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Ahmed A. H. Al-Obaidi *

Qudama A. A. Al-Ashoishi

Civil Engineering Department
College of Engineering
Tikrit University
Salahuddin
Iraq

Application of Dynamic Cone Penetration Test to Gypseous Soils

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Dynamic Cone Penetrometer (DCP)
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A B S T R A C T

Dynamic cone penetration test (DCPT) is a fast, economical and easy to conduct. It is widely used to assess the strength of natural and compacted soils. The device is introduced in the 1950s. However, it was newly introduced in Iraq. This study aims to evaluate the potentials of DCP in geotechnical explorations in the gypseous soil since it covers a large area of the country and to obtain correlations with the California bearing ratios (CBR) and investigating the effect of gypsum on the CBR-DCP relationship. Field and Laboratory tests were conducted on soil sample retrieved from six sites with different gypsum contents (28-41) %. Laboratory tests include performing CBR and DCP tests in a cylindrical mold. A statistical analysis of the results shows that gypsum content is an affecting factor on DCP and good CBR-DCP correlations on gypsum content were obtained.

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تطبيقات فحص اختراق المخروط الديناميكي في الترب الجبسية

الخلاصة

فحص اختراق المخروط الديناميكي هو فحص سريع، اقتصادي ويمكن اجراءه بسهولة. يستخدم هذا الفحص بشكل واسع لتقييم مقاومة الترب الطبيعية والمحدولة. على الرغم من ان هذا الفحص تم استحداثه في الخمسينيات الا انه لم يستخدم في العراق الا حديثا. تهدف هذه الدراسة الى تقييم إمكانات هذا الفحص في التحريات الحقلية للتربة الجبسية حيث انها تغطي مساحات شاسعة من البلد، وكذلك تهدف الى الحصول على علاقات ترابطية مع فحص (نسبة التحمل الكاليفورني) وكذلك استكشاف تأثير نسبة الجبس على هذه العلاقة. تم اجراء فحوصات حقلية ومختبرية على عينات من 6 مواقع بنسب جبس تتراوح من (28-41) % وباستخدام قوالب فحص اسطوانية. أظهر التحليل الاحصائي للنتائج ان هناك تأثير لنسبة الجبس على نتائج فحص اختراق المخروط الديناميكي وتم الحصول على علاقات تربط بين نتائج الفحصين بالاستناد على نسبة للجبس.

1. INTRODUCTION

One of the important factors in geotechnical engineering is the site investigation, where specific soil properties are assessed using suitable laboratory and field tests for the safe design of structures. However, sometimes samples obtained from field undergo what is called (disturbance) which affect the natural structure of the sample and may alter some of its characteristics, resulting in inaccurate results from the Laboratory test. For this purpose, many field tests have been introduced and one of the key elements in developing a field test is that the test has to be cost and time effective. Moreover, due to the rapid increase in construction projects in Iraq especially projects that cover large areas such as (roads, airports ….etc.). There is a need for a special test equipment that saves time, effort and cost. The dynamic cone penetration test (DCP) is one of these devices that was developed to provide rapid and repeatable use in the field.

2. DYNAMIC CONE PENETROMETER

The dynamic cone penetrometer (DCP) is a hand-held instrument designed to evaluate the in-situ strength of fine-grained and granular subgrade, subbase and granular base materials. A typical sketch of the dynamic cone penetrometer (DCP) is shown in Fig. 1. The DCP has an upper and lower steel shafts. The top shaft with an 8 kg hammer and a 575 mm free fall height and is connected to the lower shaft by the anvil. The lower shaft has an anvil and a steel cone attached to the end of the shaft. The cone is replaceable (reusable or disposable) and has a 60-degrees cone angle. As a reading device, an additional rod or steel ruler is used as an attachment to the lower shaft with marks similar to measuring tape. The lower shaft containing the

* *Corresponding author: E-mail* : dr.obaidi.a.h@tu.edu.iq

cone moves independently from the reading rod sitting on the testing surface throughout the test. To perform the DCPT, two operators are required. One person lifts and drops the hammer and the other records measurements. The first step of the test after assembling the device is to put the cone tip on the testing surface. The first reading is not usually equal to zero due to the disturbance of the ground surface and the weight of the testing equipment. The test is carried out by lifting and dropping off the hammer until the desired depth is reached.

