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BUILDING RESEARCH NOTE

63

CENTRAL BUILDING RESEARCH INSTITUTE, INDIA

SUB SOIL DEFORMETER FOR SOIL EXPLORATION

Introduction

In soil exploration work one has to resort to both laboratory tests and field tests. The former have the advantage of close control over various factors, whereas the latter conform to the actual site conditions and are more realistic. Particularly in the determination of soil strength for the purpose of foundation design, field tests have a definite advantage over others because soil disturbance is minimum. There are various well established in-situ tests like the Standard Penetration Test, Dynamic Cone Test, and Static Cone Test. One common thing in these tests is that a pointed end of the drill rod is driven into the soil either by hammering or by continuous pressure. The resistance offered by the soil against penetration is measured in terms of the number of hammer blows (in the first two cases) and of the concentrated pressure (in the third case), and this resistance is taken as a measure of the strength of the soil.

In these cases it is to be noted that this resistance represents the maximum that a particular soil layer offers against penetration. It does not give any idea about how the soil deforms when the driving force is less than the maximum. In other words, these deep tests give empirical information on the strength of the soil layer, but say nothing about the deformation pattern. In case of plate load test, we do get a definite relationship between the load and deformation but this test is confined to shallow depths.

Requirements of a Field Test

For correct assessment of the load bearing characteristics of a soil, we need a test which must satisfy the following six requirements :—(i) The test must give complete stress-deformation characteristics of the soil from 'natural' stress to 'failure'. (ii) It must be conducted in one layer only at a time. (iii) It must be capable of being conducted layer after layer to any desired depth. (iv) one test should not affect subsequent tests at greater depths. (v) Test results should be known immediately and (vi) the test must be based upon sound theoretical principles. It is obvious that none of the conventional tests mentioned above satisfies all these requirements. This Institute has designed and developed a SUB-SOIL DEFORMETER (Fig. 1) for this purpose and made it readily available* to practising engineers.

What is Sub-Soil Deformeter

It is an instrument used in soil exploration for finding stress-deformation characteristics of soil-strata under in-situ conditions. It is based on the principle of the well known pressuremeter test and the part that actually goes into the bore hole is made to the same dimensions and standards as in pressuremeter. But the control panel of Sub-Soil Deformeter carries several instrumentational improvements over the corresponding dart of pressuremeter, making it simpler to operate. This development has been made keeping in view

*Exclusive manufacturers : M/s. Associated Instrument Manufacturers (I) Pvt., Ltd., 35-B, Najafgarh Road, New Delhi—110015.

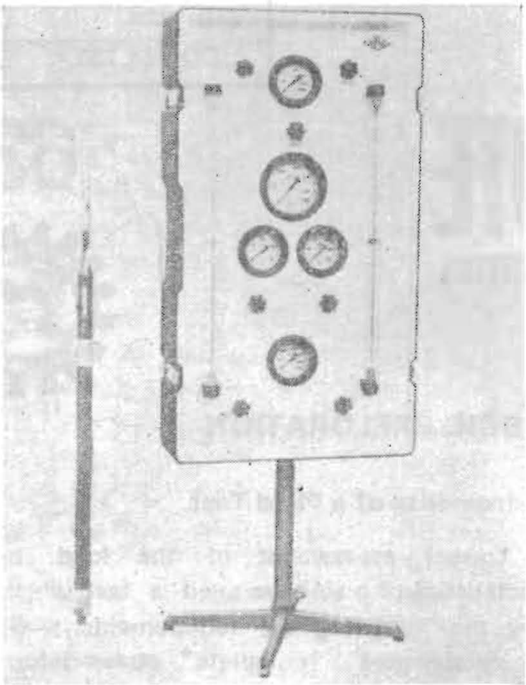


Fig. 1 SUB-SOIL DEFORMETER

the conditions prevailing in India and other semi-industralised countries.

