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An Estimated Correlation between California Bearing Ratio (CBR) with some Soil Parameters of Gypseous Silty Sandy Soils

Taha Yaseen Abdulnabi*
Zena Ghazi Abdulrazzaq

Ministry of Construction and Housing, National Center for Construction Laboratory (NCCL) Baghdad , Iraq

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ABSTRACT

California Bearing Ratio (CBR) value represents the main soil characteristic factor for paving design of flexible pavements & paving of airport sites. It should be used to determine subgrade modulus of crust soil layer, by using certain correlations. It is a very important engineering parameter for soil condition for design of subgrade of flexible roads. CBR values of soil may be affected by other parameters, like maximum dry density (MDD) & optimum moisture content (OMC), soil types, (coarse material of gravel and sand content), etc. for un-soaked condition of samples. Evaluation of CBR in direct test is a time waste process. This case study was conducted to find out the relationship between CBR values with MDD, OMC, standard penetration test (SPT) and coarse material content of some soil samples collected from the investigated project during 2011 with approximate area about (30) Km^2, with Latitude (32.319810° -32.412226°) and Longitude (44.144141° - 44.243775°). A statistical method was used for estimating the relationship between the CBR and MDD, OMC, standard penetration test (SPT) and coarse material content of the soil desiring to obtain a relationship and a formula combining the previous two variables. A reasonable relationship represented by first degree formula was obtained. On the other hand, the time and efforts will be minimized in estimation of CBR instead of the used processing to determine the soil parameter.

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علاقة تقديرية بين قيم التحمل الكاليفورني وبعض خواص الترب الجبسية الرملية الطينية

طه ياسين عبدالنبي / وزارة الاعمار والاسكان والبلديات والاشغال العامة - المركز الوطني للمختبرات الأنشائية
زينة غازي عبدالرزاق / وزارة الاعمار والاسكان والبلديات والاشغال العامة - المركز الوطني للمختبرات الأنشائية

الخلاصة

إن نسبة التحمل الكاليفورني (CBR) تعتبر من القيم المهمة في معطيات الخواص الهندسية للتربة وتكمن أهميتها في تصميم الطرق المرنة ومدرج المجالات الجوية. ويمكن أيضا أن تستخدم لتحديد معامل رد فعل للتربة بعلاقة متبادلة. وهي من أهم خصائص التربة الهندسية في التصميم. إن قيمة نسبة التحمل الكاليفورني للتربة تعتمد على العديد من العوامل مثل الكثافة العظمى الجافة (MDD)، محتوى الرطوبة الأمثل (OMC) ونوع التربة (التي تحتوي المواد الخشنة من الحصى والرمال)، وغيرها للحالة غير المشبعة من العينات. إن تحديد قيمة CBR عبارة عن عملية تستغرق وقتا طويلا. ويتمثل البحث في محاولة لإيجاد علاقة بين قيم ال(CBR) مع قيم (MDD، OMC) وضربات فحص الاختراق القياسي (SPT) وكذلك محتوى المواد الخشنة لعينات من التربة تم جمعها من تحريات لمشروع مطارفي محافظة كربلاء خلال عام 2011 ويمتد على مساحة تقارب حوالي (30) كم مربع وكما هو مبين في مخطط الموقع في الملحق ، حيث يقع بين كربلاء (شمالاً) والنجف (جنوباً)، نهر الفرات (شرقاً) والصحراء الغربية (غرباً) في العراق. تم استخدام طريقة إحصائية لتقدير العلاقة بين قيمة نسبة التحمل الكاليفورني CBR و(MDD، OMC) وضربات فحص الاختراق القياسي (SPT) ومحتوى المواد الخشنة من التربة لغرض الحصول على علاقة وصيغة الجمع بين المتغيرين السابقة .وتم الحصول على علاقة منطقية ممثلة بالصيغ المحددة في الاستنتاجات. وذلك لتقليل الوقت والجهد في تخمين قيمة CBR التي تعتمد على ما سبق ذكره من معامل التربة المذكورة أنفاً.

