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CORRELATION BETWEEN CALIFORNIA BEARING RATIO (CBR) AND SOME SOILS PROPERTIES

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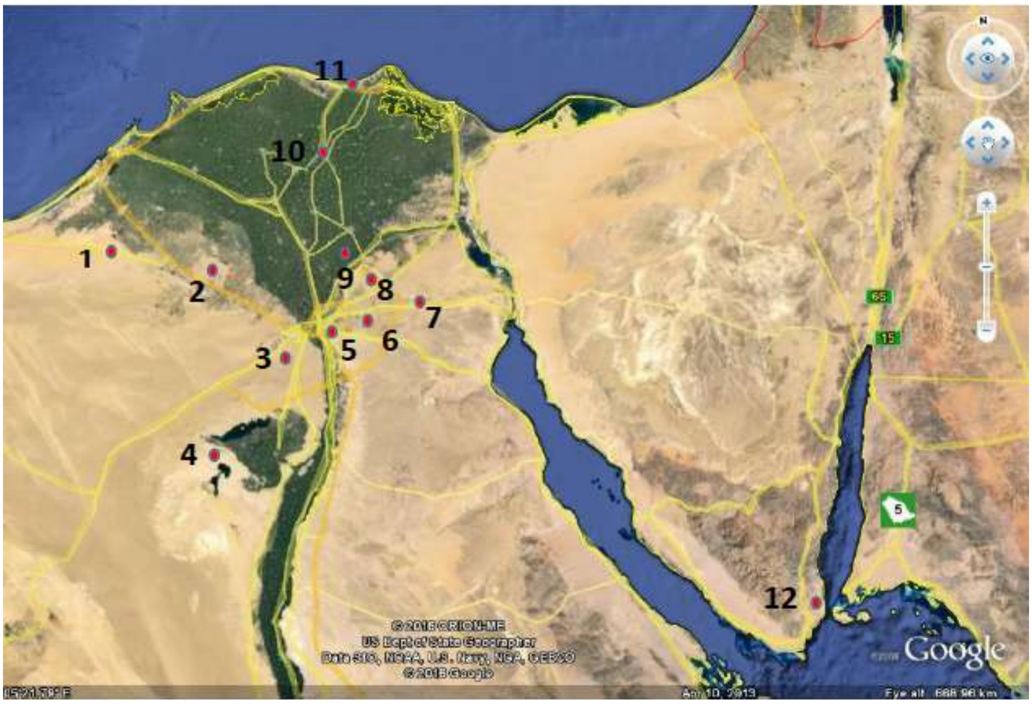
ABSTRACT

Soil properties massively affected the decision of whateverthis soil can carry specific structures of engineering works or not. Thus, accurate analysis of soil is important to ensure that these structures remain safe or not. California Bearing Ratio (CBR) value is an important soil parameter for design of flexible pavements and runway of air fields and can be used for determination of sub grade reaction of soils. Because of laboratory CBR test is time consuming, hence a method is proposed for correlating CBR value with some soil properties (which directly affected CBR%) like maximum dry density (MDD), optimum moisture content (OMC), liquid limit (LL), plastic limit (PL), plasticity index (PI) which. In this research, we aimed to determine the correlation between California Bearing Ratio value with Maximum Dry Density (MDD), Optimum Moisture Content (OMC) and plasticity index (PI) and evaluate the difference between laboratory and predicted value of CBR of some soil samples which were collected from different locations of Egypt. A number (50) of soil samples (disturbed) were collected from 12*city (Fig.1). Soil samples were analyzed and classified according to AASHTO classification also, percentages of different fractions of soil were determined. CBR, MDD, MOC, LL, PL and PI were determined. Simple and multiple linear regression analysis were used for estimating CBR. The results indicated that there was a strong positive correlation between (CBR) and MDD% in some types of studied soils and oppositely CBR value correlated negatively with MOC%. Wile, PI correlated negatively (to the lesser extent) with CBR value. Slight difference was noticed between the laboratory and the predicted CBR in A-1a, A-1-b and A-3 type of soil but a large variation was notices between the two values in A-2-4 and A-2-6 types of soil. And we can conclude that correlation equation can be used for evaluating different values of CBR.*

Keywords: *California Bearing Ratio, Maximum Dry Density (MDD), Optimum Moisture Content (OMC), Plasticity index (PI) and Soil properties.*

1. INTRODUCTION

In civil engineering works such as construction of highways, building structures, dams and other structures, the proper analysis of soil is necessary to ensure that these structures remain safe and free endue settling and collapse. These structures need a strong layer of soil to make sure the structure are strong and stable.