The test is carried out in the same manner as in pressuremeter test, so that all the theories, interpretations and applications of pressuremeter test apply to Sub-Soil Deformeter test in toto.

Principle of the Test

In this test a uniform radial pressure is applied to the walls of the borehole over a short length (Fig. 2). This causes a field of compressive stress in the horizontal plane. The Intensity of this stress is equal to the applied pressure at the borehole wall and becomes zero at infinite distance. Each annular ring of the soil gets proportionately deformed under the respective stress and the sum of all such deformations shows itself as an expansion of the borehole diameter. Since the test length is fixed, this expansion is measured as a volumetric deformation. For a given pressure, the volumetric deformation is inversely proportional to the modulus of elasticity of that layer. In other words, a hard soil will show a small volumetric deformation under a high pressure and a soft soil will do vice versa. Thus this test

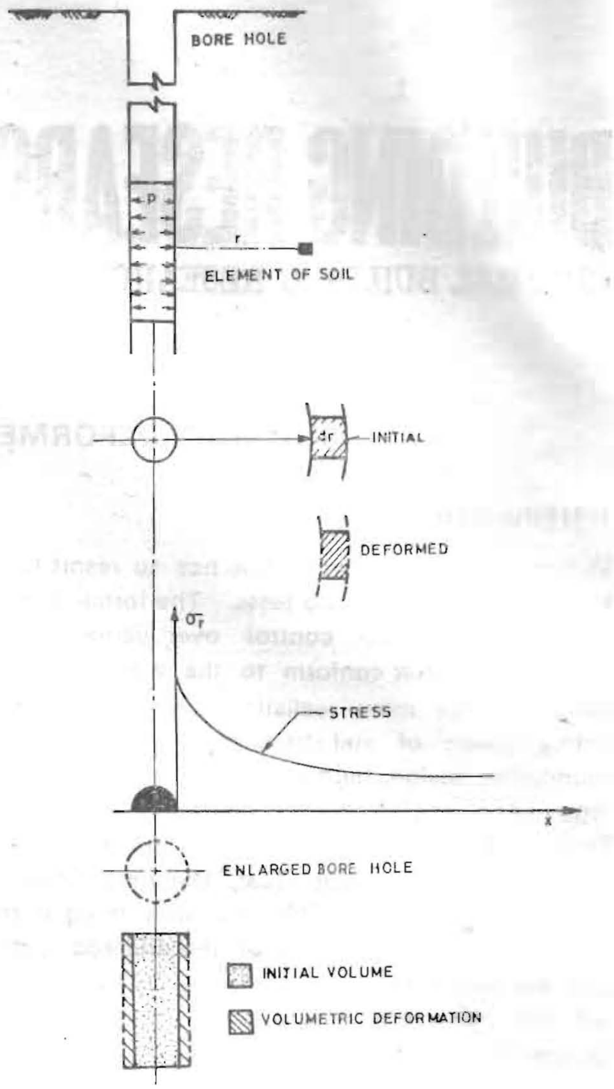
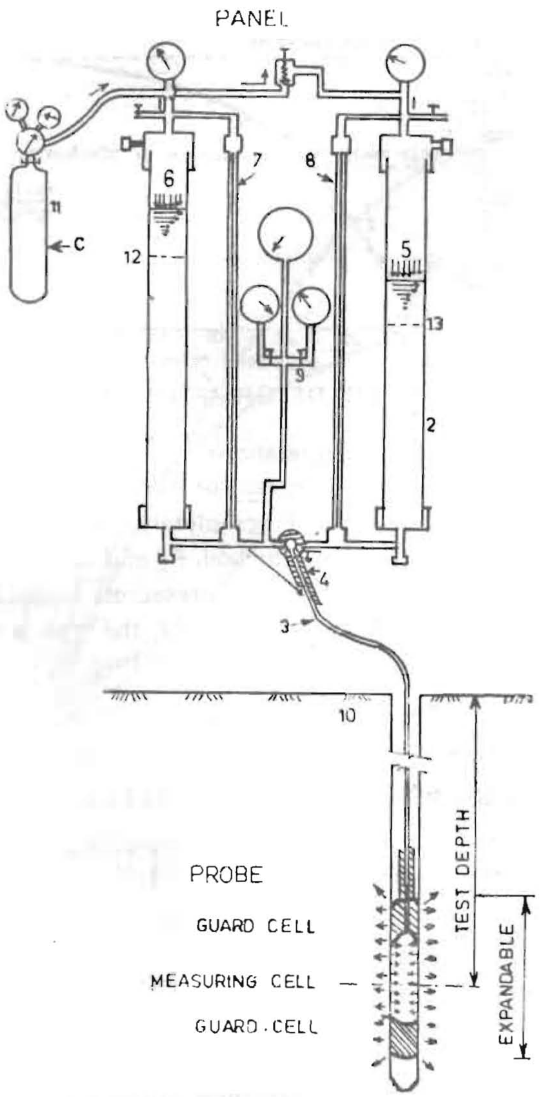


