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**FOUNDATION ENGG.
LAB MANUAL**

LIST OF EXPERIMENTS

1. Grain test size analysis of soils by hydrometer analysis.
2. Determine the shrinkage limit and calculate the shrinkage ratio for the given soil.
3. Find the shear strength of the soil by Undrained Triaxial Test.
4. Determine the settlements due to primary consolidation of soil by conducting one dimensional test.
5. Determine the bearing capacity of soil by Plate load test.
6. Determine the penetration value of given soil by the standard penetration test.
7. Undisturbed sampling.
8. Determine the relative density of given coarse grained material.
9. Determine the soil strength by the dynamic cone penetration test.
10. Find the shear strength of the soil by drained Triaxial Test.

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EXPERIMENT NO:- 1

AIM:-

Grain size analysis of soils by hydrometer analysis test

OBJECTIVE:-

This test is performed to determine the percentage of different grain sizes contained within a soil. The hydrometer method is used to determine the distribution of the finer particles.

EQUIPMENT:

Balance, Set of sieves, Cleaning brush, Sieve shaker, Mixer (blender), Hydrometer, Sedimentation cylinder, Control cylinder, Thermometer, Beaker, Timing device.

PROCEDURE:

1. Take the fine soil and place it into a beaker, and add 125 mL of the dispersing agent (sodium hexametaphosphate (40 g/L)) solution. Stir the mixture until the soil is thoroughly wet. Let the soil soak for at least ten minutes.
2. While the soil is soaking, add 125mL of dispersing agent into the control cylinder and fill it with distilled water to the mark. Take the reading at the top of the meniscus formed by the hydrometer stem and the control solution. A reading less than zero is recorded as a negative (-) correction and a reading between zero and sixty is recorded as a positive (+) correction. This reading is called the zero correction. The meniscus correction is the difference between the top of the meniscus and the level of the solution in the control jar (Usually about +1). Shake the control cylinder in such a way that the contents are mixed thoroughly. Insert the hydrometer and thermometer into the control cylinder and note the zero correction and temperature respectively.
3. Transfer the soil slurry into a mixer by adding more distilled water, if necessary, until mixing cup is at least half full. Then mix the solution for a period of two minutes.
4. Immediately transfer the soil slurry into the empty sedimentation cylinder. Add distilled water up to the mark.
5. Cover the open end of the cylinder with a stopper and secure it with the palm of your hand. Then turn the cylinder upside down and back upright for a period of one minute. (The cylinder should be inverted approximately 30 times during the minute.)
6. Set the cylinder down and record the time. Remove the stopper from the cylinder. After an elapsed time of one minute and forty seconds, very slowly and carefully insert the hydrometer for the first reading. (Note: It should take about ten seconds to insert or remove the hydrometer to minimize any disturbance, and the release of the hydrometer should be made as close to the

reading depth as possible to avoid excessive bobbing).

7. The reading is taken by observing the top of the meniscus formed by the suspension and the hydrometer stem. The hydrometer is removed slowly and placed back into the control cylinder. Very gently spin it in control cylinder to remove any particles that may have adhered.
8. Take hydrometer readings after elapsed time of 2 and 5, 8, 15, 30, 60 minutes and 24 hours

CALCULATION:

1. Apply meniscus correction to the actual hydrometer reading.
2. From Table 1, obtain the effective hydrometer depth L in cm (for meniscus corrected reading).
3. For known G_s of the soil (if not known, assume 2.65 for this lab purpose), obtain the value of K from Table 2.
4. Calculate the equivalent particle diameter by using the following formula:

$$D = K \sqrt[4]{t}$$

Where t is in minutes, and D is given in mm.

5. Determine the temperature correction CT from Table 3.
6. Determine correction factor " a " from Table 4 using G_s .
7. Calculate corrected hydrometer reading as follows: $R_c = R_{ACTUAL} - \text{zero correction} + CT$
8. Calculate percent finer as follows:

$$P = \frac{R_c \times a}{W_s} \times 100$$

Where W_s is the weight of the soil sample in grams.

9. Plot the grain size curve D versus the percent finer on the semi-logarithmic sheet.

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Table 1. Values of Effective Depth Based on Hydrometer and Sedimentation Cylinder of Specific Sizes

Hydrometer 151H		Hydrometer 152H			
Actual Hydrometer Reading	Effective Depth, L (cm)	Actual Hydrometer Reading	Effective Depth, L (cm)	Actual Hydrometer Reading	Effective Depth, L (cm)
1.000	16.3	0	16.3	31	11.2
1.001	16.0	1	16.1	32	11.1
1.002	15.8	2	16.0	33	10.9
1.003	15.5	3	15.8	34	10.7
1.004	15.2	4	15.6	35	10.6
1.005	15.0	5	15.5	36	10.4
1.006	14.7	6	15.3	37	10.2
1.007	14.4	7	15.2	38	10.1
1.008	14.2	8	15.0	39	9.9
1.009	13.9	9	14.8	40	9.7
1.010	13.7	10	14.7	41	9.6
1.011	13.4	11	14.5	42	9.4
1.012	13.1	12	14.3	43	9.2
1.013	12.9	13	14.2	44	9.1
1.014	12.6	14	14.0	45	8.9
1.015	12.3	15	13.8	46	8.8
1.016	12.1	16	13.7	47	8.6
1.017	11.8	17	13.5	48	8.4
1.018	11.5	18	13.3	49	8.3
1.019	11.3	19	13.2	50	8.1
1.020	11.0	20	13.0	51	7.9
1.021	10.7	21	12.9	52	7.8
1.022	10.5	22	12.7	53	7.6
1.023	10.2	23	12.5	54	7.4
1.024	10.0	24	12.4	55	7.3
1.025	9.7	25	12.2	56	7.1
1.026	9.4	26	12.0	57	7.0
1.027	9.2	27	11.9	58	6.8
1.028	8.9	28	11.7	59	6.6
1.029	8.6	29	11.5	60	6.5
1.030	8.4	30	11.4		
1.031	8.1				
1.032	7.8				
1.033	7.6				
1.034	7.3				
1.035	7.0				
1.036	6.8				
1.037	6.5				
1.038	6.2				
1.039	5.9				

Table 2. Values of **k** for Use in Equation for Computing Diameter of Particle in Hydrometer Analysis

Temperature °C	Specific Gravity of Soil Particles								
	2.45	2.50	2.55	2.60	2.65	2.70	2.75	2.80	2.85
16	0.01510	0.01505	0.01481	0.01457	0.01435	0.01414	0.0394	0.01374	0.01356
17	0.01511	0.01486	0.01462	0.01439	0.01417	0.01396	0.01376	0.01356	0.01338
18	0.01492	0.01467	0.01443	0.01421	0.01399	0.01378	0.01359	0.01339	0.01321
19	0.01474	0.01449	0.01425	0.01403	0.01382	0.01361	0.01342	0.01323	0.01305
20	0.01456	0.01431	0.01408	0.01386	0.01365	0.01344	0.01325	0.01307	0.01289
21	0.01438	0.01414	0.01391	0.01369	0.01348	0.01328	0.01309	0.01291	0.01273
22	0.01421	0.01397	0.01374	0.01353	0.01332	0.01312	0.01294	0.01276	0.01258
23	0.01404	0.01381	0.01358	0.01337	0.01317	0.01297	0.01279	0.01261	0.01243
24	0.01388	0.01365	0.01342	0.01321	0.01301	0.01282	0.01264	0.01246	0.01229
25	0.01372	0.01349	0.01327	0.01306	0.01286	0.01267	0.01249	0.01232	0.01215
26	0.01357	0.01334	0.01312	0.01291	0.01272	0.01253	0.01235	0.01218	0.01201
27	0.01342	0.01319	0.01297	0.01277	0.01258	0.01239	0.01221	0.01204	0.01188
28	0.01327	0.01304	0.01283	0.01264	0.01244	0.01225	0.01208	0.01191	0.01175
29	0.01312	0.01290	0.01269	0.01269	0.01230	0.01212	0.01195	0.01178	0.01162
30	0.01298	0.01276	0.01256	0.01236	0.01217	0.01199	0.01182	0.01165	0.01149

