR from the tests for soils that containing clay between 30% and 70%. On the other hand, very poor agreements were found for soils contain clay less than 30% and more than 70%. Hence, the local correlation formula is only valid for in-clayey sand or sandy clay.

CONCLUSIONS

This research has been performed to find local correlation between CBR un-soaked test results and CBR soaked values. A linear correlation has been put forward for the local correlation between the two values. Verification of the formula shows that the correlation can be used relatively accurately for predicting the difference CBR values from the CBR with and without soaked test for in-organic soils (sand, clay and sand-clay mixture). The formula needs to be modified and further research need to be done for peat soils.

REFERENCES

Annual Book of ASTM Standards, 1997, Standard Test Method for CBR (California Bearing Ratio) of Laboratory-Compacted Soils, ASTM D1883, West Conshohocken, PA

Anonyms, 2007, In Situ Testing and Soil properties Correlation, International Conference on In Situ Measurement of Soil Properties and Case Histories, Bali, Indonesia

CRAIG, R., F, 2004, Soil Mechanic, 7th Edition, Taylor & Francis e-library, McGraw-Hill 270 Madison Ave, New York, USA.

DAS, Braja, M., 2008, Advanced Soils Mechanic, 3rd Edition, Taylor & Francis Group, McGraw-Hill 270 Madison Ave, New York, USA

FARRSHAD A, 2003, Potential Applications of dynamic and Static Cone Penetrometer in MDOT Pavement Design and application, Final Report, Department of Civil Engineering Jackson State University, Corporate Department of Transportation and US Department of Transportation Federal Highway Administration, Mississippi

KLIMOCHKO, Dennis, 1991, the Application of the Dynamic Cone Penetrometer Test in Determining In Situ Sub-grade CBR. Paper submitted for the 44th Annual Conference, Saskatoon, Western Association of Canadian Officials, Geotechnical and Materials Branch, Saskatchewan Highways and Transportation, Regina, Saskatchewan, Canada.

SMITH, R.B., and PRATT, D.N.,1983, *A Field Study of In Situ California Bearing Ratio and Dynamic Cone Penetrometer Testing for Road Design Investigations,* Australian Road Research, pp. 285-294,

VAN VUUREN, 1969, *Rapid Determination of CBR with the Portable Dynamic Cone Penetrometer,.* Reprint from "The Rhodesian Engineer".

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