BUILDING DIGEST

CENTRAL BUILDING RESEARCH INSTITUTE, INDIA

DEEP SOUNDING BY CBRI CONE PENETRATION TEST

Introduction

For enonomic and safe design of foundation for structures it is essential that a reasonably accurate estimate about the properties of underlying material is known. A closely spaced sub-soil investigation is necessary because local variation and erratic substrata condition are very common. The widely used method of sub soil exploration is the bore-hole study but they are time consuming and costly if carried out at close spacings. Some reliable, simpler and cheaper method is therefore necessary.

Probing is the simplest test to find out the firmness of a ground. Considerable work has been carried out on penetration tests during recent years. These tests do not require a bore hole yet they provide a useful and continuous record of sub-strata.

Deep sounding by static cone penetration tests (Dutch-cone) is getting popular and correlations between static cone resistance (Cr) and N value have been suggested. However, it has limitations in hard grounds. Also due to the non-availability and expensive nature of the equipment, its use is limited.

The other method of deep sounding is the dynamic (standard) penetration test. Normally a 2 inch outer diameter spoon sampler is driven through a bore hole by a 140 lbs. (64 kg.) drop-weight falling from a height of 30 inches (75 cms.) and the number of blows (N) per foot (30 cms.) of penetration provides the penetration resistance. The dynamic cone test is no doubt a much simpler test but here again a bore hole has to be made in advance of the test. The use of* a cone in place of the tube sampler makes the process still simpler since it dispenses with the need of making a bore hole. It has been found that dynamic cone penetration values (Nc) agree fairly well with N-values if the test is carried out in a prescribed manner.

Technique of Dynamic Cone Penetration Test

Dynamic cone penetration test is carried out similar to a Standard penetration test by driving a 60° cone having a base diameter of 6.5 cms. The friction on the drill rods connecting the cone is eliminated by circulation of bentonite slurry. The number of blows per 30 cm of penetration of the cone (Nc) provides the penetration resistance.

Bentonite Slurry

Bentonite belongs to the montmorrilonite group of clay which swells on coming in contact with water. The slurry provides an impervious lining and stabilizes the sides of the bore hole. It also lubricates the drill rods during penetration.

A good commerical variety of bentonite (swelling index not less than 100) should be used. Its concentration in the slurry should be 5% (by weight). Poorer grades of bentonite may be used by activating the slurry with about ½% soap solution. The slurry should be of uniform consistency. Presence of bentonite in forms of lumps in the slurry may cause choking up of the equipment. Properties of some of the Indian bentonites are given in Appendix-1. A suggested procedure for the preparation of slurry is given in Appendix-11.

Testing Procedure

The diagram of the cone and the general assembly of the test showing flow lines of bentonite slurry is shown in Fig. 1.

The cone (A) is connected to driving rods (B). The connection may be threaded or push fit so that the cone is either withdrawn or left in the soil when the drill rods are extracted on completion of the test. The idea of leaving the cone behind is to avoid undue pulling effort. Four vanes (C) minimum 15 cm long are welded on the drill rod just above the cone. Along the shelf of the vanes, a few 3mm dia. holes are provided for the escape of the slurry. The drill rods are connected to a driving head (D). A guide rod (E) is connected to a water swivel (F) through a flexible tube connection (G) and then to a reciprocating hand pump (I) through a bent tube and a flexible hose (H). The inlet tube (j) of the pump is kept immersed in a feeding tank (K) containing bentonite slurry. The drop weight (monkey) (M) is operated by means of a rope going round a fixed pulley (H) and winch (O) fitted on the tripod hoist. The movement of boring assembly with swivel is controlled with a rope passing over another pulley (N).

Normally 6 persons are required to conduct the test. Driving of cone and pumping of slurry are simultaneously carried out. Efficient circulation of slurry is very necessary to get reliable results. This is effected by

*IS:4968 (Part II)-1968, Method for Subsurface Sounding for soils, Part II Dynamic method using cone and bentonite slurry.

