A COMPARISON OF (CBR) SOAKED TEST WITH BRITISH SPECIFICATIONS FOR FINE-GRAINED SOILS FROM AL-KUT IN IRAQ

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ABSTRACT:

The California bearing ratio (CBR) test has been widely used in pavement design since mid 1940's. It is a relative measure of sub-grade soil or base/sub-base aggregate strength. Nine samples, about 50 kg are taken from different test pits dig to 1.5m from natural ground surface, the soil is fine grained either silt or clay. The nine (CBR) specimens were compacted at optimum moisture content and at 95% of the maximum dry density of the modified compaction test were prepared.

All specimens were soaked for periods of 96hr with more than 4.5kg surcharge load. Penetration test was done for both two faces (top and bottom) of the specimen. The tests denoted that most CBR curves are convex upwards so no correction is needed. CBR number is less than 20 so is very poor to fair, where the best using for sub grade due to its fine grained soil. Mostly CBR number that is calculated from bottom face is grater than top face, as they are less wetting than top face.

The paper reveals that most CBR values are small, depended from 5mm penetration of the bottom face of specimens, which no correction method is needed for curves.

Key Words: **CBR Test, Fine-Grained Soils, Proctor's Compaction test, Soaking**

مقارنة اختبار معدل التحمل (CBR) المغمور مع المواصفات البريطانية لتربة دقيقة الحبيبات من الكوت في العراق

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الخلاصة

فحص معدل التحمل (CBR) يتم استخدامه بشكل واسع في تصميصم الطرق منذ منتصف أربعينات القرن الماضي. حيث يعتبرالفحص مقياس نسبي لقوة تربة التدرج او ركام طبقات السبيس او تربة التسوية. تسعةعينات بحدود 50 كغم اخذت من حفر اختبارية مختلفة بحفر يصل الى 1,5 متر من سطح الارض, التربة هي دقيقة الحبيبات أما غرين او طين. نماذج (CBR) التسعة قد تم رصها حسب محتوى الرطوبةالأمثل واعدادها عند مستوى 95% من الكثافة الجافة القصوى لفحص الرص المعدل .

ثم جميع النماذج تم غمرها بالماء لمدة 96ساعة مع 4.5 كغم او أكثر من الاحمال الدافعة. تم أجراء فحص الأختراق لكلا وجهي النموذج (العلوي و السفلي). أشرت الاختبارات ان معظم المخططات هي محدبة الى الاعلى لذلك لا تحتاج الى تصحيح وان قيمة (CBR) أقل من 20% لذلك التقيم هو من فقيرجداً الى مناسب، الاستعمال الافضل كتربة طبقة سفلية بسبب حبيباتها الدقيقة. وأن معظم قيم (CBR) المقاسة من الوجه الاسفل هي أكبر من قيم الوجه العلوي للنموذج، لأنه اقل رطوبة من ألوجه الاعلى للنموذج.

يوضح البحث أيضاً ان معظم (CBR) للنماذج هي صغيرة، حيث تم اعتماده من اختراق الـ(5 ملم) من الوجه السفلي للنماذج، ولم تكن هناك حاجة لوسيلة التصحيح للمخططات.

NOMENCLATURE

I. **CBR: California Bearing Ratio**
II. **USCS: Unified Soil Classification System**
III. **LL: Liquid Limit**
IV. **PL: Plastic Limit**
V. **PI: Plasticity Index**
VI. **CL: Clay Low Cohesive**
VII. **ML: Silt Low Cohesive**

INTRODUCTION:

In the last two decades, there has been rapidly expanding road construction programs in the Middle East and in many of world's hot desert regions where evaporation exceeds precipitation, to minimize the construction cost for road projects in such regions, the use of locally available materials will always be necessary task of highways engineers (Razouki, 2003).

In the field of highways and roads construction, the California Bearing Ratio (CBR) test has been widely used in pavement design since mid 1940's. It is a relative measure of sub- grade soil or base/sub-base aggregate strength (Hossain, 2005).

The standard shape of force-penetration curve corresponding to a CBR value is convex upward as shown in **Fig. (1)** Of typical test result.

