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IS 2911-4 (1985): Code of practice for design and construction of pile foundations, Part 4: Load test on piles [CED 43: Soil and Foundation Engineering]



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IS : 2911 (Part 4) - 1985
(Reaffirmed 2010)

Indian Standard
CODE OF PRACTICE FOR
DESIGN AND CONSTRUCTION OF
PILE FOUNDATIONS
PART 4 LOAD TEST ON PILES
(First Revision)

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Indian Standard
**CODE OF PRACTICE FOR
DESIGN AND CONSTRUCTION OF
PILE FOUNDATIONS**
PART 4 LOAD TEST ON PILES
(First Revision)

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AMENDMENT NO. 1 MAY 1989
TO
IS : 2911 (Part 4) - 1985 CODE OF PRACTICE
FOR DESIGN AND CONSTRUCTION OF
PILE FOUNDATIONS

PART 4 LOAD TEST ON PILES

(First Revision)

(Page 9, clause 6.1.6.1) — Substitute the following for the existing clause:

'6.1.6.1 However, routine test shall be carried for a test load of at least equal to the working load; the maximum settlement of the test loading in position being not exceeding 25 mm.'

(BDC 43)

Reprography Unit, BIS, New Delhi, India

**AMENDMENT NO. 2 JUNE 2010
TO
IS 2911 (PART 4) : 1985 CODE OF PRACTICE FOR
DESIGN AND CONSTRUCTION OF
PILE FOUNDATIONS**

PART 4 LOAD TEST ON PILES

(First Revision)

(Page 6, clause 4.2, second line) — Substitute '0.5' for 'one-half'.

(CED 43)

Reprography Unit, BIS, New Delhi, India

Indian Standard

**CODE OF PRACTICE FOR
DESIGN AND CONSTRUCTION OF
PILE FOUNDATIONS**

PART 4 LOAD TEST ON PILES

(First Revision)

0. FOREWORD

0.1 This Indian Standard (Part 4) (First Revision) was adopted by the Indian Standards Institution on 20 February 1985, after the draft finalized by the Foundation Engineering Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 Piles find application in foundation to transfer loads from a structure to competent subsurface strata having adequate load bearing capacity. The load transfer mechanism from a pile to the surrounding ground is complicated and could not yet be fully ascertained, although application of piled foundations is in practice over many decades. Broadly, piles transfer axial loads either substantially by skin friction along its shaft or substantially by the end bearing. Piles are used where either of the above load transfer mechanism is possible depending upon the subsoil stratification at a particular site. Construction of pile foundations require a careful choice of piling system depending upon the subsoil conditions, the load characteristics of a structure and the limitations of total settlement, differential settlement and any other special requirement of a project. The installation of piles demands careful control on position, alignment, depth and involve specialized skill and experience.

0.3 Pile load test is the most direct method for determining the safe loads on piles including its structural capacity with respect to soil in which it is installed. It is considered more reliable on account of its being *in-situ* test than the capacities computed by other methods, such as static formula, dynamic formulae and penetration test data. There are widely varying practices followed for load tests on piles. Particularly, the difficulties regarding the establishment of an acceptable criterion, for determining the ultimate and safe bearing capacity of piles, and predicting the pile group behaviour from the test data obtained from individual load test on single piles, cannot be under-estimated as the factors

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affecting are many. However, an attempt is made to bring out an unified approach to the various aspect of load test on piles. This standard was first prepared in 1979. The revised version has been prepared so as to give more details in regard to the rate of loading and unloading and the details of the situations when the different types of tests are conducted.

0.4 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard (Part 4) covers the load test on all types of piles covered in IS : 2911 (Part 1/Sec 1)-1979†, IS : 2911 (Part 1/Sec 2)-1979‡, IS : 2911 (Part 1/Sec 3)-1979§, IS : 2911 (Part 1/Sec 4)-1984||, IS : 2911 (Part 2)-1980¶ and IS : 2911 (Part 3) 1980** and provides guidelines for determination of safe load based on the following types of loadings.

- a) Vertical load test (compression),
- b) Lateral load test, and
- c) Pull-out test.

1.2 Load tests under vibratory loads, moments and other forces and sequence of loading under special circumstances like yield load capacity of buckling piles are not covered in this standard.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions shall apply.