1	**Wady Natrun**	5	**El-Maady**	9	**Abu-Zabel City**
2	**El-Sadat City**	6	**New Cairo City**	10	**Talkha City**
3	**6 October City**	7	**Badr City**	11	**Damitta El-Gededa**
4	**Wady El-Rayyan**	8	**El-Obour City**	12	**Sharm Al-Skeikh**

Figure (1): Explain the sample position

Soil conditions vary from one location to another. So, it is difficult to predict the behavior of soil consequently, the conditions must be tested properly.

California Bearing Ratio is defined as the ratio of the resistance to penetration of a material to the penetration resistance of a standard crushed stone base material **(Das, 2006)**. The California Bearing Ratio (CBR) test is an empirical method of design of flexible pavement. It is a load test applied to the surface and used in soil investigations and it is also an indirect measure which represents comparison of the strength of subgrade.

Additionally, California Bearing Ratio is the main design input in pavement construction to assess the stiffness modulus and shear strength of subgrade material. The method was developed by the California Division of Highways as part of their study in pavement failure at World War II **(Yang, 2004)**.In CBR test, soil sample has to be collected from the location selected (Soil sample takes at least 4 days for CBR laboratory test), from which a remolded specimen has to be prepared at predetermined Optimum moisture content (OMC) and maximum dry density (MDD) with standard proctor compaction, for the test to be conducted **(Shirur and Hiremath, 2014)**.

Furthermore CBR value of the soil is influenced by different soil properties like LL, PL, PI, OMC, MDD etc. and also these tests are quick and easy to perform.

Internationally, it is to be noted that CBR test is widely accepted as a reliable method of pavement design and in soil classification of base and subbase (road base) materials for highway designs and construction. Thus it becomes necessary to add to the existing knowledge by using linear regression equations to predict the range of CBR values for use as a function of index properties where constraints as to the level of expertise and equipment arise in laboratory determination of CBR [19].

A variety of classification systems has been developed to enable the classification ofsoils as regard their mechanical physical/chemical properties. The mostimportant and best known systems are the AASHTO and the U.S.C.S. system.The AASHTO system of soil classification was developed in 1929 as the Public Road Administration Classification System. It has undergone several revisions, with the present version proposed by the Committee on Classification of Materials for Sub grades and Granular Type Roads of the Highway Research Board in 1945 **(ASTM designation D-3282 AASHTO method M14.5)**.

Soil is classified according to ASHTOO system into seven major groups: A -l through A-7. Soils classified under groups A-1, A-2. and A-3 are granular materials of which 35% or less of the particles pass through the No. 200 sieve. Soils of which more than 35% pass through the No. 200 sieve are classified under groups A-4, A-5, ,4-6,and A-7. These soils are mostly silt and clay-type materials. The classifications system is based on the following criteria:

1. Grain size

a. Gravel fraction passing in the75mm(3-in.) sieve and retained on the No. l0 (2-mm) U.S. sieve

b. Sand fraction passing the No. 10 (2-mm) U.S. sieve and retained on the No.200 (0.075 mm) U.S. sieve

c. Silt and clay: fraction passing the No. 200 U.S. sieve

2. Plasticity:The term silty is applied when the fine fractions of the soil have aplasticity index of 10 or less. The term clayey is applied when the fine fractions have a plasticity index of l1 or more.

3.*If cobbles and boulders* (size larger than 75 mm) are encountered, they are excludedfrom the portion of the soil samplefrom which classificationis made.

However, the percentage of such material is recorded.

Many researchers studied the correlation between CBR value and different properties of soil. **Patel and Desai (2010)** studied the relation between experimental and predicted CBR by regression analysis. Also, **Singh et al. (2011)**, **Ramasubbarao et al. (2013)**, **Talukdar (2014)**, **Shirur and Hiremath (2014)** and **Rakaraddi and Gomarsi, (2015)** studied the correlation between CBR and soil properties.

In this study we attempt to determine the correlation between California Bearing Ratio value with Maximum Dry Density (MDD), Optimum Moisture Content (OMC) and plasticity index (PI) and evaluate the difference between laboratory and predicted value of CBR of some soil samples which were collected from different locations of Egypt.

2. EXPERIMENTAL WORK

- ***Soil samples collection*:**

  Number of soil samples (disturbed) were collected from different location ofEgypt.

- ***Classification of soil and particle size determination:***

Various sizes of particles in all soil samples were analyzed and determined and the percentages of different fractions **also, AASHTO method M14.5)** was used to classify different soil samples and all of this date is presented in Table (1).