Where the forces corresponding to standard curve are: 11.5 KN at 2mm penetration, 13.2 KN at 2.5mm, 17.2KN at 4mm, 20KN at 5mm, 22.2KN at 6mm and 26.3KN at 8mm. According to the curve shape, it will be no correction needed where this shape is convex upward as stated by BSI (BS 1377-9).

Laboratory tests of Iraqi fine grained soils (Clay and Silt soils) for these 9 specimens in Al-Kut City shows the differences in curve shape so the forces strength.

The objective of this study is make a comparison between CBR curves that connecting of Al-Kut fine-grained soils of different sites from designed road, with the standard correction methods for laboratory (CBR) tests to obtain (CBR) number. It worth mentioning that the tests have been done by the authors themselves and for all specimens.

METHODOLOGY

Soil description

The program consists of 9 (CBR) tests on specimens of fine grained soils (Clay and Silt) according to USCS and Hydrometer test as shown in **Table (1)** of Al-Kut City (southeast area) in soaking term as worst case, the soil is placed in the compaction mold under the specification of (ASTM D1883-05) and take its test series from compaction to penetration test for both faces of specimens top face and then bottom face, where tests are controlled laboratory circumferences.

PROCEDURE OF THE TEST

Compaction

CBR tests are usually carried out on test specimens at the optimum moisture content value for the soil as determined using the standard (or modified) compaction test, depended on the grain size distribution and percentage of retained on sieve No.200. Next, using methods C of ASTM D1557-02 or D698 - 00 (for the 15.2 cm diameter mold) the specimens are made using the compaction energy as shown below in **Table (2)**(Bowels,1988)(ASTM, D 1557- D 698):

In this research the specification (ASTM D1557-02 **C** modified) is used for the soil compaction for CBR test and the equipment are explained in the following **Table (3)**:

Soaking

The flowing standard steps as mentioning were applied to soak the specimens and prepare it for the penetration test (Bowels, 1988)(ASTM, D1883).

- After the compaction, the collar was removed then the specimen was trimmed smooth and flush with mold

- The base plate and spacer disk were removed; the mold + compacted soil had been weight and determining the wet unit weight (take sample for water content determination).
- A piece of filter paper was Placed on the base plate, the specimen was inverted (so the 5.1cm gap is on top), and attach the base plate so the soil is in contact with the filter paper on the base.
- The perforated plate with adjustable stem was placed on the compacted soil and applied sufficient additional slotted weights to obtain the desired surcharge with in 2.2 kg but with a total surcharge weight of not less than 4.5 kg (the perforated plate is a part of surcharge weight).
- The mold and weights were immersed in a container of water so the water has access to both the top and bottom of the sample and attach the dial gage (reading to 0.01 mm) in its holding brackets (Tripod).
- The swell gage was set to zero to start reading and recorded the time of the start of the test .Take readings at 0, 1, 2, 4, 12, 24, 48, 72 and 96h of elapsed time.
- At the end of 96h of soaking, the sample was removed and it was let to drain for 15 min. Blot the sample surface by paper towels
- The Soaked sample including the mold was Weight.

CBR penetration

Penetration testing is accomplished in a manual compression machine using a strain rate of 1.27 mm/min. Readings of load vs. penetration are taken at each 0.5mm of penetration to include the value of 5mm and then at each 2.5mm increment there after until the total penetration is 12.7mm(Bowels,1988)(Gupta,2005).

RESULTS

Test specimens results about its swelling, CBR and curves will be explained in the following tables and figures. During soaking in CBR test, measurement of vertical movement (swelling or settlement) was carried out by means of an (0.01) mm dial gauge attached to the stem of the swelling plate (Razouki,2003), as shown in **Fig.(2)**. Therefore, **Table (4)** illustrates the swelling and CBR of the specimens.

Load- Penetration curve

The penetration loads was calculated in kilopascal (or megapascals) and the load penetration curve was drawn (ASTM, D1883). In some instances the load-penetration curve may be concave upward initially, because of surface irregularities or other causes, and in such cases the zero point shall be adjusted as shown in **Fig.(1)**, and the corrected curve shape should be taken to calculate the bearing ratio.

