FIELD EXPLORATION AND DESIGN OF FOUNDATION FOR PROPOSED SITE

Major Project Report

Submitted in partial fulfilment of the requirement for the award of Degree of

Bachelor of Engineering in **" Civil Engineering "**

Submitted To

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ABOUT THE PROJECT

The purpose of this site investigation is to determine the existing soil profile and engineering characteristics of the subsurface conditions at the site and to provide the designer with comments on the following

1. Suitable footing type, founding depths and geotechnical design parameters which will be required for safe and economic design

2. Methods of construction of foundation and footings

OVERVIEW

Soil Exploration

The knowledge of sub-soil conditions at a site is a prerequisite for safe and economical design of sub-structural elements. The field and laboratory studies carried out for obtaining the necessary information about the sub soil characteristics including the position of ground water table are termed as soil exploration.

Soil properties

2.2.1 Atterberg Limits

1) Shrinkage Limit:

This limit is achieved when further loss of water from the soil does not reduce the volume of the soil. It can be more accurately defined as the lowest water content at which the soil can still be completely saturated. It is denoted by wS.

2) Plastic Limit:

This limit lies between the plastic and semi-solid state of the soil. It is determined by rolling out a thread of the soil on a flat surface which is non-porous. It is the minimum water content at which the soil just begins to crumble while rolling into a thread of approximately 3mm diameter. Plastic limit is denoted by wP.

3) Liquid Limit:

It is the water content of the soil between the liquid state and plastic state of the soil. It can be defined as the minimum water content at which the soil, though in liquid state, shows small shearing strength against flowing. It is measured by the Casagrande's apparatus and is denoted by wL.

2.2.2 Particle Size Distribution

Soil at any place is composed of particles of a variety of sizes and shapes, sizes ranging from a few microns to a few centimeters are present sometimes in the same soilsample. The distribution of particles of different sizes determines many physical properties of the soil such as its strength, permeability, density etc.

Particle size distribution is found out by two methods, first is sieve analysis which is done for coarse grained soils only and the other method is sedimentation analysis used for fine grained soil sample. Both are followed by plotting the results on a semi-log graph. The percentage finer N as the ordinate and the particle diameter i.e. sieve size as the abscissa on a logarithmic scale. The curve generated from the result gives us an idea of the type and gradation of the soil. If the curve is higher up or is more towards the left, it means that the soil has more representation from the finer particles; if it is towards the right, we can deduce that the soil has more of the coarse grained particles.

The soil may be of two types- well graded or poorly graded (uniformly graded). Well graded soils have particles from all the size ranges in a good amount. On the other hand, it is said to be poorly or uniformly graded if it has particles of some sizes in excess and deficiency of particles of other sizes. Sometimes the curve has a flat portion also which means there is an absence of particles of intermediate size, these soils are also known as gap graded or skip graded.

For analysis of the particle distribution, we sometimes use D10, D30, and D60 etc. terms which represents a size in mm such that 10%, 30% and 60% of particles respectively are finer than that size. The size of D10 also called the effective size or diameter is a very useful data. There is a term called uniformity coefficient Cu which comes from the ratio of D60 and D10, it gives a measure of the range of the particle size of the soil sample.

2.2.3 Specific gravity

Specific gravity of a substance denotes the number of times that substance is heavier than water. In simpler words we can define it as the ratio between the mass of any substance of a definite volume divided by mass of equal volume of water. In case of soils, specific gravity is the number of times the soil solids are heavier than equal volume of water. Different types of soil have different specific gravities, general range for specific gravity of soils:

2.2.4 Shear strength

Shearing stresses are induced in a loaded soil and when these stresses reach their limiting value, deformation starts in the soil which leads to failure of the soil mass. The shear strength of a soil is its resistance to the deformation caused by the shear stresses acting on the loaded soil. The shear strength of a soil is one of the most important characteristics. There are several experiments which are used to determine shear strength such as DST or UCS etc. The shear resistance offered is made up of three parts:

Sand	2.63 – 2.67
Silt	2.65 – 2.7
Clay and Silty clay	2.67 – 2.9
Organic soil	<2.0