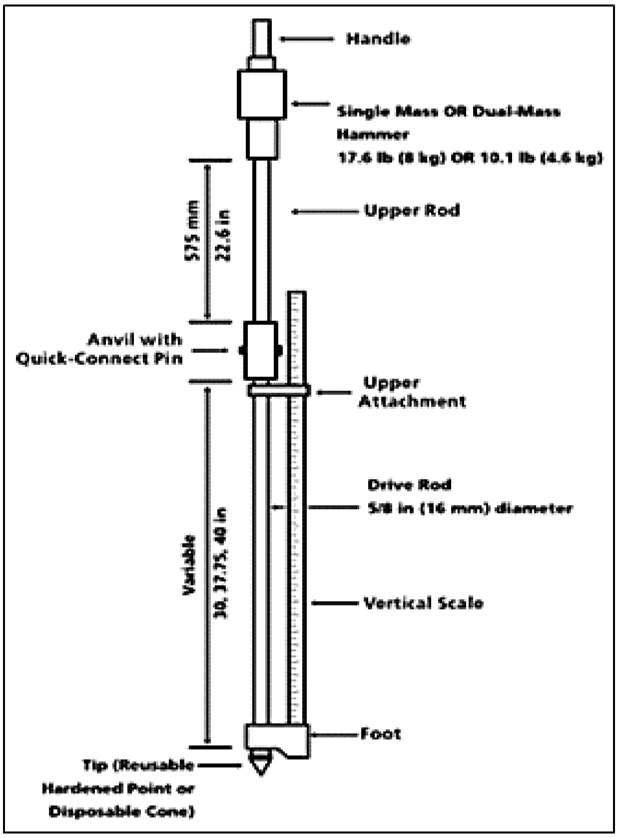


Fig. 1. Typical configuration of the dynamic cone penetrometer

3. ADVANTAGES OF THE DCP

Many authors reported the advantage of the DCP [1-6]. Below is a summary of these advantages:

- It characterizes the in-situ strength of soil;
- It characterizes the strength with depth;
- It could be used to determine the thickness and depth of underlying soil layers;
- It could be used to verify uniformity of compaction;
- It is repeatable and reliable;
- It can be used in soils with a wide range of particle sizes and strengths;
- It is manually operated and relatively inexpensive, it can be manufactured locally or purchased commercially;
- It could be used for evaluation and design purposes;
- It is simple enough to be utilized by an inexperienced person with a few minutes of training;
- It could be used to verify whether if the stabilized soil has achieved its potential stiffness;
- It has a large penetration depth compared to hand-held instruments like (Falling Weight Deflectometer (FWD), Humboldt Geogauge).

Since the device is rapidly developed and the results can be used in many geotechnical applications. Thus, it is necessary to utilize this device and correlate its results with common field tests. The first objective is to investigate the feasibility of using the device as an in-situ test device in the gypseous soil. This could be achieved by conducting a field DCP test in sites at different locations with different gypsum contents in soil formation. The second objective is to conduct field and a laboratory test. CBR test was chosen to be correlated with the DCP test, since this is the common correlation and to investigate the effect of gypsum content on the CBR-PR relationship. The final objective is to compare the obtained correlation with existing CBR-PR correlations.

4. EXPERIMENTAL WORK

4.1. Test materials

Disturbed Samples of gypseous soil were brought from six sites in Samarra city; Materials properties are shown in Table 1. In addition to two manufactured samples.