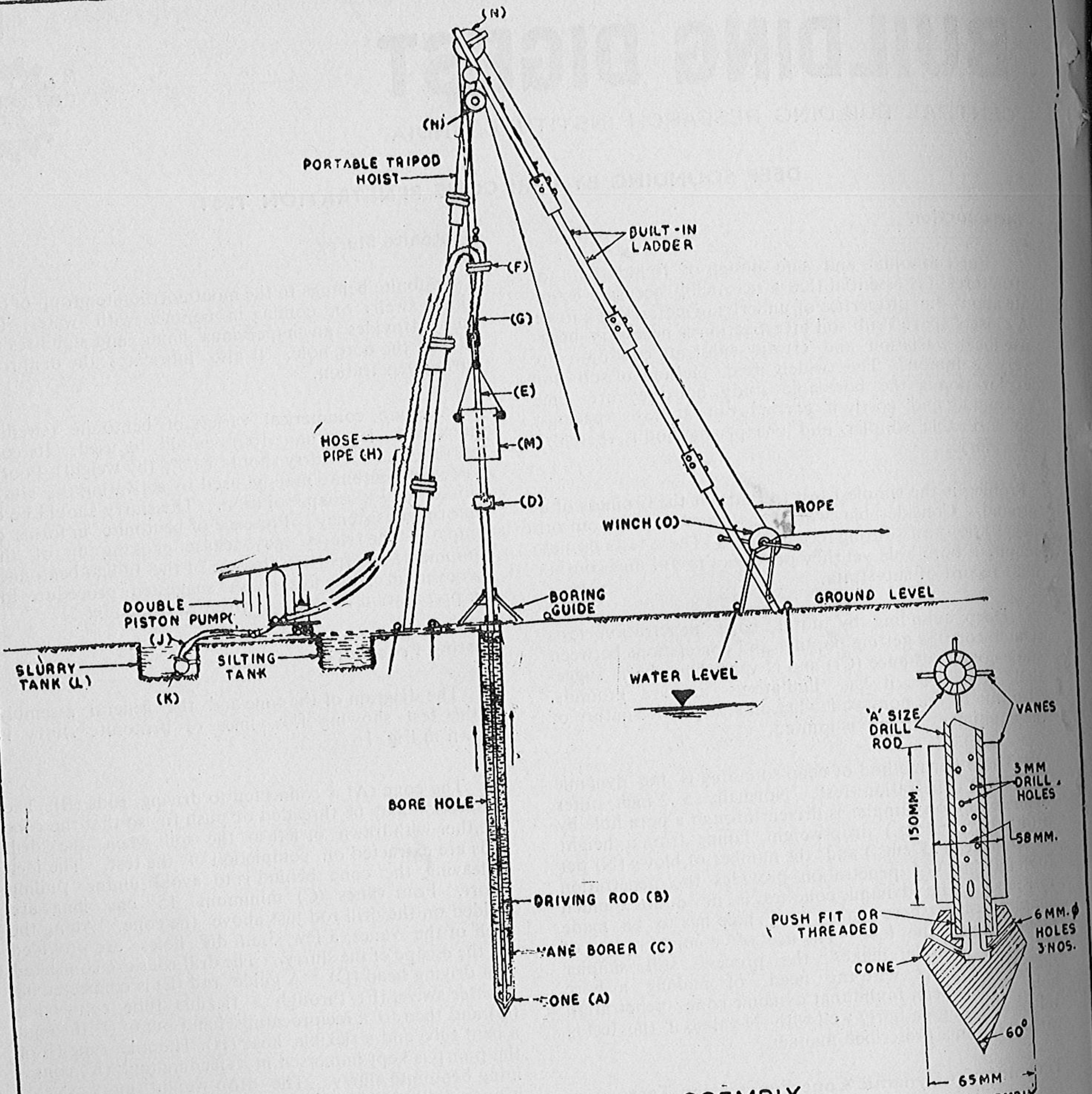

FIG. I C. B. R. I. CONE PENETRATION ASSEMBLY

rotating the drill rods from the top after each foot of penetration. The vanes help in keeping the bottom of bore hole clean.

Details of the equipment required for use with bentonite slurry are given in Appendix-III. It is simple and readily available*. Details of hoisting assembly and operation of the winch are given in Appendix-IV.

*M/s M.S.J. (Engineers) & Co. Khanjarpur, Roorkee, U.P. India.