2.1 Cut-Off Level — The level where the installed pile is cut-off to support the pile caps or beams or any other structural components at that level.

*Rules for rounding off numerical values (revised).

†Code of practice for design and construction of pile foundations: Part 1 Concrete piles, Section 1 Driven cast *in-situ* concrete piles (*first revision*).

‡Code of practice for design and construction of pile foundations: Part 1 Concrete piles, Section 2 Bored cast *in-situ* concrete piles (*first revision*).

§Code of practice for design and construction of pile foundations: Part 1 Concrete piles, Section 3 Driven precast concrete piles (*first revision*).

||Code of practice for design and construction of pile foundations: Part 1 Concrete piles, Section 4 Bored precast concrete piles.

¶Code of practice for design and construction of pile foundations: Part 2 Timber piles (*first revision*).

**Code of practice for design and construction of pile foundations: Part 3 Under-reamed piles (*first revision*).

2.2 Datum Bar — A rigid bar placed on immovable supports.

2.3 Factor of Safety — The ratio of the ultimate load capacity of a pile to the safe load of a pile.

2.4 Initial Test — It is carried with a view to determine ultimate load capacity and the safe load capacity.

2.5 Kentledge — Dead-weight used for applying a test load on piles.

2.6 Net Displacement — Net movement of the pile top from the original position after the pile has been subjected to a test load and subsequently released.

2.7 Routine Test — It is carried out on a working pile with a view to check whether pile is capable of taking the working load assigned to it.

2.8 Test Pile — A pile which is meant for initial test.

2.9 Total Displacement (Gross) — The total movement of the pile top under a given load.

2.10 Total Elastic Displacement — This is magnitude of the displacement of the pile due to rebound caused at the top after removal of a given test load. This comprises two components as follows:

- a) Elastic displacement of the soil participating in load transfer, and
- b) Elastic displacement of the pile shaft.

2.11 Ultimate Load Capacity — The maximum load which a pile or pile shaft can carry before failure of ground (when the soil fails by shear as evidenced from the load settlement curves) or failure of pile.

2.12 Safe Load — It is a load on a pile derived by applying a factor of safety on ultimate load capacity of pile as determined by load test.

2.13 Working Load — The load assigned to a pile according to design.

2.14 Working Pile — A pile forming part of foundation of a structural system which may be used for routine load test.

3. NECESSARY INFORMATION

3.1 The following information is necessary for pile(s) on which test is proposed:

- a) Pile type including material and reinforcement details, group of piles, if any;
- b) Method of driving with driving record of installation;
- c) Pile depth(s) and details of cross-section(s);

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- d) Type of test desired;
- e) Layout of the pile(s) — space available around and position in the group for single pile test;
- f) Depth of water table and soil strata details with soil test results;
- g) Safe load and ultimate load capacity, and the method(s) on which based;
- h) Availability and provision of type of piles or anchors or kentledge for reaction;
- j) Nature of loading/loading plan with a particularly mention of pile(s) which may be free standing when scour is expected; and
- k) Any other information concerning planning and conducting the tests including the relevant past experience concerning similar test(s).

4. TYPES OF TESTS

4.0 There are two types of tests for each type of loading (that is, vertical, lateral and pullout), namely, initial and routine test.

4.1 Initial Test — This test is required for one or more of the following purposes. This is done in case of important and/or major projects and number of tests may be one or more depending upon the number of piles required.

NOTE — In case specific information about strata and past guiding experience is not available, there should be a minimum of two tests.

- a) Determination of ultimate load capacities and arrival at safe load by application of factor of safety,
- b) To provide guidelines for setting up the limits of acceptance for routine tests,
- c) To study the effect of piling on adjacent existing structures and take decision for the suitability of type of piles to be used,
- d) To get an idea of suitability of piling system, and
- e) To have a check on calculated load by dynamic or static approaches.

4.2 Routine Test — This test is required for one or more of the following purposes. The number of tests may generally be one-half percent of the total number of piles required. The number of the test may be increased up to 2 percent in a particular case depending upon nature, type of structure and strata condition:

- a) One of the criteria to determine the safe load of the pile;
- b) Checking safe load and extent of safety for the specific functional requirement of the pile at working load; and

- c) Detection of any unusual performance contrary to the findings of the initial test, if carried out.