4.2. Field tests

Field tests include DCP test and sand cone test. Both tests were conducted in accordance with the ASTM standard [7,8].

4.3. Laboratory tests

The following tests were carried out:
Chemical tests and determination of gypsum content test.
Liquid limit and plastic limit tests [9], and [10].
Grain size distribution test [11].
Standard compaction test [12].

Soaked and unsoaked CBR and DCP tests in cylindrical molds with 50 cm diameter and 30 cm height. As shown in Fig. 2. The purpose of using these molds was to simulate field conditions by overcoming the confinement effect of the standard CBR mold.

5. RESULTS AND DISCUSSIONS

5.1. DCP vs. dry field density

Fig. 3 shows the variation of the PR with in-situ dry density, The PR tend to decrease indicating higher penetration resistance (higher strength) with increasing density.

Table 1
Test material properties.

Test Name	Site1	Site2	Site3	Site4	Site5	Site6
U.S.C.S	SP	SP	SP	SP	SP	SP
Coefficient of uniformity	5.89	5.76	2.07	3.04	5.09	37.7
Coefficient of curvature	0.80	0.86	0.95	0.90	0.78	0.33
Liquid limit	41.2	38.8	30.0	32.0	34.6	53.0
Plastic Limit	N.P	N.P	N.P	N.P	N.P	N.P
Field density(kg/m^3)	1813	1620	1280	1278	1575	1307
Moisture content %	11.3	9.0	4.0	3.0	2.0	3.0
Gypsum %	35.2	31.8	32.7	28.6	38.7	41.6
T.D.S %	44.21	38.72	34.75	30.69	47.52	42.11
Organic %	0.11	0.15	0.17	0.18	0.03	0.05
pH	7.97	8.01	7.99	8.00	7.88	7.85
M.D.D (kg/m^3)	1677	1680	1710	1700	1655	1645
O.M.C %	14.2	13.8	13.4	12.0	14.0	15.6

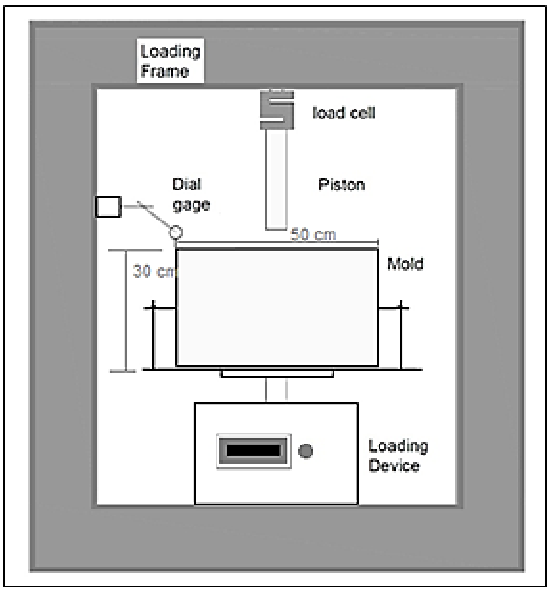


Fig. 2. CBR and DCP tests in 50 cm diameter mold.

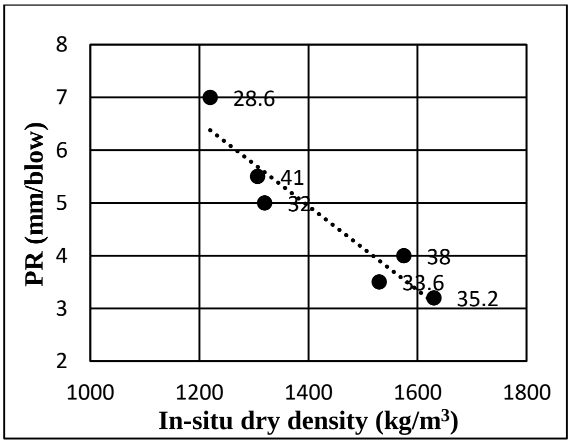


Fig. 3. DCP vs. dry field density (gypsum content labeled).

