HIGHWAYS RESEARCH STATION

SOILS LAB

PILE LOAD TEST

MANUAL

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1. SCOPE AND PURPOSE

This manual provides comprehensive guidelines for conducting a Vertical Compressive Load Test (also called Axial Compression Load Test) on RCC Cast-in-Situ Piles using the Kentledge (dead weight) system as the reaction arrangement. The procedures outlined herein comply with the requirements of Indian Standard IS 2911 (Part 4):2013.

1.1 Objectives

- To verify the adequacy of the designed pile capacity under vertical compressive loads.
- To determine the load-settlement behaviour of the pile under axial compressive loading.
- To establish the ultimate load carrying capacity of the pile.
- To identify failure load and assess factor of safety over working load.
- To serve as proof test for initial/trial piles before commencement of production piling.

1.2 Types of Tests Covered

The following types of vertical compressive pile load tests are addressed in this manual:

- Maintained Load Test (MLT) – Standard method as per IS 2911 (Part 4):2013
- Cyclic Load Test (CLT) – To separate shaft friction from end bearing
- Constant Rate of Penetration Test (CRP) – For determination of ultimate load

1.3 Applicability

This manual applies to:

- RCC Cast-in-Situ Bored Piles (rotary/percussive drilling)
- RCC Driven Cast-in-Situ Piles
- Pile diameters ranging from 300 mm to 1500 mm (or as specified)
- Pile lengths as designed by the Geotechnical Engineer
- Both initial (test) piles and routine (working) piles

NOTE: This manual must be read in conjunction with the applicable project drawings, geotechnical investigation report, pile design calculations, and the specific test specifications issued for the project.

2. REFERENCED INDIAN STANDARDS

The following Indian Standards and codes of practice form the basis of this manual:

Standard No.	Title
IS 2911 (Part 4):2013	Code of Practice for Design and Construction of Pile Foundations – Part 4: Load Test on Piles (Second Revision)
IS 2911 (Part 1/Sec 1):2010	Code of Practice for Design and Construction of Pile Foundations – Driven Cast In-situ Concrete Piles
IS 2911 (Part 1/Sec 2):2010	Code of Practice for Design and Construction of Pile Foundations – Bored Cast In-situ Concrete Piles
IS 1888:1982	Method of Load Test on Soils (Second Revision)
IS 14593:1998	Design and Installation of Ground Anchors – Code of Practice
IS 456:2000	Plain and Reinforced Concrete – Code of Practice (Fourth Revision)
IS 2720 (Part 1):1983	Methods of Test for Soils – Part 1: Preparation of Dry Soil Samples
IS 13941:1994	Guidelines on Instrumentation for Piles under Lateral and Axial Loading
IRC: 78:2014	Standard Specifications and Code of Practice for Road Bridges – Section VII: Foundations and Substructure
IS 5249:1992	Method of Determination of Dynamic Properties of Soil

3. TERMINOLOGY AND DEFINITIONS

For the purpose of this manual, the following terms and definitions shall apply:

Term	Definition
Safe Load	The load which the pile can carry without undue settlement, typically 50% of the ultimate load or based on specified criteria.
Working Load (Qw)	The load that the pile is designed to carry under service conditions. Also termed as 'Design Load'.
Ultimate Load (Qu)	The maximum load at which the pile fails by plunging or by excessive settlement. Determined from load-settlement curve.
Test Load	The maximum load applied during the load test, typically 2.0 to 2.5 times the working load for initial piles.
Kentledge	Dead weight (usually concrete blocks, steel plates, or pig iron) used as reaction to the jack load during pile load test.
Settlement	Downward movement of the pile top under applied load. Measured using dial gauges or LVDTs referenced to an independent datum.
Maintained Load Test (MLT)	Load test in which each load increment is maintained until the rate of settlement is less than a specified value before next increment is applied.
Cyclic Load Test (CLT)	Load test with repeated loading and unloading cycles at different load levels to separate shaft friction from end bearing.
CRP Test	Constant Rate of Penetration Test – pile is jacked into the ground at a constant rate and load is measured continuously.
Initial Pile	A test pile installed before production piling to confirm design parameters. Also called 'Trial Pile'.
Routine Pile	Production pile selected for load testing after installation to verify workmanship.
Reference Beam	A rigid steel beam supported on independent supports away from the test pile and anchor piles, used to mount dial gauges.
Datum Peg	A fixed peg in the ground at a distance from all influence zones, used as reference to check reference beam stability.

Elastic Settlement	Recoverable settlement upon removal of load. Used to assess pile behaviour.
Residual Settlement	Permanent (non-recoverable) settlement after complete unloading.
Net Settlement	Gross settlement minus elastic rebound; equals residual settlement.

4. PRE-TEST REQUIREMENTS AND PRELIMINARY WORK

4.1 Minimum Age of Pile Before Testing

The minimum period between completion of pile concreting and commencement of load test shall be as follows:

Condition	Minimum Curing Period
Normal Portland Cement (OPC)	28 days
Blended Cement (PPC/PSC)	28 days minimum; preferably 42 days
If approved by Engineer	Not less than 14 days with proven 28-day cube strength

NOTE: Concrete cube compressive strength shall achieve minimum 90% of specified 28-day characteristic strength before testing. Test certificates for concrete cubes shall be made available to the Engineer.

4.2 Documentation to be Reviewed Before Test

- Approved pile design drawings and calculations
- Geotechnical Investigation Report (Soil Boring Logs, SPT / CPT data, laboratory test results)
- Pile installation records (boring log, concrete pour record, integrity test report)
- Pile integrity test (PIT) results – to confirm pile is structurally sound before load test
- Approved test programme / method statement
- Calibration certificates for all load measuring and settlement measuring equipment
- Third-party inspection report (if applicable)

4.3 Pile Top Preparation

1. Cut off pile head to the specified test level; remove laitance and weak concrete.
2. Expose minimum 150 mm of reinforcing bars above pile cut-off level.
3. Prepare pile top surface to be truly horizontal (level within 1:500 tolerance) by grinding or lean concrete cap.
4. Dimensions of the pile head shall be measured and recorded.
5. Apply high-strength capping concrete (M40 or higher) if pile top is damaged; cure before testing.
6. Mark reference lines and cross-marks at the pile centre for monitoring.

4.4 Survey and Layout

- Set out exact position of test pile, kentledge supports, reference beam supports, and datum pegs.
- Establish benchmark level connected to Temporary Bench Mark (TBM) for settlement monitoring.
- Minimum distance of kentledge supports from test pile edge: 1.5 times pile diameter or 1.5 m, whichever is greater.
- Reference beam supports shall be at minimum 3D (D = pile diameter) or 3 m from the test pile centre, whichever is greater.
- Datum pegs shall be at minimum 5D from test pile centre and 5D from kentledge supports.

