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BUILDING DIGEST

CENTRAL BUILDING RESEARCH INSTITUTE INDIA

PILE LOAD TESTS

For an economic and safe design of pile foundations it is necessary to have a fair knowledge of the actual load bearing capacity of piles. The bearing capacity is often determined from dynamic formulae and sometimes from cone penetration and other field and laboratory tests too. The results thus obtained are, however, only rough estimates due to a number of variables involved. Loading tests alone can provide this information.

In the traditional pile load test the load is applied over the pile cap in equal increments of $\frac{1}{4}$th of design load. Each load is maintained for 24 hours before the next increment is put on and corresponding settlement is recorded. The full design load is maintained for a week. Loading is subsequently increased in steps and finally $1\frac{1}{2}$ times the design load is again maintained for a week. The load is then removed and the net settlement is observed. A load-settlement curve is drawn and the ultimate load is taken to be the value corresponding to a total settlement of $\frac{1}{2}$ inch. It is also required that the net settlement should not exceed $\frac{1}{4}$ inch. The tests are generally conducted on one or two test piles after most of the piles are already driven. Except in rare instances when the pile is unsafe, it generally provides an oversafe and costly design. Hence this is not a good practice. The tests should be conducted soon after the piling has started so that the values obtained may be used to revise the design if necessary.

The traditional method has many limitations. It is not possible to arrive at the ultimate bearing capacity of the pile and separation of skin friction and point bearing is also not possible. The latter is necessary for estimating the bearing capacity of piles used for foundations subject to scour or vibration.

As an improvement over the traditional method a number of alternative methods are available. These are (a) Cyclic Load Method (b) Housel's Method, (c) Constant Rate of Penetration Method, and (d) Method of Equilibrium. This digest reviews these methods and puts forward their relative merits and demerits.

The cyclic load method[1] has a number of distinct advantages. It is possible to separate skin friction and point bearing; thus providing for the effect of scour and negative skin friction where necessary. The fluctuations of loads can be taken into account as in case of grain silos. The time required in testing is reduced. Since total load is put on the platform for obtaining the reaction through a hydraulic jack, the possibility of eccentric loading is also considerably reduced. This method has since been incorporated in the Indian Standard code of Practice for Design and Construction of Pile Foundations-IS : 2911 (Pt. I)-1964.

The cyclic load test technique is therefore described in fair detail (Appendix I) and other methods are briefly mentioned in Appendix II.

Set up for cyclic load test

The test is conducted on single piles with or without a cap or on a group of piles having a rigid cap unaided by any other support. The load is applied by hydraulic jacks. For high capacity piles, a loading platform (Fig. 1 & 2) is put up and preloaded to a mini-