الكلمات الدالة: نسبة التحمل الكاليفورني، تربة رملية غرينية ، تربة جبسية ، النسبة المثلى للمحتوى المائي ، القيمة العظمى للكثافة.

* Corresponding Author: E-mail: tahayaseen58@yahoo.com

1. INTRODUCTION

The California bearing ratio (CBR) is described as penetration test to estimate the mechanical strength of natural soil, sub-grades and base courses beneath new carriage way construction. It was developed by the California division of highway in 1929 to predict the behavior of pavement materials. It is a common and comprehensive test currently practiced in the design of flooring to assess the stiffness values and shear strength of ground material so as to determine the thickness of overlying pavement layers. In road construction, civil engineers always encounter difficulties test in tests determining the representative CBR values for the design of roads.

The applied pressure is then divided by the pressure required to achieve an equal penetration on a standard crushed rock material. The CBR test is described in ASTM Standards [1] D-1883-05 (California bearing ratio of laboratory compacted soils for laboratory prepared samples) and D - 4429 (California bearing ratio for soils in place), and AASHTO T193 [2]. The CBR test is fully explicated in BS 1377: soils for civil engineering purposes: Part 4, compaction related tests, and in Part 9: In-situ tests, [3].

The CBR ratio was developed for evaluating the load-bearing capacity of soils used for construction of roads. The CBR ratio can also be used for measuring the load-bearing capacity of unimproved air strips or for soils under paved air strips. Hardening of surface means higher CBR ratio. A CBR value is equal to 3% for tilled farmland, while CBR equal to 4.75% for turf as moist clay and moist sand, while moist sand may have a CBR% value of 10%. And in high quality crushed rock, the CBR value is over 80% compared to standard material for this test is crushed California limestone which has a value of 100% [4], meaning that it is not easy to encounter CBR values of above100% in well compacted areas.

$$CBR = (Ƥ / Ƥs) \times 100 \qquad (1)$$

Where: Ƥ = applied pressure for site soils (N/mm²)

Ƥs = pressure to achieve same penetration on California crush stone (N/mm²)

The explanation and enrolling of (CBR) values of specimen at 2.54 mm penetration and 5.08 mm penetration, in general, the (CBR) value at 2.54 mm will be greater that at 5 mm and in such above case the it shall be taken as (CBR) of 2.54 mm penetration for design purpose. If (CBR) for 5.08 mm exceeds that of 2.54 mm, then the test should be repeated. If identical results follow, the (CBR) corresponding to 5.08 mm penetration should be taken in design. In general, most of the Iraqi road system are identified as flexible paving. There are different methods of design of flexible paving.

The design for new pavements should be based on the strength of the subgrade and subbase layers, which are made at optimum moisture content (OMC) matching with Proctor compaction. In case of existent road demanding improving of subgrade layer, the soil should be oscillated and trimmed at the suitable field water content and inundated for 96 hours before testing. But, Bindra [5] reported that, inundation for 96 hours may be very effective and may deteriorate in some cases. This test method is used to evaluate the potential strength of subgrade and subbase, and base course material, including recycling materials, corresponding with the criteria of sustainability for use in road and airfield pavements. Selected soil, the CBR value, generally in road design, will depend essential on the field density and the water content of the soil. It also depends on soils types. CBR % is more suitable for sandy soil than clayey soil. But (CBR) test is hard and time consuming; Furthermore, the results sometimes are not accurate due to bad quality of proficiency for the technical worker of testing the soil specimens in the laboratory, Shirur and Hiremath [6]. To minimize these site difficulties, an attempt has been made in this study to find statistical relationship between CBR value with maximum dry density (MDD), optimum moisture content (OMC) values, standard penetration test (SPT) and coarse material content of the soil [7-8], because these tests are wide used in sites and can be completed with optimum period of time with large scale of soil texture [9-13].