5. TEST EQUIPMENT AND INSTRUMENTATION

5.1 Hydraulic Jack

The hydraulic jack is the primary load-applying device and shall comply with the following requirements:

Parameter	Requirement
Jack Capacity	At least 10% more than the maximum test load; never use jack at >90% of rated capacity
Type	Double-acting hydraulic cylinder (centre-hole or solid) with precision machined bore
Calibration	Calibrated by accredited laboratory; calibration valid within 6 months of test date
Calibration Standard	NABL-accredited laboratory; calibration traceable to national standards
Stroke	Sufficient for anticipated settlement + 25 mm margin minimum
Centre Hole	Required if load cell is used in line with jack; diameter suitable for instrumented wire
Number of Jacks	Multiple jacks may be used if needed; all must be calibrated; hydraulic manifold required for synchronous loading
Base Plate	Rigid steel base plate not less than 25 mm thick and larger than jack base; placed on pile cap

5.2 Hydraulic Pump and Pressure Gauge

- Electric motor-driven or hand-operated hydraulic pump with pressure relief valve.
- Pressure gauges: minimum two gauges used simultaneously; Bourdon type or digital manometer.
- Gauge accuracy: minimum 0.5% of full scale range.
- Gauges calibrated within 3 months of test date; NABL-accredited calibration.
- Pressure range: not less than 120% of maximum test pressure.
- Isolating valves to permit reading while maintaining pressure.

5.3 Load Measurement

5.3.1 Primary Method – Hydraulic Pressure Gauge

Load is calculated from the calibration chart of the jack using the hydraulic pressure reading. The jack calibration certificate gives the relationship between pressure (kPa/MPa) and load (kN).

5.3.2 Secondary Method – Proving Ring / Load Cell

A calibrated proving ring or electronic load cell (strain gauge type) shall be used as an independent check on the applied load. This is mandatory for initial/trial pile tests.

- Load cell capacity: at least 10% more than maximum test load.
- Load cell accuracy: ±1% of applied load.
- Load cell shall be placed between jack and kentledge beam in line with pile axis.
- Load cell connected to a digital indicator / data logger.

5.4 Settlement Measurement System

5.4.1 Dial Gauges

- Minimum four dial gauges on the pile top (at four quadrants equidistant from pile centre).
- Type: mechanical dial gauges with 0.01 mm least count and 50 mm travel, or LVDTs (Linear Variable Displacement Transducers).
- All gauges mounted on the reference beam, reading against targets fixed firmly on the pile.
- Reference beam to be independently supported on firm ground away from zone of influence.

5.4.2 Reference Beam Specification

- Steel I-section or channel section of adequate stiffness (negligible deflection under self-weight).
- Resting on firm supports minimum 3D (pile diameter) from test pile and 3D from kentledge supports.
- Shaded from direct sunlight and wind to minimise thermal expansion effects.
- Stability of reference beam checked against datum peg using precise levelling at start and end of each load stage.

5.4.3 Datum Pegs

- Minimum two datum pegs – one near reference beam supports, one at far distance.
- Used to detect any movement of the reference beam itself.
- Precise levelling survey carried out at each load step to verify reference beam stability.

NOTE: LVDTs connected to a data logger with automatic time-stamped recording are preferred for improved accuracy and continuity of settlement data, especially for overnight or long-duration tests.

5.5 Instruments Summary Table

Instrument	Quantity	Specification	Calibration
Hydraulic Jack	1 (or more)	Capacity > max test load	6 months
Pressure Gauge	2 minimum	0.5% full scale accuracy	3 months
Load Cell / Proving Ring	1	Capacity > max test load	12 months
Dial Gauges / LVDTs	4 minimum	0.01 mm least count, 50 mm travel	6 months
Reference Beam	1	Adequate stiffness, independently supported	N/A
Data Logger	1 (if electronic)	Minimum 8 channels, 1 Hz sampling	12 months
Precision Level	1	Automatic level, 1mm/km accuracy	12 months
Jack Base Plate	1	25 mm min. thick, larger than jack base	N/A

6. KENTLEDGE SYSTEM – DESIGN AND SETUP

6.1 Principle

The kentledge system uses dead weight stacked on a platform girder system as reaction to the upward force exerted by the hydraulic jack on the pile. The dead weight must be sufficient to exceed the maximum test load by an appropriate margin. The system must be structurally stable and safe throughout the test.

6.2 Components of Kentledge System

6.2.1 Dead Weight (Kentledge Mass)

- Materials: RCC/PCC concrete blocks, cast iron ingots/pig iron, steel kentledge plates, or structural steel sections.
- Total weight to be at least 10% more than maximum intended test load.
- Individual blocks to be uniform in size for ease of stacking and weight computation.
- Each block must be permanently marked with its weight (confirmed by weighing).
- Blocks to be stacked symmetrically about the pile centre.
- Maximum height of stack to ensure stability (height:base ratio guidance per structural analysis).

6.2.2 Main Kentledge Girder / Platform Beam

- Two or more heavy steel I-beams (typically ISMB/ISWB series) spanning across the test pile.
- Designed as simply supported or cantilever beams to transfer kentledge weight to reaction supports.
- Span determined based on kentledge weight, safe bearing capacity of ground at supports, and required clearance.
- Minimum clearance of 100 mm between underside of girder and top of jack at start of test.
- Girder to be checked by a structural engineer for stresses, deflections, and connections.
- Web stiffeners and bearing plates at all support points.

6.2.3 Crib / Sleeper Supports

- Heavy timber sleepers or steel grillage under the main girder ends, bearing on firm ground.
- Bearing area sized to keep contact pressure within safe bearing capacity of ground.
- Contact pressure on ground at kentledge supports: typically limited to 100 kPa for normal soils; check against soils investigation data.
- Minimum distance of crib from pile edge: 1.5D or 1.5 m (whichever is greater) as per IS 2911 (Part 4):2013.

6.3 Kentledge Weight Calculation

The required kentledge weight (W) is calculated as follows:

Parameter	Value / Formula
Maximum Test Load (P_test)	= 2.0 x Qw (for routine piles) or 2.5 x Qw (for initial piles)
Required Kentledge Weight (W)	W ≥ 1.10 x P_test (minimum 10% surplus)
Working Load (Qw)	As per approved pile design
Weight of Platform Girder	Included in W or added separately; must be accounted for
Unit Weight of Concrete Blocks	24–25 kN/m^3 (verify each block)
Unit Weight of Steel/Pig Iron	78 kN/m^3

NOTE: The weight of the kentledge platform beam/girder self-weight shall NOT be included as reaction load unless it is verified that the full self-weight acts on the reaction supports. In many setups, the girder rests on the jack and can contribute; this must be checked carefully before crediting.

6.4 Kentledge Setup Sequence

7. Mark out locations of crib supports, girder ends, and kentledge stack boundary on ground.
8. Place sleeper cribs / steel grillage at the computed support locations; verify level.
9. Erect main kentledge girder over the test pile using crane; verify alignment with pile centre.
10. Place hydraulic jack centrally on the pile cap base plate under the kentledge girder.
11. Place spreader beam on jack head if required for wider bearing on girder.
12. Stack kentledge blocks symmetrically and progressively on platform girder; verify stability at each stage.
13. Ensure total weight computed matches or exceeds required minimum with 10% surplus.
14. Erect reference beam independently supported on pegs outside the influence zone.
15. Mount dial gauges / LVDTs on reference beam pointing at pile head targets.
16. Connect load cell, pressure gauges, and data logger; perform dummy reading checks.
17. Record initial readings of all instruments before applying any test load.