- ***Determination of Compaction Property and CBR value.***

California Bearing Ratio (CBR): Fresh sets of 3kg air-dried soil were mixed with suitable amount of water of about 5% of its weight of water. The sample was completed following the standard procedure **(Das, 2016)**. The sample was put in CBR mould in 3 layers with each layer compacted with 62 blows using 2.5kg hammer at a drop of 450mm (standard proctor test). The compacted soil and the mould were weighed and placed under CBR machine following the standard procedure. Load was recorded at penetration of 0.625, 1.9, 2.25, 6.25, 7.5, 10 and 12.5mm.

Compaction properties are determined by standard Proctor test as per IS:2720 (PartVII).The test was performed in a cylindrical mould of 1000 ml capacity using a rammer of weight 2.6 kg with 310 mm height of free fall. Soaked CBR values of soil sample were determined as per procedure laid down in IS: 2720 (Part XVI) - 1979. The values are shown in Table 1. Also, liquid limit and was determined by usingCasagrande and plastic limit was obtained by thread rolling method.

Plastic limit and plasticity index: Soil sample weighing 200g was taken from the material passing the 425μm test sieve and then mixed with water till it become homogenous and plastic to be shaped into a ball. The ball of soil was rolled on a glass plate to form threads which cracked at approximately 3mm diameter. The moisture content of the thread-like soil is taken as the Plastic Limit (PL). Also, plasticity index was determined.

- ***Statistical Analysis of Soil Properties.***

Both simple linear regression analysis (SLRA) and multiple linear regression analysis (MLRA), were developed for estimating soaked CBR value by using **SPSS** program.CBR value is considered as independent variable and soil the rest of properties such MDD and OMC are considered as the dependent variables.The relation of CBR value with different soil properties (MDD, OMD and PI) are presented in Figures (2:11).

Regression equation model:

$$y= b_0+b_1x_2+ b_2x_2+\dots\dots\dots+b_0x_0.$$

Where,

y : CBR (%).

$b_1, b_2, b_3 \dots b_n$.: constants.

$x_1, x_2, x_3 \dots\dots x_n$: soil properties considered in the equation.

3. RESULT AND DISCUSSION:

3.1 Soil analyses

Table (1) represents the analyses of soil, Compaction Characteristics and CBR (%) of different soil samples. The results showed that Maximum dry density values were 2.09, 2.06, 2.07, 1.91 and 1.77 for A-1-a, A-1-b, A-2-4, A-2-6 and A-3 ,respectively. For Optimum moisture content, the were 7.76, 8.24, 6.80, 9.39 and 12.9 for A-1-a, A-1-b, A-2-4, A-2-6 and A-3 ,respectively. However, CBR values were 95.8, 35.6, 38, 23.9 and 24.3 for A-1-a, A-1-b, A-2-4, A-2-6 and A-3 ,respectively.

Table (1): Analyses of soil, Compaction Characteristics and CBR.

Soil type	Gravel (%)	Sand (%)	Fines (%)	LL (%)	PL (%)	Compaction Characteristics		CBR (%)
						MDD	OMC	
A-1-a	84	14.5	1.5	11	3	2.09	7.76	95.8
A-1-b	57	23	20	14	4	2.06	8.24	35.6
A-2-4	29	45	26	21	10	2.07	6.80	38.0
A-2-6	23	60	17	26	14	1.91	9.39	23.9
A-3	0	100	0	16	16	1.77	12.9	24.3

3.2 Correlation between MDD (%) and CBR (%) of different soil types.

Results of table (2) presents the correlation coefficients between maximum dry density (MDD%) and CBR (%) for different type of soil. For A-1-a, there was a strong significant ($P \leq 0.05$)positive correlation between CBR and MDD and this indicates that as MDD increases CBR value decreases (R^2 = 0.61) and this also insure a reasonable fit to the data which indicate that when MDD increases CBR value decreases (fig. 2). While, for A-1-b, A-2-4 and there was almost no correlation between CBR % and MDD (fig. 3 &4). Moderate significant ($P \leq 0.05$)positive correlation was found in A-2-6 type of soil (fig. 5). Oppositely, very strong significant negative correlation was found in A-3 type of soilwhich indicated that when the value of MDD increased the value of CBR decreases linearly (R^2 = -0.96), and this also matched with the data (fig. 6). These results agreed with the results of **(Shirur and Hiremath, 2014)** who found strong positive correlation between CBR% and MDD%. Also, **Korde and Yadav, (2015)** and **Rakaraddi and Gomarsi**, (2015)found similar results.

