# CORRELATION BETWEEN CALIFORNIA BEARING RATIO AND SHEAR STRENGTH MEASUREMENT OF SOILS

BY

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**ABSTRACT**

*For several years, some pentration tests such as SPT and DCP are being used to determine the CBR values of soil without requiring the digging of test pits. This paper presents their correlative equations which have recently been modified due to several bearing capacity evaluation works of subgrades soils. Results indicate that the modified correlations can be used for translating values of the above pentration tests into in-situ CBR values with plausible reliability. Additionally, this paper indicates that vane shear test or the unconfined compression test can be used for the same purpose but with a somewhat lower reliability. The two latter tests, which are limited to clayey and silty soil only, are used for predicting in-situ CBR values where drilling operations are needed in any event.*

## 1-INTRODUCTION

For several years, some penetration tests such as DCP,DPA and SPT have been used to determine the CBR values of soils without requiring the digging of test pits. Their ability to do so with test pits is the great advantage of these tests,as it is thus possible to reduce costs. Practically, these tests can be termed semi non destructive tests. Moreover, the direct in-situ CBR test occasionally leads to considerable scatter of results, sometimes as high as a coefficient of variation of 65%, Livneh (1987) and Smith and Pratt, (1983), leading to diminished predictive power .Therefore,in such cases, the above penetration tests are preferable, as their coefficient of variation is usually lower, Smith and Pratt (1983).

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For SPT test ,drilling through the subgrade layers is required.Thus, in these cases, the vane shear test can be used to determine the in-direct CBR values of the existing subgrade, when the subgrade is, of course,of clayey or silty type. Also, in these cases, the unconfined compression test can be carried out in the laboratory on undisturbed samples extracted from the soil in the course of the drilling process.

Naturally, the correlative equations used in calculating the CBR value from the above test results are empirical ones, and it is therefore necessary to occasionally test their need for modifications. And, indeed, this paper presents the needed modifications for these correlations as recently tested in several investigations of soil bearing capacity. The analysis for these modifications was made possible by carrying out the above tests in combination with the direct in-situ CBR test, after digging test pits.The above modified correlative equation are described in this paper with the aim of contributing to the issue of the applicability of the DCP, SPT, DPA tests, as well as of the vane shear and the unconfined compression tests.

## 2-THE DYNAMIC CONE PENETROMETER TEST (DCP)

A description of this test is presented in a number of works such as kleyn(1975),and therefore not included in this paper. At the same time, the equation from DCP to CBR values,is slightly different from those presented in the technical literature, and its expression is (kleyn,1975):-

$$\log CBR = 2.20 - 0.71(\log DCP)^{1.5} \text{-----------------(1)}$$

where:-

DCP is the ratio between the depth of penetration in millimeters and the number of blows required to achieve such penetration,

CBR is the material CBR in % in depth of the DCP penetration

A comparison of the above expression and other expressions presented in the technical literature is shown by kleyn(1975).This comparison indicates that the plausible validity of equation (1) .Recently however, an additional correlation obtained from field and laboratory studies, has been published, and an additional comparison with it is warranted.This correlation is :

$$\log CBR = 2.81 - 1.32 (\log DCP) \text{ --------------------(2)}$$



Table (1) presents the required comparisons for a number of typical DCP values.

| DCP (mm/blow) | CBR IN % ACCORDING TO EQUATION | |
|---|---|---|
| | (1) | (2) |
| 100 | 1.56 | 1.48 |
| 80 | 2.17 | 1.99 |
| 60 | 3.29 | 2.90 |
| 40 | 5.76 | 4.96 |
| 20 | 14.01 | 12.39 |
| 10 | 30.90 | 30.90 |
| 1 | 158.49 | 645.65 |

Table (1) indicates that the equation (1) leads to CBR values which are approximately 16% higher than those obtained by means of equation (2) ,for DCP values of approximately 20 mm/blow and upward. This increase stems from the fact that the cone head angle is 30$^{o}$ in the test which leads to equation No. (1) and 60$^{o}$ in the test which leads to equation No.(2 ) . The difference between the above two penetrometers, as obtained in a special investigation designed to assess it (Kleyn,1975), was indeed of a similar order of magnitude,(Figure1).Additionally,it is important to note that the advantage of Equation(1) , is in the lower range of DCP values ,where the CBR values calculated by means of this equation are more plausible than those calculated by means of Equation (2).