5. GENERAL REQUIREMENTS APPLICABLE TO ALL TYPES OF TESTS

5.1 Pile test may be carried out on a single pile or a group of piles as required. In case of pile groups, caps will be provided such that the required conditions of actual use are fulfilled.

5.2 Generally the load application and deflection observation will be made at the pile top.

5.3 In particular cases where upper part of pile is likely to be exposed later on due to scour, dredging or otherwise then capacity contributed by that portion of the pile during load test shall be duly accounted for. The pile groups in these conditions shall be tested without their cap resting on the ground.

5.4 The test should be carried out at cut-off level wherever practicable, otherwise suitable allowance shall be made in the interpretation of the test results/test load if the test is not carried out at cut-off level.

6. VERTICAL LOAD TEST (COMPRESSION)

6.1 General — In this type of test, compression load is applied to the pile top by means of a hydraulic jack against rolled steel joist or suitable load frame capable of providing reaction and the settlement is recorded by suitably positioned dial gauges. Maintained load method as given in 6.2 should be used for determination of safe load. However, for specific requirements cyclic and CRP methods, which are alternate methods, may be used as mentioned in 6.3 and 6.4. The general requirements applicable for these three methods are given from 6.1.1 to 6.1.6, unless otherwise specified.

6.1.1 Preparation of Pile Head — The pile head should be chipped off to natural horizontal plane till sound concrete is met. The projecting reinforcement should be cut off or bent suitably and the top finished smooth and level with plaster of Paris or similar synthetic material where required. A bearing plate with a hole at the centre should be placed on the head of the pile for the jacks to rest.

6.1.2 Application of Load — (Not applicable to CRP method.) The test should be carried out by applying a series of vertical downward incremental load each increment being of about 20 percent of safe load on the pile. For testing of raker piles it is essential that loading is along the axis.

6.1.3 Reaction — The reaction may be obtained from the following:

- a) **Kentledge** placed on a platform supported clear of the test pile. In case of load test below under-pinned structure, the existing structure if having adequate weight and suitable construction may serve as kentledge. The centre of gravity of the kentledge should generally be on the axis of the pile and the load applied by the jack should also be coaxial with this pile.
- b) **Anchor piles** with centre-to-centre distance with the test pile not less than 3 times the test pile shaft diameter subject to minimum of 2 m. If the anchor piles are permanent working piles, it should be ensured that their residual uplift is within limits. Care should be exercised to ensure that the datum bar supports are not affected by heaving up of the soil.
- c) **Rock anchors** with distance from the nearest edge of the piles at rock level being 2 times the test pile shaft diameter or 1.5 m whichever is greater.

6.1.3.1 The reaction to be made available for the test should be 25 percent more than the final test load proposed to be applied.

6.1.4 Settlement — (Not Applicable for CRP Test.) Settlement shall be recorded with minimum 2 dial gauges for single pile and 4 dial gauges of 0.01 mm sensitivity for groups, each positioned at equal distance around the piles and normally held by datum bars resting on immovable supports at a distance of $3D$ (subject to minimum of 1.5 m) from the edge of the piles, where D is the pile stem diameter of circular piles or diameter of the circumscribing circle in the case of square or non-circular piles.

6.1.5 The safe load on single pile for the initial test should be least of the following:

- a) Two-thirds of the final load at which the total displacement attains a value of 12 mm unless otherwise required in a given case on the basis of nature and type of structure in which case, the safe load should be corresponding to the stated total displacement permissible.
- b) 50 percent of the final load at which the total displacement equal 10 percent of the pile diameter in case of uniform diameter piles and 7.5 percent of bulb diameter in case of under-reamed piles.

6.1.5.1 However routine test shall be carried for a test load of at least one and half times the working load; the maximum settlement of test loading in position being not exceeding 12 mm.

6.1.6 The safe load on groups of piles for initial test shall be least of the following:

- a) Final load at which the total displacement attains a value of 25 mm unless otherwise required in a given case on the basis of nature and type of structure, and
- b) Two-thirds of the final load at which the total displacement attains a value of 40 mm.

