A Laboratory Manual for

Soil Mechanics (Program Elective) (2940605)

BE Civil PDDC (Part Time) Semester IV

Directorate of Technical Education
Gandhinagar, Gujarat

Shantilal Shah Engineering College, Bhavnagar

Certificate

This is to certify that Mr./Ms. _____ _____ Enrollment No. _____ of BE PDDC (Part Time) Civil Engineering of this Institute (GTU Code: _____) has satisfactorily completed the Practical / Tutorial work for the subject Soil Mechanics (2940605) for the academic year 2023-24.

Place: _____
Date: _____

Name and Sign of Faculty member

Head of the Department

Preface

The basic aim of laboratory/practical/field work is to enhance the required skills as well as creating ability amongst students to solve real time problem by developing relevant competencies in psychomotor domain. By keeping this in view, GTU has designed competency focused outcome-based curriculum for engineering degree programs where sufficient focus is given to the practical work. It shows importance of enhancement of skills amongst the students and pays attention to utilize every second of time allotted for practical amongst students, instructors and faculty members to achieve relevant outcomes by performing the experiments rather than having merely study type experiments. It is must for effective implementation of competency focused outcome-based curriculum that every practical is keenly designed to serve as a tool to develop and enhance relevant competency required by the various industry among every student. These psychomotor skills are very difficult to develop through traditional chalk and board content delivery method in the classroom. Accordingly, this lab manual is designed to focus on the industry defined relevant outcomes, rather than old practice of conducting practical to prove concept and theory.

By using this lab manual students can go through the relevant theory and procedure in advance before the actual performance which creates interest and students can have basic idea prior to performance. This in turn enhances pre-determined outcomes amongst students. Each experiment in this manual begins with industry relevant skills, course outcomes as well as practical outcomes (objectives). The students will also achieve safety and necessary precautions to be taken while performing practical.

This manual also provides guidelines to faculty members to facilitate student centric lab activities through each experiment by arranging and managing necessary resources in order that the students follow the procedures with required safety and necessary precautions to achieve the outcomes. It also gives an idea that how students will be assessed by providing rubrics.

Soil Mechanics is the elective course which deals with the behavior of the soil mass under different environment, pressure, drainage and loading conditions. It provides a platform for students to apply the basic principles of Soil Mechanics to solve real life problems for various ground conditions.

Utmost care has been taken while preparing this lab manual however always there are chances of improvement. Therefore, we welcome constructive suggestions and comments for improvement and removal of errors if any from those who use it.

Practical – Course Outcome matrix

Course Outcomes (COs):

CO.1: Classify the soil, understand its behavior and will be able to compute/estimate index parameters.

CO.2: Interpret soil behavior due to compaction, consolidation, and analyze various theories and calculate parameters needed in design.

CO.3: Compute earth pressure, stress distributions and FOS for slopes using various graphical and analytical tools for various engineering projects/site.

CO.4: Differentiate, compare, formulate and evaluate soil parameters through Performing various tests as per site conditions or project needs ethically and professionally

CO.5: Suggest suitable type of foundation as per soil type, estimate bearing capacity, Settlements and demonstrate its socio-economic feasibility

Sr. No.	Objective(s) of Experiment	CO 1	CO 2	CO 3	CO 4	CO 5
1.	To conduct auger boring at a given location.	√				
2.	To perform standard penetration test to obtain the penetration resistance (N-value) along the depth at a given site.	√			√	√
3.	To determine the unit point resistance of soil by static cone penetration method.		√		√	
4.	To determine permeability of each subsurface strata encountered up to bed rock and to ascertain overall permeability of strata.	√		√	√	
5.	Primary investigation to determine the swelling potential of the soil.	√			√	√
6.	To determine the Swelling Pressure of Soils.	√			√	
7.	To determine the load bearing capacity of a single pile by static pile load test.		√		√	
8.	(a) To plan out the visit preferably for Standard Penetration Test nearby area of institute. (b) To understand and interpret the data collected during site investigation.	√			√	√

Industry Relevant Skills

The following industry relevant competencies are expected to be developed in the student by undertaking the practical work of this laboratory.

1. Collection of important data and specific information required to complete a construction project in a best way.
2. Analysis of the data and preparing reports about the geotechnical conditions of a location.

Guidelines for the Faculty members

1. Teacher should provide the guideline with demonstration of practical to the students with all features.
2. Teacher shall explain basic concepts/theory related to the experiment to the students before starting of each practical.
3. Involve all the students in performance of each experiment.
4. Teacher is expected to share the skills and competencies to be developed in the students and ensure that the respective skills and competencies are developed in the students after the completion of the experimentation.
5. Teachers should give opportunity to students for hands-on experience after the demonstration.
6. Teacher may provide additional knowledge and skills to the students even though not covered in the manual but are expected from the students by concerned industry.
7. Give practical assignment and assess the performance of students based on task assigned to check whether it is as per the instructions or not.
8. Teacher is expected to refer complete curriculum of the course and follow the guidelines for implementation.

Instructions for Students

1. Students are expected to carefully listen to all the theory classes delivered by the faculty members and understand the COs, content of the course, teaching and examination scheme, skill set to be developed etc.
2. Students shall organize the work in the group and make record of all observations.
3. Students shall develop maintenance skill as expected by industries.
4. Student shall attempt to develop related hand-on skills and build confidence.
5. Student shall develop the habits of evolving more ideas, innovations, skills etc. apart from those included in scope of manual.
6. Student shall refer technical magazines and data books.
7. Student should develop a habit of submitting the experimentation work as per the schedule and s/he should be well prepared for the same.

Common Safety Instructions

Follow the safety instructions displayed in the laboratory.

Index
(Progressive Assessment Sheet)

Sr. No.	Objective(s) of Experiment	Page No.	Date of performance	Date of submission	Assessment Marks	Sign. of Teacher with date	Remarks
1.	To conduct auger boring at a given location.						
2.	To perform standard penetration test to obtain the penetration resistance (N-value) along the depth at a given site.						
3.	To determine the unit point resistance of soil by static cone penetration method.						
4.	To determine permeability of each subsurface strata encountered up to bed rock and to ascertain overall permeability of strata.						
5.	Primary investigation to determine the swelling potential of the soil.						
6.	To determine the Swelling Pressure of Soils						
7.	To determine the load bearing capacity of a single pile by static pile load test.						
8.	(a) To plan out the visit preferably for Standard Penetration Test nearby area of institute. (b) To understand and interpret the data collected during site investigation						
Total							

Experiment No: 1

Auger boring/sampling

Date:

Relevant CO:

CO-1: Classify the soil, understand its behavior and will be able to compute/estimate index parameters.

Objectives: To conduct auger boring at a given location.

Equipment/Instruments: Hand auger, helical auger, post hole auger, Extension rod of 1 m length, T-piece for fitting the handle, Handle for rotating the auger

Theory: Auger boring is an economical and simplest method of sub-soil investigation. Auger boring is carried out for preparation of borehole log and for getting information for soil classifications. Augers may be operated manually by labor or may be power driven. Hand augers used in boring are about 150 mm to 200 mm in diameter. Hand augers are usually suitable for depths up to 5-7 m in soft to firm clays or sands with some cohesion. Mechanical augers are suitable for depths up to 12 m depth. Vertical holes are advanced by rotating the cross arm of the auger and pushing the auger into the ground. When the auger is filled with the soil, it is withdrawn. The soil is removed from the auger and examined. The samples of the soil are recovered at regular intervals (or whenever there is a change in strata) for conducting tests in laboratory for identification of soils. Through auger boring, disturbed samples are obtained which are required for different tests to find index properties and geotechnical properties of soil.

