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Contents

Bearing Capacity Correlation by Using Dynamic Cone Peneterometer Test and California Bearing Ratio Test for Mining Equipment Recommendation

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ABSTRACT

Coal mining in Indonesia has grown larger in the late century. According to a great market demand to fulfill coal supply, the coal mining company increases the coal production. Therefore, the coal mine area would be expanded to increase coal production and it needs study. Furthermore, one of the studies is bearing capacity study which is required to expand pit area. Purpose of this study is to determine the correlation of two bearing capacity methods and give the recommendation for appropriate mining equipment in field. Dynamic Cone Penetrometer (DCP) test and California Bearing Ratio (CBR) test are two methods, which are compared to obtain the best value of bearing capacity. Clay, coal, sandy clay materials are tested as sample materials. The result of this study indicates that bearing capacity value from DCP test is higher than CBR test. An increment and degresion of bearing capacity value of DCP test are not followed by CBR test, it can be concluded that bearing capacity value of CBR test is used as basic reference to recommend the mining equipment. As the result, ground pressure of mining equipment would not be more than 124kPa, as recommendation.

Keywords : bearing capacity, DCP test, CBR test, correlation

INTRODUCTION

To expand mining area requires several studies, one of them is bearing capacity study. This study aims to provide a mine equipment recommendation that could be applied in the mine are. PT. Senamas Energindo Mineral (PT. SEM) one of the mining company would like to do this study. PT. SEM is a mining company located in Central Kalimntan with an Mining Business Permitted Area approximately 2000Ha. PT. SEM will expand the mining area in Pit 2 and Pit 3, thus it will needs bearing capacity for some existing material. Studies of bearing capacity required testing that could be done either insitu or laboratory with certain condition.

OBJECTIVES

The objectives of this study is to determine the mine equipment recommendation based on materials bearing capacity in Pit 2 and Pit 3 of PT. SEM.

METHODOLOGY

This study tested bearing capacity using insitu or laboratory test. Insitu bearing capacity test is using Dynamic Cone Penetrometer (DCP). Laboratory test for bearing capacity using California Bearing Ratio test (CBR).

Firstly sampling point has been determined. After that, DCP test could be done at the location. After completing DCP test, followed by material sampling at the same point for CBR test.

For any laboratory test, sample always need preparation phase. Therefore, before entering CBR test, the sample must be prepared. Once the preparation has done, continued for physical test and proctor test.

After getting the bearing capacity value from both testing, the result will be correlated by using scatter diagram and linier regression. The correlation result used as a basic recommendation for determining mine equipment.

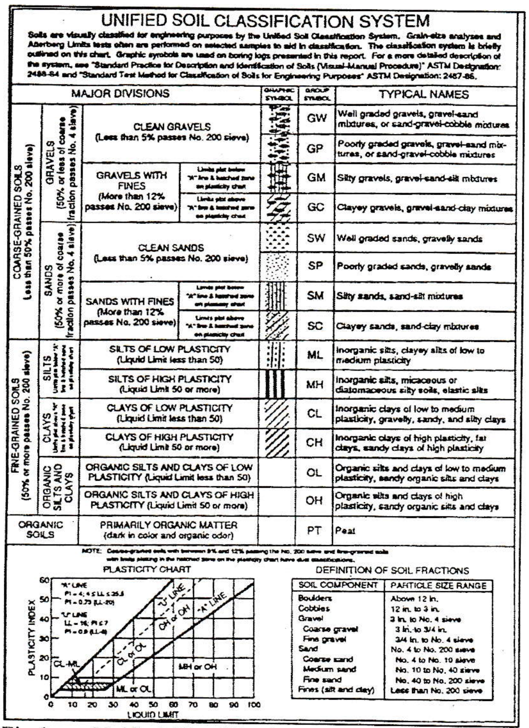
SOIL DEFINITION

Soil has several definitions in several disciplines. According to civil engineering expert, soil is defined as a natural aggregate of mineral grains that can be mechanically separated as soluble in water. According to experts in geological engineering, soil definition is the result of weathering of rock material that can be caused by plants. From those opinions could be concluded that soil is the result of weathering of rock material consisting of organic and inorganic material (Terzaghi, 1996).