3.2 Correlation between OMC (%) and CBR (%) of different soil types.

Table (2) also, presents the correlation coefficients between optimum moisture content OMC (%) and CBR (%) for different type of soil. Strong significant ($P \leq 0.05$)negative correlation was found in A-1-a, A-1-b and A-2-4 types of soil, this indicates that as the value of OMC increases resulted in decreasing the value of CBR (figs. 7, 8 & 9) however, weak negative correlation was found in A-2-6 type (fig. 10). On the other hand, very strong significant (P≤ 0.05)positive correlation was found in A-3 type of soil between OMC (%) and CBR (%),(fig. 11). These results are in line with the results of **(Shirur and Hiremath, 2014)** who found strong negative correlation between CBR% and OMC% and this means that as the increase of MOC, CBR vale decreases. Also, **Korde and Yadav, (2015)** and **Rakaraddi and Gomarsi**, (2015)found similar results.

3.3 Correlation between PI (%) and CBR (%) of different soil types.

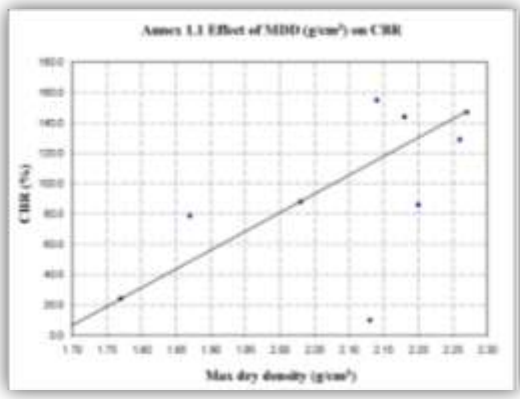
Results indicated that there was a weak positive (non significant) correlation between P (%) and CBR (%) for A-2-4 type of soil (fig. 12). On the other hand, for A-2-6 type, there was a negative (non significant), and that means almost no correlation between CBR and PI (fig. 13).These results a greed partly **agreed with Korde and Yadav, (2015), Rakaraddi** and **Gomarsi**, **Talukdar (2014)** who reported that PL (%) had strong negative correlation with CBR (%).

Table (2): Correlation coefficient between CBR and Other properties of soil:

Soil type	Correlation coefficient (R^2) (CBR*MDD)	Correlation coefficient (R^2) (CBR*OMC)	Correlation coefficient (R^2) (CBR*PI)
A-1-a	0.61*	-0.54*	-
A-1-b	0.12^{NS}	-0.45*	-
A-2-4	-0.06^{NS}	-0.60*	0.24^{NS}
A-2-6	0.33*	-0.09^{NS}	-0.12^{NS}
A-3	-0.96*	0.87*	-

NS **Not significant.**

- **significant (P≤ 0.05).**



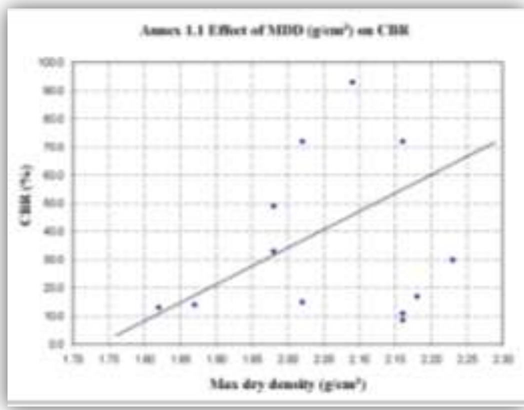


Figure (2): Relation between MDD and CBR of A-1-a soil. **gure (3): Relation between MDD and CBR of A-1-b soil.**

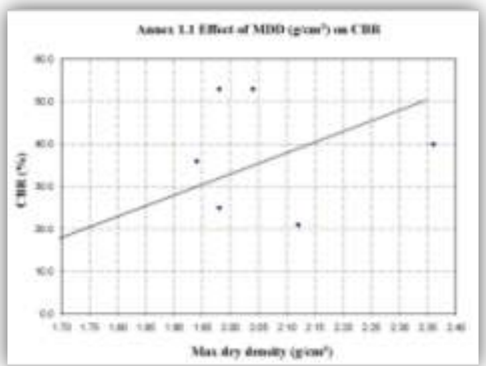


Figure (4): Relation between MDD and CBR Of A-2-4 soil.