6.1.6.1 However routine test shall be carried as in 6.1.5.1 the maximum settlement not exceeding 25 mm.

6.2 Maintained Load Method — This is applicable for both initial and routine test. In this method application of increment of test load and taking of measurement or displacement in each stage of loading is maintained till rate of displacement of the pile top is either 0.1 mm in first 30 minutes or 0.2 mm in first one hour or till 2 h whichever occur first. If the limit of permissible displacement as given in 6.1.5 or 6.1.6 is not exceeded, testing of pile is not required to be continued further. The test load shall be maintained for 24 h.

6.3 Cyclic Method — This method is used in case of initial test to find out separately skin friction and point bearing load on single piles of uniform diameter. The procedure as given in Appendix A or by instrumentation may be used.

6.4 CRP Method — This method which is used for initial test is generally considered to be more suitable for determining ultimate bearing capacity than the maintained load test but the load/deflection characteristics are quite different from those of the maintained load test and cannot be used to predict settlement of the pile under working load conditions. This method should not be included in routine test. The procedure is given in Appendix B.

7. LATERAL LOAD TEST ON PILES

7.1 The test may be carried out by introducing a hydraulic jack with gauge between two piles or pile groups under test or the reaction may be suitably obtained otherwise. If it is conducted by jack located between two piles or groups, the full load imposed by the jack shall be taken as the lateral resistance of each pile or group. The loading should be applied in increments of about 20 percent of the estimated safe load.

7.2 The next increment should be applied after the rate of displacement is nearer to 0.1 mm per 30 minutes.

7.3 Displacements shall be read by using at least two dial gauges of 0.01 mm sensitivity (see Fig. 1) spaced at 30 cm and kept horizontally

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one above the other on the test pile and the displacement interpolated at cut-off level from similar triangles where cut-off level is unapproachable and for approachable cut-off level, however, one dial gauge placed diametrically opposite to the jack shall directly measure the displacement. Where, it is not possible to locate one of the dial gauges in the line of the jack axes, then two dial gauges may be kept at a distance of 30 cm at a suitable height and the displacement interpolated at load point from similar triangles.

NOTE — One of the methods for keeping dial gauge on pile surface is to chip off uneven concrete on the side of the pile and to fix a piece of glass 20 to 30 mm square. The dial gauges tips shall rest on the central portion of the glass plate.

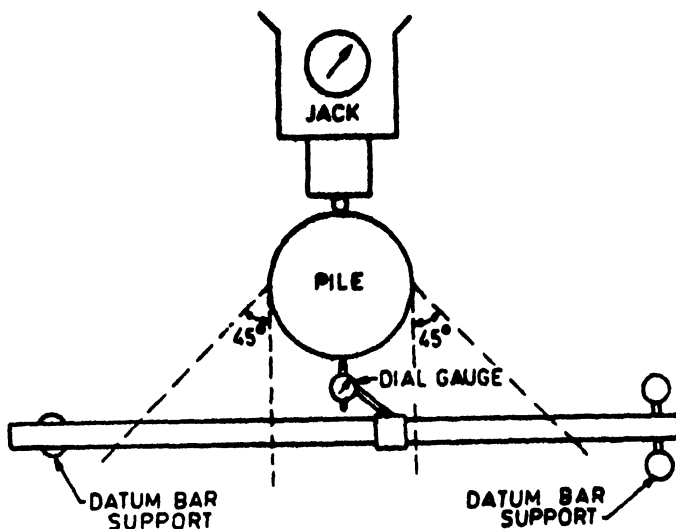


FIG. 1 POSITION OF DATUM BAR SUPPORTS

7.4 The safe lateral load on the pile shall be taken as the least of the following:

- a) Fifty percent of the final load at which the total displacement increases to 12 mm;
- b) Final load at which the total displacement corresponds to 5 mm; and
- c) Load corresponding to any other specified displacement as per performance requirements.

NOTE — The displacement is at the cut-off level of the pile.