Table 3. Correction factor for **a** for unit weights of solids

Unit Weight of Soil Solids, g/cm ³	Correction factor a
2.85	0.96
2.80	0.97
2.75	0.98
2.70	0.99
2.65	1.00
2.60	1.01
2.55	1.02
2.50	1.04

Table 4. Temperature Correction for C_T

Temperature °C	factor C_T
15	1.10
16	-0.90
17	-0.70
18	-0.50
19	-0.30
20	0.00
21	+0.20
22	+0.40
23	+0.70
24	+1.00
25	+1.30
26	+1.65
27	+2.00
28	+2.50
29	+3.05
30	+3.80

OBSERVATION TABLE:

Hydrometer Number (if known): _____

Specific Gravity of Solids: _____

Dispersing Agent: _____

Weight of Soil Sample: _____ gm

Zero Correction: _____

Meniscus Correction: _____

Elapsed Time(min)	Temp °C	Actual Hydro. Rdg. R_a	Hyd. Corr. For Meniscus	L from Table 1	K from Table 2	D in mm	C_T from Table 3	a from Table 4	Corr. Hydr. Rdg. R_c	% Finer P

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EXPERIMENT NO:- 2

OBJECTIVE:-

To determine the shrinkage limit and calculate the shrinkage ratio for the given soil

THEORY:-

As the soil loses moisture, either in its natural environment, or by artificial means in laboratory it changes from liquid state to plastic state, from plastic state to semi-solid state and then to solid state. Volume changes also occur with changes in water content. But there is a particular limit at which any moisture change does not cause soil any volume change. Soils which undergo large volume changes with change in water content may be troublesome. Volume changes may not be equal.

A shrinkage limit test should be performed on a soil.

1. To obtain a quantitative indication of how much change in moisture can occur before any appreciable volume change occurs
2. To obtain an indication of change in volume.

The shrinkage limit is useful in areas where soils undergo large volume changes when going through wet and dry cycles (as in case of earth dams)

APPARATUS:-

1. Evaporating Dish. Porcelain, about 12cm diameter with flat bottom.
2. Spatula
3. Shrinkage Dish. Circular, porcelain or non-corroding metal dish (3 nos) having a flat bottom and 45 mm in diameter and 15 mm in height internally.
4. Straight Edge. Steel, 15 cm in length.
5. Glass cup. 50 to 55 mm in diameter and 25 mm in height, the top rim of which is ground smooth and level.
6. Glass plates. Two, each 75 and 75 mm one plate shall be of plain glass and the other shall have prongs.
7. Sieves. 2mm and 425- micron IS sieves.
8. Oven-thermostatically controlled.
9. Graduate-Glass, having a capacity of 25 ml and graduated to 0.2 ml and 100 cc one mark flask.
10. Balance-Sensitive to 0.01 g minimum.
11. Mercury. Clean, sufficient to fill the glass cup to overflowing.
12. Wash bottle containing distilled water.

PROCEDURE:-

Preparation of soil paste:-

1. Take about 100 gm of soil sample from a thoroughly mixed portion of the material passing through 425- micron I.S. sieve.
2. Place about 30 gm the above soil sample in the evaporating dish and thoroughly mixed with distilled water and make a creamy paste.
Use water content around the liquid limit.

Filling the shrinkage dish:-

3. Coat the inside of the shrinkage dish with a thin layer of Vaseline to prevent the soil sticking to the dish.
4. Fill the dish in three layers by placing approximately 1/3 rd of the amount of wet soil with the help of spatula. Tap the dish gently on a firm base until the soil flows over the edges and no apparent air bubbles exist. Repeat this process for 2nd and 3rd layers also till the dish is completely filled with the wet soil. Strike off the excess soil and make the top of the dish smooth. Wipe off all the soil adhering to the outside of the dish.
5. Weigh immediately, the dish with wet soil and record the weight.
6. Air-dry the wet soil cake for 6 to 8hrs, until the colour of the pat turns from dark to light. Then oven-dry them to constant weight at 105⁰C to 110⁰C say about 12 to 16 hrs.
7. Remove the dried disk of the soil from oven. Cool it in a desiccator. Then obtain the weight of the dish with dry sample.
8. Determine the weight of the empty dish and record.
9. Determine the volume of shrinkage dish which is evidently equal to volume of the wet soil as follows. Place the shrinkage dish in an evaporating dish and fill the dish with mercury till it overflows slightly. Press it with plain glass plate firmly on its top to remove excess mercury. Pour the mercury from the shrinkage dish into a measuring jar and find the volume of the shrinkage dish directly. Record this volume as the volume of the wet soil pat.

Volume of the Dry Soil Pat:-

10. Determine the volume of dry soil pat by removing the pat from the shrinkage dish and immersing it in the glass cup full of mercury in the following manner.

Place the glass cup in a larger one and fill the glass cup to overflowing with mercury. Remove the excess mercury by covering the cup with glass plate with prongs and pressing it. See that no air bubbles are entrapped. Wipe out the outside of the glass cup to remove the adhering mercury. Then, place it in another larger dish, which is, clean and empty carefully.

Place the dry soil pat on the mercury. It floats submerge it with the pronged glass plate which is again made flush with top of the cup. The mercury spills over into the larger plate. Pour the mercury that is displaced by the soil pat into the measuring jar and find the volume of the soil pat directly.

CALCULATION:-

Determine the moisture content

$$\text{Shrinkage limit (WS)} = (W - (V - V_0) \times \gamma_w / W_0) \times 100$$

Where,

W = Moisture Content of wet soil paste (%) V =

Volume of wet soil paste in cm^3

V_0 = Volume of dry soil paste in cm^3 W_0 =

Weight of oven dry soil in gm

TABULATION AND RESULTS:-

Determination No.	1	2	3
Wt. of container in gm, W_1			
Wt. of container + wet soil pat in gm, W_2			
Wt. of container + dry soil pat in gm, W_3			
Wt. of oven dry soil pat, W_0 in gm			
Wt. of water in gm			
Moisture content (%), W			
Volume of wet soil pat (V), in cm^3			
Volume of dry soil pat (V_0) in cm^3			
By mercury displacement method			
a. Weight of displaced mercury			
b. Specific gravity of the mercury			
Shrinkage limit (Ws)			
Shrinkage ratio (R)			

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EXPERIMENT NO:- 3

OBJECTIVE:-

To find the shear strength of the soil by Undrained Triaxial Test

NEED AND SCOPE OF THE TEST:-

The standard consolidated undrained test is compression test, in which the soil specimen is first consolidated under all round pressure in the triaxial cell before failure is brought about by increasing the major principal stress.

It may be performed with or without measurement of pore pressure although for most applications the measurement of pore pressure is desirable.