2. EXPERIMENTAL WORKS

2.1 Subsoil Stratification of Airport Site in Sacred Karbala

According to the Unified Soil Classification System (USCS), the subsoil profile for this site can be summarized as follows [14]: -

The main soil is a cohesion-less soil, which consists of loose to very dense, light brown to brown, slightly to highly gypseous clayey sand or silty sand to sand with silt or sand (SC, SM, SP-SM, SP). In general, this layer extends from natural ground surface (N.G.S) down to the end of boring at (20.0 – 30.0) m. depth. Through this layer lenses or thin layers of cohesive soil, which consists of very stiff to hard brown to slightly or highly gypseous lean or sandy lean clay to fat clay or sometimes silt or sandy silt to elastic silt sometimes with sand (CL, CH, ML, and MH) are observed in some boreholes locations at different depths. Details of soil stratification for three boreholes are shown in soil profile at Fig. 1.

2.2 Collection of Soil Samples

Fifteen locations of compaction and CBR tests (No. 1-15) are marked in site plan drawing nearby boreholes within (3) m distance from CBR tests locations in the site [14], as shown in Table 1. It shows the soil data for compaction, CBR tests, in-situ tests (SPT) in boreholes, and laboratory test represented by sieve and chemical tests

2.3 Method and Techniques Used

Compaction characteristics are limited by modified Proctor test as fixed in ASTM D1557–07. CBR value of soil sample was obtained in procedure listed in ASTM D1883–07. The values are shown in Table 2.

3. RESULTS AND DISCUSSION

Table (3) shows the results of various soil properties from the experiments conducted in the laboratory for fifteen samples taken for present investigation. The properties include standard penetration test blows and gypsum content, compaction characteristics such as maximum dry density and optimum moisture content, grain size distribution analysis such as gravel (G%) and sand (S%), California Bearing Ratio test is conducted at optimum moisture content.

The relationship between CBR values and other different soil properties are presented in Fig.2 to Fig.10. The CBR values that have been observed in Fig.1 decrease with the increase in the value of optimum moisture content (OMC.), and maximum dry density (MDD) values decreases with increase in the value of (OMC.) of soil as shown in Fig.2. Also Fig.3 explains the stacked area for (CBR, MDD & OMC.).

On the other hand, the CBR values that have been observed in Fig. (4) increase with increase in values of course materials (sand & gravel %), and CBR value increase with the increase in the value of SPT blows for same depths as shown in Fig.5, while the Fig.6 explains the stacked area for (CBR, SPT & OMC), Fig.7 explains that the CBR values increase with the increase in maximum dry density (MDD) and decrease with the increase in gypsum content as shown in Fig.10.

4. STATICAL ANALYSIS

From statically calculations, the equation No. (2 and 3) can be used to estimate the (CBR) ratio by using standard penetration test blows (SPT) and (MDD) as proposed in equations for airport zone as shown in Figs (5-7).

$$CBR = 1.045*SPT + 1.563 \quad (2)$$

$$CBR = 4.013MDD - 59.46 \quad (3)$$

By using T- test statistics to check the test results of actual CBR values from in-situ test & proposed equation (CBR=1.045*SPT+1.563) during a hypothesis test, the following statistical information were achieved Table 4, which are indicated as reasonable values with T-test average equal to (-0.099).