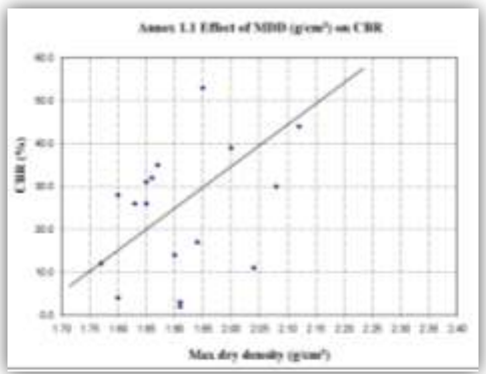


Figure (5): Relation between MDD and CBR of A-2-6 soil.

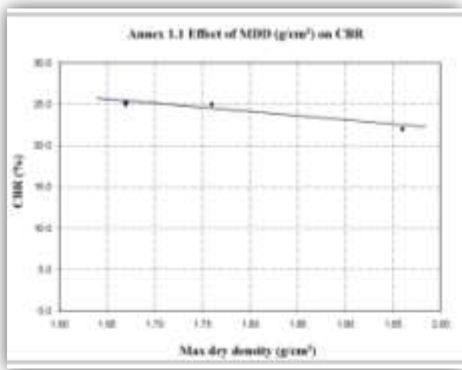
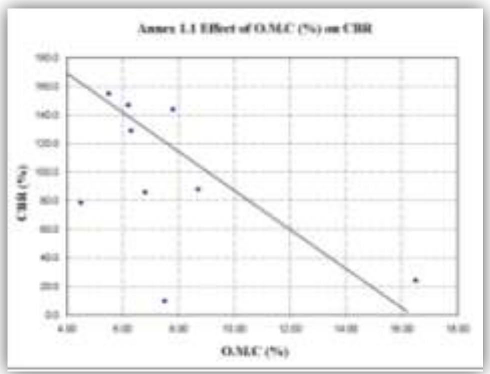


Figure (6): Relation between MDD and CBR of A-3 soil.



: Relation between MOC and CBR of A-1-a soil.

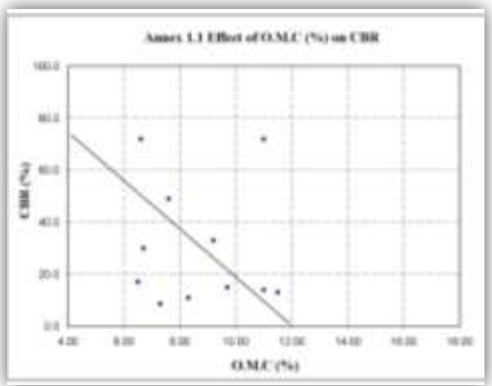
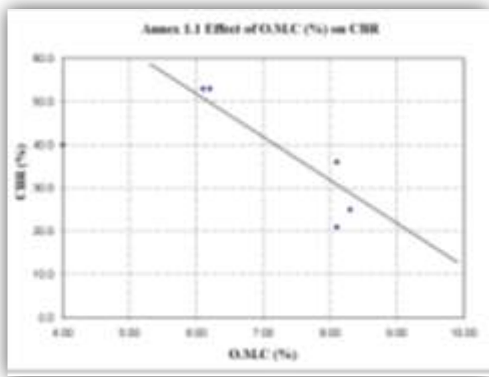
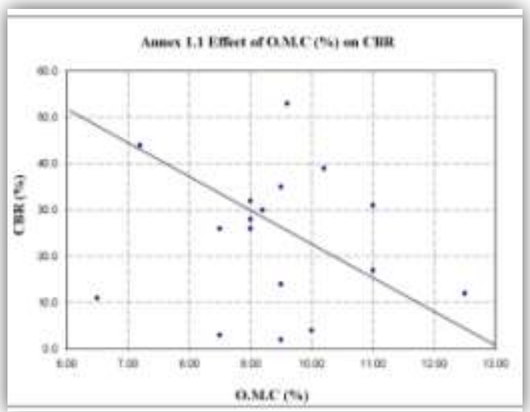


Figure (8): Relation between MOC and MOC of A-1-b soil.



: Relation between MOC and CBR of A-2-4 soil.