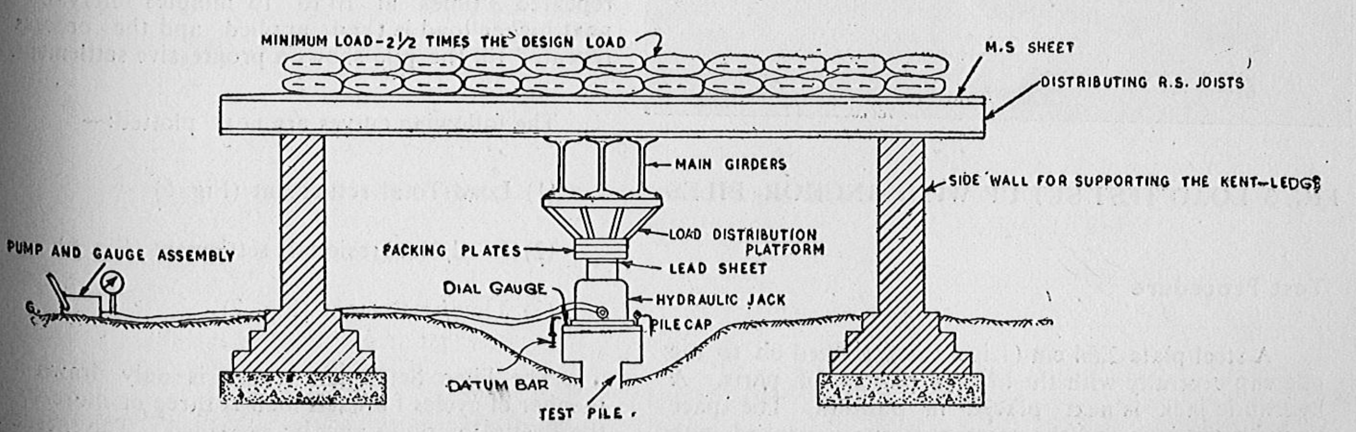

FIG. 1. DETAILS OF LOADING PLATFORM

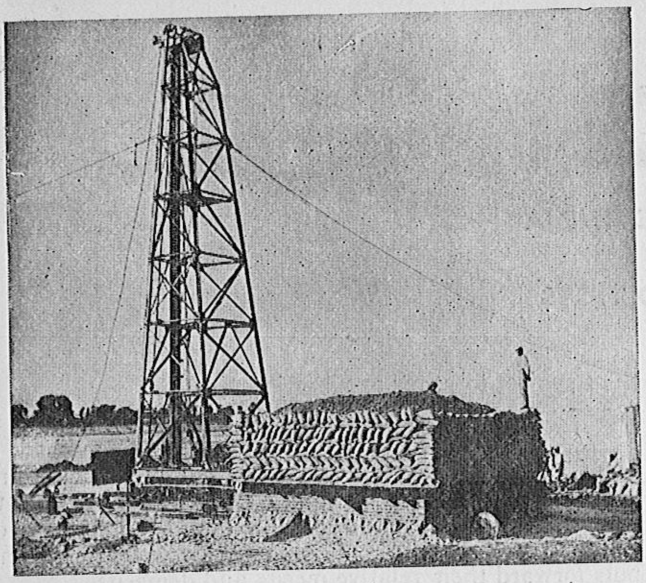

FIG. 2 LOAD TEST SET UP WITH REACTION PLATFORM.

mum of 2½ times the estimated safe load carrying capacity of the test pile. As an alternative, jacks may react against a proper frame work held down by anchor piles (Fig. 3).

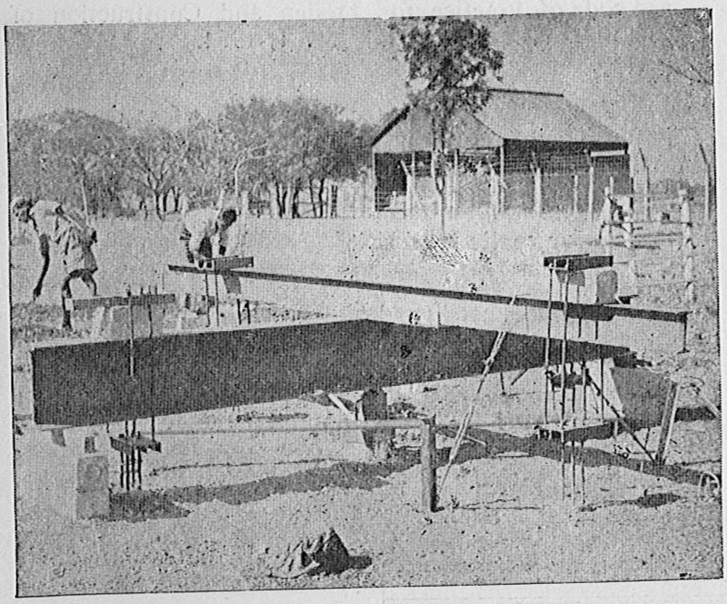

FIG. 3 LOAD TEST SET UP WITH ANCHOR PILES

Test Procedure

A steel plate 2.54 cm (1 in.) thick is fixed on to the pile cap centrally with the help of plaster of paris. A hydraulic jack is next placed in position. The space between the jack and the reaction frame is packed with steel plates or a suitable frame (Fig. 4).