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Table 1
Soil data for compaction, C.B.R and boreholes tests

Type of Soil	Sample depth (m) From	To	SPT Blows	Gyp. %	Clay & Silt %	Sand %	Gravel %	B.H. or T.P. No.
brown slightly gypseous silty sand	0.00	0.25		5.38	12	85	3	1
brown highly gypseous sand with silt	0.5	1.0	36	43.89	7	60	33	2
brown moderately gypseous silty sand	0.00	0.25		13.92	13	79	8	4
Light brown highly gypseous silty sand	0.00	0.25		28.88	13	84	3	5
brown highly gypseous sand with silt	0.00	0.25		45.69	11	86	3	6
Light brown highly gypseous silty sand	0.00	0.25		42.89	17	80	3	7
Light brown highly gypseous silty sand	0.00	0.25		34.69	17	83	0	8
Light brown highly gypseous silty sand	0.00	0.25		36.46	28	69	3	9
brown slightly gypseous silty sand	0.0	0.25	-	9.3	14	86	0	10
Light brown sandy gypseous soil	0.0	0.25	-	54.42	24	76	0	11
Light brown sandy gypseous soil	0.0	0.25	-	1.89	17	77	6	12
Light brown sandy gypseous soil	0.0	0.25	-	5.13	15	85	0	15
Light brown sandy gypseous soil	0.5	1.0	16	23				CPT3
Light brown sandy gypseous soil	0.5	1.0	7	6.06				CPT12
Light brown sandy gypseous soil	0.5	1.0	21	4.6				1-17
Light brown sandy gypseous soil	0.5	1.0	15	5.35				CPT20
Light brown sandy gypseous soil	0.5	1.0	17	5.96				CPT6
Light brown sandy gypseous soil	0.5	1.0	11	5.72				CPT10
Light brown sandy gypseous soil	0.5	1.0	15	20				SPT20
Light brown sandy gypseous soil	0.5	1.0	9	51.3				SPT11
Light brown sandy gypseous soil	0.5	1.0	16	17				SPT10
Light brown sandy gypseous soil	0.5	1.0	22	.65				SPT17
Light brown sandy gypseous soil	0.5	1.0	21	20.3				SPT15
Light brown sandy gypseous soil	0.5	1.0	15	2.86				SPT6
Light brown sandy gypseous soil	0.5	1.0	16	50.3				SPT8
Light brown sandy gypseous soil	0.5	1.0	7	0.19				CPT19

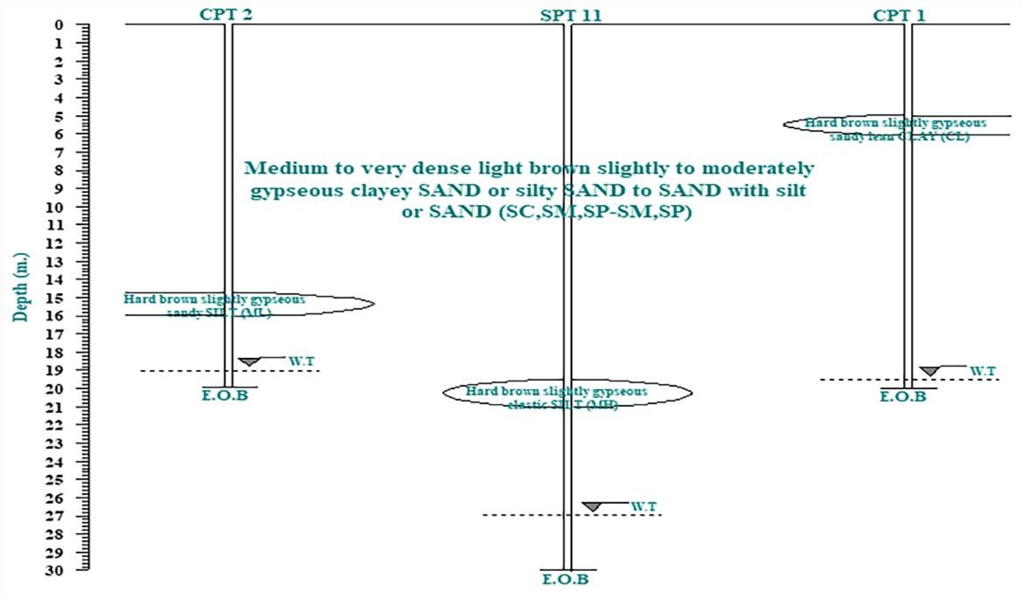

Fig. 1. Soil profile through boreholes (CPT 2, SPT 11 & CPT 1)

