Bearing Capacity from Dynamic Cone Penetration Tests

by

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Introduction

PENETRATION tests are common and are widely used for probing the soil. Out of the various types, the standard penetration test (SPT) which is a dynamic test, is most widely used for determining allowable soil pressures and relative densities specially for non-cohesive soils. The test is conducted in a 10 to 15 cm. diameter bore-hole, into which a 5 cm. outer diameter tube known as the standard sampler is lowered and is driven into the soil under an impact load of 63·5 kg. falling from a height of 75 cm. The number of blows per 30 cm. of penetration (from 15 to 45 cm.) are recorded. These are correlated to different parameters of soil such as relative density, angle of internal friction and allowable soil pressure.

Terzaghi and Peck (1948) have given a chart correlating N_c with safe allowable pressures for a 2·5 cm. settlement and different width of footing on sandy soil. They too have, however, not taken into account the effect of surcharge on the N-value which is considerable at large depths.

Meyerhof (1965) has stated that N-value depends on the effective overburden pressure. He has further suggested that the bearing pressures estimated by SPT method could safely be increased by 50 per cent, with the corresponding predicted settlements would vary from about 0·8 to 2 times the observed values.

Since the standard penetration test is rather cumbersome and time consuming, other workers such as Palmer and Stuart (1957), Meyerhof (1956), Schultze and Knausenberger (1957) have tried to replace it with a dynamic cone penetration test. In this, the cone is driven into the ground without a bore-hole in the same manner as in normal SPT test and the 'N_c' values are recorded for every 30 cm. They have recommended different diameter of the cones and different relationship with SPT. A comparative study with cones of different diameters was carried out by the authors (1970) and they have recommended the use of 6·25 cm. diameter

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TABLE

Comparison of

Sl. No.	Location	Classi- fication	Depth in meters	Sur- charge kg /cm².	'N_s' from B.H.	Correc- ted 'N_s' at sur- face	Allowable pressure for 7·5 mm. settle- ment PLT. kg./cm.²
1	2	3	4	5	6	7	8
1.	Church Buildiug, Lucknow	SM	3·3	0·63	6	2	1·47
2.	Indraprastha, N. Delhi	,,	2·4	0·42	7	4	1·80
3.	Delhi Polytechnic, Delhi	SM-ML	1·8	0·35	5	2	1·87
4.	Indian Law Institute, N. Delhi	SM	1·5	0·28	4	2	1·40
5.	Medical Enclave, Amritsar	,,	1·5	0·28	6	4	3·00
6.	Girls Hostel Medical College, Amritsar	,,	1·5	0·28	7	4	2·96
7.	I.T.R.C., Lucknow	,,	1·5	0·28	5	3	1·80
8.	-do-	,,	3·0	0·56	5	2	1·50
9.	Boiler Site, Faridabad	SM-ML	2·4	0·42	10	7	3·40
10.	Tractor Factory Site, Ghaziabad	SM	1·5	0·28	8	5	2·40
1.	-do-	,,	1·5	0·28	9	6	2·50
12.	New Hostel, CBRI	,,	0·75	0·14	4	3	1·87
13.	CBRI Site	,,	0·5	0·10	18	18	8·50
14.	-do-	,,	1·0	0·18	11	10	5·10
15.	-do-	,,	0·75	0·14	4	3	1·75

cone. A relationship with SPT has also been given and with its aid the values of allowable soil pressure were determined indirectly from the existing charts and formulae. The values of soil pressures thus obtained are conservative (Table I).

In view of this it was felt necessary to carry out a proper study to establish a direct relationship between N_c values and allowable pressures.

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allowable pressures.

Allowable pressure for 3 m. footing (kg./cm^2.)				Per cent differences w.r.t. PLT.			
Terzaghi	Meyerhof	CBRI	Granger	Terzaghi	Meyerhof	CBRI	Granger
9	10	11	12	13	14	15	16
0·3	0·6	1·4	0·31	—80	—59	—5	—79
0·4	0·7	2·4	0·45	—78	—61	+33	—75
0·3	0·5	1·4	0·22	—84	—73	—25	—88
0.25	0·4	1·4	0·14	—82	—72	0	—90
0·3	0·6	2·4	0·31	—90	—80	—20	—90
0·4	0·7	2·4	0·45	—86	—76	—19	—85
0·3	0·5	1·8	0·22	—83	—72	0	—88
0·3	0·5	1·4	0·22	—80	—67	—7	—85
0·75	1·0	3·2	0·80	—78	—71	—6	—76
0·65	0·8	2·6	0·56	—73	—67	+8	—76
0·70	0·9	2 8	0·67	—72	—64	+12	—73
0·25	0·4	1·8	0·14	—87	—78	—4	—92
1·8	1·8	7·8	1·65	—79	—79	—8	—80
0·9	1·1	4.5	0·94	—82	—78	—12	—81
0·25	0·4	1·8	0·14	—86	—78	+3	—92