6.5 Spacing Requirements Summary (as per IS 2911 Part 4:2013)

Element	Minimum Distance from Test Pile Centre
Kentledge crib edge	1.5D or 1.5 m (whichever is greater)
Reference beam support	3D or 3 m (whichever is greater)
Anchor pile / ground anchor	3D or 3 m (whichever is greater)
Datum peg	5D or 5 m (whichever is greater); also 5D from kentledge supports

7. REACTION SYSTEM – ANCHOR PILES / GROUND ANCHORS

While this manual focuses on the kentledge system, some projects may supplement kentledge with anchor piles or ground anchors if the weight alone is insufficient. The following requirements apply if such supplementary reaction systems are used.

7.1 Anchor Piles

- Anchor piles may be used to supplement kentledge capacity or as an alternative reaction system.
- Minimum distance of anchor pile centre from test pile centre: 3D (pile diameter) or 3 m, whichever is greater.
- Anchor piles must be verified to have adequate uplift capacity under test load.
- Connection of kentledge girder to anchor piles must be designed to resist full uplift force plus eccentricities.
- Anchor piles shall be tested for pull-out resistance separately or confirmed by calculation.

7.2 Ground Anchors

- Design and installation as per IS 14593:1998.
- Minimum distance of ground anchor from test pile: 3D.
- Pull-out capacity to exceed maximum test load by a minimum factor of 1.5.
- Stressing and lock-off sequence to be carried out prior to test pile load application.

8. PILE PREPARATION AND INSTRUMENTATION

8.1 Pile Head Preparation

18. Cut off pile to test level; remove all weak/laitance concrete.
19. Expose main reinforcement and trim to required length.
20. Grind pile head to a flat, horizontal, smooth surface; level tolerance ≤ 1:500.
21. If required, construct a RCC/steel pile cap – cure before testing.
22. Verify pile head dimensions match design; record measurements.

8.2 Strain Gauge Instrumentation (For Initial Piles)

Vibrating wire strain gauges or electrical resistance strain gauges may be installed within the pile to measure axial load distribution along the pile shaft. This helps to separate shaft friction and end bearing:

- Gauges installed at strategic levels: typically at pile head, base, and at soil layer interfaces.
- Gauges installed in diametrically opposite pairs at each level to cancel bending effects.
- All gauge leads brought to pile top through conduit and protected from concrete pour.
- Readings recorded at each load step along with pile head load and settlement data.
- Gauge installation and interpretation by specialist instrumentation contractor.

8.3 Tell-Tale Rods (for base settlement measurement)

For long piles, tell-tale rods may be installed to measure pile base movement directly:

- Steel rod (25–50 mm dia) placed in a greased PVC sleeve reaching the pile base.
- Top of rod monitored by dial gauge mounted on the reference beam.
- Pile base settlement = pile head settlement – elastic compression (computed or measured via tell-tale).
- Elastic compression = pile base settlement subtracted from pile head settlement.

9. TEST PROCEDURE – MAINTAINED LOAD TEST (MLT)

The Maintained Load Test (MLT) is the standard procedure specified in IS 2911 (Part 4):2013 and is the most commonly used method in India for pile load testing.

9.1 Load Increments

The test load is applied in equal increments. Unless otherwise specified, the following load schedule shall be adopted:

Stage	Applied Load	Hold Duration	Settlement Rate Criterion
1	20% of Working Load (Qw)	Min. 1 hour	< 0.1 mm per 30 min
2	40% Qw	Min. 1 hour	< 0.1 mm per 30 min
3	60% Qw	Min. 1 hour	< 0.1 mm per 30 min
4	80% Qw	Min. 1 hour	< 0.1 mm per 30 min
5	100% Qw (Working Load)	Min. 12 hours (overnight)	< 0.1 mm per 2 hours
6	120% Qw	Min. 1 hour	< 0.1 mm per 30 min
7	140% Qw	Min. 1 hour	< 0.1 mm per 30 min
8	160% Qw	Min. 1 hour	< 0.1 mm per 30 min
9	180% Qw	Min. 1 hour	< 0.1 mm per 30 min
10	200% Qw (Max Test Load – routine pile)	Min. 24 hours	< 0.1 mm per 2 hours

NOTE: For initial (trial) piles, the maximum test load is typically 2.5 times the working load (250% Qw). Additional load stages at 220%, 240%, and 250% Qw shall be included. The Engineer-in-Charge may specify a different load schedule.

9.2 Settlement Observation Schedule

Settlement readings shall be taken at the following intervals during each load stage:

- Immediately after load application (t = 0)
- At t = 5 minutes
- At t = 10 minutes
- At t = 20 minutes
- At t = 30 minutes
- At t = 1 hour
- Every 1 hour thereafter until the settlement rate criterion is achieved
- Immediately before applying next increment (just prior to load change)

9.3 Criteria to Apply Next Load Increment

The next load increment shall be applied only when:

- The rate of settlement at the current load level is less than 0.1 mm in 30 minutes for intermediate load stages.
- The rate of settlement is less than 0.1 mm in 2 hours for the hold stages (100% Qw and 200% Qw).
- If settlement continues at a higher rate beyond the specified hold period, extend the hold period and record settlement vs. time until the criterion is met.

9.4 Unloading Procedure

After the maximum test load has been held for the specified duration, the load is removed in equal decrements:

- Unloading in 4 equal stages: 75%, 50%, 25%, and 0% of maximum test load.
- Each unloading stage held for 30 minutes; settlement (rebound) recorded at 5, 10, 20, 30 minutes.
- After complete unloading (zero load), hold for minimum 1 hour and record final rebound.
- Final residual settlement recorded after 12–24 hours of complete unloading (where possible).

9.5 Re-loading (Second Cycle – if applicable)

For initial piles, a second loading cycle may be specified by the Engineer to evaluate elastic behaviour and hysteresis. Loading and unloading procedures shall be repeated as above, unless a specific cyclic load test is planned (see Section 10).

9.6 Failure During Test

The test shall be terminated (or the load held constant) if any of the following conditions arise:

- Total settlement exceeds 10% of pile diameter under test load.
- Settlement continues to increase rapidly without any load increment (plunging failure).
- Visible distress in the pile head concrete, kentledge structure, or reaction system.
- Any safety concern observed by the Engineer-in-Charge.
- Any instrument gives unreliable or inconsistent readings that cannot be resolved immediately.

10. TEST PROCEDURE – CYCLIC LOAD TEST (CLT)

The Cyclic Load Test separates skin friction from end bearing by loading and unloading at progressively increasing loads. This provides detailed pile load transfer characteristics.

10.1 Loading Schedule for CLT

Cycle	Load Range	Steps	Hold at Peak
1	0 → 50% Qw → 0	25% increments / decrements	1 hour at 50% Qw
2	0 → 100% Qw → 0	25% increments / decrements	12 hours at 100% Qw
3	0 → 150% Qw → 0	25% increments / decrements	1 hour at 150% Qw
4	0 → 200% Qw → 0	25% increments / decrements	24 hours at 200% Qw

10.2 Data Interpretation for CLT

- Plot Load vs. Settlement for loading and unloading of each cycle.
- Elastic compression (pile shaft) = pile head settlement – pile base movement (from tell-tale).
- Skin friction mobilised = load carried in shaft = total load – load at base (from strain gauges if available).
- Permanent/residual set at each cycle is an indicator of progressive shear failure in skin friction zone.