Soil Classification

Soil has a certain grain size that can determine the type of soil. Determination of the type of soil called soil classification (Terzaghi, 1996). Existing soil classification methods vary, but the commonly used method is the Unified Soil Classification System (USCS). USCS soil classification method introduced by Casagrande (1948) further refined by the U.S. Corps of Engineer and Bureau of Reclamation (USBR) in 1963 in Soil Mechanics for Engineering Practices by Karl Terzaghi (1996).

According to USCS soil classified by grain size, percent escapes, and consistency limits (see Figure 1). To determine these parameters based on ASTM D2487 testing



UNIFIED SOIL CLASSIFICATION SYSTEM

Soils are visually classified for engineering purposes by the Unified Soil Classification System. Grain-size analyses and Atterberg Limits tests often are performed on selected samples to aid in classification. The classification system is briefly outlined on this chart. Graphic symbols are used on boring logs presented in this report. For a more detailed description of the system, see "Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)" ASTM Designation: 2488-84 and "Standard Test Method for Classification of Soils for Engineering Purposes" ASTM Designation: 2487-86.

MAJOR DIVISIONS			GROUP SYMBOL	TYPICAL NAMES
COARSE-GRAINED SOILS (Less than 50% passes No. 200 sieve)	GRAVELS (50% or less of coarse fraction passes No. 4 sieve)	CLEAN GRAVELS (Less than 5% passes No. 200 sieve)	GW	Well graded gravels, gravel-sand mixtures, or sand-gravel-cobble mixtures
			GP	Poorly graded gravels, gravel-sand mixtures, or sand-gravel-cobble mixtures
		GRAVELS WITH FINES (More than 12% passes No. 200 sieve)	GM	Silty gravels, gravel-sand-silt mixtures
			GC	Clayey gravels, gravel-sand-clay mixtures
	SANDS (50% or more of coarse fraction passes No. 4 sieve)	CLEAN SANDS (Less than 5% passes No. 200 sieve)	SW	Well graded sands, gravelly sands
			SP	Poorly graded sands, gravelly sands
		SANDS WITH FINES (More than 12% passes No. 200 sieve)	SM	Silty sands, sand-silt mixtures
			SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more passes No. 200 sieve)	SILTS	SILTS OF LOW PLASTICITY (Liquid Limit less than 50)	ML	Inorganic silts, clayey silts of low to medium plasticity
		SILTS OF HIGH PLASTICITY (Liquid Limit 50 or more)	MH	Inorganic silts, micaceous or diatomaceous silty soils, elastic silts
	CLAYS	CLAYS OF LOW PLASTICITY (Liquid Limit less than 50)	CL	Inorganic clays of low to medium plasticity, gravelly, sandy, and silty clays
		CLAYS OF HIGH PLASTICITY (Liquid Limit 50 or more)	CH	Inorganic clays of high plasticity, fat clays, sandy clays of high plasticity
	ORGANIC SILTS AND CLAYS	ORGANIC SILTS AND CLAYS OF LOW PLASTICITY (Liquid Limit less than 50)	OL	Organic silts and clays of low to medium plasticity, sandy organic silts and clays
		ORGANIC SILTS AND CLAYS OF HIGH PLASTICITY (Liquid Limit 50 or more)	OH	Organic silts and clays of high plasticity, sandy organic silts and clays
ORGANIC SOILS		PRIMARILY ORGANIC MATTER (dark in color and organic odor)	PT	Peat

DEFINITION OF SOIL FRACTIONS

SOIL COMPONENT	PARTICLE SIZE RANGE
Boulders	Above 12 in.
Cobbles	12 in. to 3 in.
Gravel	3 in. to No. 4 sieve
Coarse gravel	3 in. to 3/4 in.
Fine gravel	3/4 in. to No. 4 sieve
Sand	No. 4 to No. 200 sieve
Coarse sand	No. 4 to No. 10 sieve
Medium sand	No. 10 to No. 40 sieve
Fine sand	No. 40 to No. 200 sieve
Fines (silt and clay)	Less than No. 200 sieve

Fig 1. Unified Classification Soil System

BEARING CAPACITY TEST

Dynamic Cone Penetrometer Test

Bearing capacity could be done by insitu test using Dynamic Cone Penetrometer (DCP) test. DCP test done by wham load from a certain height to measure penetration rate per blow at the certain depth (Luo, 1998 in Perancangan Perkerasan Jalan dan Penyelidikan Tanah by Harry Christady, 2010). The testing procedure based on ASTM D6951/6951M. In general, DCP consist of two rods with one conical tipped and expenses (See Figure 2).