Bearing ratio

The load values (the normal or the corrected due to the curve shape) were taken from the load – penetration curve (curves as shown from **Fig.3** to **Fig.11**) for (2.5mm) and (5mm) penetrations were used to calculate the bearing ratios for each by the equation(1) (ASTM, D1883):

$$\text{CBR (\%)} = \frac{The \quad Calculated \quad Load}{The \quad Sandard \quad Load} \times 100 \qquad (1)$$

Where:

The calculated load = material resistance or the unit load on the piston (pressure)

for 2.5 mm or 5mm of penetration

The standard load = standard unit load (pressure) for well graded crushed stone

= for 2.5 mm penetration = 6900 kPa

= for 5 mm penetration = 10300 kPa

The bearing ratio reported for the soil is normally the one at 2.5mm penetration, when the ratio at 5mm penetration is greater, the test was rerun. If the check test gives a similar result, use the bearing ratio at 5mm penetration. Where **Table (5)** explains the calculated CBR for each specimen.

Calculation

The following **Table (6)** shows example for the calculation that was done for determination of loads and penetration for sample no.1:

For column no. 3 and no.6 the penetration was calculated as:

$$\text{Penetration (mm)} = [(Time \quad * \quad P.R) - (Factor \quad * \quad D.G.R)] \qquad (2)$$

Where

Time: readings time (min.)

P.R.: Penetration Rate = 1.27 mm/min

Factor: dial gauge factor=0.0025 mm/div.

D.G.R.: Dial gauge reading (div.)

For column no.4 and no.7 the stress was calculated as:

$$\text{Stress (kPa)} = \frac{D.G.R \quad * \quad P.R.Factor}{Area} * 98.1 \qquad (3)$$

Where:

D.G.R.: Dial gauge reading (Div.)

P.R.Factor: Proving ring factor= 0.336 kg/div.

Area: Plunger area= 19.4cm

CONCLUSIONS

This paper has presented the results of an experimental work of 9 different soil samples used as subgrade soil for road site. From the results of this work, the following conclusions can be taken:

1. The soil studied was obtained from Iraq, Waset governorate, Al-Kut city(south east area). The soil is fine-grained either Silt or Clay (where ML or CL) belonging to the unified soil classification system and Hydrometer tests.
2. CBR values are small for most specimens between 0 to14%, where depended from 5mm penetration of bottom face, so the general rating from very poor to fair, therefore; best using for sub grade usually, due to its fine grained particles.
3. Mostly CBR values that were determined from bottom face of specimen are greater than top face, because that the upper layer in the mold during compaction becomes the bottom face of the specimen for CBR test.
4. The closing and faring between top and bottom curves like **Fig.5 and Fig 6** depend on classification of soil, Silt mostly has closing values for top and bottom curves, so clay has faring values between top and bottom.
5. The intersection of top and bottom curves in **Fig.6** resulted from low cohesive silt soil of high moisture content to dry unit wet.
6. The linear behaviour of curves like in **Fig.11** explains the constant increasing for strength of soil to penetration due to particle size of high percentage of silt.

ACKNOWLEDGMENT

Special thanks to Andrea Engineering test laboratory to allow us to use their devices and information.

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Table (1) Geotechnical properties for Al-Kut Specimens

Sample No.	Sieve Analysis & Hydrometer			Index Properties			Natural Water Content%	USCS
	Sand%	Silt%	Clay%	LL%	PL%	PI%		
1	6.6	46.5	46.9	44	23	21	10	CL
2	4.5	33.2	62.3	43	23	20	14.3	CL
3	7.3	62.6	30.1	41	26	15	13.1	ML
4	5.9	64.4	29.7	34	23	11	12.8	ML
5	8.1	53.5	38.4	36	21	15	14.1	CL
6	6.8	63.3	29.9	36	25	11	14.6	ML
7	5.3	71.5	23.2	35	24	11	13.8	ML
8	6.4	51.9	41.7	41	20	21	18.8	CL
9	7.2	67.7	25.1	32	23	9	28.9	ML

Table (2) CBR Compaction Specification

Method		Mould (mm)	Passing Sieve No.	Layers	Blows	Rammer weight (N)
D 698:	**A**	101.6	4	3	25	24.5
	B	101.6	9.5mm	3	25	24.5
	C	152.4	19mm	3	56	24.5
D 1557:	**A***	101.6	4	5	25	44.5
	B	101.6	9.5mm	5	25	44.5
	C	152.4	19mm	5	56	44.5