APPARATUS :-

- a) 3.8 cm (1.5 inch) internal diameter 12.5 cm (5 inches) long sample tubes.
- b) Rubber ring.
- c) An open ended cylindrical section former, 3.8 cm inside dia, fitted with a small rubber tube in its side.
- d) Stop clock.
- e) Moisture content test apparatus.
- f) A balance of 250 gm capacity and accurate to 0.01 gm.

PROCEDURE:-

1. The sample is placed in the compression machine and a pressure plate is placed on the top. Care must be taken to prevent any part of the machine or cell from joggling the sample while it is being setup, for example, by knocking against the bottom of the loading piston. The probable strength of the sample is estimated and a suitable proving ring selected and fitted to the machine.
2. The cell must be properly set up and uniformly clamped down to prevent leakage of pressure during the test, making sure first that the sample is properly sealed with its end caps and rings (rubber) in position and that the sealing rings for the cell are also correctly placed.
3. When the sample is setup water is admitted and the cell is fitted under water escapes from the bleed valve, at the top, which is closed. If the sample is to be tested at zero lateral pressure water is not required.
4. The air pressure in the reservoir is then increased to raise the hydrostatic pressure in the required amount. The pressure gauge must be watched during the test and any necessary adjustments must be made to keep the pressure constant.

- The handle wheel of the screw jack is rotated until the under side of the hemispherical seating of the proving ring, through which the loading is applied, just touches the cell piston.
- The piston is then removed down by handle until it is just in touch with the pressure plate on the top of the sample, and the proving ring seating is again brought into contact for the beginning of the test.

OBSERVATION AND RECORDING:-

The machine is set in motion (or if hand operated the hand wheel is turned at a constant rate) to give a rate of strain 2% per minute. The strain dial gauge reading is then taken and the corresponding proving ring reading is taken the corresponding proving ring chart. The load applied is known. The experiment is stopped at the strain dial gauge reading for 15% length of the sample or 15% strain.

Size of specimen:

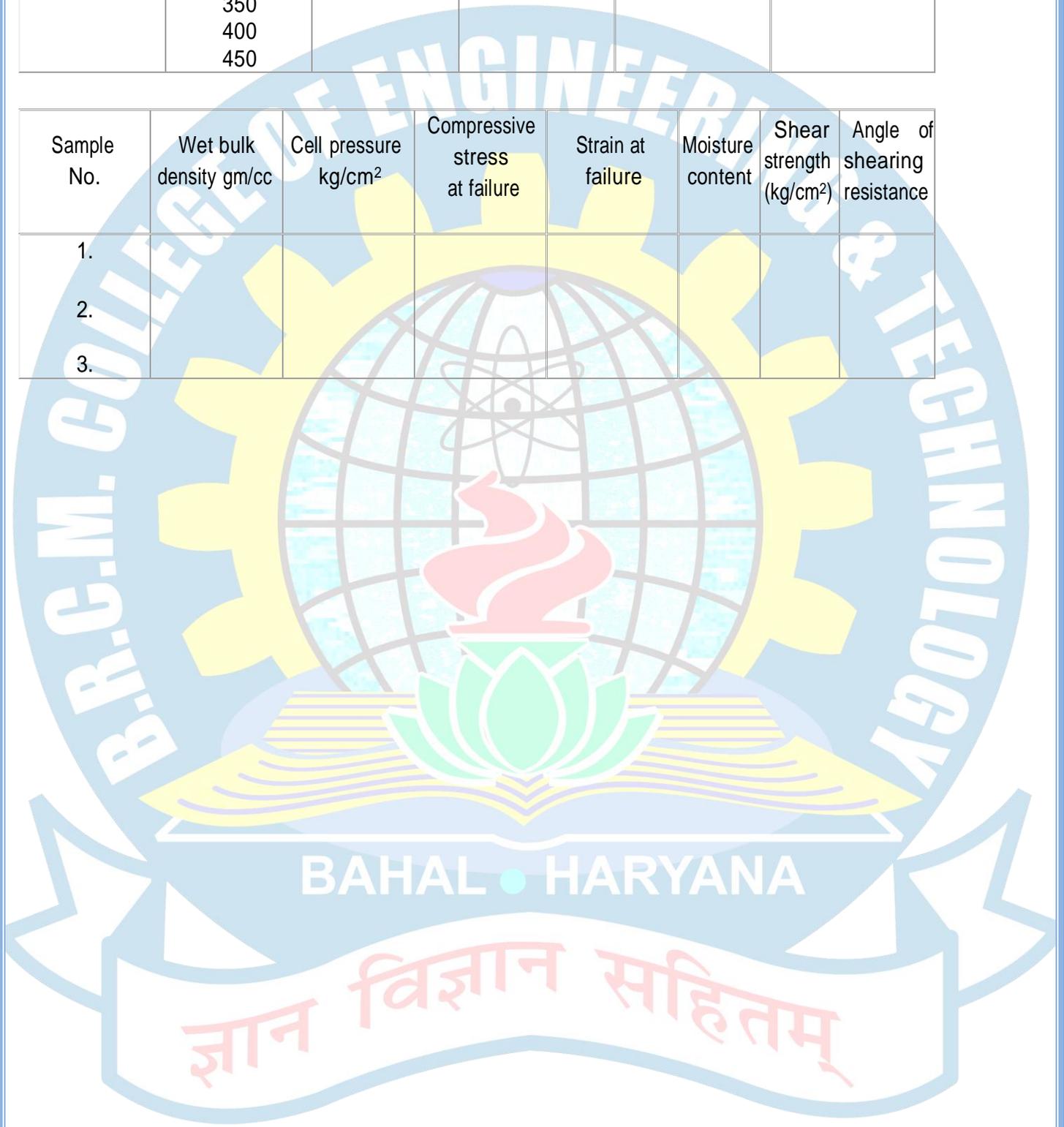
Length : Proving ring constant : Diameter : Initial area L:

Initial Volume : Strain dial least count (const) :

Cell pressure kg/cm ² 1	Strain dial ²	Proving ring reading 3	Load on sample kg 4	Corrected area cm ² 5	Deviator stress 6
0.5	0				
	50				
	100				
	150				
	200				
	250				
	300				
	350				
	400				
	450				
0.5	0				
	50				
	100				
	150				
	200				
	250				
	300				
	350				
	400				
	450				
0.5	0				
	50				
	100				

	150				
	200				
	250				
	300				
	350				
	400				
	450				

Sample No.	Wet bulk density gm/cc	Cell pressure kg/cm ²	Compressive stress at failure	Strain at failure	Moisture content	Shear strength (kg/cm ²)	Angle of shearing resistance
1.							
2.							
3.							



EXPEIMENT NO:- 4

OBJECTIVE:-

To determine the settlements due to primary consolidation of soil by conducting one dimensional test

NEED AND SCOPE:-

The test is conducted to determine the settlement due to primary consolidation.

To determine :

- i. Rate of consolidation under normal load.
- ii. Degree of consolidation at any time.
- iii. Pressure-void ratio relationship.
- iv. Coefficient of consolidation at various pressures.
- v. Compression index.

From the above information it will be possible for us to predict the time rate and extent of settlement of structures founded on fine-grained soils. It is also helpful in analyzing the stress history of soil. Since the settlement analysis of the foundation depends mainly on the values determined by the test, this test is very important for foundation design.