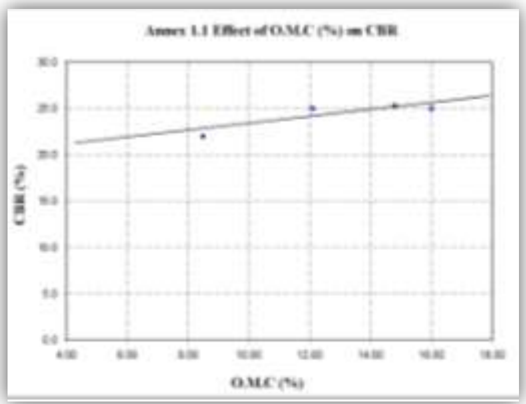
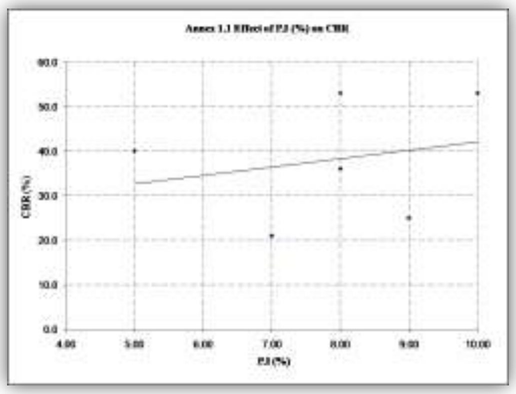


Figure (10): Relation between MOC and CBR of A-2-6 soil.

Figure (11): Relation between MOC and CBR of A-3 soil.



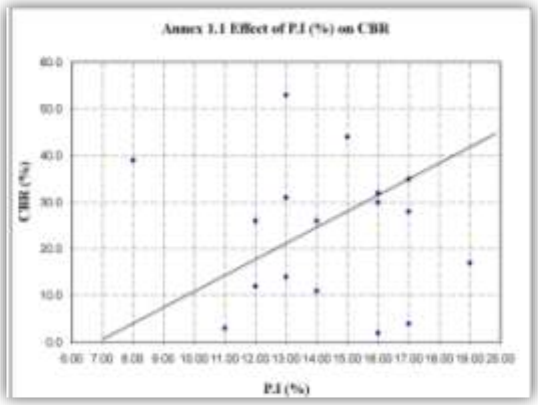


Figure (12): Relation between PL and CBR of A-2-4 soil.

Figure (12): Relation between PL and CBR of A-2-6 soil.

3.4 Results of regression Analysis

Regression analysis between CBR value with different soil properties were presented in Figures (2:12) and table (3). It shows the linear trend line, which shows the effect of various soil properties with CBR value. The regression analyses has been carried out by considering CBR value as the dependent variable and soil properties as independent variable. The results are included in table (3). It is clear that the maximum dry density (MDD) and optimum moisture content (OMC) affects directly the CBR value. However, Plasticity index (PI)did not have obvious affect on the CBR value.

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Table (3): Regression equations of CBR for different soil types.

Description		Regression model
A-1-a	CBR vs. MDD	-411.68 + 246.15*MDD
	CBR vs. MOC	210.408 - 12.922*O.M.C
	CBR vs. MDD & MOC	-100.636 + 123.075*MDD - 6.461*O.M.C
A-1-b	CBR vs. MDD	-224.516 + 129.032*MDD
	CBR vs. MOC	108.457 - 9.114*O.M.C
	CBR vs. MDD & MOC	-58.029 + 64.516*MDD - 4.557*O.M.C
A-2-4	CBR vs. MDD	-67.5 + 50*MDD
	CBR vs. MOC	110 - 9.756*O.M.C
	CBR vs. PI	-11 + 6.25*P.I
	CBR vs. MDD & MOC & PI	50.28 MDD – 70.22
A-2-6	CBR vs. MDD	-165 + 100*MDD
	CBR vs. MOC	99 - 7.667*O.M.C
	CBR vs. PI	-24.15 + 3.45*P.I
	CBR vs. MDD & MOC & PI	-45.075 + 50*MDD - 3.83*O.M.C + 1.725*P.I
A-3	CBR vs. MDD	49.8 - 14*MDD
	CBR vs. MOC	19.4 + 0.4*O.M.C
	CBR vs. MDD & MOC	34.6 - 7*MDD + 0.2*O.M.C

3.5 Comparison between laboratory and computed CBR (%) for different soils

From the results of regression analyses as we remained above it is clear that maximum dry density (MDD) and optimum moisture content (OMC) affects directly the CBR value for different soil type. This means that CBR value prediction model based on regression analyses are near to experimental values for different soil type and we can depends on it to predict the value of CBR (figs. 13, 14, 15,16 & 17).