## 3-THE SPT TEST

The SPT test is very common in site-investigation works for building foundations. The easy availability of this test permits its application in determining bearing capacity of soil as well , especially in those cases where penetration by means of the DCP is difficult,or in cases where soil thickness exceeds 800mm, which is the maximum thickness of which the DCP test can be applied.

The equation for transforming SPT values into CBR values has been presented by (Livneh and Ishai 1987), and was viel field data have been gathered, it is possible to determine the following recommended expression:

$$\log CBR = -4.16 + 5.65 (\log SPT)^{-0.25} \quad \text{-----------------(3)}$$

N =25

$R^2$ =0.96

SPT is the relationship between the depth of penrteration in millimeters (300mm.) and the number of blows required for such penetration. A description of the above equation and the results of the field tests, are presented in fgure (2). Finally, it is important to mention that the applicability of this test in the SPT range corresponding to CBR ranges from approximately 13% to very high values.

**4. THE VANE SHEAR TEST**

The vane shear test has been used for many years to determine the indirect CBR of clayey and silty subgrades of soils, Wiseman and Zeitlen (1961).The published of correlation equation for calculating the CBR values from the vane shear strength values is given by the following expression (from Livneh and Ishai,1987)

$$CBR = 3.0 \times T_f \rightarrow 5.0 \times T_f \quad \text{---------------------------(4)}$$

where:

$T_f$ = is the vane shear strength in kg/cm

CBR= is the calculated in-situ CBR in %

Recent soil investigation -works carried out in Abha city in the Kingdom of Saudi Arabia, led to the following correlation:

$$CBR = 3.8 \times (T_f)^{0.92} \quad \text{-----------------------------------(5)}$$

$R^2$ =0.75

N =35



In the above correlation ,the logarithmic relationship has been chosen in order to enforce a predicated CBR value of zero (for a given $T_f$ value of zero) .It can be seen that the modified correlation conforms with equation (4), where the predicated equals 3.0 x $T_f$ for high values of a given $T_f$ and the predicated CBR equals 5.0 x $T_f$ for low values of a given $T_f$. In addition,it should be noticed that the value of $R^2$ is not sufficiently high,suggesting limitations in the use of the vane shear test for the prediction of the in-situ CBR values .However, it is still recommended to apply this test as an indirect CBR test. Figure(3) shows that, the relationship between CBR and vane shear strength for equation No.(5).

**5. UNCONFINED COMPRESSION TESTS**

Unconfined compression tests can be run on undisturbed samples taken from the soil, using drilling equipment. The correlative equation between the unconfined compression strength the corresponding CBR value is:

$$CBR = 7.35 \times C_f \qquad (6)$$

$R^2$ = 0.63

N=30

where :-

$C_f$ = unconfined compression strength ($kg/cm^2$)

CBR= calculated in- situ CBR in%

Comparison of equation (6) with equation (5) indicates that $C_f$ equals $2T_f$ .For lower values of $T_f$ and $C_f$ is lesser than $2T_f$. These facts are due ,among other reasons,to the difference in the shearing rate of these two tests. The use limitations of this test, which stem from the low value of $R^2$ ,are more significant than those associated with the vane shear test .Figure (4) shows that ,the relationship between unconfined compression strength and CBR from equation No.(6).

**6. SUMMARY AND CONCLUSION**

It is well known that the advantage of various penetration tests, such as DCP and SPT, in assessing the bearing capacity of soil ,is that;

they do not require the digging of test pits in existing soil .This advantage is, of course, expressed in a lower cost of execution and less disturbances to passing building. Practically, these tests can be termed semi non -destructive tests.The same applies to the vane shear and the unconfined compression tests in clayey or silty soils only. This paper presents testing and empirical correlations between direct-in-situ CBR tests and above mentioned tests.