Investigations

A model study to establish a direct correlation of 'N_s' and 'N_c' with the allowable soil pressure was carried out in the laboratory on two types of sands (fine and coarse).

The gradation curves are given in Figure 1. Sands were compacted in a container 75 cm. diameter and 150 cm. high (Figure 2) at different relative densities obtained by compacting in 15 cm. layers by a surface vibrator for different time intervals. The relative density *versus* time of vibration curves for both the sands are given in Figure 3. Penetration tests (SPT and dynamic cone) were conducted at different relative densities and overburden pressures. The latter was applied by means of jack (Figure 4).

The sand under test being confined in a drum, the pressure applied on the top of the soil was not distributed uniformly to the lower depths. It was measured by putting pressure cells at various depths and was found to decrease by 5 to 10 per cent at the normal penetration depths of 15 to 45 cm.

Air dry sands were used and the moisture content check was made from time to time. Density check was made with the help of containers kept in each layer of 15 cm.

The SPT results at different overburden pressure and relative densities have been averaged out in Figure 5. These results are in agreement with Gibbs and Holtz (1957). The effect of overburden pressure

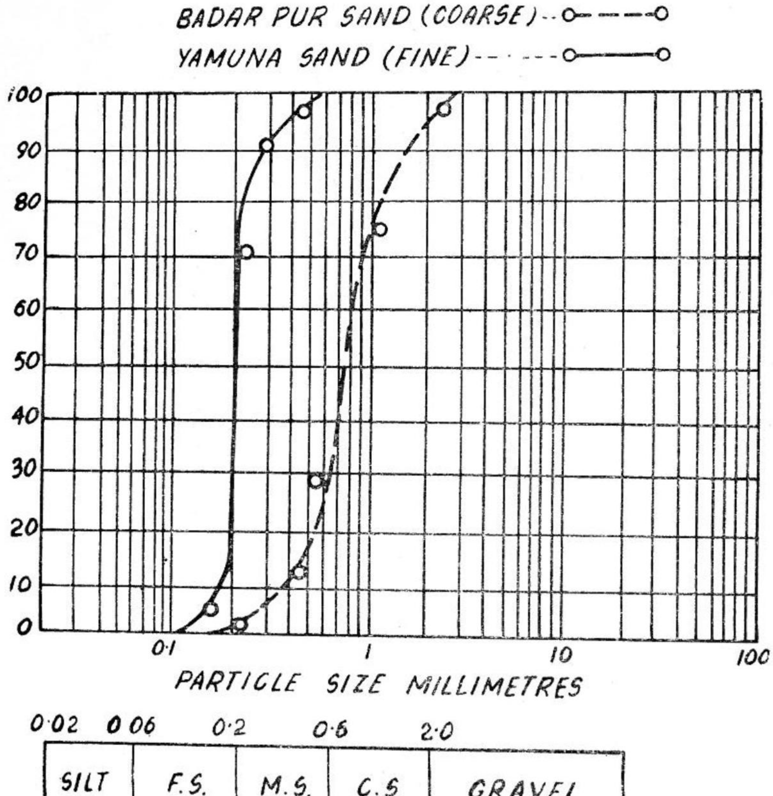

FIGURE 1 : Gradation curves for fine and coarse sands.