PROCEDURE:-

1. Saturate two porous stones either by boiling in distilled water about 15 minute or by keeping them submerged in the distilled water for 4 to 8 hrs. Wipe away excess water. Fittings of the consolidometer which is to be enclosed shall be moistened.
2. Assemble the consolidometer, with the soil specimen and porous stones at top and bottom of specimen, providing a filter paper between the soil specimen and porous stone. Position the pressure pad centrally on the top porous stone.
3. Mount the mould assembly on the loading frame, and center it such that the load applied is axial.
4. Position the dial gauge to measure the vertical compression of the specimen. The dial gauge holder should be set so that the dial gauge is in the begging of its releases run, allowing sufficientmargin for the swelling of the soil, if any.
5. Connect the mould assembly to the water reservoir and the sample is allowed to saturate. The level of the water in the reservoir should be at about the same level as the soil specimen.
6. Apply an initial load to the assembly. The magnitude of this load should be chosen by trial, such that there is no swelling. It should be not less than 50 g/cm^3 for ordinary soils & 25 g/cm^2 for verysoft soils. The load should be allowed to stand until there is no change in dial gauge readings fortwo consecutive hours or for a maximum of 24 hours.
7. Note the final dial reading under the initial load. Apply first load of intensity 0.1 kg/cm^2 start the stop watch simultaneously. Record the dial gauge readings at various time intervals. The dial gauge readings are taken until 90% consolidation is reached. Primary consolidation is gradually reached within 24 hrs.

8. At the end of the period, specified above take the dial reading and time reading. Double the load intensity and take the dial readings at various time intervals. Repeat this procedure for successive load increments. The usual loading intensity are as follows :
0.1, 0.2, 0.5, 1, 2, 4 and 8 kg/cm².
9. After the last loading is completed, reduce the load to of the value of the last load and allow it to stand for 24 hrs. Reduce the load further in steps of the previous intensity till an intensity of 0.1 kg/cm² is reached. Take the final reading of the dial gauge.
10. Reduce the load to the initial load, keep it for 24 hrs and note the final readings of the dial gauge.
11. Quickly dismantle the specimen assembly and remove the excess water on the soil specimen inoven, note the dry weight of it.

OBSERVATION AND READING:-

Table 1

Data and observation sheet for consolidation test pressure, compression and time. Depth of the sample : 2m

Empty weight of ring : 635 gm

Diameter of ring : 76.2 mm (7.62 cm)

Height of ring : 25.4 (2.54 cm)

No: Dial Gauge = 0.0127 mm (least count)

Description of soil :

Area of ring : 4560 mm² (45.60 cm²)

Volume of ring : 115.82 cm³

Specific gravity of soil sample

Pressure Intensity (Kg/cm ²)	0.1	0.2	0.5	1	2	4	8
Elapsed Time							
0.25							
1							
2.5							
4							
6.25							
9							
16							
25							
30							
1 hr							
2 hrs							
4 hrs							
8 hrs							
24 hrs							

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Observation Sheet for Consolidation Test : Pressure Voids Ratio

Applied pressure	Final dial reading	Dial change	Specimen height	Height solids	Height of voids	Void ratio
0						
0.1						
0.2						
0.5						
1.0						
2.0						
4.0						
8.0						
4.0						
2.0						
1.0						
0.5						
0.2						
0.1						

CALCULATIONS:-

1. **Height of solids (HS)** is calculated from the equation $HS = WS/G \times A$

2. **Void ratio.** Voids ratio at the end of various pressures are calculated from equation $e = (H \times HS)/HS$

3. **Coefficient of consolidation.** The Coefficient of consolidation at each pressures

$$C_v = 0.197 d^2/t_{50} \text{ (Log fitting method)}$$

$$C_v = 0.848 d^2/t_{90} \text{ (Square fitting method)}$$

In the log fitting method, a plot is made between dial reading and logarithmic of time, the time corresponding to 50% consolidation is determined. In the square root fitting method, a plot is made between dial readings and square root of time and the time corresponding to 90% consolidation is determined. The values of C_v are recorded in table .

4. **Compression Index.** To determine the compression index, a plot of voids ratio (e) Vs $\log t$ is made. The initial compression curve would be a straight line and the slope of this line would give the compression index C_c .

5. **Coefficient of compressibility.** It is calculated as follows

$$a_v = 0.435 C_c / \text{Avg. pressure for the increment}$$

where C_c = Coefficient of compressibility

6. **Coefficient of permeability.** It is calculated as follows $K = C_v \cdot a_v \cdot (\text{unit weight of water}) / (1+e)$.

EXPERIMENT NO:- 5

OBJECTIVE:- To determine the bearing capacity of soil by Plate load test.

THEORY:

Plate Load Test is a field test for determining the ultimate bearing capacity of soil and the likely settlement under a given load. The Plate Load Test basically consists of loading a steel plate placed at the foundation level and recording the settlements corresponding to each load increment. The test load is gradually increased till the plate starts to sink at a rapid rate. The total value of load on the plate in such a stage divided by the area of the steel plate gives the value of the ultimate bearing capacity of soil. The ultimate bearing capacity of soil is divided by suitable factor of safety (which varies from 2 to 3) to arrive at the value of safe bearing capacity of soil.

Test Setup:

A test pit is dug at site up to the depth at which the foundation is proposed to be laid. The width of the pit should be at least 5 times the width of the test plate. At the centre of the pit a small square depression or hole is made whose size is equal to the size of the test plate and bottom level of which corresponds to the level of actual foundation. The depth of the hole should be such that the ratio of depth to width of the loaded area is approximately the same as the ratio of the actual depth to width of the foundation. The mild steel plate (also known as bearing plate) used in the test should not be less than 25 mm in thickness and its size may vary from 300 to 750 mm. The plate could be square or circular in shape. Circular plate is adopted in case of circular footing and square plate is used in all other types of footings. The plate is machined on side and edges.

Testing Procedure:

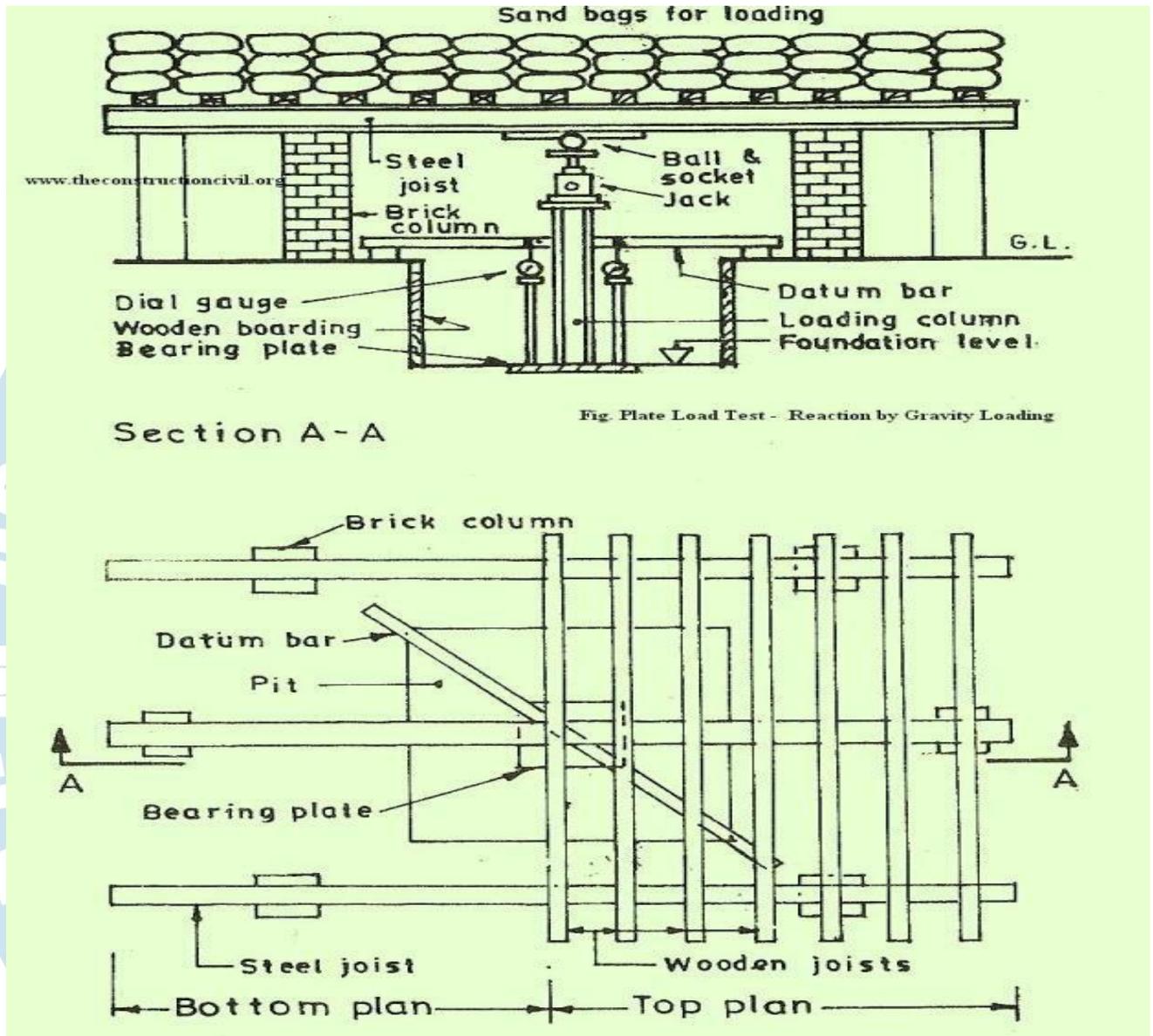
The load is applied to the test plate through a centrally placed column. The test load is transmitted to the column by one of the following two methods :

- (i) By gravity loading or reaction loading method
- (ii) By Reaction Truss Method.

(i) Gravity loading or reaction loading method:

In case of gravity loading method, a loading platform is constructed over the column placed on the test plate and test load is applied by placing dead weight in the form of sand bags, pig iron, concrete blocks, lead bars etc. on the platform. Many times a hydraulic jack is placed between the loading platform and the column top for applying the load to the test plate - the

reaction of the hydraulic jack being borne by the loaded platform. This form of loading is termed as reaction loading.



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Plate load Test Method - Reaction by gravity loading

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Reaction Truss Method:-

In case of reaction truss method, instead of constructing a loading platform, a steel truss of suitable size is provided to bear the reaction of the hydraulic jack. The truss is firmly anchored to the ground by means of steel anchors and guy ropes are provided for ensuring its lateral stability. When the load is applied to the test plate, it starts sinking slowly. The settlement of the plate is recorded to an accuracy of 0.02 mm with the help of sensitive dial gauges. At least two dial gauges are used to account for differential settlement. The dial gauges are placed at diametrically opposite ends of the plate and one dial gauge is mounted on independently supported references beam or datum rod. As the plate sinks, the ram of the dial gauge moves down and the settlement is recorded. The magnitude of load is indicated on the load-gauge of the hydraulic jack. The load is applied in regular increment of about 2KN or 1/5th of the expected ultimate bearing capacity, whichever is less. Settlement should be observed for each increment of load after an interval of 1, 4, 10, 20, 40 and 60 minutes and thereafter at hourly intervals until the rate of settlement becomes less than 0.02 mm per hour. The maximum load to be applied for the test should be about 15 times the expected ultimate bearing capacity of the soil. In case of clayey soils the, time settlement curve should be plotted at each load stage and load should be increased to next stage either when the curve indicates that the settlement has exceeded 70 to 80% of the probable ultimate settlement at that stage or at the end of 24 hour period.

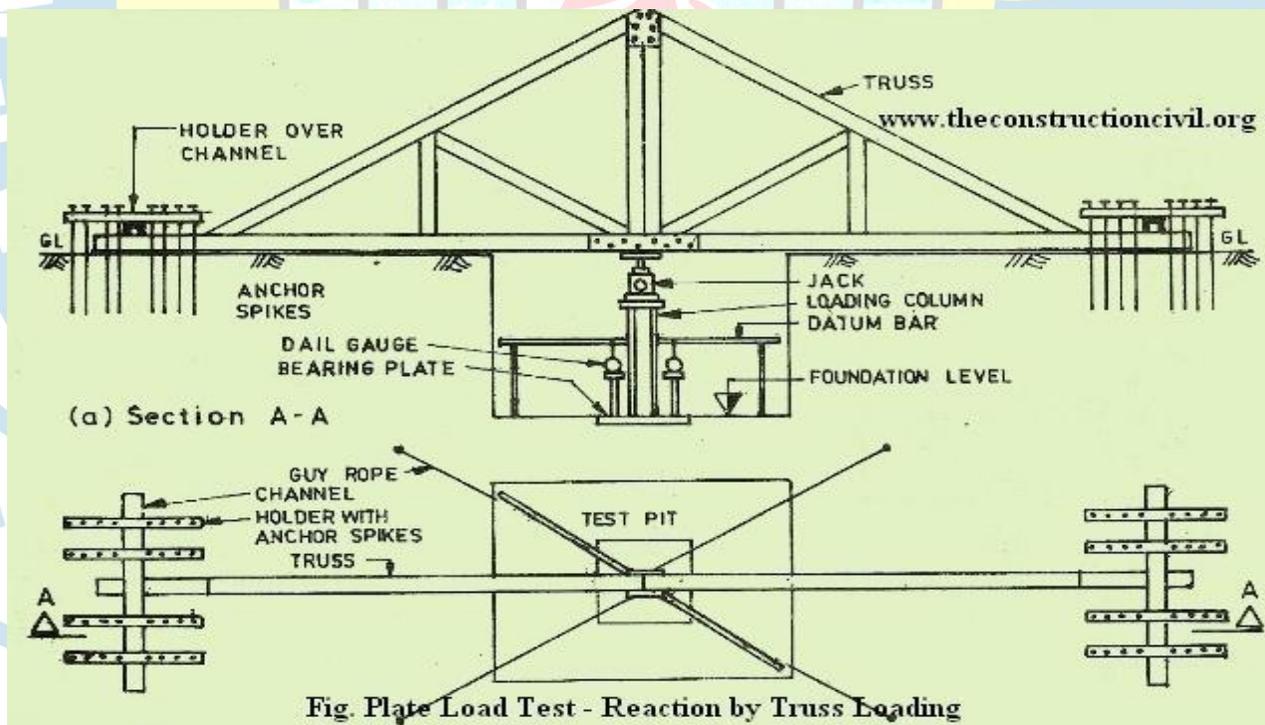


Plate Load Test – Reaction by Truss Loading

For soils other than clayey soils, each load increment should be kept for not less than one hour or upto a time when the rate of settlement gets appreciably reduced (to a value of 0.02 mm per mm.). The next increment of load should then be applied and observations repeated. The test is continued till a settlement of 25 mm under normal circumstances or 50 mm in special cases (such as dense gravel, and sand mixture) is obtained or till failure occurs, whichever is earlier.