11. TEST PROCEDURE – CONSTANT RATE OF PENETRATION (CRP) TEST

The CRP test is used primarily to determine the ultimate bearing capacity of the pile. The pile is jacked into the ground at a constant pre-specified rate, and the load required to maintain this rate is measured continuously.

11.1 Rate of Penetration

- Rate of penetration for cohesive soils: 0.75 mm/min ± 25%
- Rate of penetration for non-cohesive soils / mixed soils: 1.5 mm/min ± 25%
- Rate selected based on soil conditions as recommended by the Engineer.

11.2 CRP Test Procedure

23. Set the hydraulic pump to maintain the specified constant penetration rate.
24. Monitor penetration rate using a dial gauge with timer or data logger.
25. Record load and settlement continuously at 15-second intervals minimum (data logger preferred).
26. Continue until one of the following:
    - Plunging failure (load drops significantly with continued penetration)
    - Total settlement equals 10% of pile diameter
    - As specified by the Engineer
27. Do not unload during the test unless specified.
28. Final reading recorded when test is terminated; pile left undisturbed and final rebound noted after 24 hours.

11.3 Termination Criteria for CRP

- When load has been constant for a penetration of at least 5 times the pile diameter OR
- When total settlement is 10% of pile diameter

12. LOAD SCHEDULE AND ACCEPTANCE CRITERIA

12.1 Test Load Requirements

Type of Pile / Test	Maximum Test Load
Initial / Trial Pile	2.5 times Working Load (250% Qw)
Routine / Working Pile	2.0 times Working Load (200% Qw)
Proof Load Test (working pile verification)	1.5 times Working Load (150% Qw) – minimum

12.2 Acceptance Criteria (as per IS 2911 Part 4:2013)

A pile shall be considered acceptable if it satisfies the following criteria under the test load:

12.2.1 Settlement Criteria

Criterion	Limiting Value
Total settlement at 2.0 Qw (routine pile)	≤ 12 mm OR ≤ 4% of pile diameter, whichever is less
Net (residual) settlement at 2.0 Qw after unloading	≤ 6 mm OR ≤ 2% of pile diameter, whichever is less
Total settlement at 1.5 Qw (proof load test)	≤ 12 mm
Settlement at working load after reloading (if 2nd cycle)	≤ Settlement at Qw in 1st cycle

NOTE: For large-diameter piles (D > 600 mm), the settlement criteria based on percentage of pile diameter typically governs. The Engineer may specify project-specific criteria more stringent than those above based on structural requirements.

12.2.2 Load Criteria

- The pile shall sustain the maximum test load (2.0 or 2.5 Qw) without plunging failure.
- The load-settlement curve shall not show an abrupt change in gradient (indicative of pile failure) at loads less than the test load.
- The ultimate load (from Mazurkiewicz or other methods) shall exceed 2.0 times the working load.

13. OBSERVATIONS, MEASUREMENTS AND DATA RECORDING

13.1 Personnel Responsibilities

Responsibility	Duties
Test Engineer (In-Charge)	Overall supervision of test; approval of each load stage; decision to terminate test; sign-off on data sheets
Instrument Observer	Reading and recording dial gauges / load cell at specified intervals; maintaining observation log
Pump Operator	Operating hydraulic pump; maintaining specified pressure; monitoring for leaks
Surveyor	Checking reference beam level against datum pegs at each load stage; recording in survey book
Safety Officer	Monitoring kentledge stability, structural safety; enforcing exclusion zone; emergency protocols

13.2 Data to be Recorded at Each Observation

- Date and time of reading
- Cumulative elapsed time from start of test (minutes)
- Applied hydraulic pressure (kPa) from each pressure gauge
- Corresponding applied load (kN) computed from jack calibration chart
- Load cell reading (kN)
- Individual dial gauge readings (mm) – all four gauges
- Average settlement (mm) = mean of all four gauges
- Calculated settlement since start of current load stage
- Rate of settlement (mm per 30 min) or (mm per 2 hours)
- Reference beam level check vs. datum peg (mm)
- Tell-tale rod readings (if installed)
- Strain gauge / vibrating wire readings (if installed)
- Weather conditions (temperature, wind, rain) – at start and end of each shift
- Any abnormalities observed
- Initials of observer

13.3 Data Sheets

All observations shall be recorded on pre-printed, numbered data sheets (proforma provided in Section 18). Field data sheets shall be in ink; corrections made by single line strike-through (not erased) with initials. A bound logbook is preferred for field observations.

> NOTE: Photocopies of handwritten field data shall be made and stored separately. Original data sheets are legal records. If an electronic data logger is used, raw data files shall be exported and backed up at the end of each test day.

13.4 Graphical Plots During Test

The following plots shall be maintained in real-time during the test:

- Load (kN) vs. Settlement (mm) – Load on X-axis or Y-axis (both conventions used)
- Settlement (mm) vs. Time (minutes) for each load stage – plotted on logarithmic time scale
- These plots allow the Test Engineer to monitor pile behaviour and detect anomalies immediately.

14. INTERPRETATION OF TEST RESULTS

14.1 Load-Settlement Curve

The primary output of the pile load test is the Load vs. Settlement curve. This is plotted from the observed data and interpreted to determine pile capacity and stiffness.

14.2 Methods to Determine Ultimate Load (Qu)

14.2.1 IS 2911 (Part 4):2013 – Direct Observation Method

- The load at which total settlement is 10% of pile diameter (for driven piles) or 12 mm (for bored piles) under maintained test load is taken as the failure load.
- In the absence of a well-defined failure, the load at total settlement of pile diameter / 10 is taken as Qu.

14.2.2 Mazurkiewicz Method

- Plot load vs. settlement at equal settlement intervals.
- Draw tangents to the load axis at equal settlement increments.
- Intersection of these tangents (extrapolated) indicates the ultimate load Qu.
- This method is graphical and gives consistent results for bored piles.

14.2.3 Chin-Kondner Method

- Plot s/Q versus s (where s = settlement, Q = load).
- A straight line through the points gives: 1/slope = Qu (ultimate load).
- This method tends to over-predict ultimate load and should be used with caution.

14.2.4 Brinch Hansen 80% Criterion

- Qu = load at which 4 times the settlement occurs at 80% of Qu.
- Requires extrapolation of the load-settlement curve beyond measured data.

14.2.5 Decourt Method (Log-Log Plot)

- Plot log(Q) vs. log(s) to identify change in slope indicative of failure.
- Used for CRP and MLT data.

14.3 Pile Stiffness and Elastic Compression

Elastic compression of the pile shaft can be estimated:

$$\delta\_elastic = Q \times L / (A \times Ec)$$

Where: Q = applied load, L = pile length, A = pile cross-sectional area, Ec = modulus of elasticity of concrete

- Compare computed elastic compression with measured pile head settlement to check if elastic behaviour is occurring.
- Residual settlement = Pile head settlement – Elastic rebound after unloading.