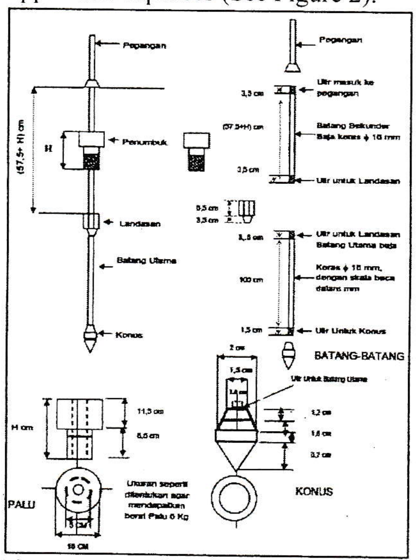


Fig 2. DCP Equipment

From DCP testing results will be obtained data sum pe blow number and depth of penetration. According t the United States Army Engineer (USAE) formulate as follows:

$$PI = \frac{\Delta Dp}{\Delta Bc} \quad \text{......} (1)$$

Description :

PI = Penetration Index (DCP Value)

ΔD_p = Penetration depth (mm)

ΔB_c = Sum of Blow based on penetration

Based on Webster (1992) in Perancangan Perkerasa Jalan dan Penyelidikan Tanah by Harry Christad (2010) bearing capacity value could be obtained b CBR value from DCP test. The correlation of DCP an CBR value formulated as follows :

$$\text{Log (CBR)} = 2.46 - 1.12 \log (\text{PI}) \quad \text{......} (2)$$

Description :

CBR = CBR value (%)

PI = Penetration Index/DCP value (mm/blow)

California Bearing Ratio Test

Bearing capacity test conducted in laboratory usin California Bearing Ratio (CBR) test. CBR test could b done by natural sample condition or modifiying sampl condition to saturated. CBR testing based on AST D1883. CBR testing is done by compacting sample i mold and conditioning sample in some ways the penetrate the piston with rating of 0.1 inches to compacted sample (Yoder&Witzak, 1975).

CBR value can be determined by the followin formula :

$$CBR_{0.1} = \frac{Corrected\ Weight\ (P)}{3 \times 1000} \times 100\% \quad \text{......} (3)$$

With P value obtained from :

$$P = k \times \text{dial} \quad \text{......} (4)$$

Description :

k = callibration (lbs)

dial = dial measurement (div)

BEARING CAPACITY

Bearing capacity is the ability of soil to withstand th load when the land was given as the burden of loadin foundation and mechanical equipment withou inducing collapse (Meyerhoff, 1947 in Soil Mechanic for Engineering Practices 1996). Bearing capacity ca be determined by USAE formula as follows :

$$BC = 1.6649 + 4.3592 \log CBR \quad \text{......} (5)$$

Description :

BC = Bearing Capacity (kg/cm^2)

CBR = CBR value (%)

GROUND PRESSURE

A mine equipment placed above materials will provide ground pressure. Wheels burden for each vehicle determined based on the specificatios ofthe manufactures. In each calculation, the largest wheel loads used as the basis for determining load and bearing capacity. If the subgrade is capable to support the greatest load on the wheel, the smaller wheel does not need to be taken. Mine equipmnet ground pressure can be adjusted to type, brand and used equipment.

CORRELATION ANALYSIS

Correlation is the relationship between the two variables is positive and negative (Supranto, 1990). Correlation analysis can be determined using scatter diagram.