A typical dynamic cone penetration curve is shown in Fig. 2.

These tests can also be conducted without using bentonite slurry. However, the depth should be then

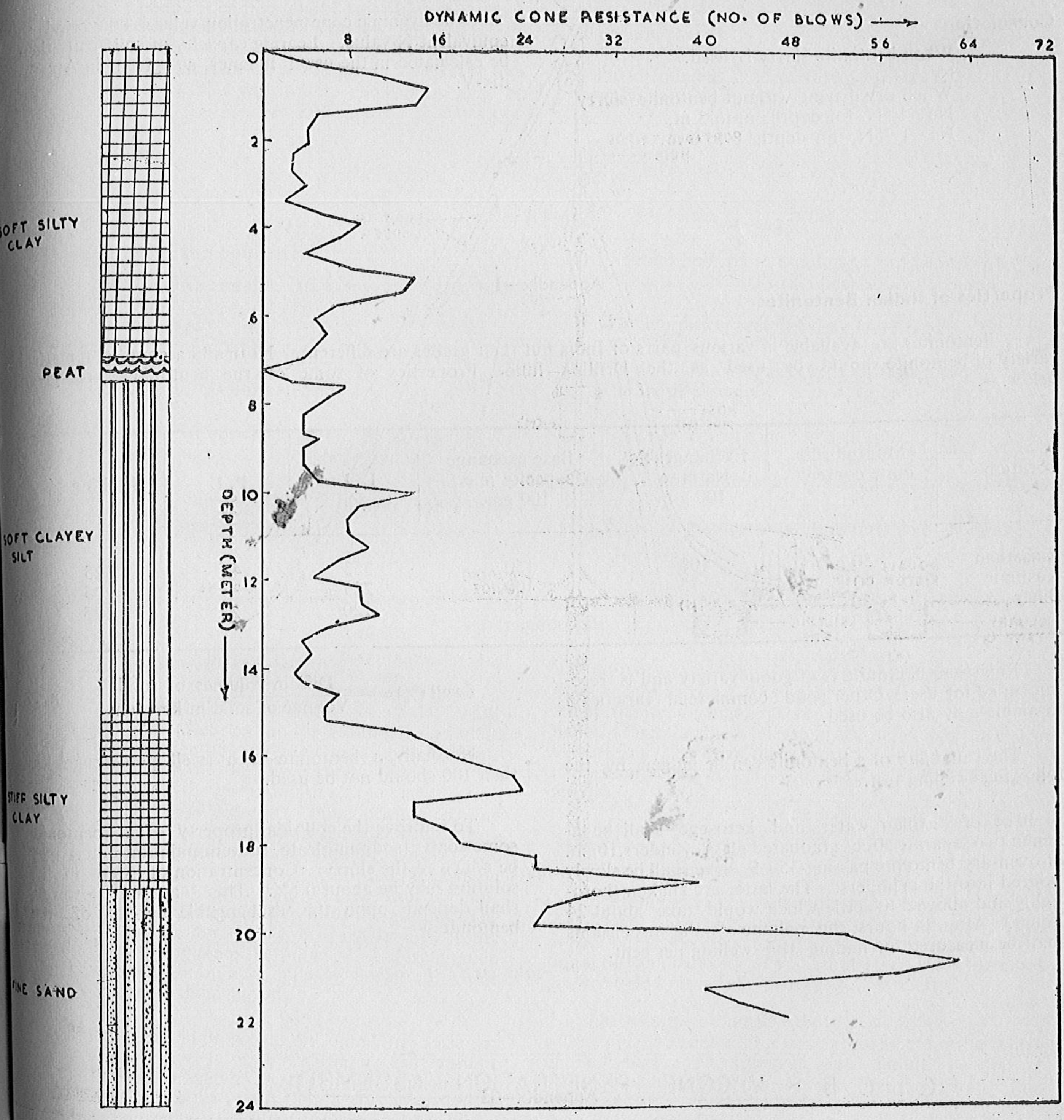

FIG. 2 DYNAMIC CONE RESISTANCE CURVE

imited to 6 meters as the effect of skin friction increases considerably thereafter.

Correlations

When bentonite slurry is used.
$N_c = N$
When dry driving without bentonite slurry
$N_c = 1.5N$, for depths upto 3 m,
$N_c = 1.75N$, for depths 3 to 6 m.