FIG. 2 PRINCIPLE OF SUB-SOIL DEFORMETER TEST

measures the strength of the soil layer as well as its deformation properties.

Description

The part of the deformeter which goes into the borehole is known as 'Probe' (Fig. 3). It consists of rubber membranes stretched over a core. Only the central portion known as the measuring cell is used for measurement. The two end portions known as guard cells serve merely to avoid end convergence over the measured portion. The control panel at ground level essentially consists of two reservoirs of water (1,2). The measuring cell is



LEGEND .—

1. Measuring Cell Reservoir
2. Guard Cell Reservoir
3. Hose to Measuring Cell
4. Hose to Guard Cell
5, 6. Initial Water Level
7, 8. Volumeters
9. Pressure Gauges
10. Borehole
11. Compressed Gas Cylinder
12, 13. Fallen Water Levels

FIG. 3 : SUB-SOIL DEFORMETER WORKING

connected to the bottom of the measuring cell reservoir by means of a hose (3). Another hose (4) running co-axially over this hose connects the two guard cells to the guard cell reservoir (2). The reservoirs are filled with deaired water, whose levels (5, 6) are seen in the graduated volumeters (7, 8). A set of pressure gauges (9) measures the pressures and a set of valves controls the flow of water.

The probes are of two standard sizes AX and BX (44 and 58 mm diameter respectively). The manual augers are of matching sizes and are operated with simultaneous wash boring. Drilling rigs may also be used where necessary, but the boreholes must be of AX or BX size as the case may be; (Sub-Soil Deformeter cannot be used in the same boreholes as are normally made for SPT and undisturbed sampling). If casing is used, it is stopped at least a metre above the test depth.

Test Procedure

First a borehole (10) of proper diameter is made to the test depth and the auger withdrawn. The probe is attached to the drill rod in place of auger, lowered into the borehole and held at test depth. All valves are opened so that the system attains equilibrium under atmospheric pressure. Water level of the measuring cell reservoir is noted. The instrument is set ready for test by closing or opening the relevant valves. Then from a compressed gas cylinder (11) a small step of pressure is let into the system. This pressure causes the probe to expand and consequently the water levels to fall (12, 13). The pressure is maintained constant for that-step and the measuring cell volumeter readings are noted (8), 30 and 60 seconds after letting in of pressure.

After the sixtieth second, the next step of pressure is let in and observations continued as before. This way, the test is carried out with equal increments of pressure (each increment being maintained constant throughout that step) till the soil fails. Then the pressure is released, probe is allowed to contract to its original size and is withdrawn to the ground level. This constitutes one test at a given depth. The borehole is then extended to the next test depth and the test repeated in the same manner. For best results, drilling in virgin soil testing and driving the casing down to the tested depth are donemetre after metre in the said sequence till the desired depth is reached.