Table 2
Compaction parameters and California bearing ratio

Sample No.	Max. dry density kN/m^3	Optimum moisture content %	CBR %
1	18.26	10.5	20.1
3	17.40	10.5	8.1
4	19.90	8.0	23.3
5	18.76	6.2	21.0
6	17.23	9.4	15.0
8	20.21	7.9	20.0
9	18.32	10.2	26.8
10	19.70	8.6	15.2
12	19.76	6.6	22.5
13	19.76	6.2	22.0
15	17.92	9.8	30.0
16	18.80	8.4	10.2
18	18.12	10.6	12.0
19	18.51	6.8	13.6
22	18.68	8.6	23.6
23	19.51	11.5	22.1
24	17.61	7.0	17.4
26	17.26	11.0	8.5
27	19.93	8.6	22.4
29	18.00	8.0	8.0
max	20.21	11.50	23.30
min.	17.23	6.20	8.00
average	18.68	8.72	15.76

Fig. 9 explains the relationship between measured and predicted values of C.B.R by using trend line regression (R- squared) value equal to (0.855) and standard deviation for measured and predicted values of C.B.R (5.35 -6.09) respectively

5. CONCLUSIONS

- In general, most of the Iraqi roads system are identified as flexible paving. And there are several methods of design for flexible paving. The most popular method is using the California bearing ratio (CBR) test in design of flexible roads.
- The California Bearing Ratio (CBR) test is very important as experimental method used to evaluate the mechanical strength of subgrade and coarse base. The results of (CBR) sometimes are not accurate due to bad quality of proficiency for the technical worker of testing the soil specimens in the laboratory. To minimize these difficulties, an attempt has been made in this study to find statistical relationship between CBR value with MDD, OMC values, and standard penetration test (SPT)) and coarse material content of the soil, because these tests are simple and can be completed with a short period of time.
- The other estimated correlations for (CBR) with optimum moisture content (OMC) and gypsum content can be used as a guide because there are other variables that have an effect in values