5.2. DCP vs. Gypsum Content

Fig. 4 shows the variation of the PR with gypsum content of the field tests. PR increase with increasing gypsum content and at 34% gypsum content PR decrease. However, since density is one of the factors affecting PR, so to investigate whether the gypsum has an effect or not, a normalized plot which accommodate the effect of dry density is given in Fig. 5. It can be seen that the behavior is similar to that shown in Fig. 4. This indicates that gypsum is an affecting factor on PR, where it decreases with increasing gypsum content up to 34% then starts to increase. The reason for this behavior can be deduced from the behavior of internal friction angle (ø) where the mineral friction increases simultaneously with increasing gypsum content due to the high coefficient of friction of the gypsum particles, however the porosity of the gypsum-soil increases with increasing gypsum content leading to a reduction in (ø) which affects the shear strength. [13].

5.3. Results of CBR and DCP Tests

Fig. 6(a) and (b) shows the test result from the 500mm on normal scale and log scale respectively and gypsum content shown in the legend. A trend can be observed relating CBR to PR, this curve trend is shown to be linear when plotted in semi Log scale.

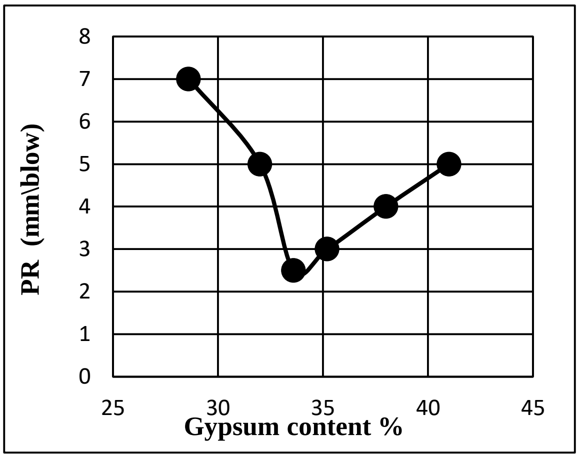


Fig. 4. DCP vs. gypsum content.

5.4. Comparison with Existed Correlations

Several researchers introduced different CBR-PR correlations. All of these correlations are in Log-Log form. The equations obtained in this work are shown below:
For gypsum content< 35%.

$$\log CBR = 2.868 - 1.434 \times \log PR \quad (1)$$

For gypsum content > 35%

$$\log CBR = 2.919 - 1.453 \times \log PR \quad (2)$$

Fig. 7 shows the correlations obtained from this work with the existed correlations.