14.4 Separation of Shaft Friction and End Bearing

- From strain gauge data: load distribution at each gauge level gives local shaft friction and base load.
- From tell-tale: pile base movement is directly measured; shaft compression = pile head movement – base movement.
- From cyclic load test: elastic component largely represents shaft friction mobilisation; residual set represents progressive failure/mobilisation of end bearing.

14.5 Summary Table of Results

Parameter	Value / Remarks
Working Load (Qw) – Design	kN
Maximum Test Load Applied	kN (= × Qw)
Total Settlement at Maximum Test Load	mm
Residual Settlement after Full Unloading	mm
Ultimate Load (Qu) – Mazurkiewicz	kN
Ultimate Load (Qu) – Chin-Kondner	kN
Factor of Safety = Qu / Qw	(should be ≥ 2.5 for IS criteria)
Settlement at Working Load	mm
Elastic Rebound at Working Load	mm
Acceptance as per IS 2911 (Part 4):2013	PASS / FAIL

15. SAFETY REQUIREMENTS

15.1 General Safety Principles

The pile load test involves heavy equipment, high hydraulic pressures, and large dead loads at elevation. Strict adherence to safety protocols is mandatory throughout the test period.

15.2 Exclusion Zone

- An exclusion zone of minimum 5 m radius from the kentledge stack boundary shall be enforced.
- Only essential personnel directly involved in the test are permitted within the exclusion zone.
- Clear barriers (safety tape or fencing) and warning signs to be erected before commencement.
- No personnel shall pass under the kentledge stack or girder at any time.

15.3 Structural Safety of Kentledge

- Structural stability of the kentledge arrangement (girder, blocks, supports) verified by a Structural Engineer before test commencement.
- Kentledge blocks must be adequately interlocked or restrained to prevent toppling.
- The crib/support ground bearing capacity verified; no settling of cribs during test allowed.
- Girder connections and welds inspected before and during test.
- Any tilting or instability of kentledge noted immediately – stop test and evacuate.

15.4 Hydraulic System Safety

- Hydraulic hoses inspected for condition (no cracks, abrasion, or leaks) before test.
- Pressure relief valve set and tested before starting.
- No hydraulic connections to be changed under pressure.
- Personnel to stand clear of pressurised hoses; hydraulic oil at high pressure can penetrate skin.
- Jack to be operated only by trained personnel.
- In case of hydraulic failure, load is gradually released using the pump relief valve.

15.5 Personal Protective Equipment (PPE)

- Hard hat: mandatory at all times within test zone.
- Safety shoes / boots with steel toe-cap: mandatory.
- High-visibility vest: mandatory.

- Safety glasses: mandatory for hydraulic system operations.
- Gloves: when handling heavy equipment or sharp steel edges.

15.6 Emergency Procedures

- Emergency stop: close pump valve immediately; do not slam or jerk the system.
- In case of kentledge instability: stop test, evacuate area, assess and rectify before resuming.
- First aid kit and emergency contact numbers to be posted at test site.
- Local emergency (fire brigade / ambulance) numbers to be available at site.
- Incident report to be filed for any near-miss, injury, or equipment failure.

> NOTE: Night testing requires adequate lighting (minimum 150 lux at working level), and no reduction in safety supervision. A Toolbox Talk shall be conducted at the start of every shift change.

16. REPORTING

16.1 Test Report Contents

A comprehensive pile load test report shall be submitted by the Testing Agency within 7 working days of test completion (or as specified). The report shall include:

16.1.1 Executive Summary

- Project name, location, date of test
- Pile identification number, coordinates, dimensions
- Working load, test load, type of test
- Summary of results – pass/fail, ultimate load, factor of safety

16.1.2 Site and Pile Information

- Site location plan and pile layout drawing
- Soil investigation summary (bore log, SPT N-values, soil profile)
- Pile design details (diameter, length, reinforcement, concrete grade)
- Pile installation record (date, pile reference, concrete volume, set/driving record)
- Pile integrity test (PIT) results

16.1.3 Equipment Details

- Jack make, model, serial number, and calibration certificate
- Load cell / proving ring details and calibration certificate
- Dial gauge / LVDT details and calibration certificates
- Reference beam dimensions and support details
- Kentledge arrangement drawing with weight schedule

16.1.4 Test Data

- Complete tabulated field data (all dial gauge readings, load cell readings, time, applied load)
- Load vs. Settlement tabular summary
- Settlement vs. Time tables for each load stage
- Scanned copies of original field data sheets

16.1.5 Graphs and Plots

- Load vs. Settlement curve (gross and net)
- Settlement vs. Log Time for each load stage
- Mazurkiewicz plot for determination of Qu

- Chin-Kondner plot (s/Q vs. s)
- Load distribution curves (if strain gauges installed)

16.1.6 Analysis and Interpretation

- Determination of ultimate load by at least two methods
- Computation of factor of safety
- Assessment against acceptance criteria of IS 2911 (Part 4):2013
- Comparison with predicted pile capacity from design calculations
- Recommendations (if pile fails or results are marginal)

16.1.7 Annexures

- Calibration certificates for all instruments
- Concrete cube test results
- Pile integrity test report
- Pile installation record (concrete pour sheet)
- Structural analysis of kentledge arrangement
- Photographs of test setup, instrumentation, and kentledge arrangement

16.2 Photographs Required

Stage	Photographs Required
Pre-test	Pile head after preparation, pile reference mark, overall site layout
Kentledge Setup	Crib supports, main girder placement, kentledge stacking, hydraulic jack, load cell position
Instrumentation	Dial gauge mounting on reference beam, LVDT connections, data logger
During Test	Overall view of test setup, instruments, data recording team, clock showing time
Post-test	Pile head after test, any distress observed, final instrument reading view

17. CHECKLISTS

17.1 Pre-Test Checklist

S.No.	Item to be Checked	Status
1	Approved pile design drawings available at site	☐ ☐
2	Soil investigation report reviewed; soil profile understood	☐ ☐
3	Pile curing period completed (minimum 28 days for OPC)	☐ ☐
4	Concrete cube compressive strength meets ≥ 90% of specified 28-day strength	☐ ☐
5	Pile integrity test (PIT) completed; no major defects found	☐ ☐
6	Pile head cut to correct level; laitance removed; surface leveled	☐ ☐
7	Kentledge weight calculated; minimum 110% of maximum test load verified	☐ ☐
8	Kentledge blocks individually weighed and marked; total weight confirmed	☐ ☐
9	Main girder structural capacity verified by Structural Engineer	☐ ☐
10	Crib/support ground bearing pressure checked against soil capacity	☐ ☐
11	Kentledge support distance from pile edge: ≥ 1.5D or 1.5 m	☐ ☐
12	Hydraulic jack calibration valid (≤ 6 months); calibration chart available	☐ ☐
13	Two pressure gauges available; both calibrated (≤ 3 months)	☐ ☐
14	Load cell calibrated (≤ 12 months); reading verified against pressure gauge	☐ ☐
15	Minimum four dial gauges / LVDTs mounted on reference beam	☐ ☐
16	Reference beam supported independently at ≥ 3D from test pile	☐ ☐
17	Datum pegs installed at ≥ 5D from test pile and kentledge supports	☐ ☐
18	Initial readings of all instruments recorded; zero set	☐ ☐
19	Data sheets pre-printed and numbered; observer identified	☐ ☐
20	Emergency and safety protocols briefed to all personnel	☐ ☐
21	PPE available for all personnel in test zone	☐ ☐