Presentation of Results

A sample of test data is given in Table 1. Fig. 4 shows the plot between applied pressure against the sixty second readings (V_{60}). It is to be noted that the graph consists of three parts. Part AB represents the expansion of the probe in the initial air gap. Part BC which is a straight line, represents

TABLE I—TEST DATA

Site : New Hostel
Borehole No. : 2
Test Depth : 15 m
Depth of Water table : 8 m
Date . 21.1.1977
Time : 11.30 A.M.
Remarks : G.K.
Observations on last one metre of boring : Silty Clay

Applied Pressure (kPa)	Volumeter Readings (cc)	
	At 30 Sec	At 60 Sec
P	V_{30}	V_{60}
0		0
100	85	89
200	114	116
300	138	140
400	155	157
500	170	172
600	187	189
700	203	205
800	218	220
900	238	240
1000	258	261
1100	285	289
1200	318	321
1300	356	362
1400	410	419
1500	474	485
1600	552	568
1700	660	678

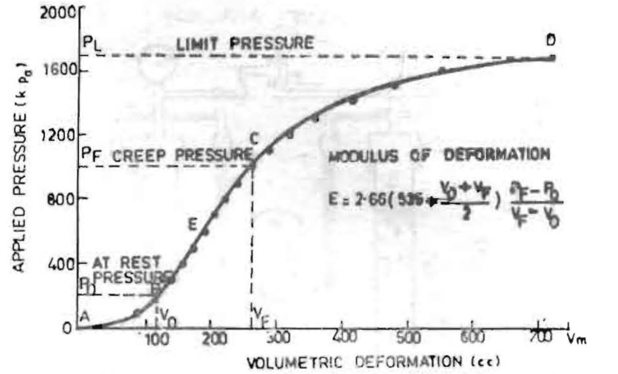


FIG. 4 SUB-SOIL DEFORMETER TEST CURVE

the stress deformation relationship of the soil. Part CD represents the progress of failure of the soil. At D the soil has failed completely. P_o represents the 'natural stress' in the soil, P_f and P_l are termed 'Creep pressure' and 'Limit pressure' respectively. The modulus of deformation 'E' of the soil is calculated from the slope of the curve from the straight line portion BC.

$P_o = 200\ P_a$ $\qquad V_o = 116$ c.c.

$P_f = 1000\ P_a$ $\qquad V_f = 261$ c.c.

$$E = 2.66 \left(535 + \frac{116+261}{2}\right) \times \frac{1000-200}{261-116}$$

$$= 10{,}620\ kP_a$$

The values of p_o, p_f, p_l and E obtained from the field plot between volumetric deformation and applied pressure are uncorrected values. There are simple methods for correcting these values for the rigidity of the probe material, ground water table and the expansion of the instrument. Depending upon the stiffness of the soil and other test conditions some of these corrections become important and others not. The corrected values of the modulus of deformation E and limit pressure p_l are plotted with depth, along with the bore log as in Fig. 5.

Interpretation

The family of such curves from one borehole is shown in Fig. 6. In general, a curve which lies low and flat (e.g. 2m) represents a soft or loose soil and a curve which rises steep (e.g. 12m) represents a stiff or dense soil.