7.5 Pile groups shall be tested under conditions as per actual use in the structure as far as possible.

8. PULL-OUT TEST ON THE PILES

8.1 Uplift force may preferably be applied by means of hydraulic jack(s) with gauge using a suitable pull out set up.

NOTE — One of the methods for pull out tests that may be used is where hydraulic jack is made to rest on rolled steel joist(s) resting on two supports on the ground. The jack reacts against a frame attached to the top of the test pile such that when the jack is operated, the pile gets pulled up and the reaction is transferred to the ground through the supports which are at least $2.5D$ away from the test pile periphery (where D is pile stem diameter of circular piles or diameter of the circumscribing circle in the case of square piles). The framework can be attached to the pile top with the reinforcement bars which may be threaded or to which threaded bolts may be welded. As an alternative it is sometimes preferable to use a central rod designed to take pile load and embedded centrally in the pile to a length equal to the bond length load required. It will have threads at top for fixing it to the framework. For larger loads the number of rods may have to be more and depending on the set-up these may be put in a line or in any other symmetrical pattern. For routine tests, the framework is normally attached to the reinforcing bars but a central rod may also be used in case the upper portion of the pile is required to be built up.

8.2 The test pile shall have adequate steel to withstand pulling. In some cases, in order to allow for neck tension in a pull out test, it may be necessary to provide additional reinforcement in the piles to be tested.

8.3 The pull out load increments and consequent displacement readings shall be read as in the case of vertical load test.

8.4 The safe load shall be taken as the least of the following:

- a) Two-thirds of the load at which the total displacement is 12 mm or the load corresponding to a specified permissible uplift, and
- b) Half of the load at which the load-displacement curve shows a clear break (downward trend).

8.5 The initial test shall be carried out up to twice the estimated safe load or until the load displacement curve shows a clear break (downward trend).

8.6 Routine test shall be carried out to one-and-a-half times the estimated safe load or 12 mm total displacement whichever is earlier.

9. RECORDING OF DATA AND PRESENTATION

9.1 The pile test data essentially concerns three variables, namely, load, displacement and time. These are to be recorded sequentially for the tests under consideration and recorded in a suitable tabular form along with the information about the pile.

9.2 The data may be suitably presented by curves drawn between the variables and safe loads shown on the graphs. Load displacement curve should be an essential part of presentation.

A P P E N D I X A

(Clause 6.3)

CYCLIC LOAD TEST METHOD

A-1. METHOD

A-1.1 Alternate loading and unloading shall be carried out at each stage as in 6.1.2 and each loading stage shall be maintained as in 6.2 and each unloading stage shall be maintained for at least 15 minutes and the subsequent elastic rebound in the pile should be measured accurately by dial gauges as in 6.1.4. The test may be continued up to 50 percent over the safe load.

A-2. ANALYSIS OF RESULTS FOR FRICTIONAL RESISTANCE

A-2.1 Graphical Method

A-2.1.1 The analysis shall be done as explained in Fig. 2.

A-2.1.2 Assuming that there is no compression in the pile, plot a graph relating total elastic recovery and load at the pile top.

A-2.1.3 Draw a straight line parallel to the straight portion of curve I to divide the load into two parts and thereby obtained approximate values of point resistance and skin friction.

A-2.1.4 From the approximate value of skin friction, and knowing the loads on top of pile, compute the elastic compression of the pile corresponding to these loads, by the following formula:

$$\Delta = \frac{(T - F/2) L}{AE}$$

where

Δ = elastic compression of pile in cm,

T = load on pile top in kgf,

F = frictional resistance in kgf,

L = length of the pile in cm,

A = cross-sectional area of the pile in cm², and

E = modulus of elasticity of the pile material in kgf/cm².