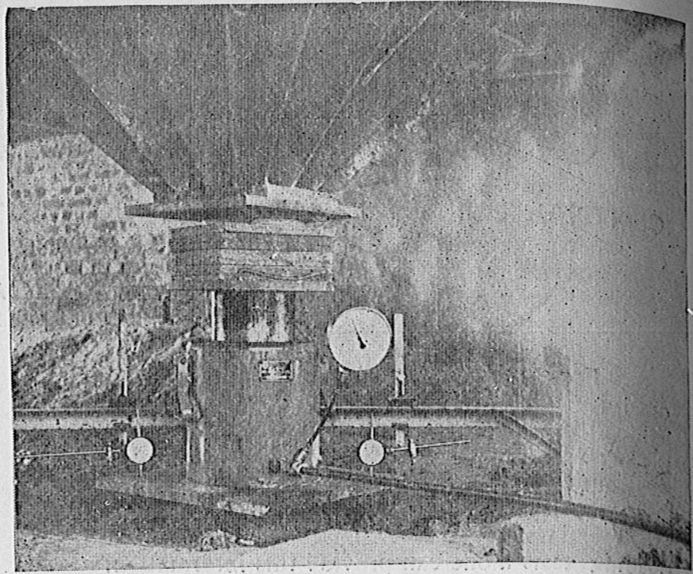

FIG. 4 CLOSE UP OF TEST ASSEMBLY WITH LOAD DISTRIBUTING FRAME

A datum bar consisting of 5 cm (2 in.) angle iron or an equally stiff steel section is fixed on two non-movable supports located at a distance of at least five times the diameter of the pile away from the centre of the test pile. The support for the datum can be in the form of a short timber pile or a suitable steel section driven into the ground to sufficient depth. Dial gauges are fixed to the datum bars by suitable clamps with the tips of the gauges resting on the steel plate fixed to the test pile (Fig. 1). These are used for measuring settlement and at least three of them, set at 120° apart, should be used. A seating load of ½ to 2 tonnes (about 2% of the design load) is applied for a few minutes and then released. All the gauges are then set to zero before starting the test.

Load is applied in equal increments of about one fifth of the estimated safe design load. Each load is maintained till the rate of settlement reduces to about 0.02 mm/hour and the corresponding settlement is recorded. In sandy soil this is normally 15 minutes. The load is then released and net (residual) settlement is noted. In order to simulate the effect of possible fluctuations of load, a cycle of loading and unloading is repeated 3 times at 10 to 15 minutes interval. The next higher load is then applied and the process is repeated till the pile shows a progressive settlement.

The following curves are next plotted:—

(1) Load/Total settlement (Fig. 5)

(2) Load/Net (residual) settlement (Fig. 6)

(3) Time/settlement (Fig. 7)

The Time Settlement curve is only drawn if the number of cycles for each load is three or more so that the hesitation point may be obtained. The hesitation point indicates the state of plastic failure.