In this study, the correlation is carried out by simple linear regression analysis. Linear regression can be used to predict, seek, and find out the relationship. The magnitude of the effect of independent variables on the dependent variables can be expressed by the coefficient of determination (r^2).

DATA AND STUDY

DCP Test Data

DCP test conducted at 15 different points in Pit 2 and Pit 3 with three different materials, clay, sandy clay and coal. DCP test result can be seen in Table 1 and Table 2. Bearing capacity value based on DCP test result using USAE formula (see equation 5) can bee seen in Table 3.

Table 1. DCP Test Result in Pit 2

Sample Code	Lithology	DCP (mm/blow)	CBR (%)
Pit 2 DCP LW B1	Sandy Clay	26,00	7,60
Pit 2DCP LW B2		13,81	21,45
Pit 2 DCP LW B3		33,14	8,00
Pit 2DCP LW B4		29,71	54,21
Pit 2 DCP LW A1	Coal	2,76	93,59
Pit 2 DCP LW A2		3,05	116,01
Pit 2 DCP LW A3		9,81	84,66

Table 2. DCP Test Result in Pit 3

Sample Code	Lithology	DCP (mm/blow)	CBR (%)
Pit 3 DCP LW B1	Clay	15,48	13,58
Pit 3 DCP LW B2		17,62	15,61
Pit 3 DCP LW B3		17,67	18,70
Pit 3 DCP LW B4		12,67	22,88
Pit 3 DCP LW A1	Coal	3,46	72,68
Pit 3 DCP LW A2		3,10	140,47
Pit 3 DCP LW A3		3,38	98,60

Table 3. Bearing Capacity Result Based On DCP Test

Sample Code	Lithology	Bearing Capacity (kg/cm^2)
Pit 2 DCP LW B1	Sandy Clay	5,50
Pit 2 DCP LW B2		7,47
Pit 2 DCP LW B3		5,60
Pit 2 DCP LW B4		9,22
Pit 3 DCP LW B1	Clay	6,60
Pit 3 DCP LW B2		6,87
Pit 3 DCP LW B3		7,21
Pit 3 DCP LW B4		7,59
Pit 2 DCP LW A1	Coal	10,23
Pit 2 DCP LW A2		10,48
Pit 2 DCP LW A3		9,98
Pit 3 DCP LW A1		9,68
Pit 3 DCP LW A2		10,84
Pit 3 DCP LW A3		10,25

CBR Test Data

Samples for CBR test comes from DCP testing points. The first stage is to do the CBR test with sample preparation. Preparation done for make uniform grain size. Next phase, is doing standar proctor test to determine optimum moisture content of material. The optimum moisture content add to sample for next preparation phase. Further, soaking sample in the mold up to 96 hours to get the weakest condition. CBR test result can be seen in Table 4 and Table 5. Bearing capacity value based on DCP test result using USAE formula (see equation 5) can bee seen in Table 6.

Table 4 Pit 2 Material CBR Test Result

Sample Code	Lithology	CBR (100% γdmax)	CBR (95% γdmax)
Pit 2 DCP LW B1	Sandy Clay	1,98	1,5
Pit 2DCP LW B2		2,12	0,59
Pit 2 DCP LW B3		1,69	1,38
Pit 2DCP LW B4		1,79	1,18
Pit 2 DCP LW A1	Coal	8,82	6,7
Pit 2 DCP LW A2		5,59	4,12
Pit 2 DCP LW A3		9,51	6,51

Table 5. Pit 3 Material CBR Test Result

Sample Code	Lithology	CBR Lab (100% γdmax)	CBR Lab (95% γdmax)
Pit 3 DCP LW B1	Clay	1,55	1,15
Pit 3 DCP LW B2		1,59	0,86
Pit 3 DCP LW B3		1,2	0,82
Pit 3 DCP LW B4		0,91	0,61
Pit 3 DCP LW A1	Coal	7,68	6,6
Pit 3 DCP LW A2		6,4	4,36
Pit 3 DCP LW A3		6,92	3,9