Bearing Capacity of Soil from test results

The dynamic cone penetration value is converted to equivalent N-value. Bearing capacity of soil can then be calculated in the usual manner as given in Appendix-V.

Appendix—I

Properties of Indian Bentonites

Bentonites are available in various parts of India but their grades are different. Normally a good commerical variety of bentonite should be used as the Drilling fluid. Properties of some of the bentonites are given below:—

Location	Montmorillonite content %	Exchangeable Na m. e./ 100 gm.	Base exchange capacity m.e./ 100 gm.	L. L. %	P. L %	Swelling %
Rajasthan	50	100	150	353	43	325
Kashmir	40	75	100	283	33	225
Bihar	30	10	85	120	25	125

Rajasthan bentonite is of good variety and is recommended for use. Other good commercial varieties if available may also be used.

The suitability of a bentonite can be judged by the following swelling test.

30 cc of distilled water and kerosene shall be taken in two separate 50 cc graduated glass cylinders. 10gm. of oven-dry bentonite passing 35 I.S. sieve shall be slowly poured into the cylinders. The latter are shaken thoroughly and allowed to settle which would take about 24 hours. After 24 hours, the volume of the suspensions shall be measured for finding the swelling per cent.

$$\text{Swell } (\%) = \frac{\text{Diff. in volumes of solids}}{\text{Volume of solid in kerosene}} \times 100$$

Normally, a bentonite with swell percentage less than 100 should not be used.

To improve the colloidal property of a bentonite some soap (sodium-oleate, sodium-palmitate etc.) may be added to the slurry. Concentration of soap in the solution may be about 0.5%. The amount however, shall depend upon the exchangable cations of the bentonite.

Appendix—II

Preparation of Bentonite Slurry

For a thorough dispersion of bentonite in water for preparation of slurry, the following method is suggested. The slurry should be kept ready at least one day ahead of the boring operation.

The slurry should first be made in barells and then transferred to the tanks. Some reserve slurry may also be kept in an adjoining vat or barrel.

To start with, the feeding and settling tanks, should be dug in the ground. These should be then lined with a thick paste of bentonite to avoid loss by percolation. The size of the tanks can be about ½m×½m×½m deep. These should then be filled with slurry which should be thinned by adding water, slowly stirring the whole mass thoroughly. In the absence of ready made slurry the tanks may first be filled with water. Bentonite can be added by sprinkling in small quantities and the water stirred at the same time vigorously. At no stage the dispersion should be hurried up. Fresh bentonite should not be added until dispersion is complete. If bentonite is added in heaps, lumps will be formed and it will be very difficult to disperse them.

Appendix—III

Various parts of the equipment

(1) 60° cones of 65 mm dia. (6.4 cm) provided with discharge holes.

(2) One drill rod fitted with 4 vanes, minimum 15cm long.

(3) 'A' type drill rods for extensions.

(4) Water swivel fitted with adopter for connection to drill rods through a flexible tube assembly.

(5) Rubber hose delivery tube 8 m long provided with circular clamps.

(6) Suction hose pipe, 8 m long, provided with foot-valve and clamps for connection with pump.

(7) Double piston reciprocating hand pump.

(8) Tripod hoist with manually operated winch. pulley and rope assembly.

(9) Spanner for rotating the drill rods.

(10) Boring guide(covered by Indian Patent No.82303).*

(11) 64 Kg drop weight with driving head assembly.

Appendix—IV

Hoisting of equipment at site

To start with, the position of the bore hole, tanks, channels etc. is first marked on the ground. The tanks and channels are then dug and the tripod hoist is installed at the location of the bore hole. To erect the tripod, it is laid on the ground with all the legs stretched apart. The two legs are then positioned and pegged. The hoist is now lifted to shoulder height from the centre by three persons, the fourth holding the central leg from slipping. It is now hoisted in position by moving the central leg only by all the four persons. All the legs are then firmly anchored to the ground. The exact location of the bore-hole is now marked by using a plumb-line hanging from the pulley. The boring guide is next placed in position and suitably anchored. The driving operation is than started.