Open Hole Auger **Helical Auger**

Fig. Types of Augers
Courtesy: IITGN- Geotechnical Lab. Manual

Procedure:

1) Remove and clean the grasses from the ground where boring is to be made.

2) Place the tip of the auger, fitted with handle on the ground.

3) Rotate the auger with the help of handle by holding the auger in vertical position. Auger should be kept vertical while boring and couple on the handle should be applied uniformly. Boring should be vertical.

4) Take out the auger from the ground when the bucket is filled with soil.

5) Remove the soil from the auger by using a trowel.

6) Collect the soil sample in a polythene bag. Different bags are used for collecting soil Samples when there is change in soil type. All samples should be clearly labeled with details about project name, date of sampling, bore hole number, depth and method of sampling.

7) The samples of the soil are recovered at regular intervals (or whenever there is a change in strata) for conducting tests in laboratory for identification of soils

8) Use extension rods of 1 m length when boring is to be made to greater depths.

9) Measure the groundwater level (if present) by lowering a stone tied with measuring tape.

Observations: Field boring record:

Location……. Date …….

Boring number…….

Diameter of bore hole…….

Depth of boring……

Sample number…….

Depth at which sample is taken…….

Type of sample…… Type of soil…….

Depth of water table…….

Result:

Conclusion:

Quiz:

1. What is the depth of holes made by hand operated augers?

2. For which type of soil strata auger boring is suitable?

Suggested Reference:

- IS: 1892-1979 Code of practice for subsurface investigation for foundation
- Soil Mechanics and Foundation Engineering, Dr. K.R. Arora, Standard Publishers Distributors, New Delhi, Year 2010.
- Soil Mechanics and Foundation Engineering, S.K. Garg, Khanna Publishers, New Delhi, Year-2005
- Soil Mechanics and Foundation Engineering, P. Purushothama Raj, Pearson India Education Services Pvt. Ltd., Noida, Year-2013
- Laboratory manual for soil testing, Dr. D.K. Maharaj, S.K. Kataria & sons, New Delhi, Year-2017

References used by the students:

Rubric wise marks obtained:

Rubrics	**1**	**2**	**3**	**4**	**5**	**Total**
Marks						

Experiment No: 2

Standard Penetration Test

Date:

Relevant CO:

CO-1: Classify the soil, understand its behavior and will be able to compute/estimate index parameters.

CO-4: Differentiate, compare, formulate and evaluate soil parameters through performing various tests as per site conditions or project needs ethically and professionally.

Objectives: To perform standard penetration test to obtain the penetration resistance (N-value) along the depth at a given site.

Equipment/Instruments:

Drilling Equipment

- Inner diameter of hole: 100 to 150 mm (Casing may be used in case of soft/non-cohesive soils)
- Split spoon sampler as per IS:9640-1980
- Drive weight assembly
    - Falling Weight = 63.5 Kg
    - Fall height = 75 cm
- Tripod (to give a clear height to about 4m one of the legs of the tripod should have ladder to facilitate a person to reach tripod head.)
- Tripod Head with hook
- Pulley
- Guide pipe assembly
- Rope (about 15m along and strong enough to lift 63.5 kg load repeatedly)
- Change pulley block
- Casing pipes
- Casing coupling
- Casing clamps
- Measuring taps
- A straight edge (50cm)
- Tool box
- Others accessories: Lifting bail, Tongs, screw jack, etc.

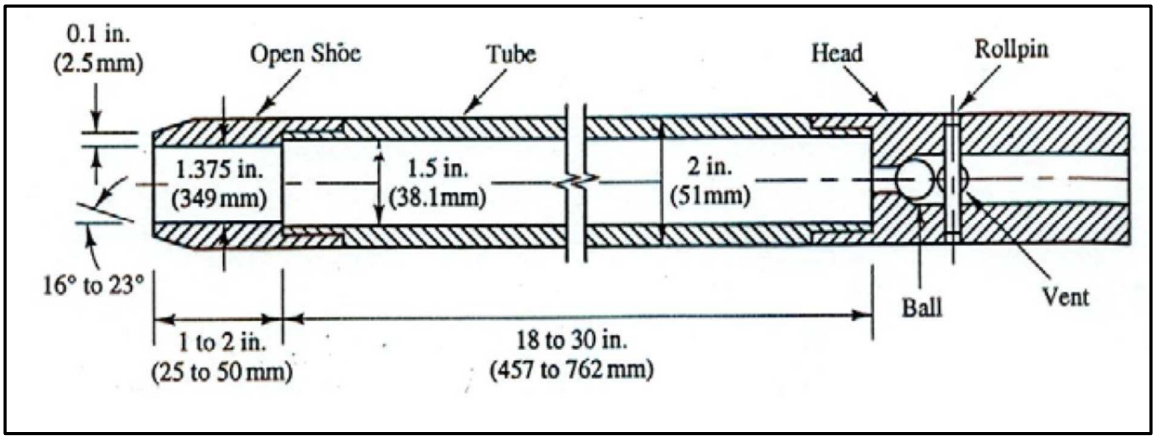


Fig. Split Spoon Sampler. IS:9640 -1980
Courtesy: IITGN- Geotechnical Lab. Manual

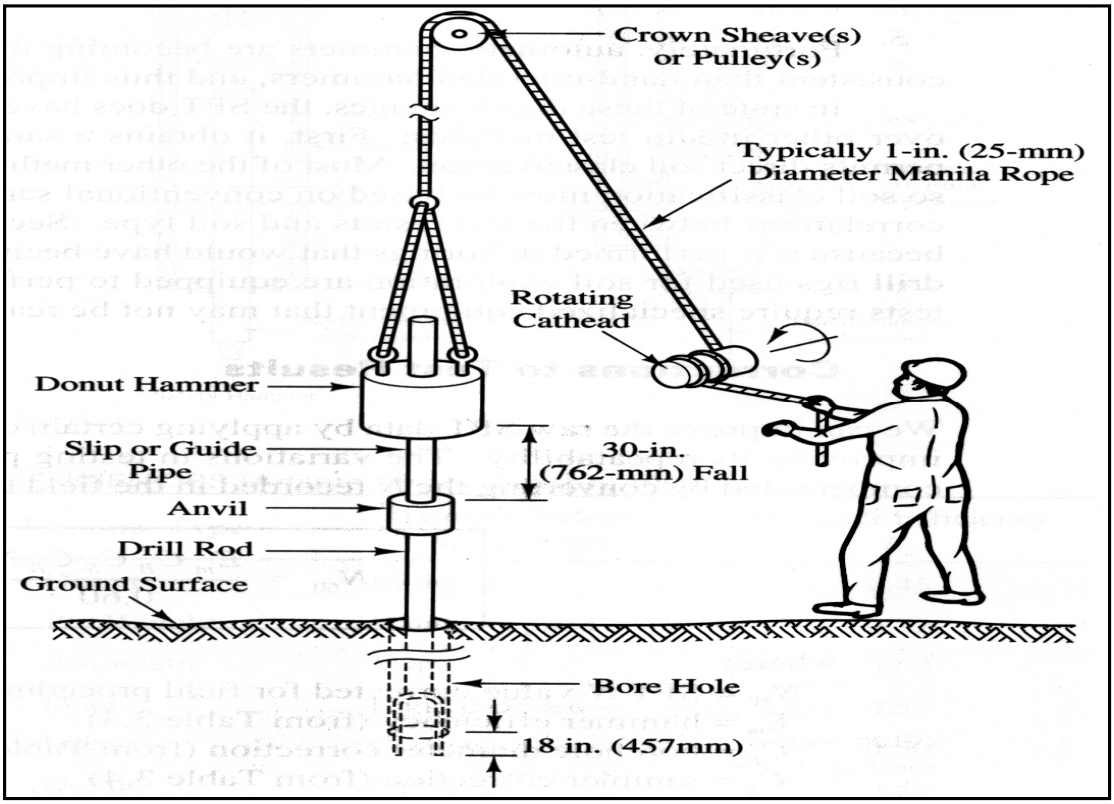


Fig. Standard Penetration Test Setup
Courtesy: IITGN- Geotechnical Lab. Manual

Theory:

SPT Corrections

- Correction for Overburden Pressure

$N' = C_N * N$

N' = Corrected value of observed N

C_N = Correction factor for overburden pressure

- Correction for Dilatancy

If the stratum consists of fine sand and silt below water table, for N'> 15, the dilatancy correction is applied as

N'' = 15 + 0.5 (N' – 15) (When N' >15) as per IS: 2131-1981

If N' $\leq$ 15, N'' = N'

Interpretations from SPT:

N''	Ø'	Dr (%)	consistency
0-4	25-30	0-15	very loose
4-10	27-32	15-35	loose
10-30	30-35	35-65	medium
30-50	35-40	65-85	dense
>50	38-43	85-100	very dense

Procedure:

1) Identify the location of testing in the field

2) Erect the tripod such that the top of the tripod head is centrally located over to testing spot. This can be reasonably ensured by passing a rope over the pulley connected to the tripod head and making the free end of the rope to come down and adjusting the tripod legs such that the rope end is at the testing spot, while erecting and adjusting the tripod legs, care should be taken to see that the load is uniformly distributed over the three legs. This can be achieved by ensuring the lines joining the tips of the tripod legs on the ground forms an equilateral triangle. Further, it should be ensured that the three legs of the tripod are firmly supported on the ground (i.e. the soil below the legs should not be loose and they should not be supported on a sloping rock space or on a small boulder which may tilt during testing)

3) Advance the bore hole, at the test location, using the auger. To start with advance the bore hole for a depth and clear the loose soil from the bore hole

4) Clean the split spoon sampler and apply a thin layer of oil to the inside face of the sampler. Connect an A-rill extends on rod to the split spoon sampler,

5) Slip the 63.6 kg weight on to the guide pipe assembly arc connects the guide pipe assembly to the other end of the A-drill rod.

6) The chain connected head the other end of the rope is pulled down manually or with help of mechanical winch. By pulling the rope down, the drive weight, guide pipe assembly, A-drill rod and the split spoon sampler will get the driving weight is tied to the rope passing over the pulley at the tripod vertically erected

7) A person should hold the guide pipe assembly split spoon sampler to be vertical with the falling weight lowered to the bottom of the guide assembly

8) Now place a straight edge cross the bore touching the A-drill rod. Mark the straight edge level all rounds the A-drill rod with the help of chalk or any other marker. From this mark, measure up along the A-drill rod and mark 15 cm, 30 cm and 45 cm above the straight edge level. Lift the driving weight to reach the top on the guide pipe assembly travel and allow it to fall freely. The fall of driving weight will transfer the impact load to the split spoon sample, which drive the split spoon sampler into the ground Again the drive weight to the lap of travel and allow it to fall freely under its own weight from a height of 75 cm. as the number of blows as applied, the split spoon sampler will penetrate into the ground and the first mark 5 cm mark) on the drill rod approaches the straight edge.

9) Count the number of blows required for the first 15 cm, second 15 cm and the third 15 cm mark to cross down the straight edge.

10) The penetration of the first 15 cm is considered as the seating drive and the number of blows required for this penetration is noted but not accounted in computing penetration resistance value. The total number required for the penetration of the split spoon sampler by 2 and 3 15 cm is recorded as the penetration resistance or N-value.

11) After the completion of the split spoon sampler by 45 cm, pull out the whole assembly. Detach the split sampler from A-drill rod and open it out. Collect the soil sample from the split spoon sampler in a sampling bag. Store the sampling bag safety with an identification tag for laboratory investigation.

12) Advance the bore hole by another 1 m or till a change of soil strata whichever is early.

13) The test is repeated with advancement of bore hole till the required depth of exploration is reached till a refusal condition is encountered. Refusal condition is said to exist if the number of blows required for the last 30 cm of penetration is more than 100.

14) The test will be repeated in number of bore holes covering the site depending on the building area, importance of the structure and variation of the soil properties across the site.

15) The SPT values are presented either in the form of a table or in the form of bore log data.

Precautions:

1) The height of free fall must be 750 mm.

2) The fall of hammer must be free, frictionless and vertical.

3) Cutting shoe of the sampler must be free from wear & tear.

4) The bottom of the bore hole must be cleaned to collect undisturbed sample.

5) When SPT is done in a sandy soil below water table, the water level in the bore hole must be maintained higher than the ground water level, otherwise quick condition arise which has very low N value.

Observations:

1) Driving mass is dropped onto the drill rod repeatedly and the sampler is driven into soil for a distance of 450 mm. The number of blows for each 150 mm penetration is recorded.

2) N-value

• First 150 mm penetration is considered as seating penetration.

• The number of blows for the last two 150 mm penetration are added together and reported as N-value for the depth of bore hole.

3) The split spoon sampler is recovered, and sample is collected from split barrel so as to preserve moisture content and sent to the laboratory for further analysis.

4) SPT is repeated at every 750 mm or 1500 mm interval for larger depths.

Calculation:

Observed N value = ----------

N' = Corrected value for Overburden Pressure = ----------

N" = Corrected value for dilatancy correction = ----------

Result:

Conclusion:

Suggested Reference:

- IS 2131: 1981 (Reaffirmed 2002) Method for standard penetration test for soils
- Soil Mechanics and Foundation Engineering, Dr. K.R. Arora, Standard Publishers Distributors, New Delhi, Year 2010.
- Soil Mechanics and Foundation Engineering, S.K. Garg, Khanna Publishers, New Delhi, Year-2005
- Soil Mechanics and Foundation Engineering, Purushothama Raj, Pearson India Education Services Pvt. Ltd., Noida, Year-2013
- Laboratory manual for soil testing, Dr. D.K. Maharaj, S.K. Kataria & sons, New Delhi, Year-2017

References used by the students: IS 2131: 1981 (Reaffirmed 2002)

Rubric wise marks obtained:

Rubrics	**1**	**2**	**3**	**4**	**5**	**Total**
Marks						

Experiment No: 3

Static Cone Penetration Test

Date:

Relevant CO:

CO-2: Interpret soil behavior due to compaction, consolidation, and analyze various theories and calculate parameters needed in design.

CO-4: Differentiate, compare, formulate and evaluate soil parameters through performing various tests as per site conditions or project needs ethically and professionally

Objectives: To determine the unit point resistance of soil by static cone penetration method.

Equipment/Instruments: Steel cone, friction jacket, sounding rods, mantle tubes, driving and measuring instruments

Theory: Among the field sounding tests the static cone test is a valuable method of recording variation in the in-situ penetration resistance of soils, in cases where the in-situ density is disturbed by boring operations, thus making the standard penetration test unreliable especially under water. The test is very useful for soft clays, soft silts, medium sands and fine sands. The Penetrometer commonly used is a cone with an apex angle 60° and base area of 10 cm^2.For obtaining cone resistance, the cone is pushed downward at a steady rate of 10 mm/sec through a depth of 35 mm each time. The cone is pushed by applying thrust and not by driving. This test is unsuitable for gravelly soil and soil for having SPTN value greater than 50.