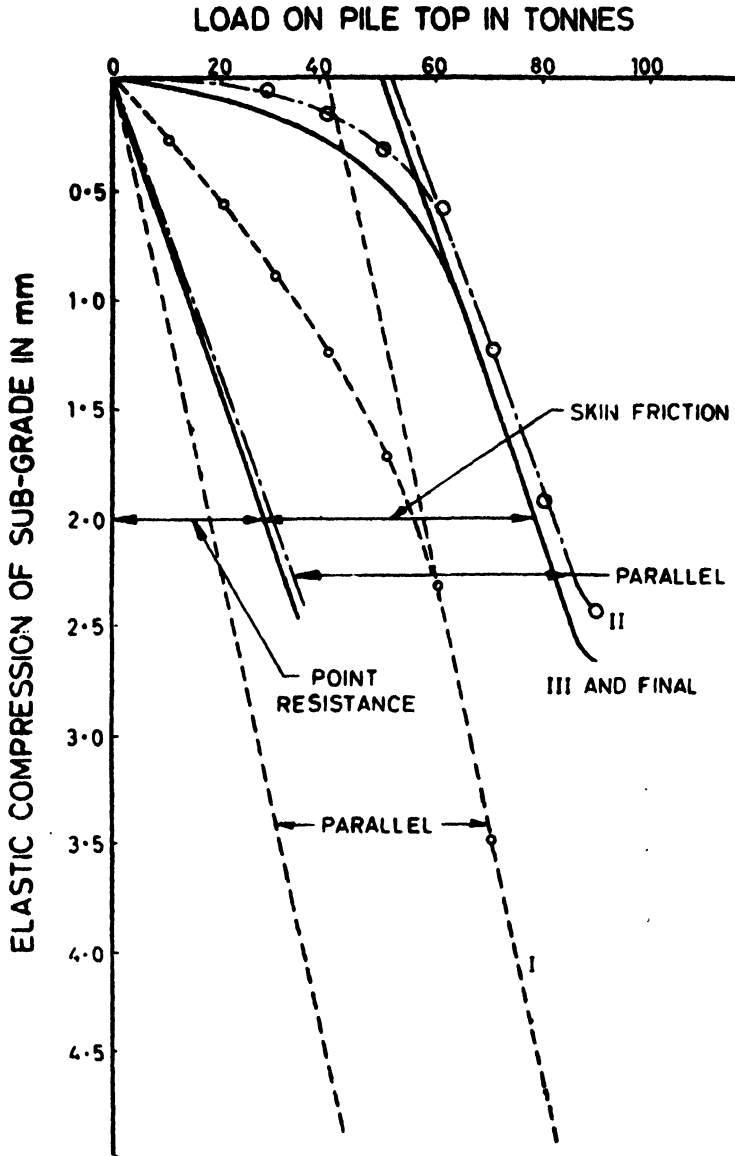


FIG. 2 ANALYSIS OF CYCLIC LOAD TEST DATA FOR SEPARATION OF SKIN FRICTION AND POINT RESISTANCE

(The value should normally be measured from an exposed portion of pile stem by means of compressometer during the load test itself.)

A-2.1.5 Obtain values of the elastic compression of the subgrade by subtracting the elastic compression of the pile from the total elastic recovery of pile, and plot the graph relating these new values to the corresponding loads on pile top. When elastic compression of the subgrade works out negative, the negative value shall be ignored until the value is positive.

A-2.1.6 Repeat the procedures given in A-2.1.3 to obtain new values of skin friction.

A-2.1.7 The process of further approximations covered in A-2.1.6 may be repeated further to any desired extent, but usually the third curve would give sufficiently accurate values for skin friction for practical purposes.

A-2.2 Analytical Method

A-2.2.1 From straight line portion of curve (see Fig. 2) calculate the value of constant from the equation (1).

$$m = \frac{\Delta_s - \left(\frac{\Delta_T}{AE} \right) L}{\Delta_T} \dots\dots (1)$$

where

m = a constant;

Δ_s = change in total elastic settlement of pile top = $(S - S)$,
in cm;

Δ_T = change in applied load = $(T_b - T_a)$ in kgf;

L = length of pile in cm;

A = cross-sectional area of pile in cm^2 ;

E = elastic modulus of the material of the pile in kgf/cm^2 ;
and

T = load on pile top in kgf.

A-2.2.2 Calculate the corrected settlement for different load increment by equation (2).

$$S = mT \dots\dots (2)$$

where

S = corrected settlement in cm, and

T = total load on pile top in kgf.

A-2.2.3 Knowing value of m and S compute skin friction and point bearing by solving simultaneous equation (3) and (4).

$$T = P + F \quad \dots\dots\dots (3)$$

$$S = mP + \frac{(T - F/2) L}{AE} \quad \dots\dots\dots (4)$$

where

P = point bearing in kgf, and

F = skin friction in kgf.