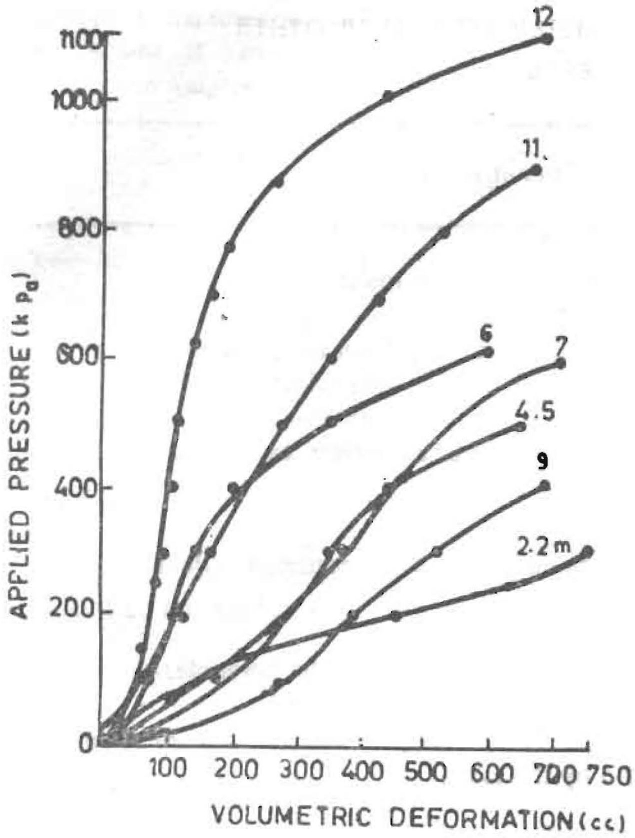


FIG. 6 CURVES FROM SAME BORE HOLE

Usual values of E and P_l for different types of soil are given in Table II.

Table II : Typical Values of E and P_l for Different Soil Types

Soil Type	Modulus of Deformation E kPa	Limit Pressure P_l kPa
Mud, Peat	200— 1500	20— 150
Soft Cley	500— 3000	50— 300
Medium Clay	3000— 8000	300— 800
Stiff Clay	8000—40000	600—2000
Marl	5000—60000	600—4000
Loose Silty Sand	500— 2000	100— 500
Silt	2000—10000	200—1500
Sand and Gravel	8000—40000	1200—5000
Sedimentary Sands	7500—40000	1000—5000
Recent Fill	500— 5000	50— 300
Old Fill	4000—15000	400—1000

Application to Design

The limit pressure and the modulus of deformation are the most important parameters obtained from this test, which are used to estimate the bearing capacity of the soil.

From Fig. 5 the values of P_l and E from relevant depths are chosen for use in designs. The P_l value is used in calculating the ultimate bearing capacity of footings, piles etc. and E value is used in estimating the settlements and deformations.

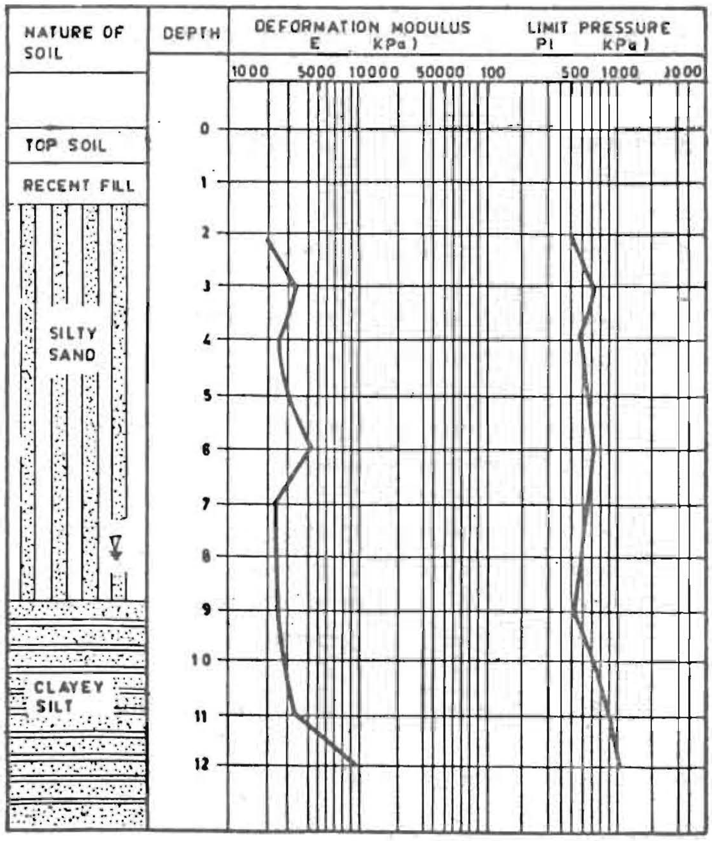


FIG. 5. SUB-SOIL DEFORMETER RESULTS FROM A BORE HOLE

Advantages of Sub-Soil Deformeter Test

A few advantages of the Sub-Soil Deformeter test over conventional test are listed in Table III. From these, it can be readily seen that the Sub-Soil Deformeter test satisfies all the requirements of a field test as enumerated earlier. Further, since the borehole is much smaller than the one in con-