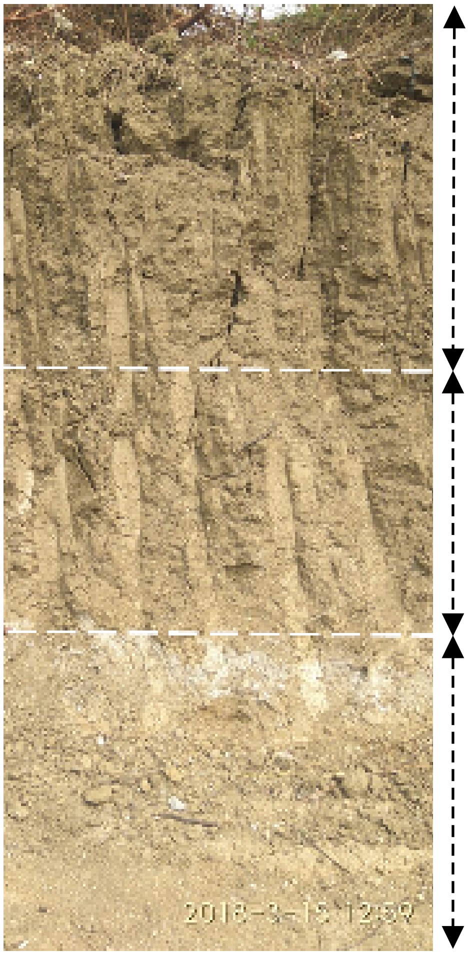
i) The structural resistance to the soil displacement caused due to the soil particles getting interlocked,

ii) The frictional resistance at the contact point of various particles, and

iii) Cohesion or adhesion between the surface of the particles.

In case of cohesionless soils, the shear strength is entirely dependent upon the frictional resistance, while in others it comes from the internal friction as well as the cohesion.

COLLECTION OF SAMPLE



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EXPERIMENTAL PROGRAMME

Lab Tests

1 Moisture Content

2 Seive Analysis

3 Specific Gravity

4 Liquid Limit

5 Unconfined Compression

6. Standard Proctor Test

Field Tests

1 Standard Penetration Test

2 Plate Load Test

MOISTURE CONTENT TEST

The natural water content also called the natural moisture content is the ratio of the weight of water to the weight of the solids in a given mass of soil. This ratio is usually expressed as percentage.

NEED AND SCOPE OF THE EXPERIMENT

In almost all soil tests natural moisture content of the soil is to be determined. The knowledge of the natural moisture content is essential in all studies of soil mechanics. To sight a few, natural moisture content is used in determining the bearing capacity and settlement. The natural moisture content will give an idea of the state of soil in the field.

APPARATUS REQUIRED

1. Air tight container
2. Electric oven
3. Dessicator
4. Balance of sufficient sensitivity

PROCEDURE

1. Clean the container with lid dry it and weigh it (W1).
2. Take a specimen of the sample in the container and weigh with lid (W2).
3. Keep the container in the oven with lid removed. Dry the specimen to constant weight maintaining the temperature between 1050 C to 1100 C for a period varying with the type of soil but usually 16 to 24 hours.
4. Record the final constant weight (W3) of the container with dried soil sample. Peat and other organic soils are to be dried at lower temperature (say 600) possibly for a longer period.

OBSERVATIONS AND RECORDING

Data and observation sheet for water content determination

S.No.	Sample No.	1	2	3
1	Weight of container with lid W_1 gm	16.750	20.250	22.500
2	Weight of container with lid +wet soil W_2 gm	24.140	42.360	52.440
3	Weight of container with lid +dry soil W_3 gm	17.773	34.723	40.820
4	Water/Moisture content $W = [(W_2 - W_3)/(W_3 - W_1)] \times 100$	13.84%	24.03%	11.358%

RESULT

The natural moisture content of the soil sample is ________

GENERAL REMARKS

1. A container without lid can be used, when moist sample is weighed immediately after placing the container and oven dried sample is weighed immediately after cooling in desiccator.