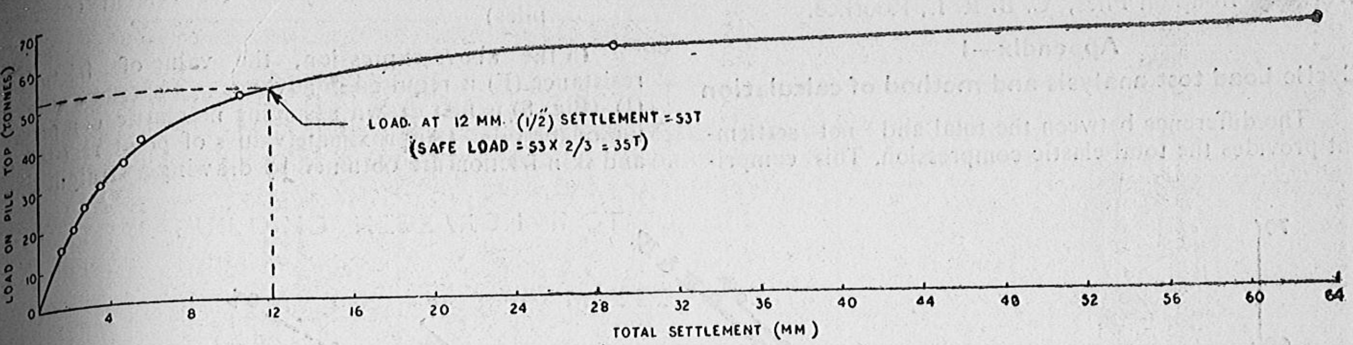

FIG. 5 LOAD–TOTAL SETTLEMENT CURVE

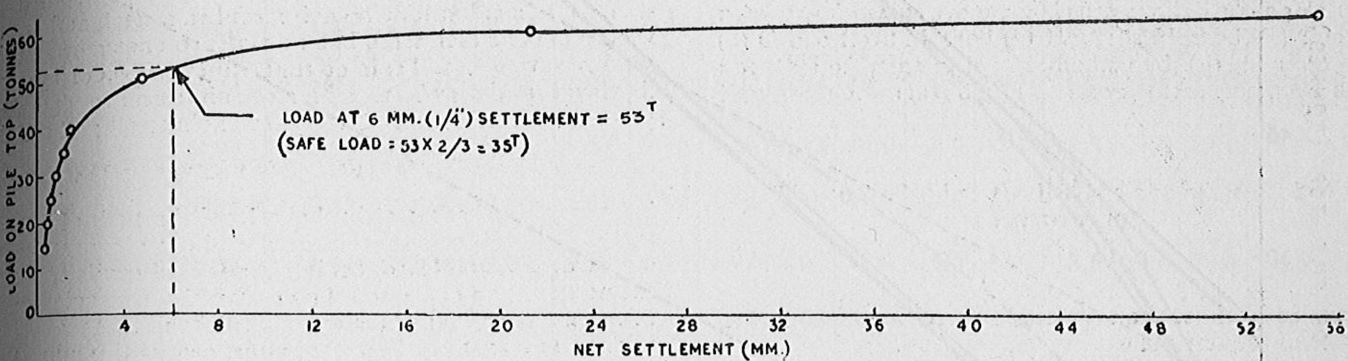

FIG. 6 LOAD–NET SETTLEMENT CURVE

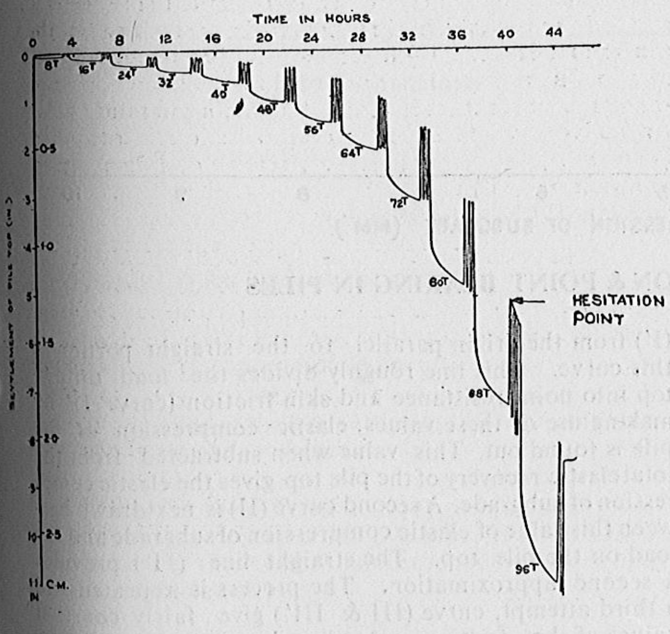

FIG. 7 TIME SETTLEMENT CURVE

The safe load on the pile is estimated as the least of the following :—

(a) ⅔rd of final load at which the total settlement attains a value of 12 mm.

(b) ⅔rd of final load at which the net settlement attains a value of 6 mm.

(c) ½ of final load at which the total settlement equals 1/10th pile diameter.

In case a larger total settlement is permissible, the actual value should be used for assessing the safe load.

Report

The report of load test should include the following information:—

(1) A description of soil profile in the vicinity of test pile.

(2) A description of pile and its driving and/or boring record.

(3) A description of the hammer used and its actual rate of operation during the driving of the test pile.

(4) A graphic representation of the test results in the form of (i) Load-total settlement curve (ii) Load-Net Settlement Curve (iii) Time-settlement curve.

(5) A graphic represantation of the separation of skin friction and point bearing (All 4 curves).

(6) Remarks concerning any unusal occurrances during the testing of the pile.

A suitable data sheet for recording all the data has been compiled and is available with the Secretary, Working Group on Piles, C. B. R. I., Roorkee.

Appendix—I

Cyclic Load test analysis and method of calculation

The difference between the total and net settlement provides the total elastic compression. This comprises of (i) elastic compression of pile and (ii) elastic compression of the subgrade (ground below the pile toe). A curve is drawn between the load on the pile top and the elastic compression of the subgrade (Fig. 8). A line from the origin, parallel to the straight portion of this curve, is found to separate the load on pile top into point resistance and skin friction.