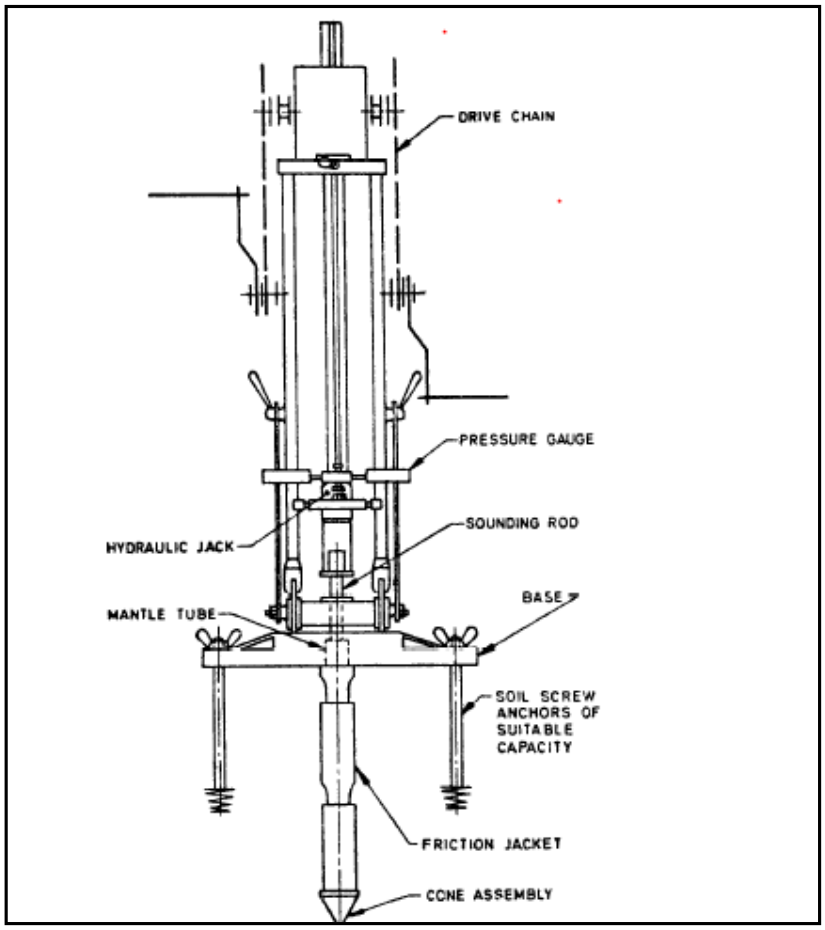


Fig. Typical Set Up for Hand Operated Static Cone Penetrometer
IS: 4968 (Part III) - 1976

Procedure:

1) After installing the equipment as per IS-4968 part-III, the cone and the friction jacket assembly are kept in a stationary position touching the ground.

2) The cone is then pushed in to the soil at the rate of 10 to 20 mm/sec in to the soil to a depth say a= 40 mm.

3) Next the sounding rod is pushed further to a depth b = 40 mm, due to which the friction jacket and the cone assembly are pushed together.

4) In step 2, the resistive force of the cone Qc, is obtained from a pressure gauge. The cone or point/tip resistance is obtained as qc = Qc/Ac (kg/cm^2) where Ac is base area (cm^2)

5) In step 3, the total resistive force is read from pressure gauge. This total resistive force (Q_t) is due to resistance of cone and the resistance due to friction jacket. Hence, the force required to push the jacket alone is Q_f = Qt - Qc (kg/cm^2)

6) Then, the outside mantle tube is pushed down to a distance a + b i.e., 80 mm depth. This brings the cone and the friction jacket to step 1.

7) Steps 1 to 6 are repeated for other depths until desired depth is reached.

Observations and calculations:

1. Site:

2. Location of test point:

3. Correction to be applied:

Correction factor = $(m+ nm_1)*10$ kg/cm^2

m = Mass of cone = 1.45 kg

m_1 = Mass of each sounding rod = 1.55 kg

n = Number of rods used during test

Static Cone Penetration Resistance

Sr.No	Depth below ground level (m)	Gauge reading (kN/m^2)	Corrected value of cone penetration resistance = gauge reading + correction factor (kN/m^2)
1	0.20		
2	0.40		
3	0.60		
4	0.80		
5	1.00		
6	1.20		
7	1.40		
8	1.60		
9	1.80		

Friction Resistance with the Help of Friction Jacket

1. Mass of friction jacket, m = 1.43 kg

2. Cone area at base, b = 10 cm^2

3. Surface area of friction jacket, a = πdh cm^2

where, d = outer diameter of friction jacket = 3.62 cm

h = Length of friction jacket = 10 + 2.5 cone length = 12.5 cm

Hence, a = πdh = 142.16 cm^2

4. Correction factor = m/a kg/cm^2 = 100 m/a kN/m^2

Friction Resistance

Sr.No	Depth below ground level (m)	Total resistance (kg/cm^2)	Uncorrected cone resistance (kg/cm^2)	Total resistance minus cone resistance (kN/m^2)	Frictional resistance (kg/cm^2) Z=(A-B)* (b/a)	Corrected Frictional resistance (kN/m^2) = (z + m/a) * 100
	A	B	A-B			
1	2.10					
2	2.20					
3	2.30					
4	2.40					
5	2.50					
6	2.60					
7	2.70					
8	2.80					

Result: Results are noted in the observation table.

Conclusion:

Quiz:

1. What are the precautions should be taken in static cone penetration test?

2. Write the application of static cone penetration test.

Suggested Reference:

- IS: 4968(Part-3) Method for subsurface sounding of soil. Static cone penetration test.
- Soil Mechanics and Foundation Engineering, Dr. K.R. Arora, Standard Publishers Distributors, New Delhi, Year 2010.
- Soil Mechanics and Foundation Engineering, S.K. Garg, Khanna Publishers, New Delhi, Year-2005
- Soil Mechanics and Foundation Engineering, P.0Purushothama Raj, Pearson India Education Services Pvt. Ltd., Noida, Year-2013
- Laboratory manual for soil testing, Dr. D.K.Maharaj, S.K.Kataria & sons, New Delhi, Year-2017

References used by the students:

Rubric wise marks obtained:

Rubrics	**1**	**2**	**3**	**4**	**5**	**Total**
Marks						

Experiment No: 4

In situ Permeability Test (Pumping out Test)

Date:

Relevant CO:

CO-1: Classify the soil, understand its behavior and will be able to compute/estimate index parameters.

CO-3: Compute earth pressure, stress distributions and FOS for slopes using various graphical and analytical tools for various engineering projects/site.

CO-4: Differentiate, compare, formulate and evaluate soil parameters through performing various tests as per site conditions or project needs ethically and professionally

Objectives: To determine permeability of each subsurface strata encountered up to bed rock and to ascertain overall permeability of strata.

Equipment/Instruments : Drilling or boring set, driving pipe, pumped water supply, delivery hose pipe, arrangement for measuring water level in the test hole, electric probe, miscellaneous equipment like stop watch, pressure gauge, graduated cylinders.

Theory: The field permeability tests carried out are either pumping in or pumping out type.