A P P E N D I X B

(Clause 6.4)

CRP TEST

B-1. PROCEDURE

B-1.1 The load shall be measured by means of pressure of 0.01 mm sensitivity load gauge. The penetration (deflection) should be measured by means of dial gauges held by a datum bar resting on immovable supports at a distance of at least $3D$ (subject to a minimum of 1.5 m) away from the rest pile edge where D is defined in 6.1.5. One of the dial gauges will be selected for conducting the test. With continuous application of pressure on the pile top by operating of the jack, a person watches the rate of settlement of the dial gauge against a stop watch held in his hand and directs the pump operator to pump faster or slower or at the same rate as needed to maintain the prescribed rate of settlement say at every 0.25 mm settlement, he gives an indication to take readings. Immediately, other persons record the pressure gauge readings and other dial gauge readings. The pump supplying the jack may be hand or mechanically operated. For force up to 200 ton hand pumping is convenient. If a mechanical pump is used, it should, for preference, have an 'infinite variable' delivery, controlled either by a bleed valve or a variable speed drive.

B-1.2 The jack should be operated to cause the pile to penetrate at uniform rate which may be controlled by checking the time taken for small increments of penetration and adjusting the pumping rate accordingly. Readings of time, penetration and load should be taken at sufficiently close intervals to give adequate control of the rate of penetration. A rate of penetration of about 0.75 mm per minute is suitable for predominantly friction piles. For predominantly end-bearing piles in sand or gravel, rate of penetration of 1.5 mm per minute may be used.

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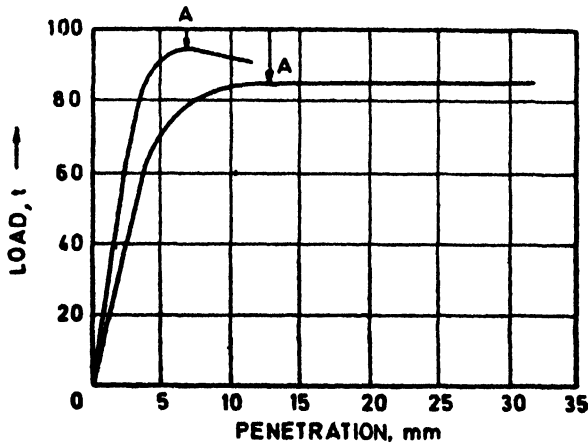
The rate of penetration, if steady, may be half or twice these values without significantly affecting the results. The test should be carried out for the penetration more than 10 percent of the diameter of the pile base.

B-1.3 As the test proceeds a curve between load and penetration should be drawn to determine when the ultimate load capacity has been reached.

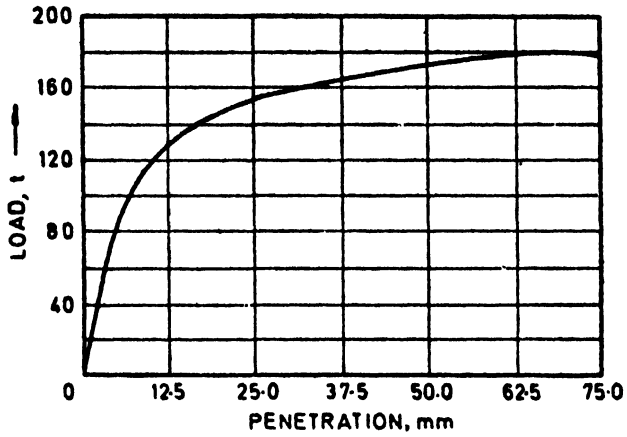
B-2. ULTIMATE LOAD CAPACITY

B-2.1 The curve of load versus penetration in the case of a predominantly friction pile will represent either a peak and the subsequent downward trend, or a peak and then almost a straight line, as shown in Fig. 3A. The peak load marked *A* in Fig. 3A will represent the ultimate load capacity of pile.

B-2.2 In the case of predominantly end-bearing pile the curve will be similar to that shown in Fig. 3B and the ultimate load capacity may be taken as the load corresponding to the penetration equal to 10 percent of the diameter of the pile base.



3A Predominantly Friction Piles



3B Predominantly End Bearing Piles

FIG. 3 LOAD vs PENETRATION CURVE IN CRP TEST

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(Continued from page 2)

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