The elastic compression of the pile is calculated by the expression (T-F/2) L/AE:

Where T=Load on pile top.

F=Total frictional resistance offered by the surface of pile.

L=Length of pile

A=Cross-sectional area of pile

E=Modulus of elasticity of the pile material (assumed 2.8×10^5 kg /cm^2 for cement concrete piles).

In the above expression, the value of frictional resistance (F) is required in advance. Therefore, curve (I) (Fig. 8) is first drawn assuming no elastic compression of the pile. Approximate values of point resistance and skin friction are obtained by drawing a straight line (I′) from the origin parallel to the straight portion of this curve. This line roughly divides the load on pile top into point resistance and skin friction (curve I). By making use of these values, elastic compression of the pile is found out. This value when subtracted from the total elastic recovery of the pile top gives the elastic compression of subgrade. A second curve (II) is next drawn between this value of elastic compression of subgrade and the load on the pile top. The straight line (II′) provides a second approximation. The process is repeated and a third attempt, curve (III & III′) give fairly constant values of skin friction and point bearing. If a fourth attempt is made, the final curve (IV & IV′) will normally coincide with the third.

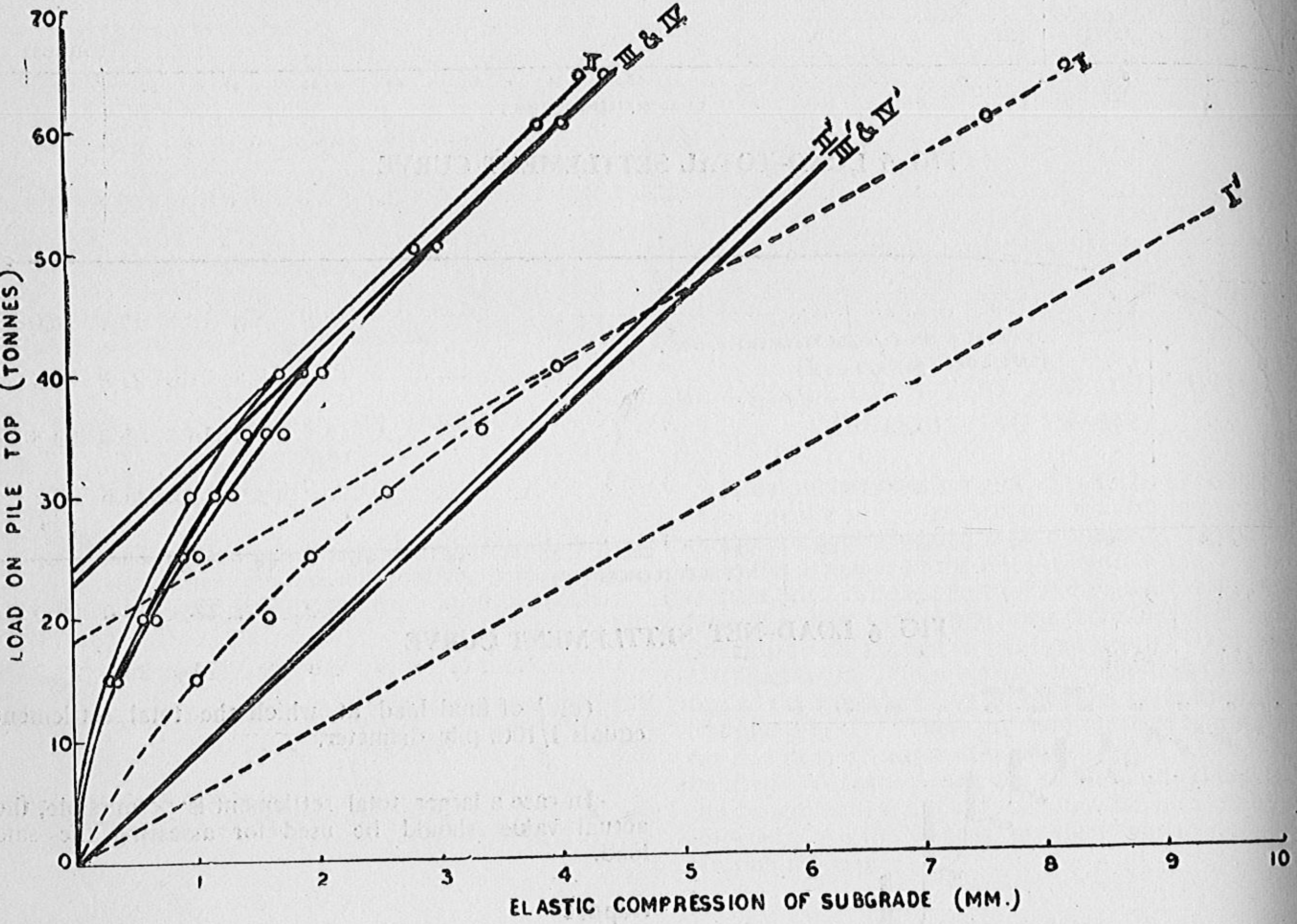

FIG. 8 SEPARATION OF SKIN FRICTION & POINT BEARING IN PILES

Example

The data obtained in a particular load test and calculations are recorded in Table I.

TABLE I.

Load on pile top (T) (tonnes)	Total settlement of top (mm)	Net settlement of top (mm)	Elastic Recovery of top (2)-(3) (mm)	Elastic compression of pile =(T -F/2) L/AE (mm)			Elastic compression of subgrade (4)—(5) (mm)			Load at toe (p) (from curves) (tonnes)				Frictional Resistance (F) (from curves) (tonnes)			
1	2	3	4	5			6			7				8			
				a	b	c	a	b	c	a	b	c	d	a	b	c	d
15	1.37	0.38	0.99	0.74	0.68	0.68	0.25	0.31	0.31	5.5	2.5	2.5	2.5	9.5	12.5	12.5	12.5
20	2.13	05.3	1.60	1.04	0.93	0.96	0.56	0.67	0.64	8.5	5.0	6.0	5.5	11.5	15.0	14.0	14.5
25	2.67	0.74	1.93	1.33	1.18	1.26	0.87	1.02	0.94	10.5	8.0	9.0	8.0	18.5	17.0	16.0	17.0
30	3.53	0.94	2.59	1.63	1.43	1.57	0.96	1.16	1.43	14.0	9.0	10.5	11.5	21.0	21.0	19.5	18.5
35	4.65	1.27	3.38	1.96	1.76	1.81	1.42	1.62	1.76	18.5	13.0	14.5	15.0	16.5	22.0	20.5	20.0