The conclusions obtained from the analysis of the works are:-

The correlative transformation from DCP or SPT values to direct CBR values, can be used with plausible reliability. The equations of modified transformations are presented in this paper by equations (1,2 and 3).

The vane shear test and the unconfined compression test can be used for estimating the in-situ CBR values of clayey or silty soils,but with a Lower reliability.

Finally, it is important to emphasize what the DCP test permits to determine the in situ CBR value of materials with any range of strength. Similarly, the SPT test permits to determine the in-situ CBR of materials with a medium to low range of strength. Owing to the strength limitation ,this test cannot occasionally be carried out from the existing soil layers and it is therefore necessary to vertically drill through the structural layers until the SPT cone achieves the depth at which the strength value of the structural layers are appropriate to the tests ability. It is applicable to materials with a strength range of medium to high. As for the vane shear and unconfined compression tests, they also necessitate vertical driling.Their applicability is limited to clayey or silty soils only.

**7. REFERENCES**

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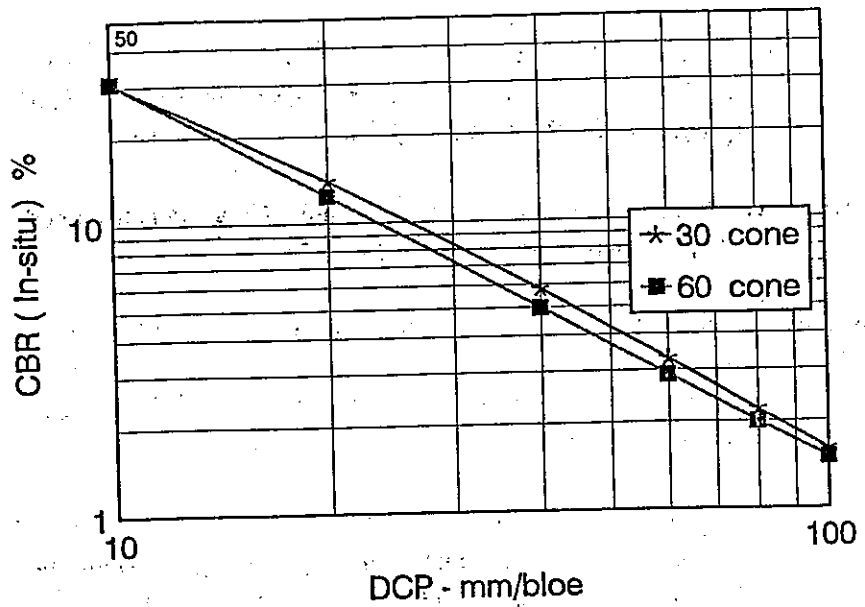