IS: 5529-Part 1(2013) specifies the methods as: Pumping in Tests (a) Constant head method (cased well, open end test); (b) Falling head method (uncased well); and (c) Slug method. Pumping out Tests (a) Unsteady state; (b) Steady state; and (c) Bailer method. When the stratum being tested is above water table, the pumping in test is carried out and when it is below water table then either pumping in or pumping out test may be conducted. For large engineering projects, it is the usual practice to measure the permeability of soil by pumping out test. Generally, these tests are carried out in boreholes where sub-surface exploration is carried out. These tests can be performed effectively up to a depth of 30 m. The pumping out test is a more general and accurate method for permeability determination below water table. There are basically two conditions, pump out test as unconfined flow (gravity well), or confined flow (artesian well) test. Of these methods, steady state method is the most suitable for all ground water problems.

Procedure:

1) For carrying out the test, the well should be first pumped up to the depth for which the overall permeability is to be determined.
2) The installation for pumping out test consists of fully or partially penetrating well and suitable number of piezometers arranged on 3 tiers preferably 120° to each other.

3) The pump should be run at a constant rate of discharge continuously till the pumped well attains equilibrium conditions in the piezometer surface.

4) This period varies from 10 hours to 100 hours depending upon the aquifer conditions, its thickness, permeability and slope.

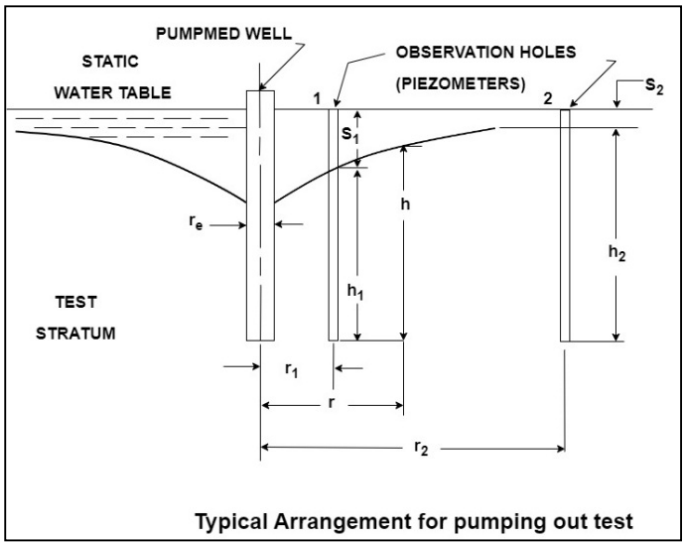
5) In the initial stages, say for the first 15 min, the observations may be taken at 30 s interval; for the next 30 min at 1 min interval; for the next 30 min at 2 min interval and for the next 2 h at 5 min interval.

6) After this it may be increased to hourly and then to 5 hourly and 10 hourly intervals till equilibrium conditions are achieved.

7) These intervals are only arbitrary and may be changed to suit the site conditions.

8) After completion of pumping out and shut down, observations for recovery should be also continued and the two sets of data, one during pumping out and the other during recovery, should be used for analysis.

9) The discharge of the well during observations should remain constant and is determined either by the V-notch or trajectory method.



Typical Arrangement for pumping out test

Observations:

Proforma for record of observations of pumping out test [IS 5529-Part 1 :2013(Clause 4.4)]

Date:

1) Test location:

2) Test hole No.:

a) Diameter of the well:

b) Level of water table:

c) Thickness of saturated strata below water table:

d) Penetration of the well:

e) Length of strainer the well:

f) Length of top blind pipe of the well:

g) Length of strata tested (RL to RL):

h) Ground level:

DRAWDOWN OBSERVATIONS

No.	Time	Line No.	Piezometer No. (As per plan) Well 1 2 3 4
1		1	
2		2	
3		3	

DISCHARGE OBSERVATIONS

By Trajectory Method

Sr. No.	X	Y	V	Amount of Seepage(m1/min)	Q_f (m1/min)
1					
2					
3					

Calculations: $\mathbf{k = 2.308 * q * \log_{10}(r_2/r_1) / \pi * (z_2^2 - z_1^2)}$

Conclusions:

Suggested Reference:

- IS: 5529(Part-1)-2013. In situ permeability tests.
- Soil Mechanics and Foundation Engineering, Dr. K.R. Arora, Standard Publishers Distributors, New Delhi, Year 2010.
- Soil Mechanics and Foundation Engineering, S.K. Garg, Khanna Publishers, New Delhi, Year-2005
- Soil Mechanics and Foundation Engineering, P. Purushothama Raj, Pearson India Education Services Pvt. Ltd., Noida, Year-2013
- Laboratory manual for soil testing, Dr. D.K. Maharaj, S.K. Kataria & sons, New Delhi, Year-2017

References used by the students:

Rubric wise marks obtained:

Rubrics	**1**	**2**	**3**	**4**	**5**	**Total**
Marks						

Experiment No: 5

Free swell index and swell potential

Date:

Relevant CO:

CO-1: Classify the soil, understand its behavior and will be able to compute/estimate index parameters.

CO-4: Differentiate, compare, formulate and evaluate soil parameters through performing various tests as per site conditions or project needs ethically and professionally.

Objectives: Primary investigation to determine the swelling potential of the soil

.

Equipment/Instruments: Graduated glass cylinders of 100 ml capacity, Sieve - 425 pm IS sieve

Theory:

- To identify the expansive nature of the soil.
- Expansive soils are one of the problematic soils found in arid and semi-arid regions.
- Black cotton soils found in India which covers almost 20% of the total area.
- Expansive soils have tendency to expand or swell (increase in volume) in presence of water and shrink (decrease in volume) in dry conditions. This results in excessive differential settlement due to repetitive cycles of swelling and shrinkage resulting in significant damage to the foundation and adjoining super structure.

Degree of expansiveness	FSI (%)
Low	Less Than 20
Moderate	20 to 35
High	35 to 50
Very high	Greater than 50

Procedure:

1) Take three specimen of 10 g of oven dried soil passing through 425-micron IS Sieve.

2) Pour each soil specimen into a graduated glass cylinders of 100 ml capacity.

3) One cylinder shall then be filled with kerosene oil and the other two cylinders with distilled water up to the 100 ml.

4) Remove entrapped air by stirring well with the glass rod. Allow the soils in all three cylinders to settle.

5) Sufficient time (not less than 24 h) shall be allowed for the soil sample to attain equilibrium state without any further change in the volume of the soils.

6) The final volume of soils in each of the cylinders shall be read out.

NOTE- In the case of highly swelling nature of soils, the sample size may be 5 g or alternatively a cylinder of 250 ml capacity may be used.

Observations:

1) Vd= Volume of soil specimen read from the graduated cylinder containing distilled water = -----

2) Vk = Volume of soil specimen read from the graduated cylinder containing kerosene = ----------

Calculation:

Free swell index (%) = ((Vd –Vk)/Vk) *100

where,

Vd= Volume of soil specimen read from the graduated cylinder containing distilled water

Vk = Volume of soil specimen read from the graduated cylinder containing kerosene

Result:

Conclusion:

Suggested Reference:

- IS : 2720 (Part XL) – 1977, Reaffirmed 1997
- Soil Mechanics and Foundation Engineering, Dr. K.R. Arora, Standard Publishers Distributors, New Delhi, Year 2010.
- Soil Mechanics and Foundation Engineering, S.K.Garg, Khanna Publishers, New Delhi, Year-2005
- Soil Mechanics and Foundation Engineering, P.Purushothama Raj, Pearson India Education Services Pvt. Ltd., Noida, Year-2013
- Laboratory manual for soil testing, Dr. D.K.Maharaj, S.K.Kataria & sons, New Delhi, Year-2017

References used by the students:

Rubric wise marks obtained:

Rubrics	**1**	**2**	**3**	**4**	**5**	**Total**
Marks						

Experiment No: 6

Swelling Pressure Test

Date:

Relevant CO:

CO-1: Classify the soil, understand its behavior and will be able to compute/estimate index parameters.