* **D1557 A** is used to determine the water content and dry unit weight

Table (3) Compaction Apparatus [1][4][7]

Equipments and Accessories	CBR Test Standard	Remarks
Loading Machine	Capacity of 44.5KN Uniform movement rate of 1.27mm/min.	
Mold Size	Diameter= 15.2 cm Height= 17.8 cm	Or Equivalent
Extension Collar	Diameter= 15.2 cm Height= 5 cm	
Spacer Disc	Diameter= 15.1 cm Height= 6.14 cm	Or 5.1 Height as available
Compaction Rammer	44.5 N weight	Or 24.5 N as Standard
Swell Base Plate	Diameter= 15 cm Height= 0.625 cm Perforated with 42 hole Hole diameter= 0.16 cm	
Surcharge weight	Diameter= 15 cm Weight= 2.268 Kg	Not less than 4.5 Kg

Table (4) Specimen Swelling and CBR Number

Sample No.	Swelling %	CBR 2.5mm		CBR 5mm		General Rating
		Top	Bottom	Top	Bottom	
1	7.5	1.3	3.69	1.74	8.55 *	Fair
2	5.25	2.4 *	6.5	1.95	7.35	Very Poor
3	3.32	4.42	7.24	5.9	8.57 *	Fair
4	1.66	2.6	2.75	3.15	2.92 *	Very Poor
5	1.34	2.25	4.5	2.55	5.35 *	Very Poor
6	4.27	4.05	13.9 *	6.33	10.95	Fair
7	4.17	3.77	7.1	5	9.24 *	Fair
8	2.85	3	3.25 *	3.15	2.7	Very Poor
9	1.65	2.3	3.45	3.3	4.15 *	Very Poor

* Represent the CBR value of specimen

Table (5) CBR Values

Sample No.	USCS	Compaction Test		CBR Value at 95% Compaction
		Max. Dry Density kN/m^3	Optimum Moisture Content %	
1	CL	18.27	10.1	8.55
2	CL	18.04	10.6	2.4
3	ML	17.85	13.2	8.57
4	ML	17.95	14.3	2.92
5	CL	17.88	12.5	5.35
6	ML	18.02	11.5	13.9
7	ML	17.91	12	9.24
8	CL	18.28	12.7	3.25
9	ML	17.95	14.9	4.15

Table (6) Sample No.1 calculations

1	2	3	4	5	6	7
Time	**Top Face**			**Bottom Face**		
(min.)	**Dial gauge reading (div.)**	**Penetration (mm)**	**Stress (kPa)**	**Dial gauge reading (div.)**	**Penetration (mm)**	**Stress (kPa)**
0	0	0	0	0	0	0
0.5	12	0.605	20.3	41	0.53	70
1	27	1.2	45	72	1.09	122
1.5	41	1.8	70	107	1.64	181
2	55	2.4	93	145	2.18	246
3	77	3.61	130	228	3.24	387
4	97	4.84	164	308	4.31	522
6	135	7.28	230	434	6.54	737
8	173	9.73	294	517	8.87	877
10	218	10.15	370	577	11.26	279