Interpretation of Results:

The load intensity and settlement observations of the plate load test are plotted in the form of load settlement curves.

The figure below shows four typical curves applied to different soils. **Curve I** is typical for loose to medium non-cohesive soils. It can be seen that initially this curve is a straight line, but as the load increases it flattens out. There is no clear point of shear failure. **Curve II** is typical for cohesive soils. This *may* not be quite straight in the initial stages and leans towards settlement axis as the settlement increases. **Curve III** is typical for partially cohesive soils. **Curve IV** is typical for purely dense non-cohesive soil. The safe bearing capacity is obtained by dividing the ultimate bearing capacity by a factor of safety varying from 2 to 3. The value of safe bearing capacity thus arrived at, is considered to be based on criterion of *shear failure*. Safe bearing capacity (SBC) based on permissible settlement. As indicated earlier the settlement of footing is also related to the SBC of the soil. The value of ultimate bearing capacity and hence the SBC in this case, can be obtained from the load settlement curves by reading the value of load intensity corresponding to the desired settlement of test plate. The value of permissible settlement (S_f) for different types of footings (isolated or raft) for different types structures are specified in the I.S. code. The corresponding settlement of test plate (S_p) can be calculated from the following formula,

$$S_f = S_p \left\{ \frac{[B (B_p + 0.3)]}{[B_p (B + 0.3)]} \right\}^2$$

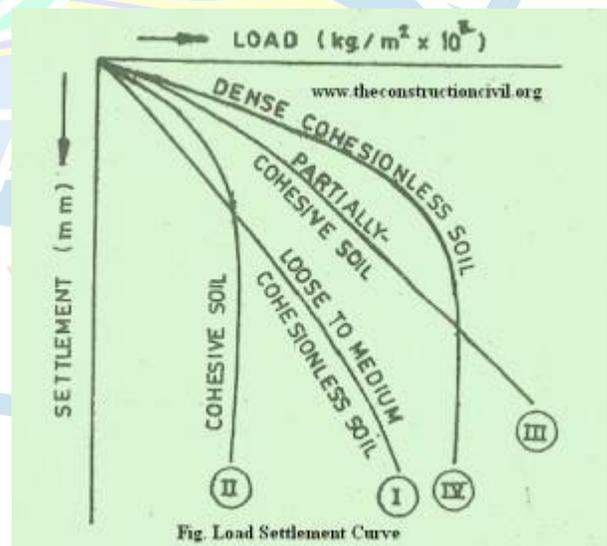
Where,

B = width of footing in mm.

B_p = width of test plate in mm. S_p =

settlement of test plate in mm. S_f =

settlement of footing in mm.



EXPERIMENT NO:-6

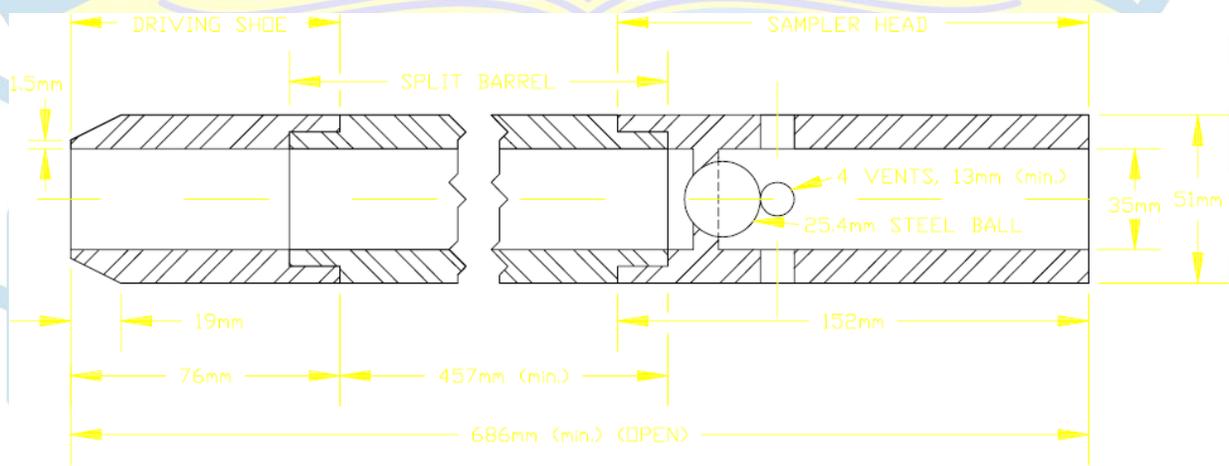
OBJECTIVE:- To determine the penetration value of given as soil by the standard penetration test.

DESCRIPTION OF TEST:-

This method describes the standard penetration test using the split-barrel sampler to obtain the resistance of soil to penetration (N-value), using a 63.5 kg hammer falling .76 m; and to obtain representative samples for identification and laboratory tests. The method is applicable to all soil types. It is most often used in granular materials but also in other materials when simple in-place bearing strengths are required. It is also used when samples cannot easily be recovered by other means.

APPARATUS AND MATERIALS:-

Drilling equipment - any drilling equipment is acceptable that provides a reasonably clean hole, which is at least 5 mm larger than the sampler or sampling rods, and less than 170 mm diameter. Sampling rods - steel A-rod is used to connect the sampler to the drive weight assembly. A-rod should be used unless otherwise directed. Split-barrel sampler - consists of 3 main parts; head, split-barrel and shoe. A core catcher should be installed to prevent loss of sample. Shoes which have been damaged should be replaced or repaired. Drive-weight assembly - consisting of a 63.5 kg weight (hammer), a driving head (anvil) and a guide permitting free fall of 0.76 m and an overlift capability of at least 100 mm. Cathead operating at approximately 100 rpm, equipped with suitable rope and overhead sheave for lifting drive-weight.



PROCEDURE:-

Test Hole

Drill the hole to the desired sampling depth and clean out all disturbed material. If a wet drill is used, flushout all cuttings.

Assembling Equipment

Attach the split-barrel sampler to the A-rod and lower into the hole until it is sitting on the undisturbed material. Attach the drive weight assembly. Lift the 63.5 kg hammer approximately 0.76 m and allow it to fall on the anvil delivering one seating blow. Mark the drill rod in 3 successive .15 m increments to observe penetration. Mark the drive weight assembly to indicate a 0.76 m hammer lift.

PENETRATION TESTING:-

Raise and drop the hammer 0.76 m successively by means of the rope and cathead, using no more than 2 1/4 wraps around the cathead. The hammer should be operated between 40 and 60 blows per minute and should drop freely. Continue the driving until either 0.45 m has been penetrated or 100 blows has been applied. Record the number of blows for each .15 m of the penetration. The first 0.15 m increment is the "seating" drive. The sum of the blows for second and third increment of 0.15 m penetration is termed "penetration resistance or "N-value". If the blow count exceeds 100 in total, terminate the test and record the number of blows for the last 0.30 m of penetration as the N-value. If less than 0.30 m is penetrated in 100 blows, record the depth penetrated and the blow count. If the sampler advances below the bottom of the hole under its own weight, note this condition on the log.