CO-4: Differentiate, compare, formulate and evaluate soil parameters through performing various tests as per site conditions or project needs ethically and professionally.

Objectives: Measurement of Swelling Pressure of Soils

Equipment/Instruments: Consolidometer, Dial Gauge, Water Reservoir, Moisture Room, Soil Trimming Tools, Oven, Desiccator, Balance, Containers, Moisture Content Cans, Loading Unit of 5000 kg Capacity (Strain controlled type), High Sensitive Proving Ring of 200 kg Capacity

Theory:

The expansive clays increase in their volume when they come in contact with water owing to surface properties of these clay types. The pressure which the expansive soil exerts, if it is not allowed to swell or the volume change of the soil is arrested, is known as Swelling Pressure of Soil. The swelling pressure is dependent upon several factors (a) the type and amount of clay in the soil and the nature of the clay mineral, (b) the initial water content and dry density, (c) nature of pore fluid, (d) the stress history of the soil including the confining pressure and (e) drying and wetting cycles to which the soils have been subjected to.

A soil with high swell pressure is considered “unsuitable” for use as embankment fill material and in case the sub-soil is having high swell pressure then suitable “ground improvement measures” may be needed before constructing embankment on such soil. One of the methods for constructing embankments on expansive soils is to lay a CNS (non-swelling clay) layer at the base of the embankment, to isolate the sub-soil from the moisture (mainly rain water) coming in vertically downwards direction. For any clay to be classified as “CNS (non-swelling clay)”, it should not have swell pressure more than the specified value (normally 0.5 kg/m^2).

In laboratory, one dimensional swelling pressure test is conducted using either fixed or the floating rings on both undisturbed and re-moulded soils in the partially saturated condition. Two methods are employed, namely, “Consolidometer method” in which the volume change of the soil is permitted and the corresponding pressure required to bring back the soil to its original volume is measured and “constant volume method” in which the volume change is prevented and the consequent pressure is measured.

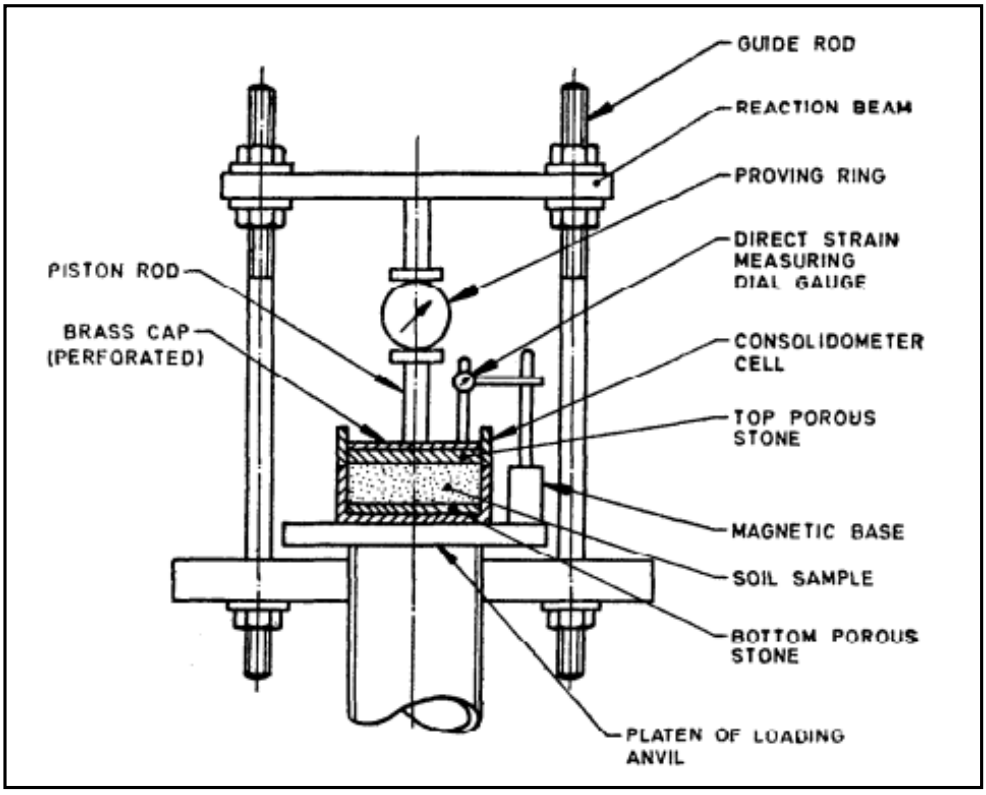


Fig. Set-Up for Measuring Swelling Pressure in Constant Volume Method

IS:2720 (Part XLI) - 1977

Procedure:

By Consolidometer Method:

1) Preparation of Specimen from Undisturbed Soil Samples: Clean and weigh the empty container. Cut-off the specimen either from undisturbed tube sample or from block sample, the latter generally being more representative of the field conditions. Remove about 30mm height from one end of the soil sample. Gradually insert the consolidation ring in the sample by pressing with hands and carefully removing the material around the ring. The soil specimen so cut shall project as far as 10mm on either side of the ring. Then trim the specimen smooth and flush with the top and bottom of the ring. Wipe the container ring clear of any soil sticking to the outside and weigh again with the soil. The whole process should be quick to ensure minimum loss of moisture and if possible, shall be carried out in the moisture room. The representative specimens from the soil trimming shall be taken in moisture content cans and their moisture content determined in accordance with IS:2720 (Part-XI).

2) Preparation of Specimen from Disturbed Soil Sample: The soil sample shall be compacted to the desired (field) density and water content in a standard compaction proctor mould.

Samples suitable sizes are cut from it as given in Para (i) above.

NOTE-1: Since swelling pressure of the soil is very much influenced by its initial water content and dry density, it shall be ensured that in the case of undisturbed soil samples, the specimen shall be collected from the field for test during the driest season of the year, so that the swelling pressure recorded shall be maximum. In case of remoulded soil sample, the initial water content shall be at the shrinkage limit or field water content, so that the swelling pressure recorded shall be maximum.

NOTE-2: The desiccated soil obtained from the field coupled with smaller thickness consolidation ring make the undisturbed soil specimen always in danger of being disturbed during trimming; hence great care shall be taken to handle the specimen delicately with the least pressure applied to the soil.

3) Saturate the porous stones by boiling in distilled water for at least 15 minutes and moisten at surfaces of the Consolidometer which are to be enclosed. Assemble the Consolidometer with the soil specimen (in the ring) and porous stones at top and bottom of the specimen, providing wet filter paper between the soil specimen and the porous stone. Then position the loading block centrally on the top porous stone.

4) Mount this assembly on the loading frame such that load applied is transmitted to the so specimen through the loading cap.

5) In the case of the lever loading system, the apparatus shall be properly counter-balanced. If jack with load measurements by platform scales is used as the loading systems the tare weight with the empty consolidation apparatus, excluding those parts which will be on top of the specimen, which rest on the platform shall be determined before filling the ring with the soil and this tare weight shall be added to the computed scale loads required to give the desire pressures at the time of loading the soil specimen.

6) Screw the holder with the dial gauge to record the progressive vertical heave of the specimen under no load.

7) Place initial setting load of 50 gf/cm2 (this includes weight of the porous stone and the loading pad) on the loading hanger and note initial reading of the dial gauge.