Table (4) presents the comparison of the means of CBR for different soil type , from the comparison of the CBR value obtained from the laboratory and the predicted CBR value from the present equation:

Predicted CBR= - 45.075 + 50*MDD - 3.83*O.M.C + 1.725*P.I

It is obvious that slight difference was noticed between the laboratory and the predicted CBR in A-1a, A-1-b and A-3 type of soil (95.8 vs 107.0, 35.6 vs. 37.1 and 24.3 vs. 24.8), (figs. 13, 14 &17) but a large variation was notices between the two values in A-2-4 and A-2-6 types of soil and this may be attributed to the inclusion of PI in these two types equations (38.0 vs. 58.8 and 23.9 vs. 39.1), (figs. 15 & 16). These results a partly agreed with the results of **(Shirur and Hiremath, 2014)**. Also, **Talukdar (2014), Korde and Yadav, (2015)** and **Rakaraddi and Gomarsi**, (2015)found similar results.

Table (4): comparison between laboratory and computed CBR (%) means for different soils.

Soil type	Laboratory CBR (%) mean	Laboratory CBR (%) mean
A-1-a	95.8	107.0
A-1-b	35.6	37.1
A-2-4	38.0	58.8
A-2-6	23.9	39.1
A-3	24.3	24.8

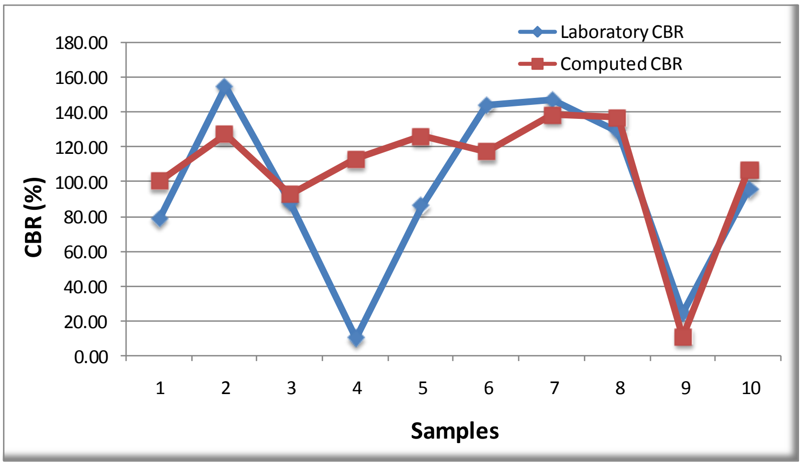

Figure (13):Comparison between experimental and predicted CBR value for A-1-a.

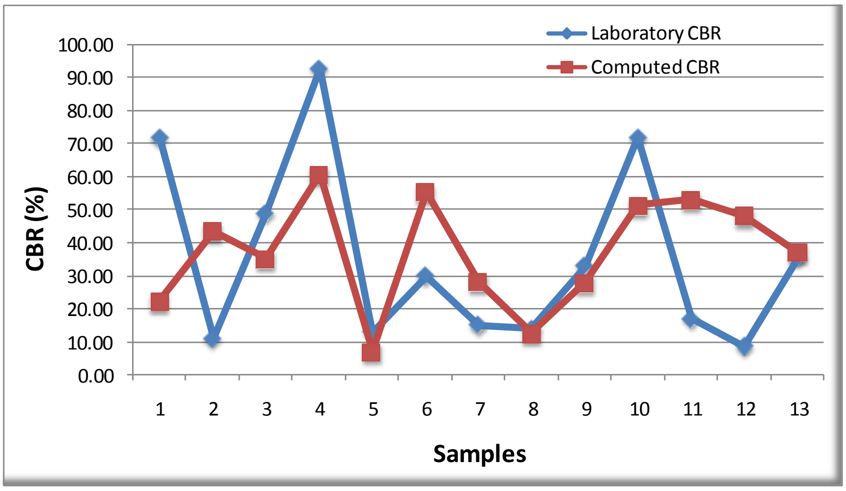

Figure (14):Comparison between experimental and predicted CBR value for A-1-b.

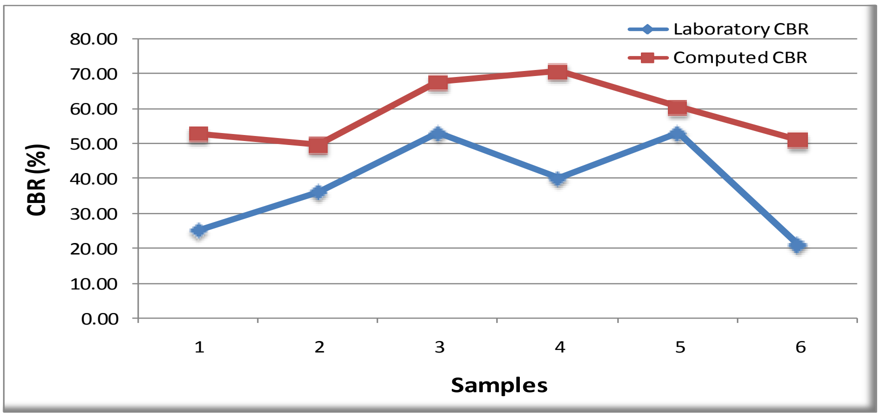

Figure (15):Comparison between experimental and predicted CBR value for A-2-4.