2. As dry soil absorbs moisture from wet soil, dried samples should be removed before placing wet samples in the oven.

SEIVE ANALYSIS

(IS 2720:PART 4-1985)

civilblog.org

OBSERVATIONS AND RECORDING

S1

Weight of soil sample: 3000 gm

Moisture content:

IS Sieve no. or size	Wt retained in each sieve (gm)	Percentage on each sieve	Cumulative %age on each sieve	% finer
20 mm	600	20	20	80
4.75 mm	1730	57.67	77.67	22.33
2.36 mm	30	1	78.67	21.33
1.18 mm	110	3.67	82.34	17.66
600 µ	220	7.33	89.67	10.33
425 µ	180	6	95.67	4.33
300 µ	50	1.66	97.33	2.67
150 µ	70	2.33	99.66	0.34

75 µ	0.5	0.0167	99.6767	0.3167
Pan	9.5	0.3167	100	-

S2

Weight of soil sample: 3000 gm

Moisture content:

IS Sieve no. or size	Wt retained in each sieve (gm)	Percentage on each sieve	Cumulative %age on each sieve	% finer
20 mm	210	7	7	93
4.75 mm	1860	62	69	31
2.36 mm	110	3.67	72.67	27.33
1.18 mm	130	4.33	77	23
600 µ	250	8.33	85.33	14.67
425 µ	210	7	92.33	7.67
300	30	1	93.33	6.67
150	140	4.67	98	2
75	1.915	0.07	98.07	1.93
Pan	58.085	1.93	100	-

S3

Weight of soil sample: 2620 gm

Moisture content:

IS Sieve no. or size	Wt retained in each sieve (gm)	Percentage on each sieve	Cumulative %age on each sieve	% finer
20 mm	350	13.35	13.35	86.65

4.75 mm	1880	71.75	85.10	14.90
2.36 mm	90	3.43	88.53	11.47
1.18 mm	85	3.24	91.77	8.33
600 µ	65	2.48	94.25	5.75
425 µ	25	0.95	95.20	4.80
300	44	1.68	96.88	3.12
150	13.2	0.50	97.38	2.62
75	12	0.46	97.84	2.16
Pan	55.8	2.13	100	-

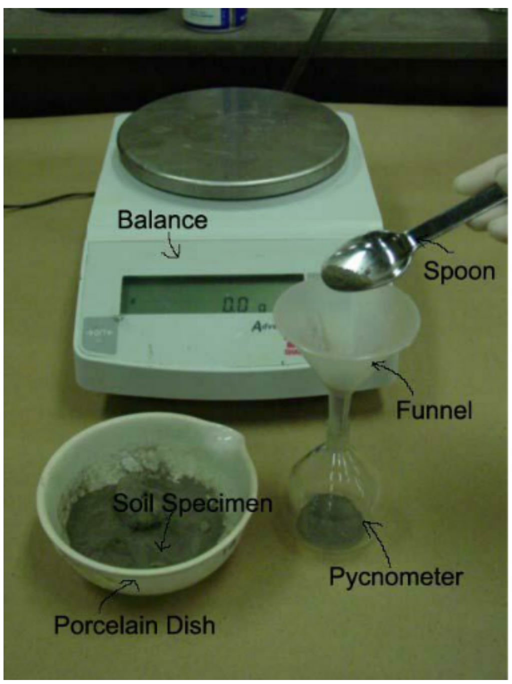
SPECIFIC GRAVITY DETERMINATION

This lab is performed to determine the specific gravity of soil by using a pycnometer. Specific gravity is the ratio of the mass of unit volume of soil at a stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature.

The specific gravity of a soil is used in the phase relationship of air, water, and solids in a given volume of the soil.

Equipment:

Pycnometer, Balance, Vacuum pump, Funnel, Spoon.



Test Procedure:

- Determine and record the weight of the empty clean and dry pycnometer, W_P.
- Place 125g of a dry soil sample (passed through the sieve No. 10) in the pycnometer. Determine and record the weight of the

pycnometer containing the dry soil, W_{PS}.

- Add distilled water to fill about half to three-fourth of the pycnometer. Soak the sample for 10 minutes.
- Apply a partial vacuum to the contents for 10 minutes longer, to remove the entrapped air.