8) Connect the system to a water reservoir with the level of water in the reservoir being at about the same level as the soil specimen and allow water to flow in the sample. Then allow the soil to swell.

9) Record the free swell readings shown by the dial gauge under the seating load at different time intervals. The dial gauge readings shall be taken till equilibrium is reached. This is ensured by making a plot of swelling dial reading versus time in hours, which plot becomes asymptotic with abscissa (time scale). The equilibrium swelling is normally reached over a period of 6 to 7 day in general for all expansive soils.

10) Then subject the swollen sample to consolidation under different pressures. Record the compression dial readings till the dial readings attain a steady state for each load applied over the specimen. The consolidation loads shall be applied till the specimen attains its origin volume.

By Constant Volume Method:

1) Preparation of Specimen from Undisturbed Soil Samples as well as Preparation of Specimen from Disturbed Soil Sample: Same as for "Consolidometer Method".

2) Keep the consolidation specimen ring with the specimen between two porous stones saturated in boiling water providing a filter paper between the soil specimen and the porous stone. The loading block shall then be positioned centrally on the top of the porous stone.

3) Then place this assembly on the platen of the loading unit. The load measuring proving ring to be attached to the load frame shall be placed in contact with the consolidation cell without an eccentricity. A direct strain measuring dial gauge shall be fitted to the cell. Inundate the specimen with distilled water and allow it to swell.

4) Note down the initial reading of the proving ring. The swelling of the specimen with increasing volume shall be obtained in the strain measuring load gauge. To keep the specimen at constant volume, the platen shall be so adjusted that the dial gauge always shows the original reading. This adjustment shall be done at every 1 mm of swell or earlier. The duration of test shall conform to the requirements given in "Consolidometer method". Then dismantle the assembly and extract the soil specimen from the consolidation ring to determine final moisture content accordance with IS: 2720 (Part-IX).

Observations:

Table 1: Details of soil specimen (By Consolidometer Method/ Constant Volume Method)

Natural Density			**Moisture Content**		
Description	**Test- 1**	**Test-2**	**Description**	**Before Test**	**After Test**
Weight of container ring+ wet specimen			Weight of container + wet soil		
Weight of container			Weight of container + dry soil		
Diameter of container			Weight of container		
Initial thickness of soil sample			Weight of water		
Wet density in g/ml			Weight of dry soil		
Dry density in g/ml			Moisture content in %		

Table 2: Data Sheet for Swell - Compression Test (By Consolidometer Method)

Elapsed Time in Hours	**Swelling dial reading**	**Elapsed Time in Hours**	**Swelling dial reading**
0		36	
0.5		48	
1		60	
2		72	
4		96	
8		120	
12		144	
24			

Table 3: Data Sheet for Swell - Compression Test (By Consolidometer Method)

Pressure Increment (kgf/cm^2)	Pressure Increment (kN/m^2)	Compression	Change in Thickness of Expanded Specimen
0.0-0.05	0-5		
0.05-0.10	5-10		
0.10-0.25	10-25		
0.25-0.50	25-50		
0.50-1.00	50-100		
1.00-2.00	100-200		
2.00-4.00	200-400		
4.00-8.00	400-800		
8.00-16.00	800-1600		

Calculation:

By Consolidometer Method:

The observed swelling dial reading recorded in Table 1 shall be plotted with elapsed time as abscissa and swelling dial reading as ordinates on natural scale. A smooth curve shall be drawn joining these points. If the curve so drawn becomes asymptotic with the abscissa, the swelling has reached its maximum and swelling phase shall be stopped, and the consolidation phase shall be

started. The compression readings shall be tabulated as in Table 3 and a plot of change in thickness of expanded specimen as ordinates and consolidation pressure applied as abscissa in semi-logarithmic scale shall be made. The swelling pressure exerted by the soil specimen under zero swelling condition shall be obtained by interpolation and expressed in kN/m^2 (kgf/cm^2).

By Constant Volume Method:

The difference between the final and initial dial readings of the proving ring gives total load in terms of division which when multiplied by the calibration factor gives the total load. This when divided by the cross-sectional area of the soil specimen gives the swell pressure expressed in kN/m^2 (kgf/cm^2).

Table 4: Swell Pressure Data (By Constant Volume Method)

Date	Time	Strain Dial Gauge Reading Before Adjustment	Proving Ring Reading	Differences	Load in kg	Swell Pressure in kg/cm^2	Remarks

Result:

Conclusion:

Suggested Reference:

- IS 2720(Part 41):1977 Reaffirmed - December 2016.
- Soil Mechanics and Foundation Engineering, Dr. K.R. Arora, Standard Publishers Distributors, New Delhi, Year 2010.
- Soil Mechanics and Foundation Engineering, S.K. Garg, Khanna Publishers, New Delhi, Year-2005
- Soil Mechanics and Foundation Engineering, P. Purushothama Raj, Pearson India Education Services Pvt. Ltd., Noida, Year-2013
- Laboratory manual for soil testing, Dr. D.K. Maharaj, S.K. Kataria & sons, New Delhi, Year-2017

References used by the students: IS 2720 (Part 41):1977 Methods of test for soils: Measurement of swelling pressure of soils. Reaffirmed - December 2016.

Rubric wise marks obtained:

Rubrics	**1**	**2**	**3**	**4**	**5**	**Total**
Marks						

Experiment No: 7

Model Pile Load Test

Date:

Relevant CO:

CO-2: Interpret soil behavior due to compaction, consolidation, and analyze various theories and calculate parameters needed in design.

CO-4: Differentiate, compare, formulate and evaluate soil parameters through performing various tests as per site conditions or project needs ethically and professionally

Objectives: To determine the load bearing capacity of a single pile by static pile load test

Equipment/Instruments: Anchor piles, hydraulic jack, reaction girder, dial gauges

Theory: Pile load test is very expensive to perform but the most reliable method for determining the load carrying capacity of a pile. The purpose of such tests is to verify the load capacity in the constructed pile when soil or rock conditions vary considerably from one portion of a project to another. This test can be performed either on a working pile that forms the foundation of the structure or on a test pile. The test method involves the direct measurement of pile head displacement in response to a physically applied load. Generally the load application and deflection observation will be made at the pile top. The Maintained load method as described in Clause 6.2 of IS-2911 (Part IV) – 1985 shall be followed for loading test pile. 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.

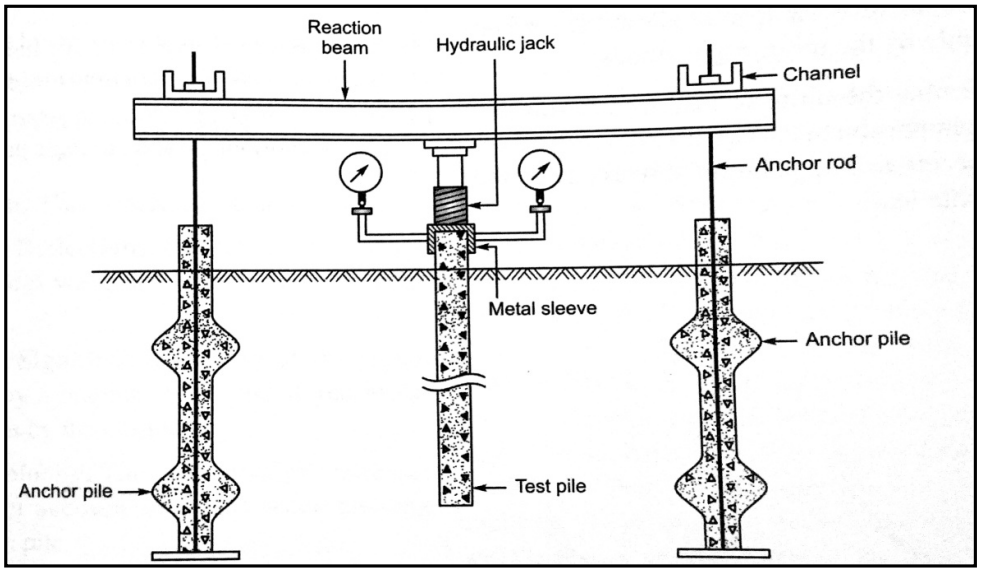


Fig.Static Pile Load Test Setup

Procedure:

1) The sets up for the load test on a pile consist of two anchor piles provided with an anchor girder or a reaction girder at their top.