Handling Sample

Bring the sampler to the surface and open it. Remove any obvious contamination from the ends or sides and drain excess water. Carefully scrape or slice along one side to expose fresh material and any stratification. Record the length, composition, color, stratification and condition of sample. Remove sample and wrap it or seal in a plastic bag to retain moisture. If the sample can be removed relatively intact, wrap it in several layers of plastic to strengthen it and seal ends with tape. Mark the sample "top" and "bottom" if applicable and label it with an identification number.

RESULTS AND CALCULATIONS:-

Reporting Result

Prepare a log of the borehole, in the field, on the "FIELD BOREHOLE LOG" report form and show:

Hole number.

Elevation and stationing.

Sample number and depth.

Drilling method and type of bit.

Description of soil.

Number of blows for each .15 m penetration or partial increment.

Type of soil depending on SPT N values:

Soil Consistency	SPT N	S_u (psf)	S_u (kPa)
Very Soft	< 4	< 250	< 12
Soft	2 – 4	250 – 500	12 – 25
Medium	4 - 8	500 – 1000	25 – 50
Stiff	8 – 15	1000 – 2000	50 – 100
Very Stiff	15 – 30	2000 – 4000	100 – 200
Hard	> 30	> 4000	> 200

Relative Density

State of Packing	Relative Density	Standard Penetration Resistance (N)	Static Cone Resistance (q_c)	Angle of Internal Friction (ϕ')
	Percent	Blows / ft	Tsf or kgf/cm ²	Degrees
Very Loose Loose Compact Dense Very Dense	< 20	< 4	< 20	< 30
	20 – 40	4 – 10	20 – 40	30 – 35
	40 – 60	10 – 30	40 – 120	35 – 40
	60 – 80	30 – 50	120 – 200	40 – 45
	> 80	> 50	> 200	> 45

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EXPERIMENT NO:- 7

OBJECT:- To take the sample without disturbing its index property.

THEORY:- Undisturbed soil samples are those that are cut, removed, and packed with the least possible disturbance. They are samples in which the natural structures, void ratio, and moisture content are preserved as carefully as possible. Samples of this type are used for determining the density (unit weight) of soil in the laboratory and investigating the strength of undisturbed soils in the laboratory by the CBR or unconfined compression tests. These samples may be shipped to more completely equipped laboratories for shear, consolidation, or other strength tests. Types of undisturbed samples are chunk samples, cut by hand with a shovel and knife, and cylinder samples, obtained by use of a cylindrical sampler or the CBR mold equipped with a sampling cutter. Expedient methods of obtaining cylinder samples are also used. The method of sampling chosen depends upon the equipment available, the tests required, and the type of soil. All undisturbed samples must be handled with care. Cohesion less soil samples must be kept in the container until ready for testing, and the container should be handled without jarring or vibration. Some soils are too hard or contain too many stones to permit sampling with the cylindrical samplers and can be sampled only by cutting out chunks by hand. Taking of un-disturbed samples frequently requires a great deal of ingenuity in adapting the sampling devices to job conditions and in devising schemes for their use. Whatever method is used, the sample must be taken and packed in the container for shipment without allowing its structure to change. Protection against change in moisture content during sampling and shipment is also required.

EQUIPMENTS & PROCEDURE:

1. Spilt Tube Sampler: The split tube sampler is an apparatus for rapid undisturbed sampling at the surface. The apparatus is very suitable for research on root systems, fertilizing and soil biology. The set consists of a split tube sampler with a handle with beating head, hammer with nylon heads (impact absorbing design), sample liners, storage containers and a steel lifting jack with lever and chain. The splittube sampler consists of two stainless steel tube halves with a working length of 40 cm. Undisturbed sampling often poses a problem when removing the sample from the sampling tube. With this type of auger, both parts can be easily separated.

The sample is located (loose or in the liner) in the detachable tube. The split tube sampler can easily be opened for immediate research of the sample or transport of the sample to the laboratory. Depending on the nature of the research, it is recommended (in order to obtain representative samples) to decontaminate the apparatus after every sampling. This one commonly used during Soil Penetration Tests.

2. Liner Sampler: With these sets undisturbed soil samples can be taken in a liner applying a stainless steel core sampler with sample tubes and cutting head. In soft soils the sampler is pressed into the soil, possibly using the push-/pull handle. In hard soils the sampler tube can be driven into the soil using the hammer with two nylon heads (impact absorbing design). The sets contain, among other things: a hand auger for pre- and clean boring of the bore hole, the core sampler with the sampler tubes and soil sample containers and maintenance equipment. The set is packed in an aluminium transport case. In case of an undisturbed sample it is often difficult to remove the sample from the sampler tube. By using sample liners it is easy to remove the sample from the tube. The sample, still in the liner, is stored in a container which can be sealed, for transport to the laboratory.

APPLICATIONS

Samples are suitable for:

- Soil fertility determinations.
- Judgement of soil structure.
- Volume weight determinations.
- Determination of granular composition.
- Soil technical measurements.
- Root system research.
- Fertilizing, chemical research and soil biology

BAHAL • HARYANA

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EXPERIMENT NO:- 8

OBJECTIVE:- To determine the relative density of given coarse grained material.

THEORY:-

Porosity of a soil depends on the shape of grain, uniformity of grain size and condition of sedimentation. Hence porosity itself does not indicate whether a soil is in loose or dense state. This information can only be obtained by comparing the porosity or void ratio of the given soil with that of the same soil in its loosest and densest possible state and hence the term, relative density is introduced. Relative density or density index is the ratio of the difference between the void ratios of a cohesion less soil in its loosest state and existing natural state to the difference between its void ratio in the loosest and densest states.

$$\text{Relative Density} = \frac{e_{\max} - e}{e_{\max} - e_{\min}}$$

Where,

e_{\max} = void ratio of coarse grained soil (cohesionless) in its loosest state.

e_{\min} = void ratio of coarse grained soil (cohesionless) in its densest state.

e = void ratio of coarse grained soil (cohesionless) in its natural existing state in the field

Relative density is an arbitrary character of sandy deposit. In real sense, relative density expresses the ratio of actual decrease in volume of voids in a sandy soil to the maximum possible decrease in the volume of voids i.e how far the sand under investigation can be capable to the further densification beyond its natural state. Determination of relative density is helpful in compaction of coarse grained soils and in evaluating safe bearing capacity in case of sandy soils.

For very dense gravelly sand, it is possible to obtain relative density greater the one. This means that such natural dense packing could not be obtained in the laboratory.

PROCEDURE:-

Calibration of mould :

1. Measure inside diameter of mould at different depths using a bore gauge and take the average.
 2. Keep the mould on a flat surface or flat plate. Measure the height at different positions and take the average (accuracy = 0.025 mm).
 3. Calculate the volume.
 4. Fill the mould with distilled water till overflowing takes place.
 5. Slid thick glass plate over the top surface of mould.
 6. Weigh the water filling the mould.
 7. Note the temperature of water.
 8. Obtain density of water for the above temperature from physical tables.
- Calculate the volume of the mould which is weight of water filling the mould /density of water.

PROCEDURE:-

1. Dry the soil sample in a thermostatically controlled electric oven.
2. Cool in the sample in a desiccator.
3. Segregate soil lumps without breaking individual particles
4. Sieve it through the required sieve size.

Minimum Density:

The mould is weighed accurately (W). Pour the dry pulverized soil into the mould through a funnel in a steady stream. The spout is adjusted so that the free fall of soil particle is always 25 mm. While pouring soil the spout must have a spiral motion from the rim to the centre. The process is continued to fill up the mould with soil upto about 25mm above the top. It is then leveled, with the soil and weight is recorded (W1).