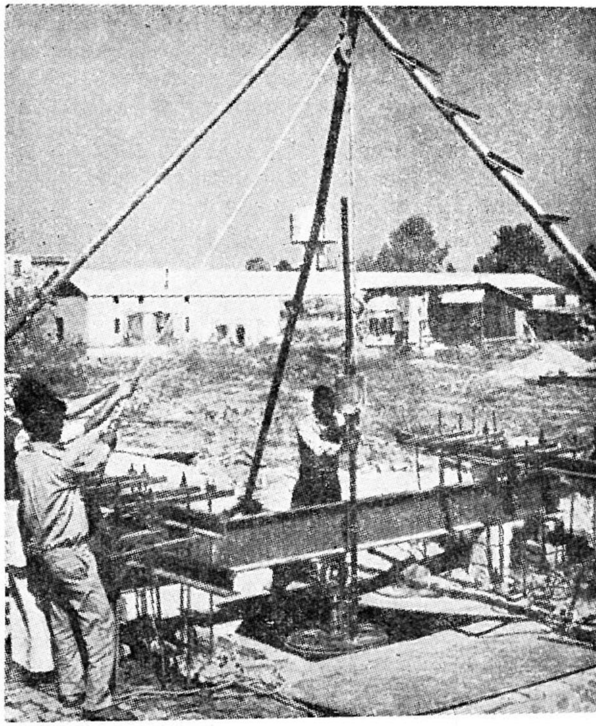

FIGURE 2 : Photograph of the model set-up for conducting S.P.T. and dynamic cone tests.

has been clearly brought out. Curves given by Gibbs and Holtz (1957) and Terzaghi and Peck (1948) are also plotted for comparison.

Dynamic cone tests were also conducted at different relative densities and overburden pressures for fine and coarse sands. In this case also, average curves are shown in Figure 6.

In the field the bearing capacity of cohesionless soil is normally determined by a plate load test. These tests were conducted in a pit of 1·5 m. × 1·5 m. × 1·5 m. The sand was compacted to different densities and load tests were conducted with a plate of 30 cm. × 30 cm. at the surface. Load settlement curves are given in Figure 7.

On the basis of load settlement curves and using Terzaghi's expression $\frac{S}{S_1} = \left(\frac{2B}{B+1}\right)^2$ allowable soil pressures for different width of the footings were computed.

Procedure to Estimate Allowable Pressure

From the point representing recorded 'N_s' or 'N_c' value and the overburden pressure curve (Figures 5 and 6) a line is drawn vertically downwards to intersect the zero overburden pressure curve. The point

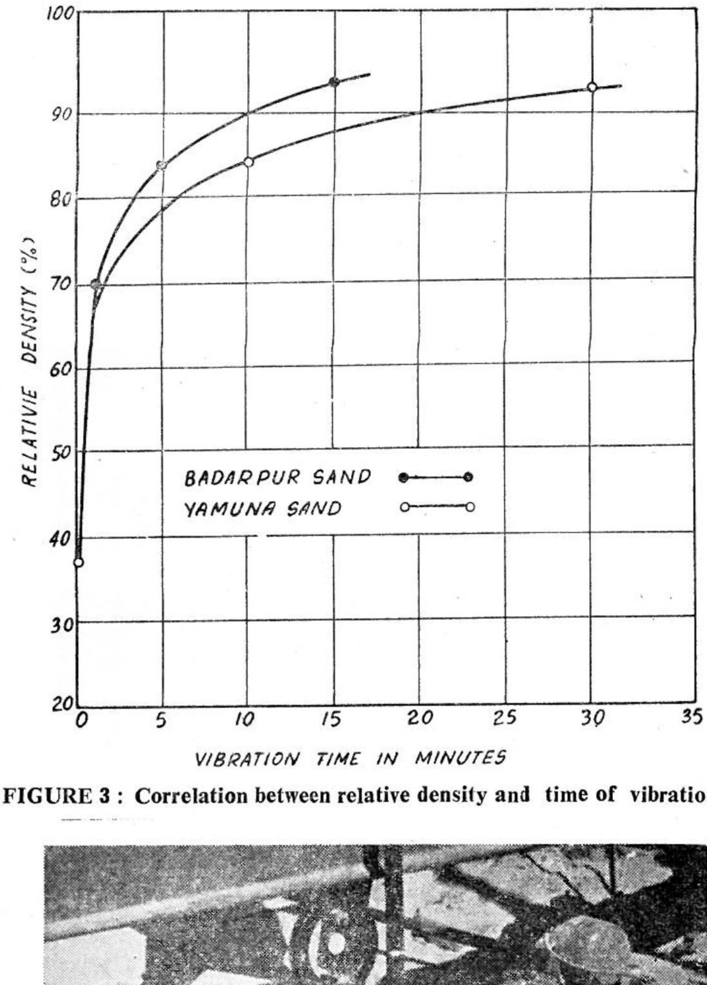

FIGURE 3 : Correlation between relative density and time of vibration.