Table 6. Bearing Capacity Result Based On CBR Test

Sample Code	Lithology	Bearing Capacity (kg/cm²)
Pit 2 DCP LW B1	Sandy Clay	2,43
Pit 2 DCP LW B2		0,67
Pit 2 DCP LW B3		2,27
Pit 2 DCP LW B4		1,98
Pit 3 DCP LW B1	Clay	1,93
Pit 3 DCP LW B2		1,38
Pit 3 DCP LW B3		1,24
Pit 3 DCP LW B4		0,73
Pit 2 DCP LW A1	Coal	5,27
Pit 2 DCP LW A2		4,35
Pit 2 DCP LW A3		5,21
Pit 3 DCP LW A1		5,24
Pit 3 DCP LW A2		4,45
Pit 3 DCP LW A3		4,24

Bearing Capacity Correlation

From Table 3 and Table 6 has been obtained values of bearing capacity value from DCP and CBR test results. Furthermore, to find the relationship between the two tests, then conducted a simple linear regression correlation analysis. The analysis is done based on the type of material and not distinguish sample location. Correlation result using Ms. Excel scatter diagram cab be seen in Figure 3, 4 and 5.

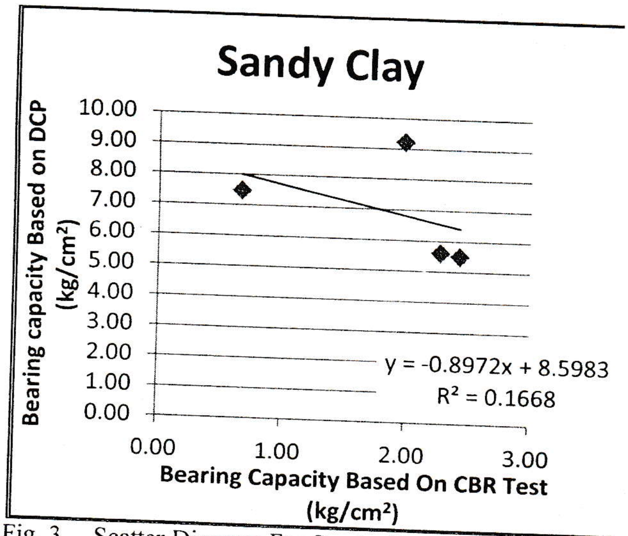


Fig. 3. Scatter Diagram For Sandy Clay

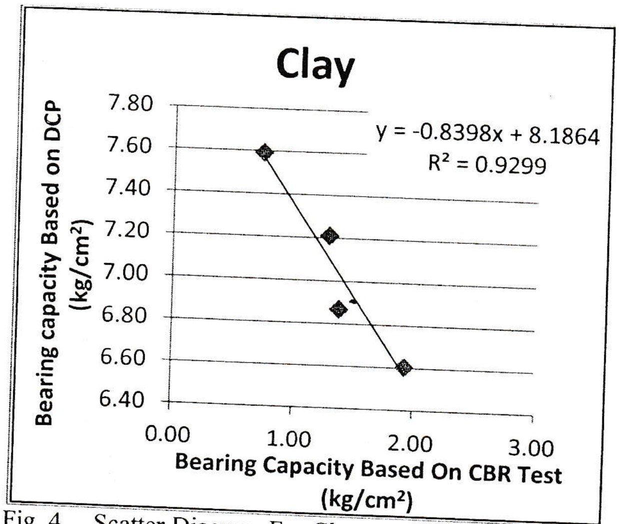


Fig. 4. Scatter Diagram For Clay

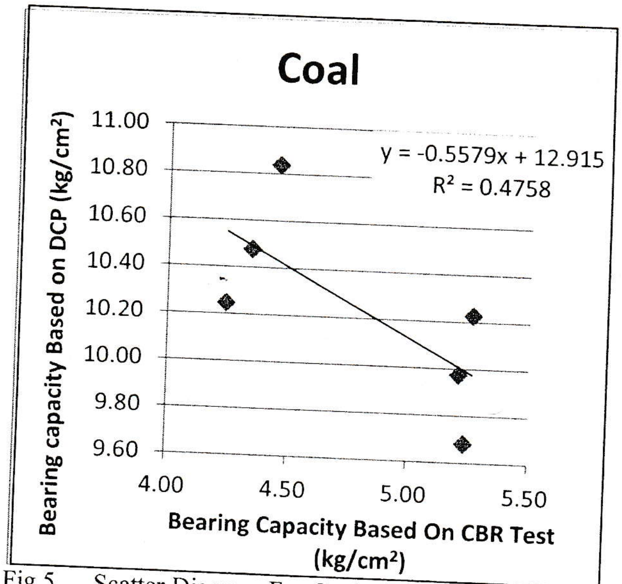


Fig 5. Scatter Diagram For Coal

Correlation is done by looking at the actual test condition. DCP test is used as dependent variable. That was done because DCP test performed directly on the field, so it would be more represent the actual conditions in field.

From the test above, DCP test was held in solid form material in field. Then CBR test was held in the weakest condition of loose materials (soaked). From the different testing condition, obtained insitu test result is more than laboratory test result.

Of correlation results using diagrams transmit and simple linear regression, it was found that more clay material has a strong correlation. It is characterized by a correlation coefficient (r^2) of 0.992. Then, for coal and sandy clay have correlation coefficient (r^2) < 0.5. It happens that the suitability test DCP and CBR will get better results if the grain size of the material is relatively uniform (Christady, 2010). In this study, clay have uniform grain size than sandy clay and coal material, mean clay having the highest coefficient correlation among all.