22	Exclusion zone barriers and warning signs erected	☐ ☐
23	Toolbox Talk conducted; signed attendance record maintained	☐ ☐

OK = ✓ NOT OK = ✗ N/A = – (Circle appropriate symbol in Status column)

17.2 During-Test Checklist (Each Load Stage)

S.No.	Item	✓ / ✗
1	Load increment applied as per approved schedule (no deviation without Engineer approval)	
2	Two pressure gauge readings taken and compared; discrepancy ≤ 2%	
3	Load cell reading cross-checked with pressure gauge load	
4	All four dial gauge readings taken and individual values recorded	
5	Average settlement computed; settlement rate checked	
6	Reference beam level checked against datum peg at each load stage	
7	Readings at specified intervals (5, 10, 20, 30 min, 1 hr, etc.) completed	
8	Settlement rate criterion checked before applying next increment	
9	No unusual cracking, settlement, or tilting of kentledge observed	
10	Hydraulic hoses and connections checked for leaks	
11	Load-settlement graph updated in real time	

18. PROFORMA FOR LOAD TEST RECORDING

18.1 Project Information

Project Name:	
Project Location:	
Client / Employer:	
Contractor:	
Testing Agency:	
Pile Reference No.:	
Pile Diameter (mm):	
Pile Length (m):	
Date of Concreting:	
Date of Test:	
Working Load, Qw (kN):	
Maximum Test Load (kN):	
Jack Serial No. & Calibration Date:	
Load Cell Serial No. & Calibration Date:	
Test In-Charge (Name & Signature):	
Engineer's Representative (Name & Signature):	

18.2 Observation Sheet – Maintained Load Test

Date & Time	Elapsed Time (min)	Pressure (kPa)	Load (kN)	DG-1 (mm)	DG-2 (mm)	DG-3 (mm)	DG-4 (mm)	Avg. Settlement (mm)	Remarks

18.3 Load-Settlement Summary

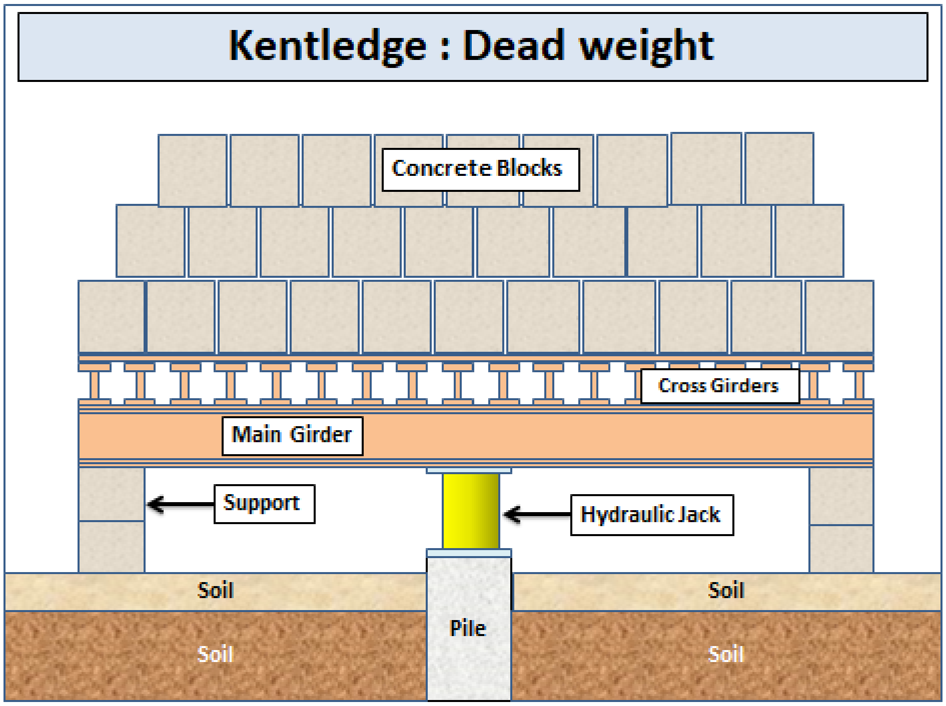
Stage	Applied Load (kN)	% of Qw	Total Settlement (mm)	Residual Settlement (mm)	Duration (hrs)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