TABLE III ADVANTAGES OF SUB-SOIL DEFORMETER TEST OVER OTHER CONVENTIONAL INSITU TESTS

	Sub-Soil Deformeter Test	Penetration Tests
1.	Gives the build-up of stress from zero to failure.	Give only the maximum resistance.
2.	Gives complete picture of deformations from natural state to failure.	Give no information whatever on deformations.
3.	Average out the soil properties over a large volume.	Give the properties of soil layers below the tip only.
4.	Influence of local hard or soft pockets is very little.	Such pockets have a pronounced effect on the results.
5.	Tests the undisturbed sides of the borehole.	Tests the disturbed bottom of the borehole.
6.	Carrying out the test at one depth does not affect the layers below.	Soil layers immediately below the tip are strongly affected by the tests.
7.	Possible to know during the test itself whether the test is running correctly or not	Not possible
8.	The final results of the test are based upon scores of intermediate observations. Hence any mistake or oversight of the opeartor can be easily detected and corrected, then or later.	The test at any depth gives one value only. It is not possible to detect a mistake and correct it later.
9.	Estimation of earth pressure at rest possible.	Not possible
10.	Unloading test possible	Not possible
11.	Is based on sound theory	Are purely empirical

	Sub-Soil Deformeter Test	Plate Load Test
1.	Can be conducted at any depth.	Limited to shallow depths only
2.	Can be conducted below water table also.	Not usually possible
3.	Test gives a wealth of basic information.	Only limited information is available.

ventional exploration and the Sub-Soil Deformeter equipment is much lighter, the progress is faster and running costs are much less. The Sub-Soil Deformeter pays back its cost in a short time. The Sub-Soil Deformeter test is the only test in which both the strength and deformability of deep soil strata are measured simultaneously and its result can be applied directly to design of foundations, without resorting to indirect correlationships amongst a multiplicity of different tests.

Since the Sub-Soil Deformeter gives reliable data on the most important properties of the soil, the number of other conventional insitu tests can be reduced.

For greater details about Sub-Soil Deformeter, its principle, test method, interpretation, application etc. please refer to Handbook on Sub-Soil Deformeter, published by this Institute.

Specifications

The Sub-Soil Deformeter is used with any of the two probes. The probes can be easily inserted in the AX or BX size bore holes (made according to DCDMA standards). Thus the probes are nominated AX and BX with nominal diameters 44 mm and 60 mm respectively. For drilling in fine grained soils (clays, silts and sands) spiral augers are supplied to suit each probe. Since the probe size has been taken into account in the formula and the rigidity of the probe accounted for by correction, the result is same whether AX or BX probe is used. The panel is compatible with both the probes.

Probe size		AX	BX
Auger diameter	mm	45	59
Borehole diameter	mm	46–52	60–66
Probe diameter	mm	44	58
Effective length of measuring cell	cm	36	21
Volume of measuring cell	cc	535	535
Overall length	cm	82	62

Length of coaxial hose = 30 m

Maximum volumetric deformation = 750 cc

Maximum limit pressure = 2500 k Pa (25.5 kg/cm^2 = 363 psi)

Maximum modulus of deformatton = 98,000 k Pa (1000 kg/cm^2 = 14,000 psi).

It is to be noted that the range of Sub-Soil Deformeter covers practically the full range of E and P_l values occurring in natural soils—from mud and peat to soft rocks.

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