The pump should be placed on some firm base so that the splashing slurry does not soften it. Soft ground below a pump will make it unstable and difficult to operate. If possible, the pump should also be anchored to the ground.

Operation of Drop weight (Monkey)

One or two persons rotate the handle of the winch. Another person pulls the rope holding the drop weight wound twice round the winch drum. This makes the drop weight to rise. The pull required is nominal. When the drop weight reaches the requisite height of 30 inches (75cm) a slight release in the pull keeps the weight in position. To drop the weight, the grip on the rope is released. This makes the drop weight fall under gravity.

Appendix–V

(i) Shear Consideration

Bearing capacity can be obtained from Figs. 3 & 4. Fig. 3 gives the safe bearing capacity for different widths of footing neglecting surcharge and Fig. 4 gives additional bearing capacity due to surcharge. The surcharges are based on a bulk density of 100 lb/cft.

The results obtained above are applicable if the water table is situated at a depth greater than the width of the footing. The values in Fig. 3 should be halved if the water-table is present at the footing level. The values of Fig. 4 should be halved if the water table is at the ground surface. For intermediate positions the values may be interpolated.

(ii) Settlement consideration

Allowable bearing pressure of soil with respect to 2.5 cm settlement can be obtined from Fig. 5. If the

*Sole Licencee M/s M. S. J. (Engineers) & Co., Khanjarpur, Roorkee, U.P. India.

water-table is at the footing level, the bearing capacity should be reduced to half.