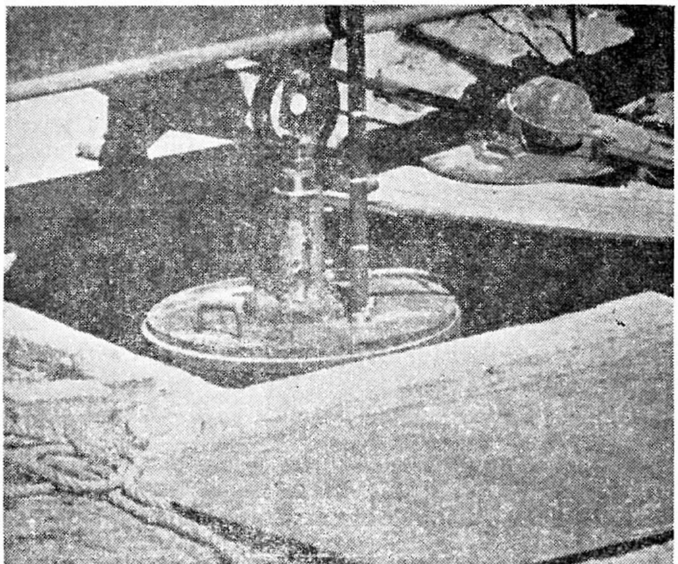

FIGURE 4 : Photograph showing the application of overburden pressure.

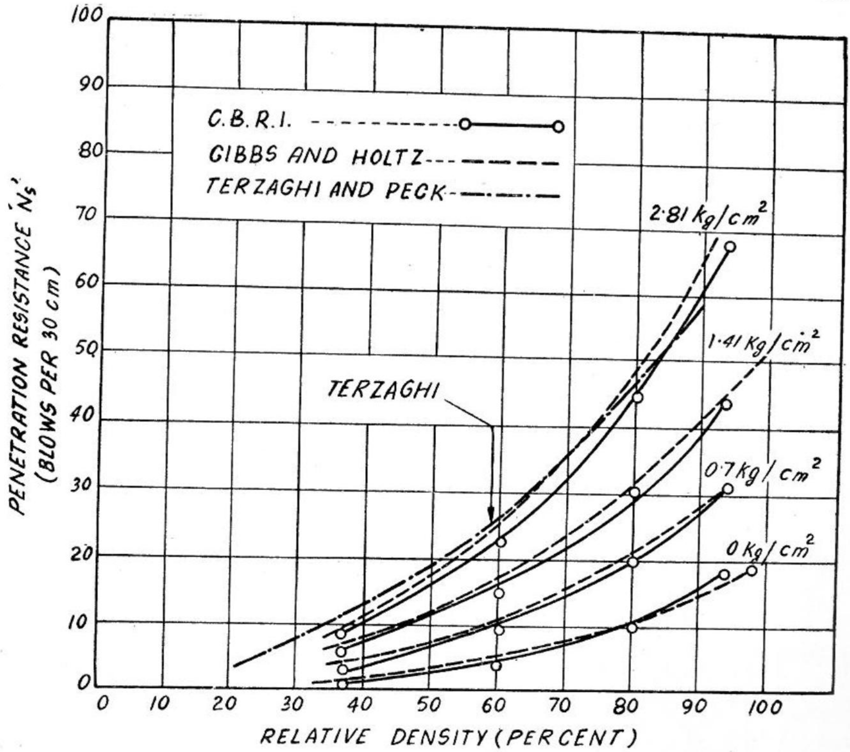

FIGURE 5 : Correlation between relative density and N_s (Standard Penetration Tests) at different overburden pressures.