- Stop the vacuum and carefully remove the vacuum line from pycnometer.
- Fill the pycnometer with distilled (water to the mark), clean theexterior surface of the pycnometer with a clean, dry cloth. Determine the weight of the pycnometer and contents, W_B.
- Empty the pycnometer and clean it. Then fill it with distilled water only (to the mark). Clean the exterior surface of the pycnometerwith a clean, dry cloth. Determine the weight of the pycnometer and distilled water, W_A.
- Empty the pycnometer and clean it.

Data Analysis:

Calculate the specific gravity of the soil solids using the following

formula:

$$\text{Specific Gravity}, G_S = \frac{W_0}{W_0 + (W_A - W_B)}$$

Where

W_0 = weight of sample of oven-dry soil, g = $W_{PS} - W_P$

W_A = weight of pycnometer filled with water

W_B = weight of pycnometer filled with water and soil

Observation

Specimen number	1	2

Pycnometer bottle number		
W_P = Mass of empty, clean pycnometer (grams)		
W_{PS} = Mass of empty pycnometer + dry soil (grams)		
W_B = Mass of pycnometer + dry soil + water (grams)		
W_A = Mass of pycnometer + water (grams)		
Specific Gravity (G_S)		

LIQUID LIMIT TEST

IS: 2720 (Part 5) – 1985

The liquid limit is the moisture content at which the groove, formed by a standard tool into the sample of soil taken in the standard cup, closes for 10 mm on being given 25 blows in a standard manner. This is the limiting moisture content at which the cohesive soil passes from plastic state to liquid state.

NEED AND SCOPE:

Liquid limit is significant to know the stress history and general properties of the soil met with construction. From the results of liquid limit the compression index may be estimated. The compression index value will help us in settlement analysis. If the natural moisture content of soil is closer to liquid limit, the soil can be considered as soft. If the moisture content is lesser than liquid limit, the soil is brittle and stiffer.

APPARATUS REQUIRED:

Casagrande apparatus confirming to IS: 9259-1979.

Grooving tool.

Balance of capacity 500 grams and sensitivity 0.01gram.

Thermostatically controlled oven with capacity up to 2500 C.

Porcelain evaporating dish about 12 to 15cm in diameter.

Spatula flexible with blade about 8cm long and 2cm wide.

Palette knives with the blade about 20cm long and 3cm wide.

Wash bottle or beaker containing distilled water.

Containers airtight and non- corrodible for determination of moisture content.