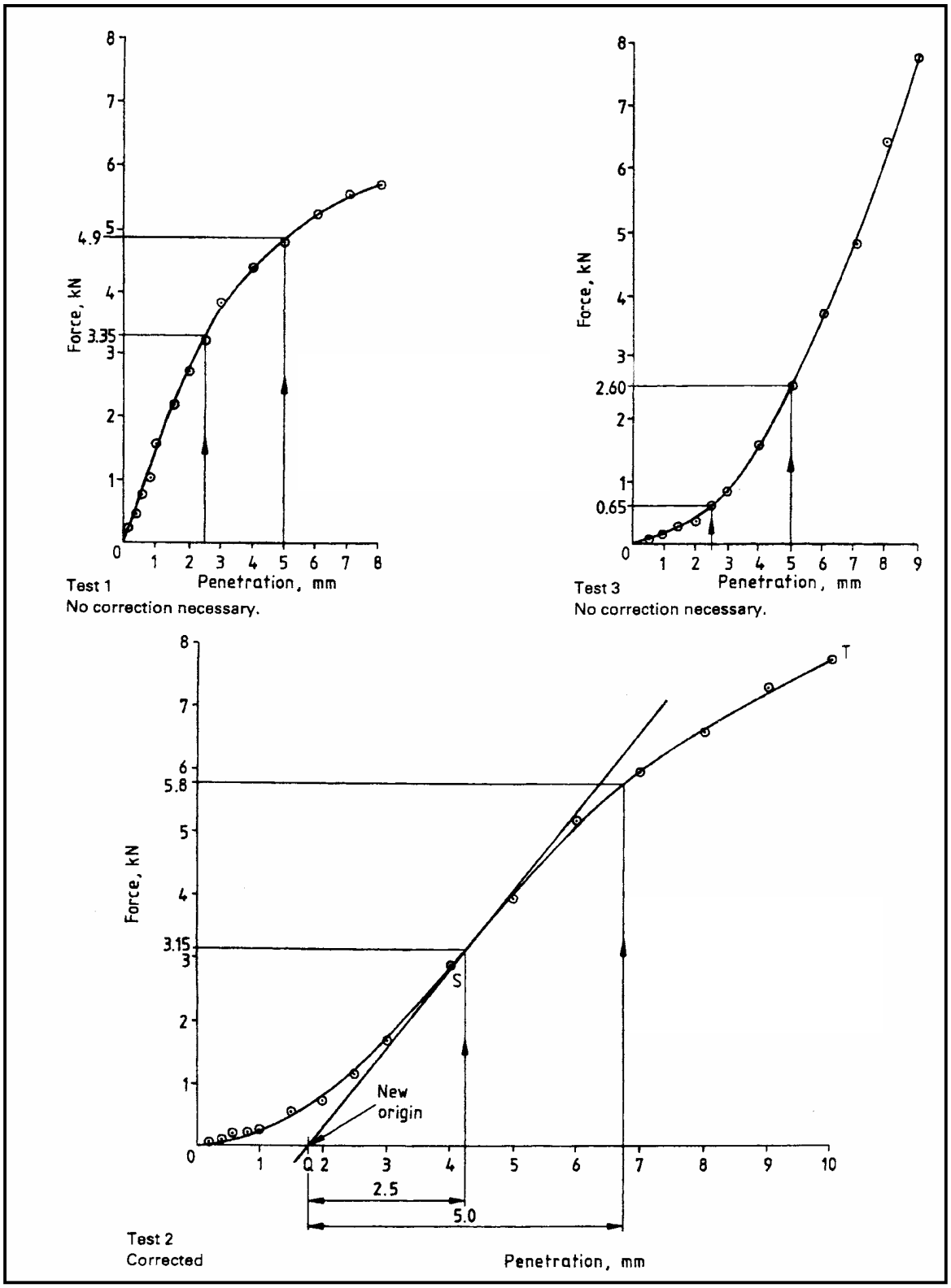

Fig.1 Typical CBR test results curves (BS 1377-9)