40	5.56	1.57	3.99	2.76	2.07	2.18	1.73	1.92	2.07	22.0	16.5	17.5	18.6	18.0	23.5	22.5	22.5
50	10.64	4.80	5.84	3.00	2.80	2.81	2.84	3.04	3.03	32.0	26.5	27.0	27.0	18.0	23.5	23.0	23.0
60	28.93	21.31	7.62	3.74	3.53	3.55	3.88	4.09	4.07	41.5	36.0	37.0	37.0	18.5	24.0	23.0	23.0
64	63.22	54.96	8.26	4.03	3.77	3.85	4.23	4.40	4.41	45.0	38.5	40.5	40.0	19.0	25.5	23.5	24.0

Pile Dimensions — Length = 1082 cms
Area of cross section = 522.5 cms

Assumed value of E for the composite section $= 2.8 \times 10^5$ kg/cm²

Column 1 is for load on the pile top.

Column 2 is for the total settlement of the pile top corresponding to the load in Column 1.

Column 3 is for the net settlement of the pile top measured when the load is removed.

Column 4 is the difference of (2) and (3) and gives the total elastic recovery of the pile top. It is assumed to be the sum of the elastic compression of subgrade and elastic compression of pile.

Column 5 is for the elastic compression of the pile and the values are obtained from the expression (T-F/2) L/AE.

A curve between the values of Columns (1) and (4) is first drawn (Fig. 8, Curve I). A line parallel to the straight portion of this curve (I′) is then drawn from the origin. This approximately divides the load on the pile top as indicated by curve (I) into skin friction and point bearing The values thus obtained are recorded in Columns (7a) and (8a). The values of Column (5a) are then computed from Columns (1) and (8a) e.g. T=15 then F=9.5 and so on. Column (6a) is next obtained by subtracting Column (5a) from column 4. A second curve (II) is now drawn between the values of columns (1) and (6a). A straight line (II′) drawn from the origin parallel to the straight portion of this curve again divides the load on pile top into skin friction and point bearing and the values so obtained are recorded in Columns (7b) and (8b). From the values of Colurmns (1) and (8b) column (5b) is computed. It is now subtracted from Column (4) and Column (6b) is obtained. A curve (III) is now drawn between values of Columns (1) and (6b) and the values of point resistance and skin friction recorded in Columns (7c) and (8c). For more accuracy a fourth curve may be drawn and the values recorded in Columns (7d) and (8d). In the example shown, the total skin frictional resistance is found to be mobilised at 50 tonnes while point resistance developed is 27 tonnes.