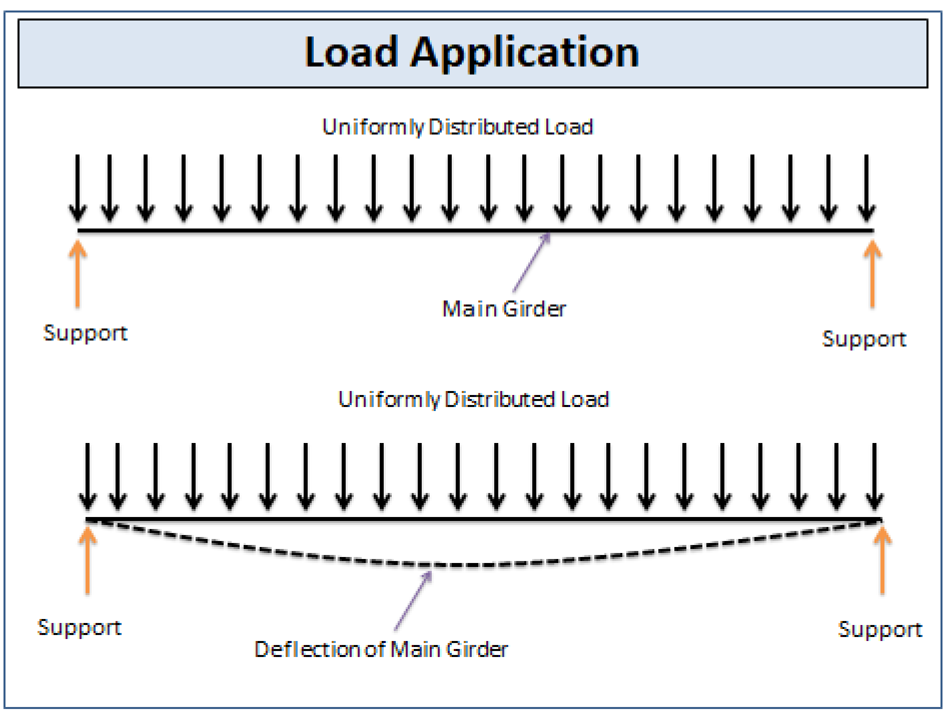
18.4 Final Test Summary

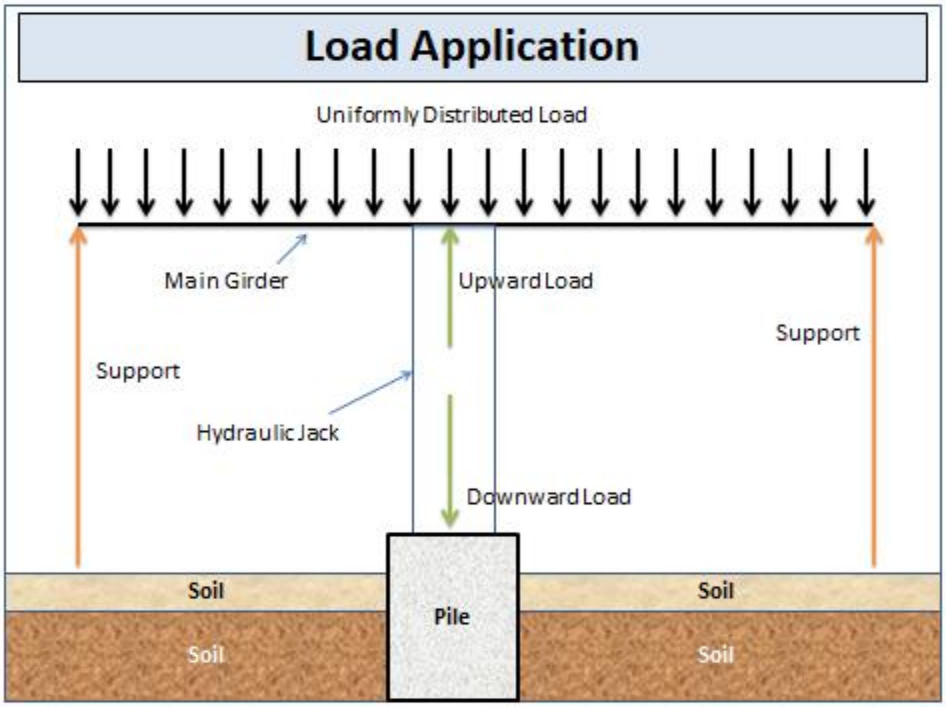
Maximum load applied (kN)	
Total settlement at max load (mm)	
Residual settlement after unloading (mm)	
Elastic rebound (mm)	
Ultimate load by Mazurkiewicz method (kN)	

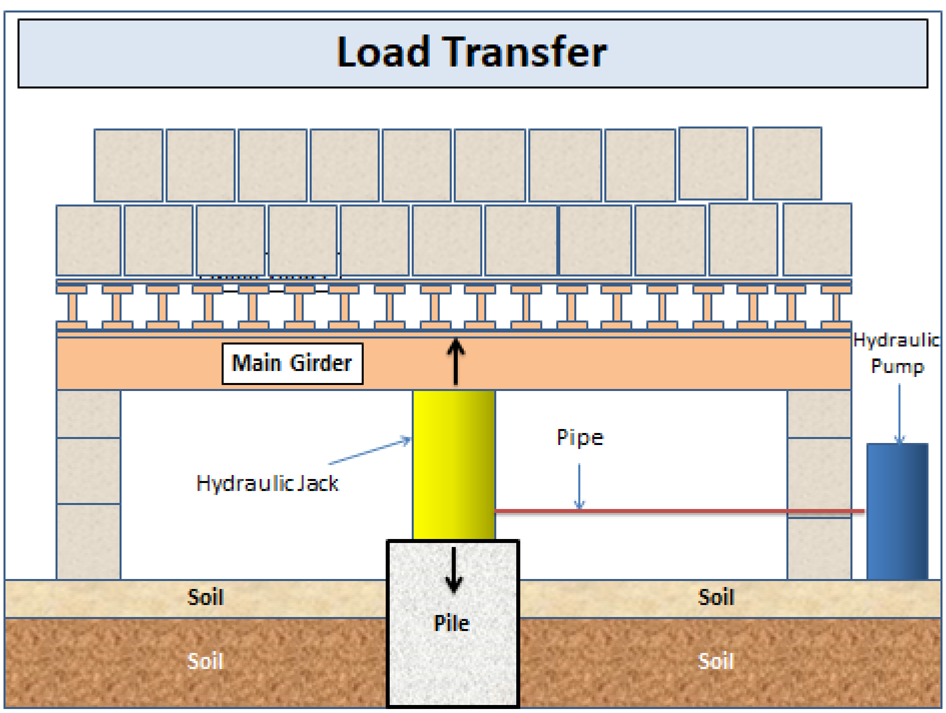
Factor of Safety (Qu / Qw)	
Acceptance as per IS 2911 (Part 4):2013	PASS / FAIL
Recommendations / Remarks	

ANNEXURE - I


Kentledge : Dead weight
Concrete Blocks
Cross Girders
Main Girder
Support
Hydraulic Jack
Soil
Soil
Pile
Soil
Soil


Load Application
Uniformly Distributed Load
Main Girder
Support
Support
Uniformly Distributed Load
Support
Deflection of Main Girder
Support


Load Application
Uniformly Distributed Load
Main Girder
Upward Load
Support
Support
Hydraulic Jack
Downward Load
Soil
Soil
Pile
Soil
Soil


Load Transfer
Main Girder
Hydraulic Pump
Pipe
Hydraulic Jack
Soil
Soil
Pile
Soil
Soil