A. Specimen in swelling tank

B. Specimen before penetration

C. CBR penetration Experimental set-up

D. Top face penetration

E. Bottom face penetration

Fig.2 CBR Penetration Apparatus

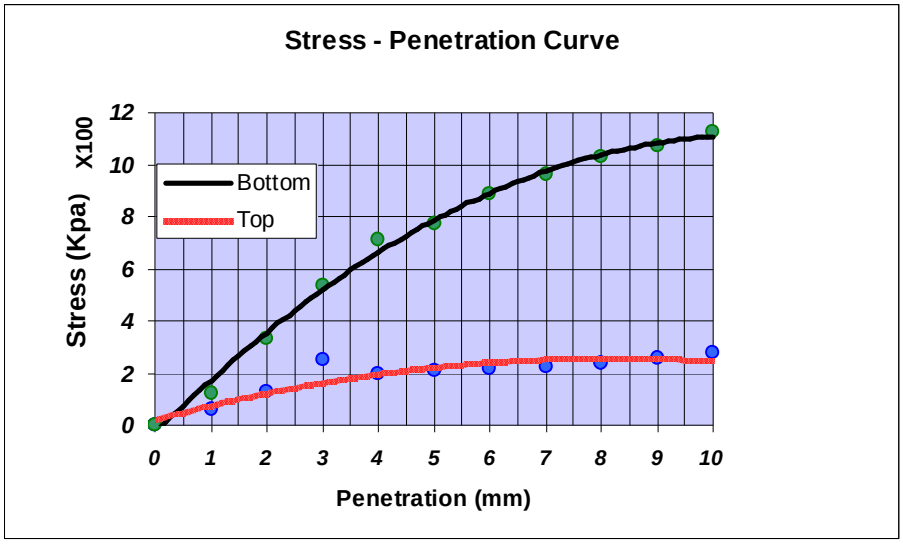

Fig. 4 CBR Curve for Test Sample No.2