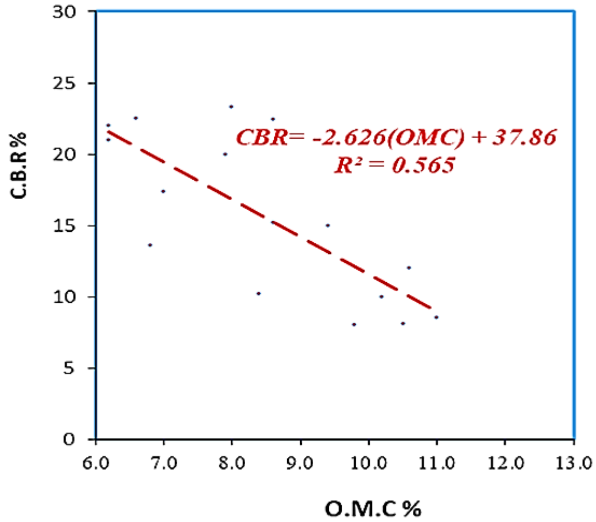

Fig.2. C.B.R% values versus O.M.C with R squared value

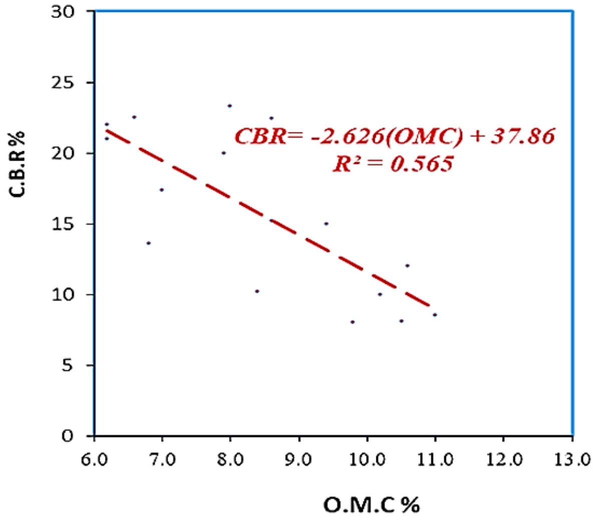

Fig. 3. Max. dry density values versus O.M.C

Table 3
Test results with proposed equations

Sample No.	SPT	MDD kN/m^3	OMC	CBR %	CBR from Eq. (2)	C.B.R from [8]	CBR from Eq.(3)
3	7	17.4	10.5	8.1	10.37	2.39	8.88
4	21	19.9	8	23.3	20.40	11.57	23.51
5	15	18.76	6.2	21	15.82	7.38	17.24
6	17	17.23	9.4	15	9.68	1.77	19.33
8	15	20.21	7.9	20	21.64	12.70	17.24
9	9	18.32	10.2	10	14.06	5.77	10.97
10	16	19.7	8.6	15.2	19.60	10.83	18.28
12	21	19.76	6.6	22.5	19.84	11.05	23.51
13	15	19.76	6.2	22	19.84	11.05	23.51
15	--	17.92	9.8	8	12.45	4.30	8.88

Table 4
Test value CBR proposed equation

CBR % from direct test	**Proposed Equation (2)**	**T-Test value**
8.1	8.88	-0.12832
23.3	23.51	-0.48231
21	17.24	0.026597
15	19.33	-0.0231
20	17.24	0.036235
10	10.97	-0.10315
15.2	18.28	-0.03247
22.5	23.51	-0.09906
22	23.51	-0.06624
8	8.88	-0.11372
-0.099		**T-Test Average**
17.6	17.76	**Median**
6.092	5.796	**Standard Deviation**
1.926	1.833	**ST. Dev. Error Main**