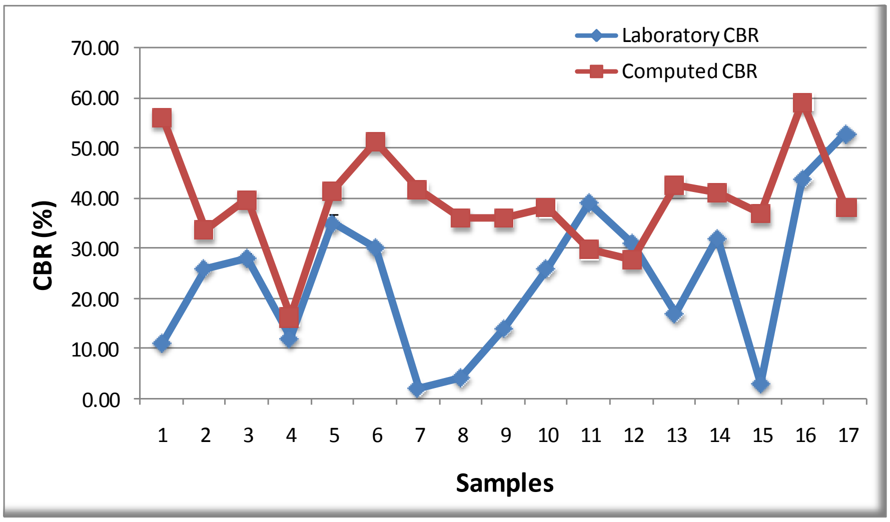

Figure (16):Comparison between experimental and predicted CBR value for A-2-6.

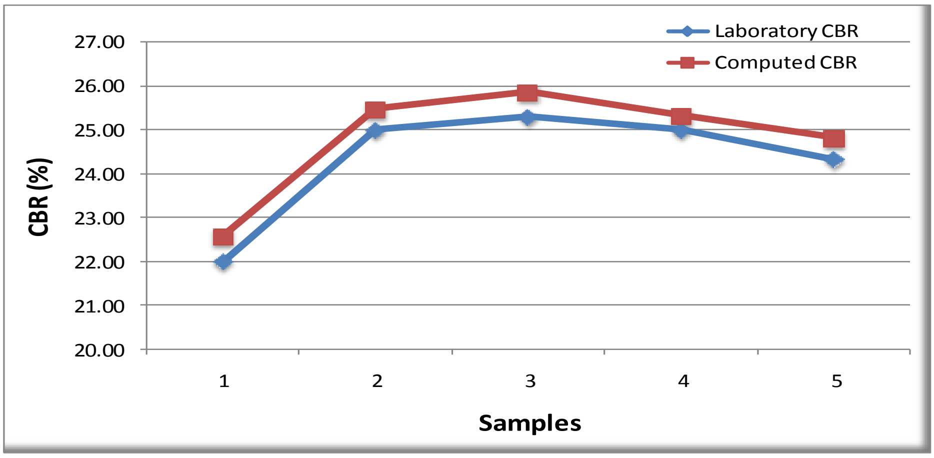

Figure (17):Comparison between experimental and predicted CBR value for A-3.

4. CONCLUSIONSAND RECOMMENDATIONS.

From the above findings, it can be concluded that:

1- There was a strong positive correlation between California bearing ratio (CBR) value and MDD% in some types of studied soils and oppositely CBR value correlated negatively with MOC%. Wile, PI correlated negatively (to the lesser extent) with CBR value.

2- The model equation (CBR= - 45.075 + 50*MDD - 3.83*O.M.C + 1.725*P.I) which was obtained from regression analysis refers a good relation in prediction of CBR value from MDD % and OMC%.

3- Slight difference was noticed between the laboratory and the predicted CBR in A-1a, A-1-b and A-3 type of soil but a large variation was notices between the two values in A-2-4 and A-2-6 types of soil.

4- Correlation equation can be used for evaluating different values of CBR.

5- Much more studies with a large number of samples must be developed to study the correlation of CBR (%) with different types of soils in Cairo as a big city and give more accurate recommendations.

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