(W1).

Volume of mould V cm³

Mass of dry soil Ms = (W1-W) gm $(\gamma_d)_{\min} = Ms/V$

$e_{\max} = G\gamma_w / (\gamma_d)_{\min} - 1$

Maximum Density:

Weigh the empty mould (W). Put the collar on top of the mould and clamp it. Fill the mould with the oven dried soil sample till 1 / 2 or 2 / 3 of the collar is filled. Place the mould on the vibrating deck and fix it with nuts and bolts. Then place the surcharge weight on it. The vibrator is allowed to run for 8 minutes. Then mould is weighed with the soil and weight is recorded (W2).

Volume of mould V cm³

Mass of dry soil Ms = (W2-W) gm $(\gamma_d)_{\max} = Ms/V$

$e_{\min} = G\gamma_w / (\gamma_d)_{\max} - 1$

Natural Density:

Weigh the mould with dry soil. Knowing the volume of the mould and weight of dry soil natural density, γ_d , can be calculated.

$e = G\gamma_w / (\gamma_d) - 1$

Relative Density = $\frac{e_{\max} - e}{e_{\max} - e_{\min}}$

EXPERIMENT NO:- 9

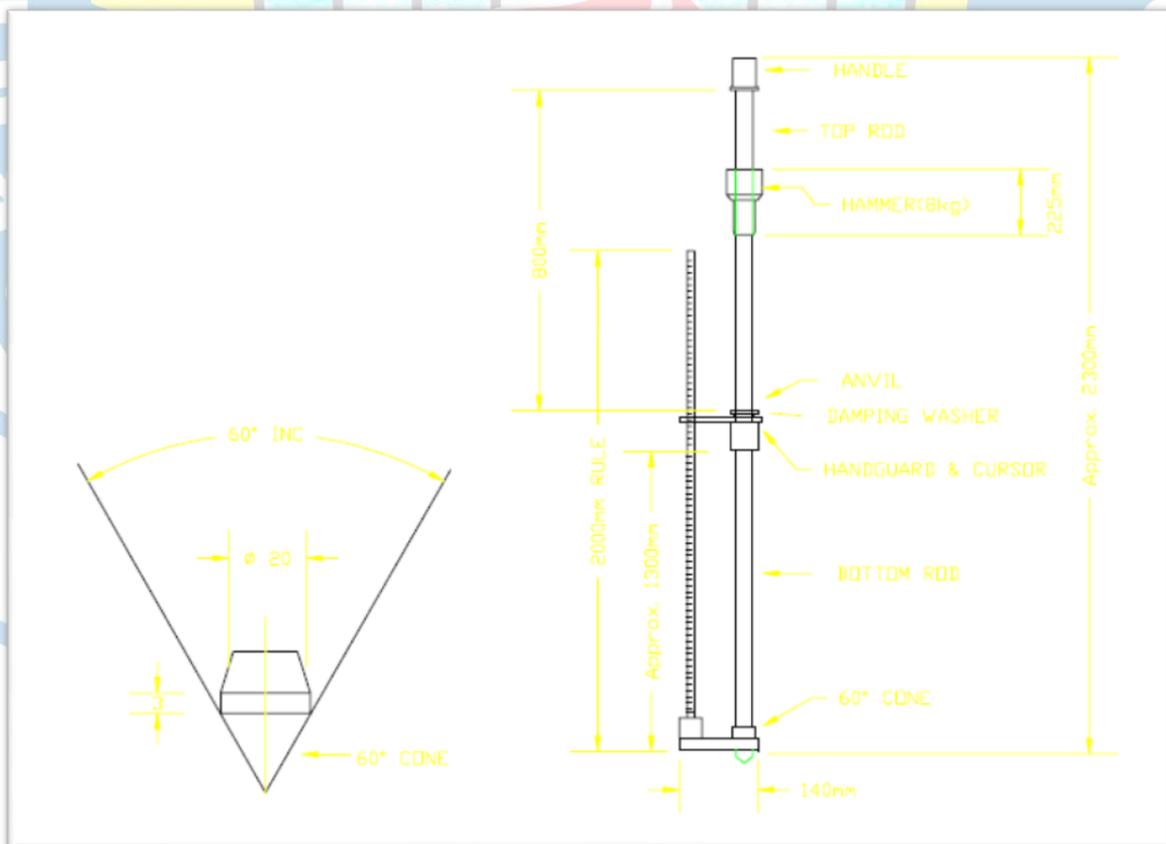
OBJECT :- To determine the soil strength by the dynamic cone penetration test

EQUIPMENT REQUIRED:-

The DCP apparatus consists of a 5/8"-inch diameter steel rod with a 60 degree conical tip. The rod is topped with an anvil that is connected to a second steel rod. This rod is used as a guide to allow an 8kg hammer to be repeatedly raised and dropped from a height of 575mm. The connection between the two rods consists of anvil to allow for quick connections between the rods and for efficient energy transfer from the falling weight to the penetrating rod.

THEORY:-

The DCP is used as a rapid means of assessing the sequence, thickness and in-situ bearing capacity of the unbound layers and underlying subgrade that comprise the pavement.



PROCEDURE:-

The steel rule attached to the guide foot is placed through the slot in the hand guard. The foot is placed on the surface to be tested and the cone tip passed through the guide hole. The entire apparatus is then held by the handle perpendicular to the surface. The technician observes the reading on the rule at the top of the hand guard and records this as the Zero Reading of DCP.

The drop weight is then raised to its maximum height and released. It is extremely important to gain maximum height for each drop but care must be taken not to strike the weight against the handle. Doing so would cause the instrument to withdraw and results would be in question. The readings are taken with each blow of the weight. If the penetration rate is below 20 mm/blow, the frequency of readings may be decreased to:

- one for every two blows with readings from 10-20 mm
- one for every five blows with readings from 5-9 mm
- one for every ten blows with readings from 2-4 mm.
- Penetration depth less than 1 mm and exceeding 20 blows is considered as refusal.

Normally, readings are taken to 1.0 m below the contact with the subgrade. No test should be less than 1.0 m from surface. Upon reaching the desired depth or refusal, the instrument is withdrawn. The forked part of the modified jack is placed under the anvil during extraction. An alternative method would be to strike the drop weight against the bottom of the handle, reversing the entry procedure. This is usually time consuming and adds additional stress to the threaded components, reducing instrument life.

CALCULATION:

All the pertinent location data, the number of blows and depth readings are recorded on the Dynamic Cone Penetrometer Test

The field data is reduced in terms of penetration versus corresponding number of blows. The number of blows is then plotted horizontally along the x-axis and the penetration reading plotted vertically along the y- axis. Depending on the pavement structure and environmental conditions the plot is divided into "best fit" straight lines. The slope values are then calculated by the change in penetration versus the change in the number of blows observed over the range for that particular straight line section - expressed as mm/blow.

Determine the relationship between DCP slope and CBR using the model derived by Kleyn and Van Harden. The soil layer DCP value is converted to CBR by projecting the corresponding soil layer DCP slope value from its location on the x-axis vertically up to Line No 1 and then horizontally over to the y-axis. This is a slow process and can be eliminated using a spreadsheet program and the following equation:

$$\text{Log CBR} = 2.628 - 1.273 \log(\text{DCP})$$

where DCP = penetration mm/blow.

Number of Blows	SUM/BLOWS	mm