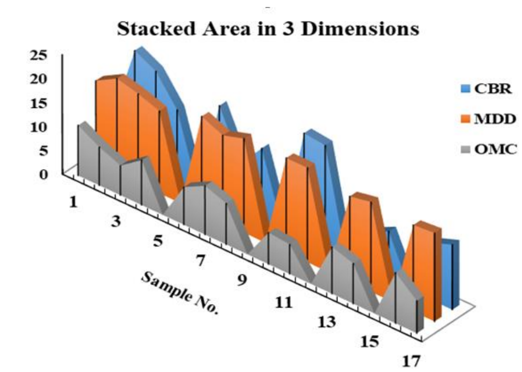

Fig. 4 C.B.R%, O.M.C and M.D.D stacked area in three dimensions

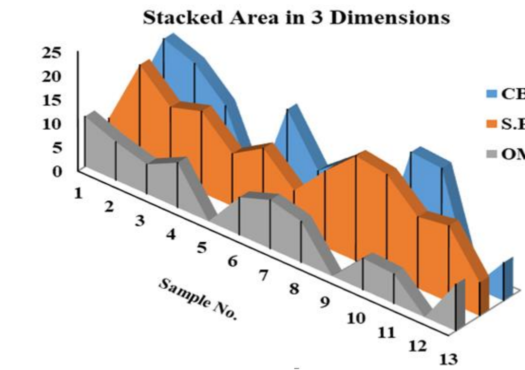

Fig. 7. C.B.R%, S.P.T and O.M.C stacked area in three dimensions

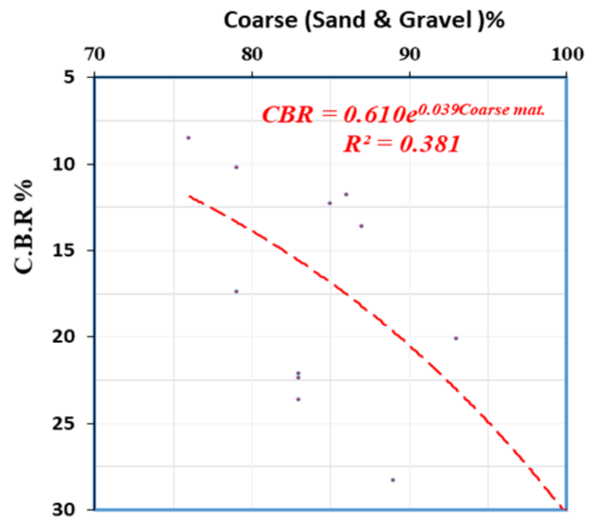

Fig. 5 C.B.R % versus (sand & gravel) %

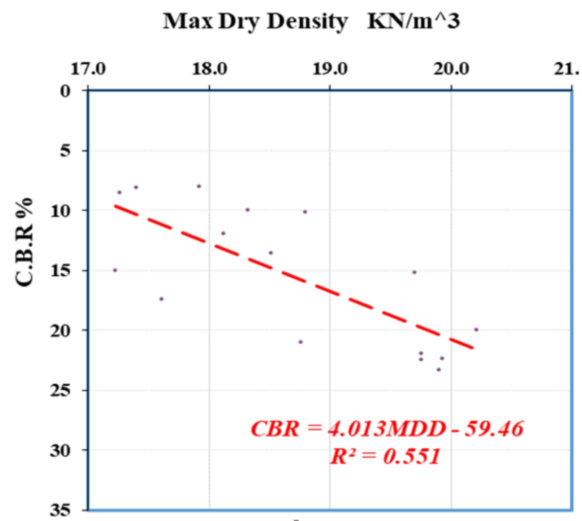

Fig. 8 C.B.R % values versus Max. dry density

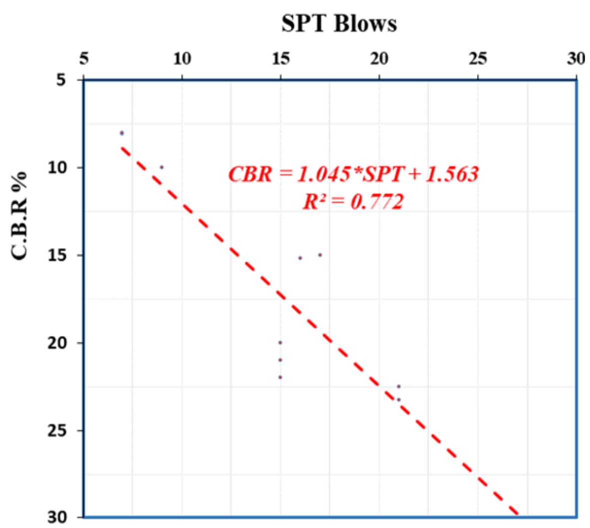

Fig. (6). C.B.R % versus S.P.T. blows

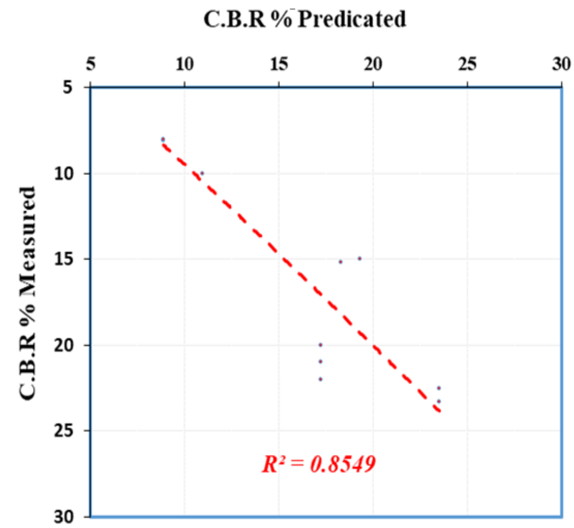

Fig. 9 Relationship between measured and predicted values of C.B.R

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