2) The test pile is generally installed between two anchor piles in such a manner in which the foundation piles are to be installed.

3) The test pit should be at least 3B or 2.5 m clear from the anchor pile.

4) The load is applied through a hydraulic jack resting on the reaction girder. The measurements of the settlement of the pile are recorded with the help of three dial gauges, with respect to a fixed reference mark.

5) The load is generally applied in an equal amount of increment, that is about 20 % of the allowable load. Settlements should be recorded with three dial gauges.

6) 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. [IS: 2911 - (Part 4) 1985.]

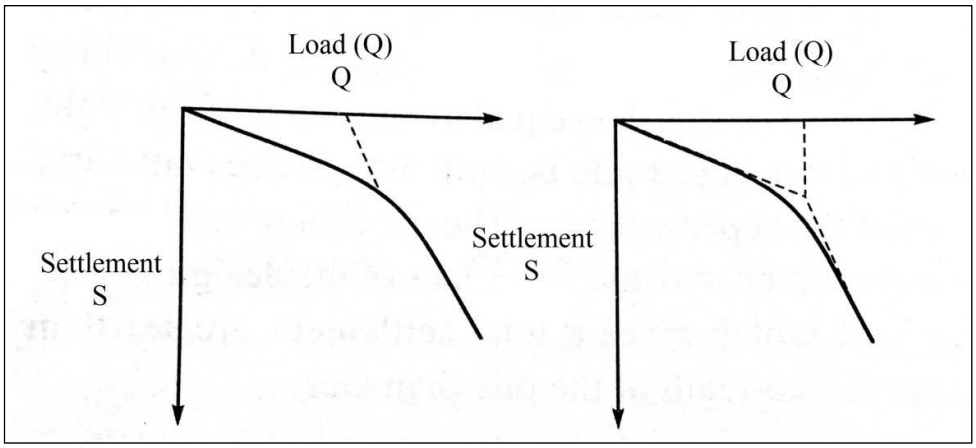
7) For each load increment, settlements are observed at 0.5, 1, 2, 4, 8, 12, 16, 20, 60 minutes. The loading should he continued up to twice the safe load or the load at which the total settlement reaches a specified value. Take the average of settlement readings of the three dial gauges. It gives the settlement o pile head.

8) The load is removed in the same decrements at 1 hour interval and the final rebound is recorded after 24 hours after the entire load has been removed.

9) The results are plotted in the form of load- settlement curve. The ultimate load is indicated by load settlement curve approaching vertical.

Observation table for load-settlement curve

Sr.No.	Load	Settlement Dial gauge 1	Settlement Dial gauge 2	Settlement Dial gauge 3	Average settlement
1					
2					
3					
4					
5					



Determination of ultimate load from load settlement curve

Observations: According to IS:2911, (Part 4) the safe load is taken as the minimum of following.

1) 50% of the ultimate load at which the total settlement becomes one-tenth of the pile diameter.

2) Two third of the final load at which total settlement attains a value of 12 mm.

3) Two third of the load which causes net plastic settlement of 6 mm.

Result:

Conclusion:

Quiz:

1.What are the working piles?

2.Can the pile load test be conducted on group of piles?

Suggested Reference:

- IS: 2911(Part-4) 1985 Code of practice for design and construction of pile foundation.
- **(**II) Soil Mechanics and Foundation Engineering, Dr. K.R. Arora, Standard Publishers Distributors, New Delhi, Year 2010.
- (III) Soil Mechanics and Foundation Engineering, S. K. Garg, Khanna Publishers, New Delhi, Year-2005.
- (IV) Soil Mechanics and Foundation Engineering, P. Purushothama Raj, Pearson India Education Services Pvt. Ltd., Noida, Year-2013.
- (V) Laboratory manual for soil testing, Dr. D. K. Maharaj, S. K. Kataria & sons, New Delhi, Year-2017

References used by the students:

Rubric wise marks obtained:

Rubrics	**1**	**2**	**3**	**4**	**5**	**Total**
Marks						

Experiment No: 8

Planning site investigation for a real-life problem

Date:

Relevant CO:

CO-1. Classify the soil, understand its behavior and will be able to compute/estimate index parameters.

CO-4. Differentiate, compare, formulate and evaluate soil parameters through performing various tests as per site conditions or project needs ethically and professionally

CO-5. Suggest suitable type of foundation as per soil type, estimate bearing capacity, Settlements and demonstrate its socio-economic feasibility

Objectives: (a) To plan out the visit preferably for Standard Penetration Test nearby area of institute.

(b) To understand and interpret the data collected during site investigation.

Equipment/Instruments: Standard Penetration Test apparatus

Theory: Site investigation is the process by which geological, geotechnical, and other relevant information which might affect the construction or performance of a civil engineering or building project is acquired. The aim of the site exploration is to get maximum information that is useful in the design and construction of the project at a minimum cost. The knowledge about the site forms a vital role in the safe and economical development of a site. A thorough investigation of the site is very essential for the construction of any civil engineering works. Public building officials may require soil data together with the recommendations of the geotechnical consultant prior to issuance of a building permit. Elimination of the site exploration, which usually ranges from about 0.5 to1 percent of total construction costs, inadequate investigation can lead to very large construction cost.

Planning the site investigation Programme: Planning of site investigation requires experience and engineering judgment. The planning of the site exploration program involves location and depth of borings, test pits or other methods to be used, and methods of sampling and tests to be carried out. The purpose of the exploration program is to determine, within practical limits, the stratification and engineering properties of the soils underlying the site. The principal properties of interest will be the strength, deformation, and hydraulic characteristics of subsurface. The program should be planned so that the maximum amount of information can be obtained at minimum cost. The investigation is therefore performed in the following phases like

1. Fact finding and geological survey:

2. Reconnaissance:

3. Preliminary exploration:

4. Detailed exploration:

Result: Based on site investigation field visit, prepare the detailed site investigation report (minimum 1500 words) as per actual field observation

Conclusion:

Suggested Reference:

- IS: 2131- 1981 Methods for standard penetration test for soils
- Soil Mechanics and Foundation Engineering, Dr. K.R. Arora, Standard Publishers Distributors, New Delhi, Year 2010.
- Soil Mechanics and Foundation Engineering, S.K. Garg, Khanna Publishers, New Delhi, Year-2005.
- Soil Mechanics and Foundation Engineering, P. Purushothama Raj, Pearson India Education Services Pvt. Ltd., Noida, Year-2013.
- Laboratory manual for soil testing, Dr. D.K. Maharaj, S.K. Kataria & sons, New Delhi, Year- 2017

References used by the students:

Rubric wise marks obtained:

Rubrics	**1**	**2**	**3**	**4**	**5**	**Total**
Marks						