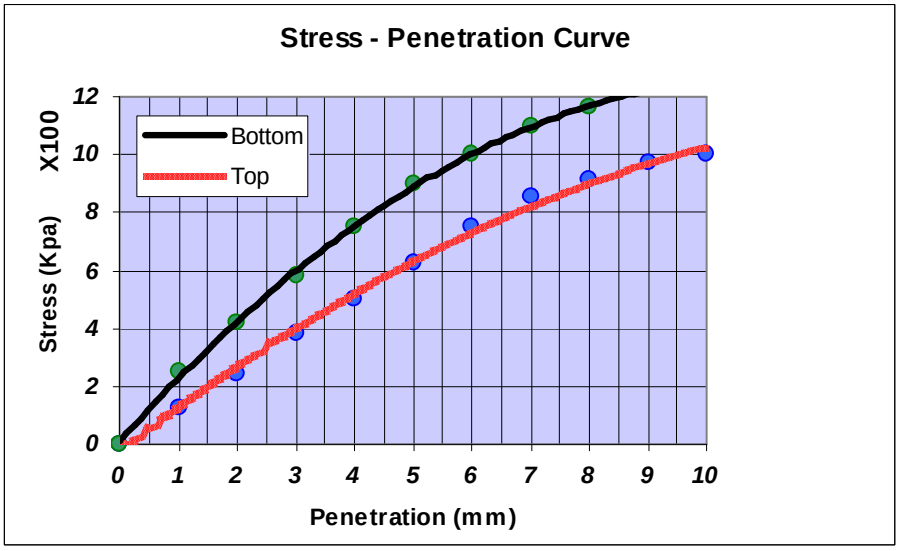

Fig.5 CBR Curve for Test Sample No.3

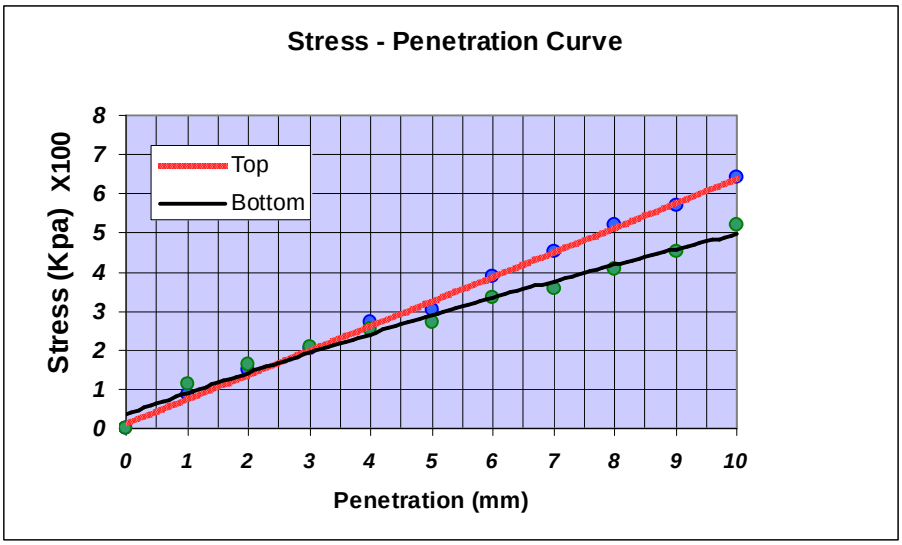

Fig.6 CBR Curve for Test Sample No.4

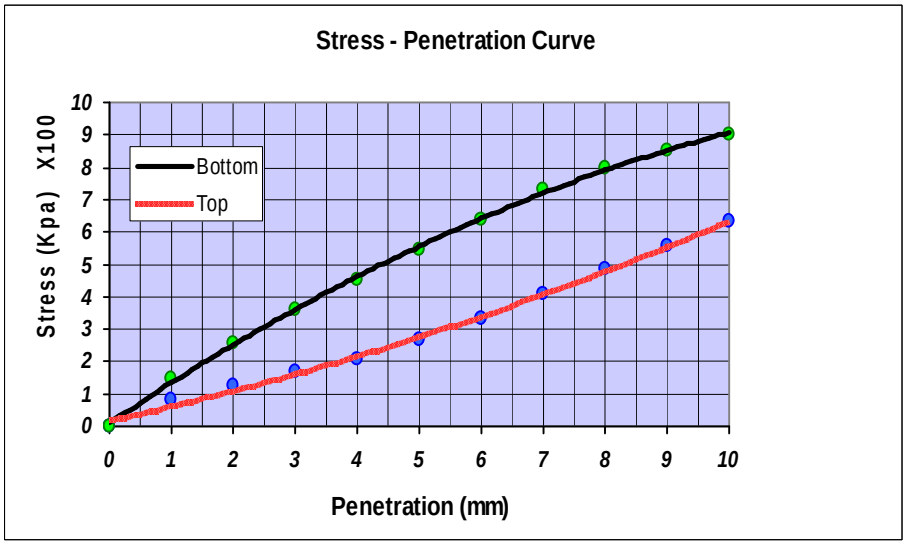

Fig.7 CBR Curve for Test Sample No.5

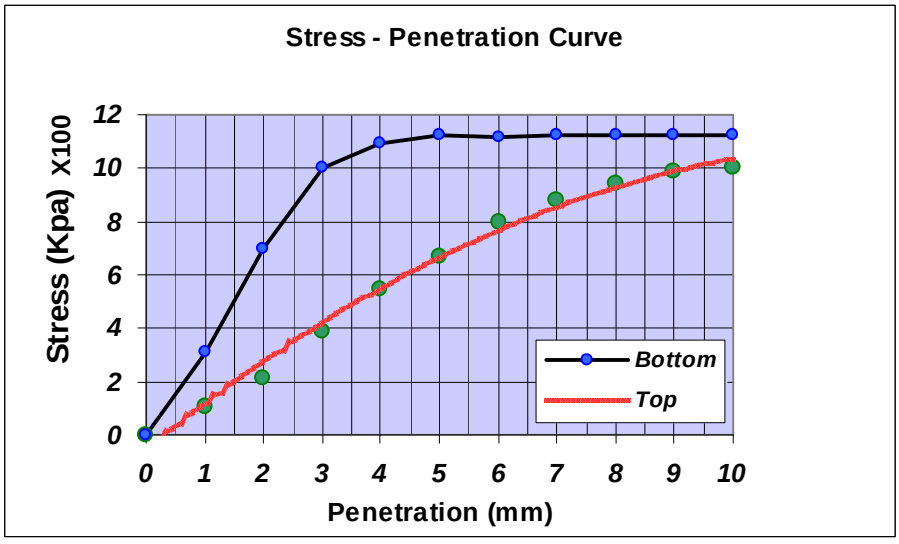