Yoder and Witzak (1975) in Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures Appendix CC-1 Correlation of CBR Values with Soil Index Properties (2001) have been approached as CBR value for several materials. The test result in comparasion with (or within) (??)this study can be seen at Figure 6.

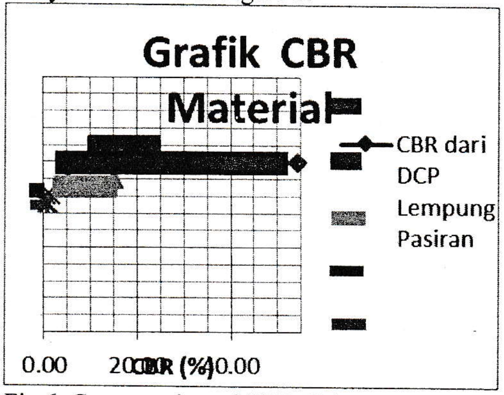


Fig 6. Comparasion of CBR Value

Figure 6 shows that unsoaked CBR for material clay CL (green bar) that held by Yoder and Witzak (1975) close to CBR value of Clay in this study (red bar). From this result could be concluded that there is a strong relationship between CBR from laboratory test and CBR value based on DCP test in the same testing condition.

Mechanical Recommendation

After performing correlation values, obtained the samlest bearing capacity value based on two study For more through application design, CBR test performed on the weakest possible condition in the field (Christady, 2010). In designing the use of carrying capacity in Indonesia using graph SKBI 2.3.26.1987 in Perencanaan Tebal Perkerasan Lentur Jalan Raya dengan Metode Analisa Komponen (1987).

On the graph that there is a minimum carrying capacity of 1 kg/cm^2. Therefore, the determination of mining equipment to use the value of CBR test results with a minimum value of the bearing capacity of 1 kg/cm^2. From the data in Table 6 obtained a minimum bearing capacity used at 1.24 kg/cm^2 (124 kPa). Mining equipment that can be used by PT SEM can be seen in Table 7.

Table 7. Mining Equipment Based on Bearing Capacity

Equipment	Brand	Type	*Ground Pressure* (kPa)
Bulldozer	Caterpillar	D10 T	116,2
Bulldozer	Komatsu	D275A-5R	109
Excavator	Caterpillar	385C L	117,6
Excavator	Komatsu	PC 800SE-8	121,61
Excavator	Volvo	EC 700NB LC	100,1

CONCLUSION

From this result of this study, it is noted that:

1. DCP and CBR test more optimal when used on materials with uniform grain size.
2. Bearing capacity value of CBR test result in certain conditions is smaller than DCP test.
3. There are strong relation between CBR test and DCP test in the same condition of sample.
4. Minimum bearing capacity used for recommendation is 124 kPa.

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