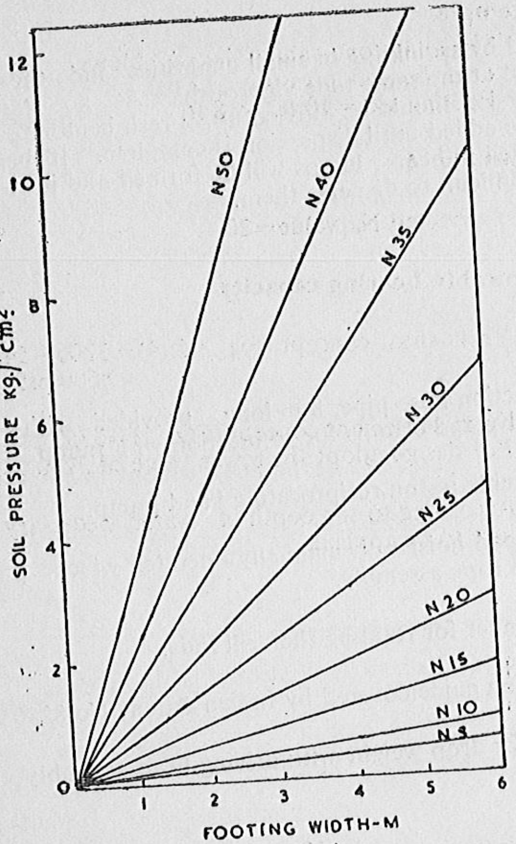

Fig. 3. Safe Soil Pressure Without Surcharge

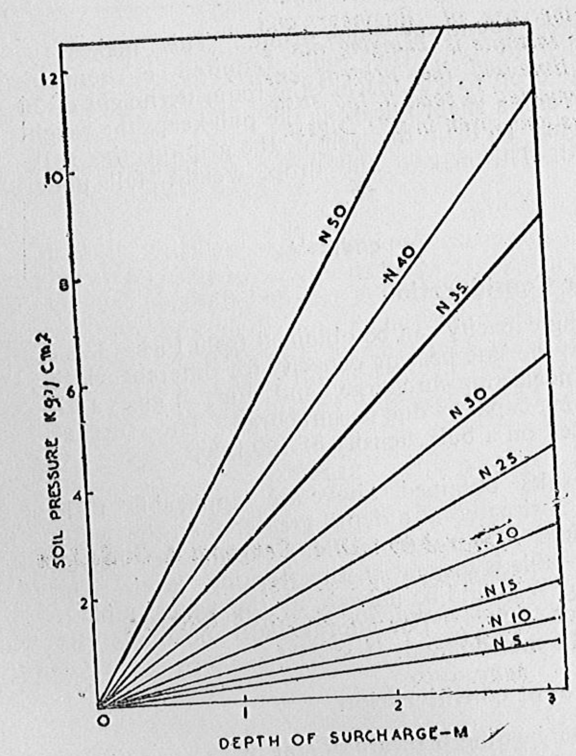

Fig. 4. Additional Safe Soil Pressure Due To Surcharge

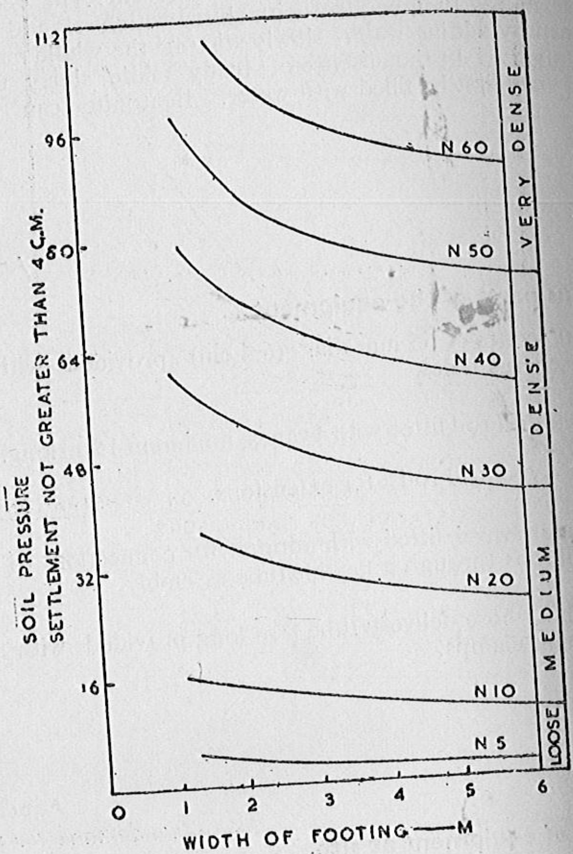

Fig. 5. SOIL PRESSURE CORRESPONDING TO ONE INCH SETTLEMENT OF FOOTING ON SAND.

Correlations

(i) Water table :

N_c value in silty and sandy soils should be corrected if the test is carried out below water table according to the following expression :

$$N'_c \text{ (corrected } N_c) = 15 + \tfrac{1}{2}(N_c - 15).$$

(ii) **Overburden**

The dynamic cone resistance will be affected due to over burden. To obtain the corrected N_c value calculate the effective over burden pressure at the required depth and find out its intersection point with the measured N value in Fig. 6.

Draw a perpendicular through this point to meet the Terzaghi and Peck dotted curve and project horizontally from the point of intersection to meet the ordinate at 'N'.

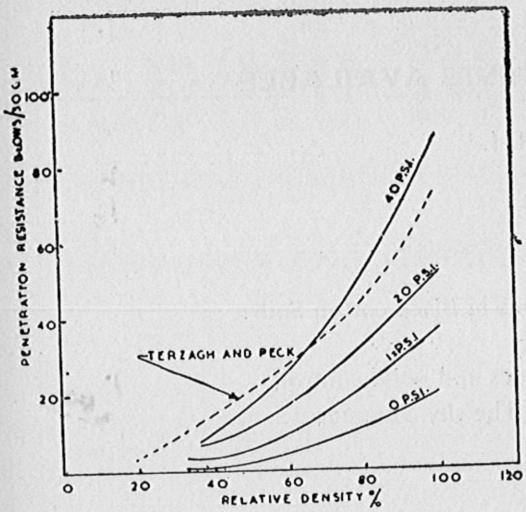

FIG. 6 EFFECT OF OVER BURDEN ON PENETRATION RESISTANCE FOR SANDY SOILS.

Example

Dynamic cone-value (N_c)=12 blows.
Over burden pressure=12 psi.
Footing size=10 ft. × 8 ft.

From Fig. 6

Corrected N_c value=20.

Allowable bearing capacity

(i) From shear concept (Fig. 3 & 4)=3200+5400 p.s.f. =8600 psf.

(ii) From settlement concept (Fig. 5)=3750 psf. For design adopt the lower value of 3750 psf.

According to the depth of water necessary corrections are to be applied.

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