Fig. (1) Relationship between DCP & CBR,

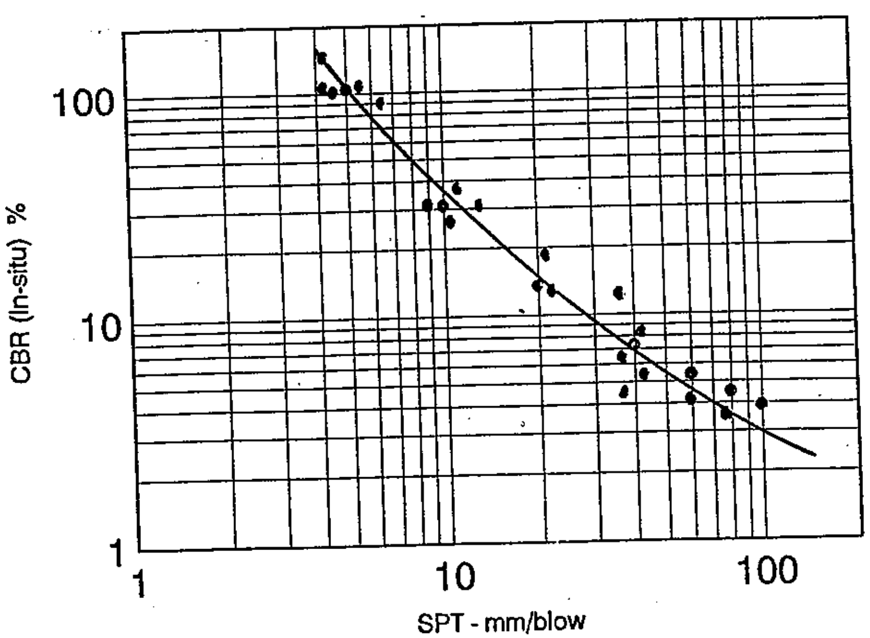


Fig. (2) Relationship between SPT & CBR



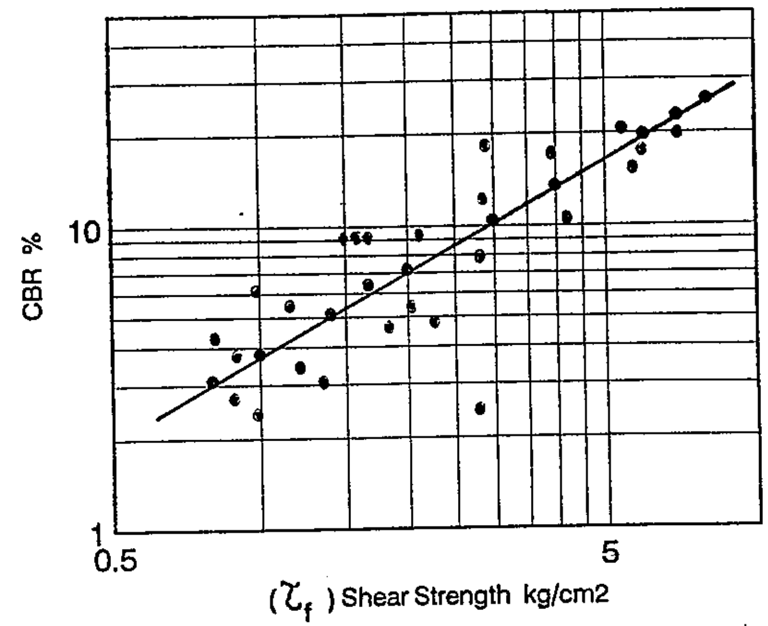


Fig. (3) Relationship between shear strength & CBR

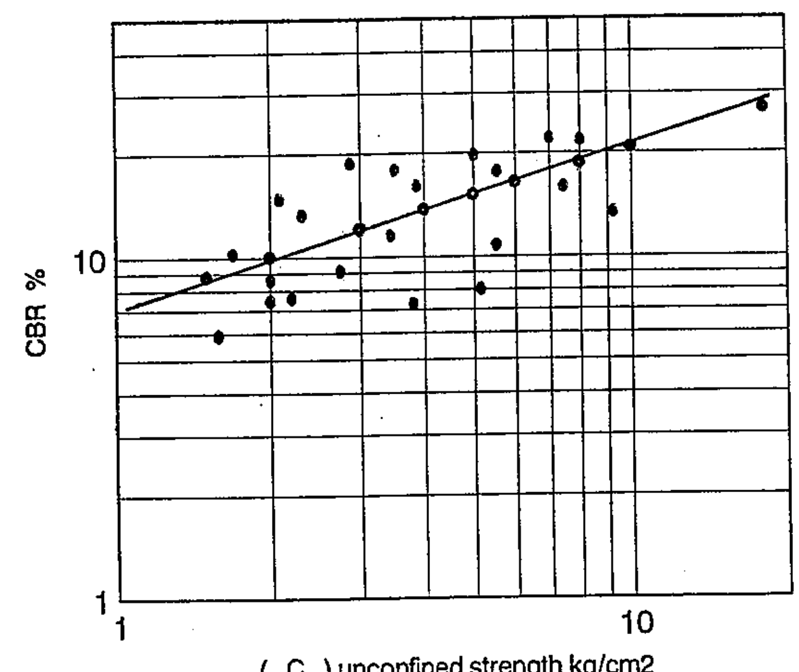


Fig. (4) Relationship between unconfined compression strength & CBR