Hydraulic Pump, Pressure Gauge & Jack

Hydraulic Pump

Pressure Gauge

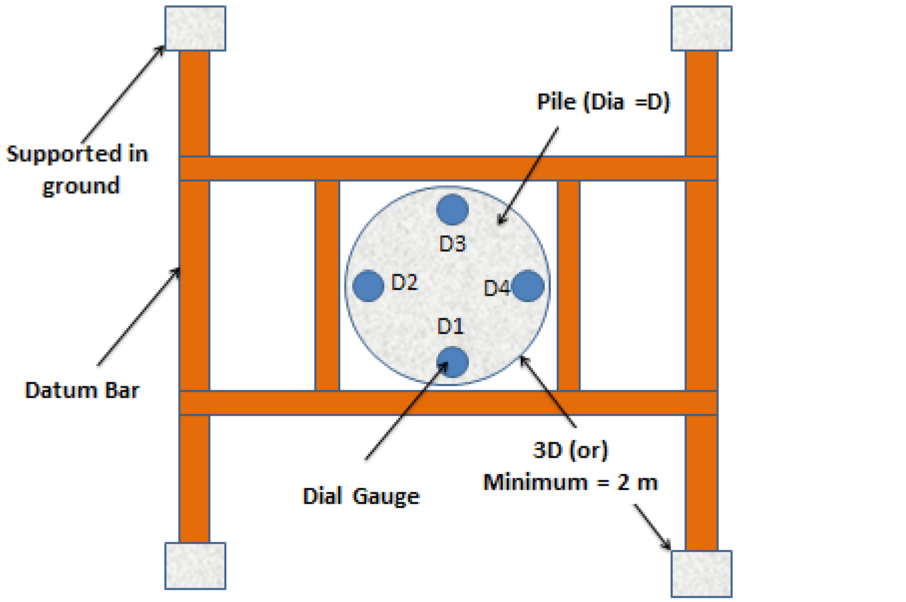
Hydraulic Jack

Dial Gauge

Dial Gauge

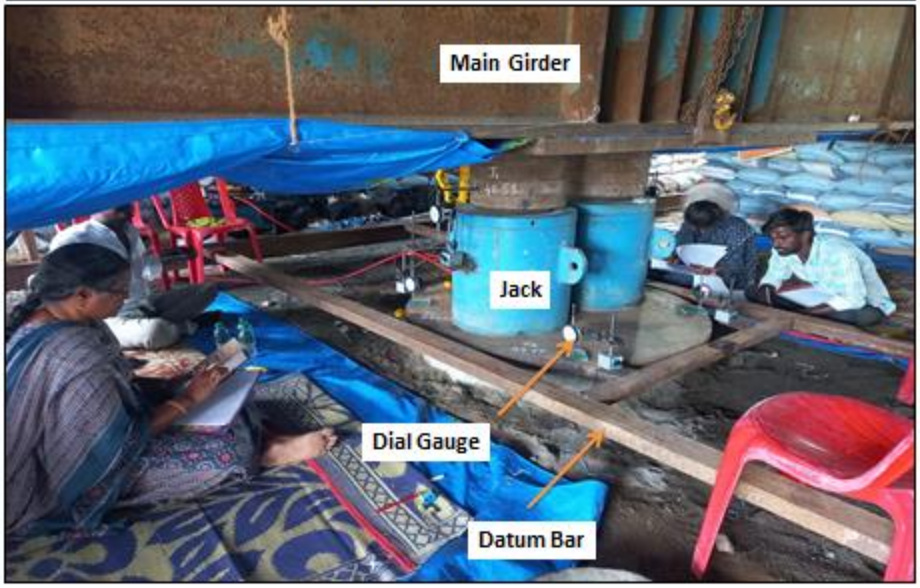
Dial Gauge with Stand

Datum Bar



Kentledge Arrangement - Checking

Observing Pile Settlement



Applied Load on Pile

Name of Work	Construction of High-Level Bridge at Km 10/6 of Thirupachur - Kadambathur - Kondancheri Road (MD-468) in lieu of Existing Causeway			
Least Count of Pressure Gauge=	20 Kg/cm2		Effective Area of Ram=	1418.60 cm2
			Revised Design Load=	276.144 MT
			Incremental Loading (20% of design load)=	55.229 MT

SL. NO	PRESSURE GAUGE DIVISION	APPLIED PRESSURE	CORRECTED PRESSURE	CORRECTED LOAD
		Kg/cm2	Kg/cm2	MT
1	2	40	41.788	59.280
2	4	80	83.576	118.561
3	6	120	124.298	176.329
4	8	160	163.954	232.585
5	10	200	203.610	288.841
6	12	240	243.202	345.006
7	14	280	282.794	401.172
8	16	320	322.386	457.337
9	18	360	361.978	513.502
10	20	400	401.570	569.667
11	22	440	441.092	625.733
12	24	480	480.614	681.799
13	26	520	520.136	737.865

Observed Load & Settlement

Pressure Gauge Division	Load (Tons)	Time (Min)	DIAL GAUGE READING				Averge Settlement(mm)	Cummulative Settlement(mm)	Ram Height at each incremental load
			D1	D2	D3	D4			
0	0	8.00	47.25	45.62	47.28	46.17	0.00	0.00	
2	59.280	8.05	46.47	44.56	46.73	45.79			
		8.10	46.47	44.45	46.70	45.78			
		8.15	46.46	44.42	46.69	45.76			
		8.20	46.45	44.41	46.67	45.74			
		8.25	46.44	44.41	46.65	45.73			
		8.30	46.42	44.40	46.62	45.70			
		8.35	46.41	44.40	46.61	45.67			
		8.40	46.41	44.39	46.60	45.66			
		8.45	46.40	44.38	46.59	45.64			
		8.50	46.40	44.37	46.56	45.64			
		8.55	46.40	44.37	46.56	45.63			
		9.00	46.40	44.36	46.56	45.63			
			0.85	1.26	0.72	0.54	0.8425	0.8425	

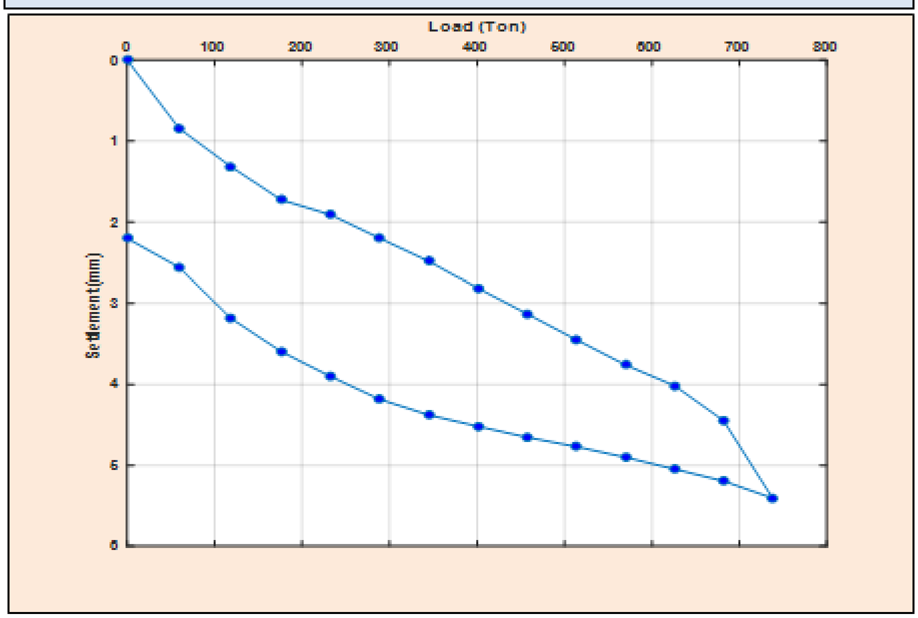
Load & Settlement Data

Sl.No.	Load (Ton)	Settlement (mm)
1	0.000	0.0000
2	59.280	0.8425
3	118.561	1.3150
4	176.329	1.7275
5	232.585	1.9100
6	288.841	2.2000
7	345.006	2.4825
8	401.172	2.8175
9	457.337	3.1325
10	513.502	3.4500
11	569.667	3.7600
12	625.733	4.0175
13	681.799	4.4475
14	737.865	5.4050

Load & Settlement

15	681.799	5.1950
16	625.733	5.0475
17	569.667	4.9025
18	513.502	4.7700
19	457.337	4.6550
20	401.172	4.5200
21	345.006	4.3775
22	288.841	4.1850
23	232.585	3.9025
24	176.329	3.5975
25	118.561	3.1850
26	59.280	2.5575
27	0.000	2.2025

Load & Settlement



Test Result

- Design Load = 254.842 Ton
- Load due to Skin Friction = 21.302 Ton
- Total Load = 254.842 + 21.302 = 276.144 Ton
- Test Load = 276.144 x 2.5 = 690.36 Ton
- Applied Test Load = 737.865 Ton
- Maximum Settlement = 5.4050 mm
- Net Settlement = 2.205 mm

Test Result

- Safe Load = 2/3 of Applied Test Load

  = 2/3 x (737.865)

  = 491.910 Ton
- Final Safe Load = Safe Load – Load due to Skin Friction

  = 491.910 – 21.302

  = 470.608 Ton

  Which is greater than Design Load of 254.842 Ton
- **Pile is Safe for Design Load**