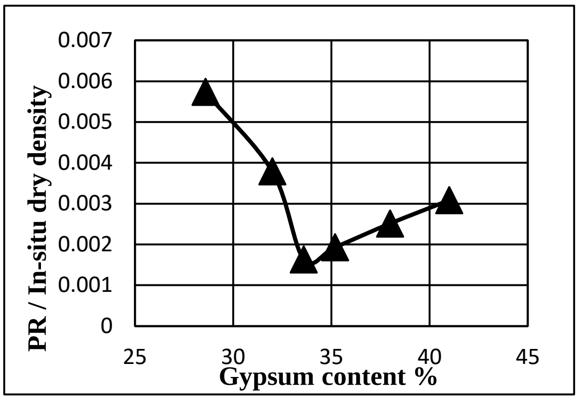
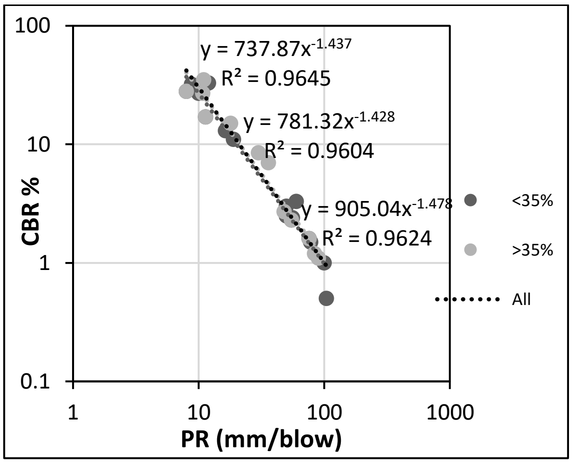
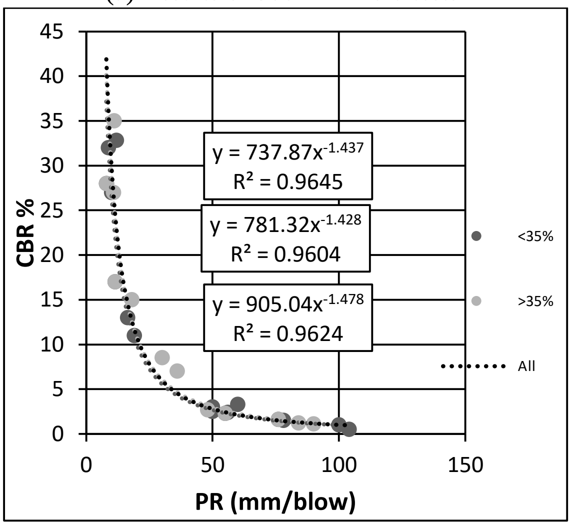


Fig. 5. DCP/ In-situ dry density vs. gypsum content.



(a) Results of 500 mm mold tests.



(b) Results of 500mm mold tests.

Fig. 6. Accumulation of PR-CBR.

Table 2
Correlations obtained with the closest existed correlation

Correlation	Author	Type of work or materials
CBR-PR 500 <35%	Harrison [14]	Laboratory.
CBR-PR 500 >35%	MnDOT [16]	Field

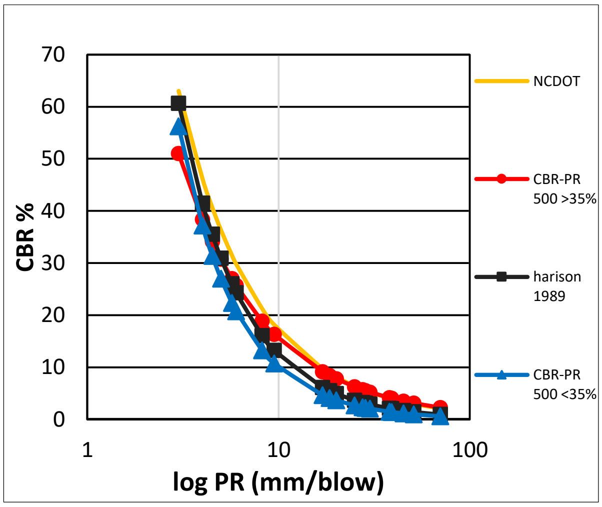


Fig. 7. Comparison of the current correlations with the existed correlations.

6. CONCLUSIONS

The DCP is fast, economical and simple to use. However, it has some limitations among which the inclined penetration and the required effort to lift and drop the hammer. In addition, extraction is difficult without a mean of extraction such as a jack especially in gypseous soil otherwise using a disposable cone would be faster and less tedious.

The DCP can detect changes in density; therefore, it is useful to check the quality of compaction in the field by comparing reading with a reference value.

The PR values obtained from field tests are higher than PR values obtained from Laboratory. Test for the same soil and density due to loss of the natural structure due to disturbance.

The CBR-PR relation is undependable of change in density.

Any of the correlations can be used to calculate CBR if gypsum content is known. Otherwise, the following correlation might be used:

$$\log CBR = 2.956 - 1.478 \times \log PR \quad (3)$$

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