Appendix II

(a) **Housel's method**— Each load is maintained for a fixed period of one hour and settlement recorded after every 15 minutes. The load settlement curve drawn between the load and the corresponding settlement during the last 30 minutes of each load application provides a typical yield value curve (Fig. 9). This, however, does not indicate the correct settlement.

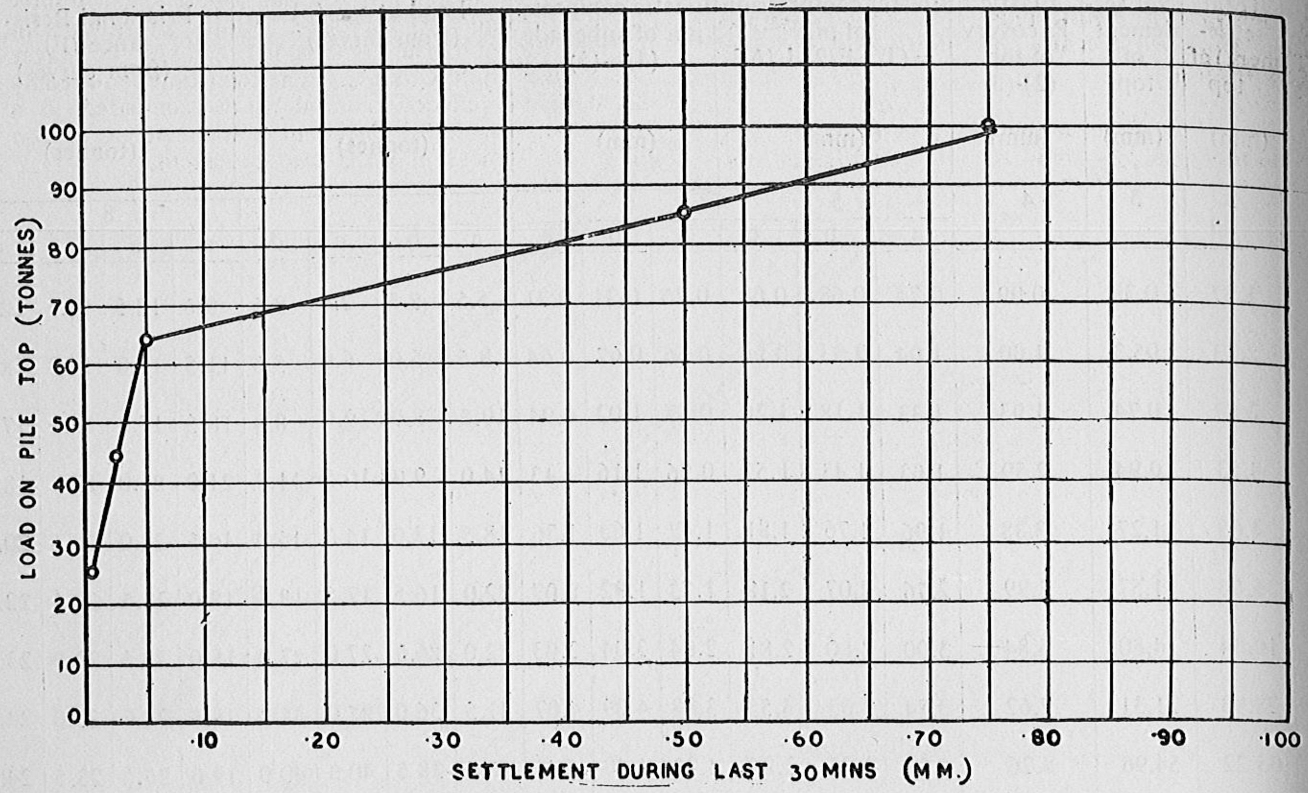

FIG. 9 LOAD SETTLEMENT CURVE BY HOUSEL'S METHOD

(b) Constant Rate of Penetration method—In carrying out CRP test the pile is made to penetrate the soil at a constant rate while the load applied at the top is measured. The normal rate of penetration is .02 to .05 inch/minute. The complete test can be over in 1½ to 2 hours. The load settlement curves obtained in case