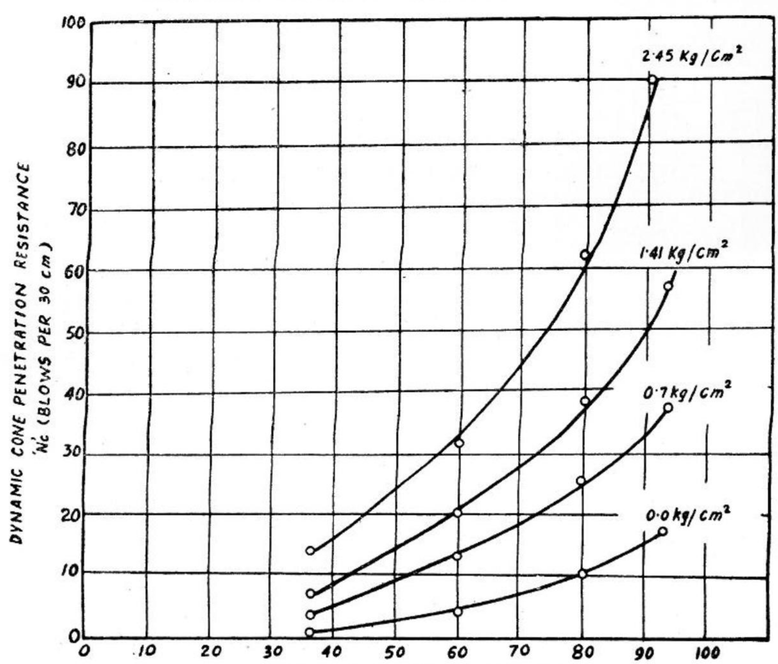

FIGURE 6 : Correlation between relative density and N_c (Dynamic Cone Tests) at different overburden pressures.

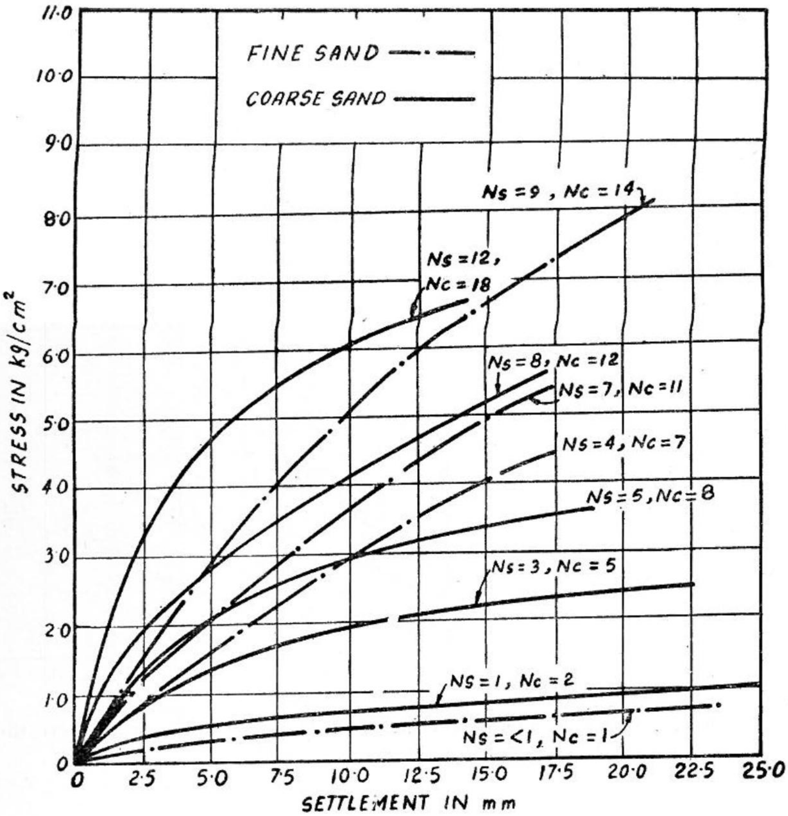

FIGURE 7 : Load settlement curves for fine and coarse sand.

of intersection is projected horizontally to give the corrected 'N_s' or 'N_c' value. Corresponding to this corrected value of N_s or N_c, the allowable soil pressure is determined with the help of Figure 8.

The values of soil pressures computed on the basis of 'N_s' values were compared with the soil pressures obtained from plate load tests on SM and ML types of soils during various site investigations conducted during the past few years. In these plate load tests the allowable pressures were noted from the load-settlement curves. These correspond to a 2·5 cm. settlement of the 3 m. footing (reduced to the corresponding settlement of the plate by using Terzaghi expression). The data for a few sites is given in Table I.

Soil pressures were also computed on the basis of the same 'N_s' values with the help of chart given by Terzaghi and Peck (1948), Granger (1963) and Meyerhof (1965) (Figure 9). The data was examined statistically. The coefficient of correlation determined in each case was found to be 0·342, 0·595 and 0·507 respectively. The coefficient of correlation for CBRI charts is 0·80.