Fig.8 CBR Curve for Test Sample No.6

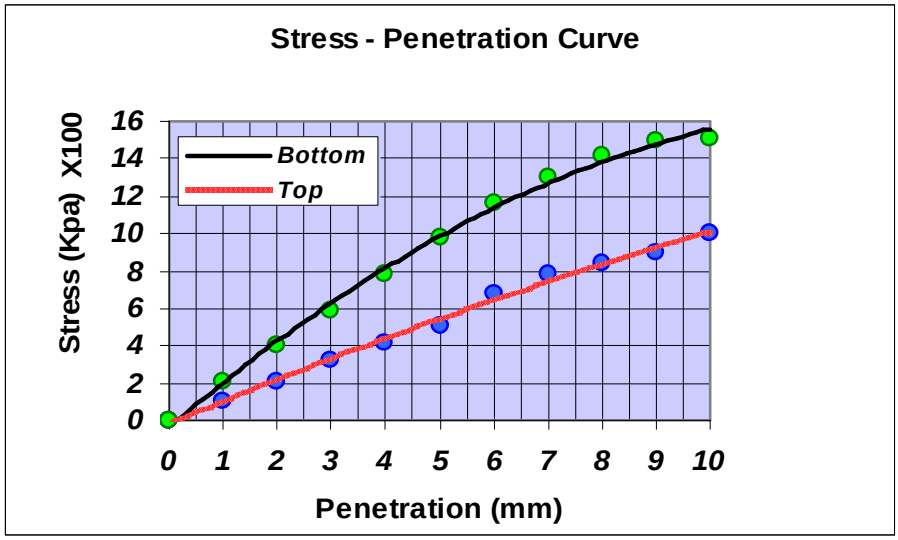

Fig.9 CBR Curve for Test Sample No.7

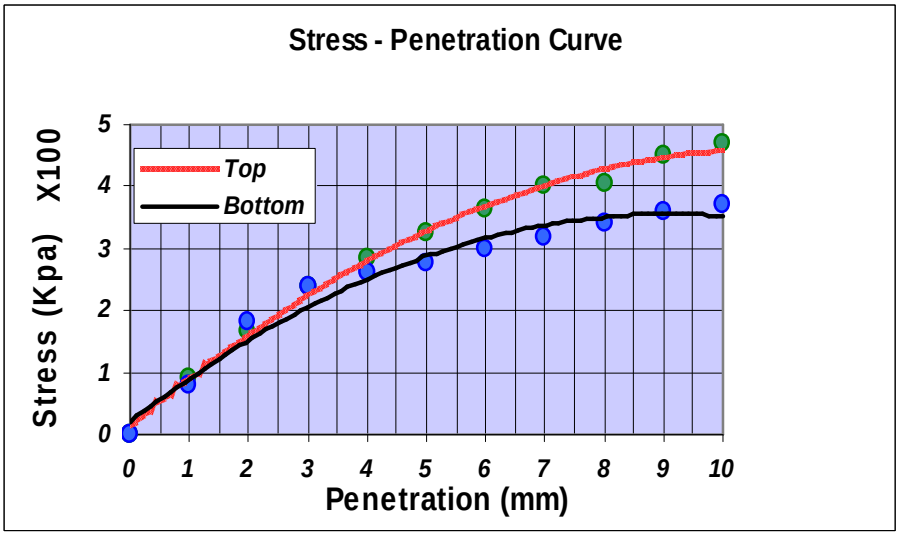

Fig.10 CBR Curve for Test Sample No.8

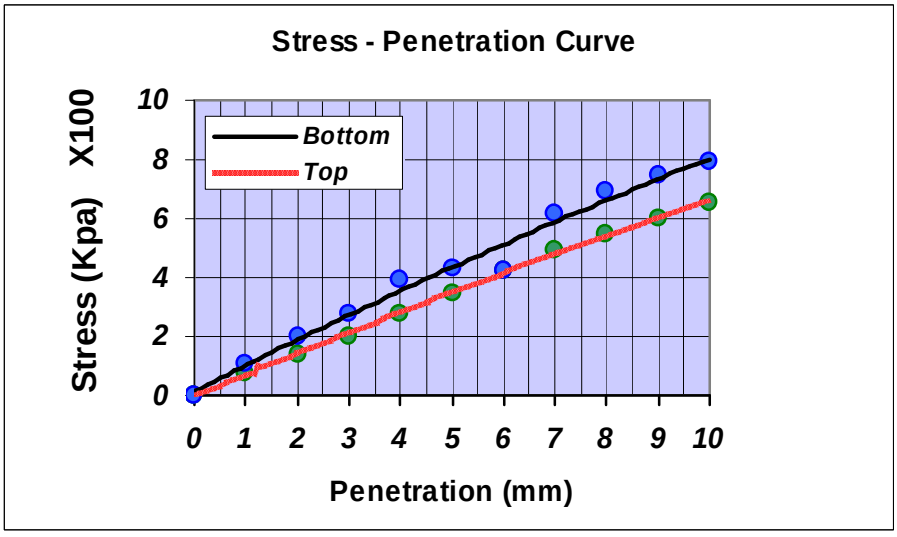

Fig.11 CBR Curve for Test Sample No.9