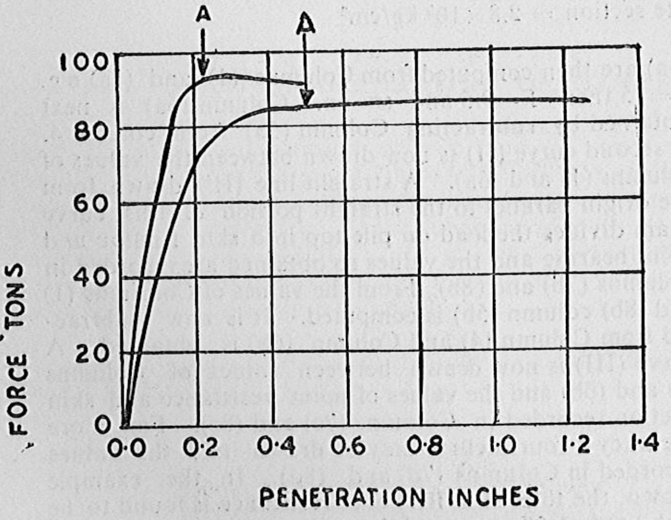

FIG.10(a) TYPES OF FORCE-PENETRATION CURVES OBTAINED WITH FRICTION PILES. THE POINT A SHOW THE VALUES OF THE ULTIMATE BEARING CAPACITY

CONSTANT RATE OF PENETRATION METHOD

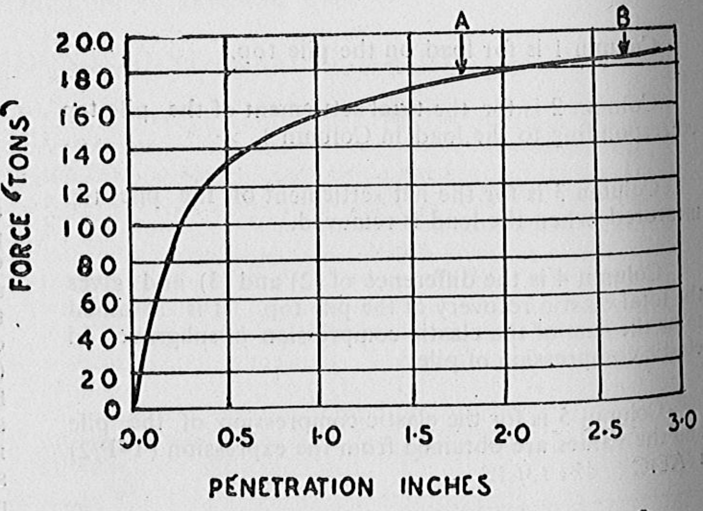

FIG. 10 (b)-TYPE OF FORCE-PENETRATION CURVE OBTAINED WITH AN END BEARING PILE THE PORTION 'AB' IS SUBSTANTIALLY STRAIGHT AND 'A' REPRESENTS THE ULTIMATE LOAD

CONSTANT RATE OF PENETRATION METHOD

of friction piles and point bearing piles are shown in (Fig. 10.) This test is more suitable for finding out the ultimate bearing of predominantly friction piles. This test also does not indicate the correct settlement.

(c) **Method of Equilibrium** [(3)] This method has been developed recently at the Central Building Research Institute.

About 1/10th of the estimated ultimate load is first applied in three to five minutes. It is maintained for about five minutes and then allowed to reduce by itself. A stage of equilibrium is generally found to reach within the next few minutes. The next higher load is then applied and the process repeated. For higher loads it is necessary to maintain the load for 10 to 15 minutes and it is then allowed to reduce. While in sandy soils the state of equilibrium is reached quickly, in clayey soils it takes slightly longer. The total time required by this method is reduced to about ⅓rd as compared to a maintained load test. The load settlement curve also gives a fair indication of the true settlement.

References

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2. Indian Standard IS: 2911 (Pt. I) — 1964
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   'A New Approach to Load Tests', Geotechnique Sept., 1967.

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