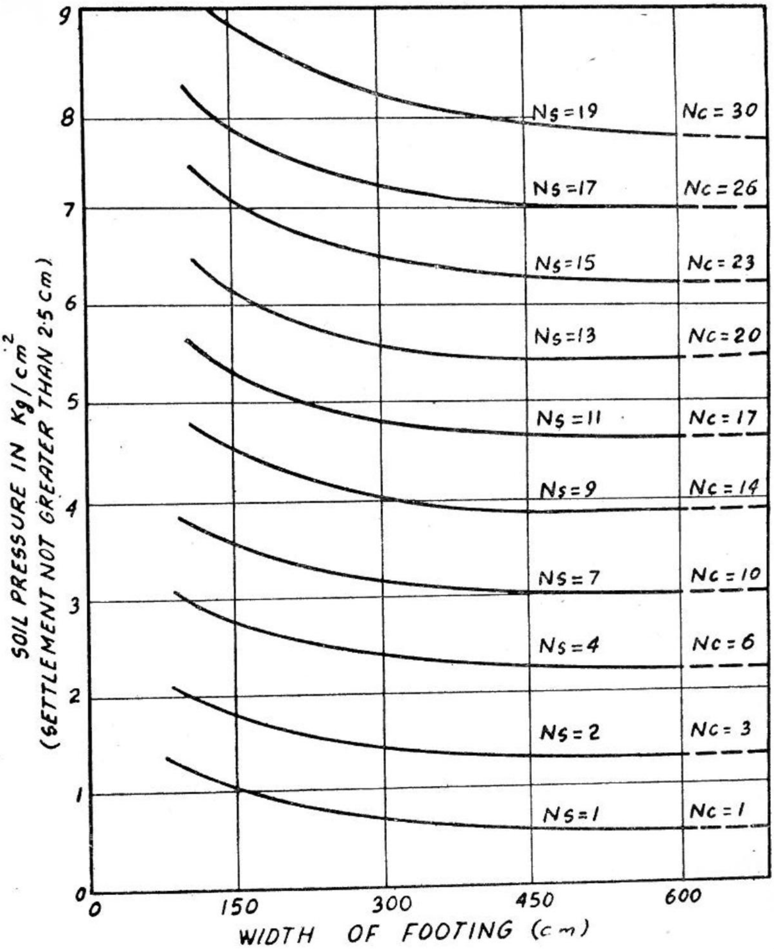

FIGURE 8 : CBRI allowable pressure chart for N_s and N_c.

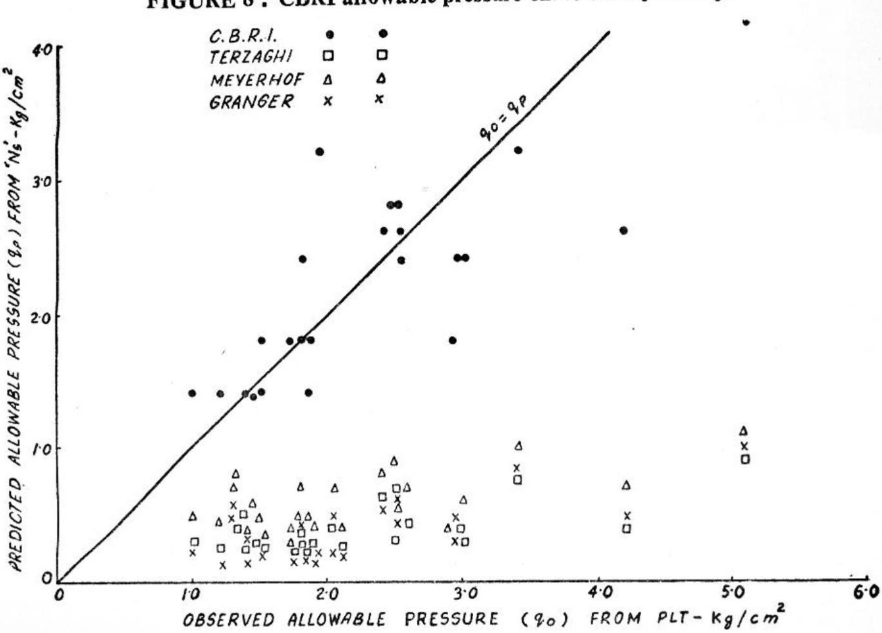

FIGURE 9 : Comparison of observed and predicted allowable pressures.

Concluding Remarks

From the above test data it would be seen that the CBRI soil pressure charts can be used with fair confidence to determine the safe allowable soil pressures.

Acknowledgement

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