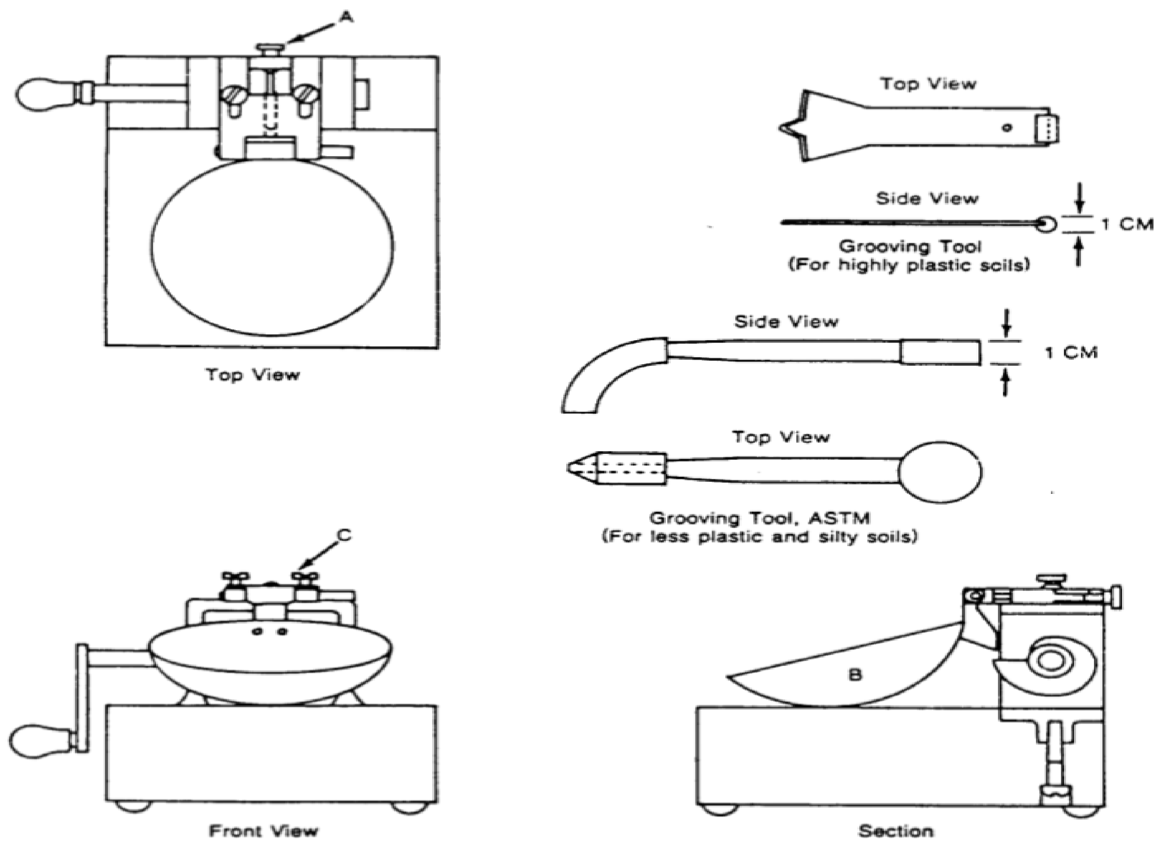


Figure: Cassagrande's Apparatus

PROCEDURE:

1. Put 250 gm of air-dried soil, passed thorough 425 mm sieve, into an

evaporating dish. Add distilled water into the soil and mix it thoroughly to form uniform paste. (The paste should have a consistency that would require 30 to 35 drops of cup to cause closer of standard groove for sufficient length.)

2. Place a portion of the paste in the cup of Liquid Limit deviceand spread it with a few strokes of spatula.

3. Trim it to a depth of 1cm at the point of maximum thickness and return excess of soil to the dish.

4. Using the grooving tool, cut a groove along the centre line of soil pat in the cup, so that clean sharp groove of proper dimension (11 mm wide at top, 2 mm at bottom, and 8 mm deep) is formed.

5. Lift and drop the cup by turning crank at the rate of two revolutions per second until the two halves of soil cake come in contact with each other for a length of about 13mm by flow only, and record the number of blows, N.

6. Take a representative portion of soil from the cup for moisture content determination.

7. Repeat the test with different moisture contents at least five more times for blows between 15 and 35.

OBSERVATIONS:

Natural moisture content-

Room temperature-

Soil sample Number	S_1	S_2	S_3
Container number			

Weight of container (W_1)			
Weight of container + wet soil (W_2)			
Weight of container + dry soil (W_3)			
Weight of water ($W_w=W_2-W_3$)			
Weight of dry soil ($W_s=W_3-W_1$)			
Moisture content (%) =(W_w/W_s)			
No. of blows (N)			

COMPUTATION :

Plot a flow curve with the points obtained from each determination on a semi logarithmic graph representing water content on the arithmetical scale and the no of drops on the logarithmic scale.

The flow curve is a straight line drawn as nearly as possible through the four or more plotted points.

The moisture content corresponding to 25 drops as read from the curve shall be rounded off to the nearest second decimal and is reported as liquid limit of the soil.

Liquid limit: $W_L =$

(At 25 blows, from semi log- graph of water content Vs. No. of blows)

Flow index: $I_f = (W_2 - W_1)/\log(N_1/N_2)$

$=$ slope of the flow curve

$=$

STANDARD PROCTOR TEST

THEORY:

In geotechnical engineering, soil compactionis the process in which a stress applied to a soilcauses densification as air is displaced from the pores between the soil grains. It is an instantaneous process and always takes place in partially saturated soil (three phase system). The Proctor compaction test is a laboratory method of experimentally determining the optimal moisture content at which a given soil type will become densest and achieve its maximum dry density.

NEED &SCOPE:

Determination of the relationship between the moisture content and density of soils compacted in a mould of a given size with a 2.5 kg rammer dropped from a height of 30 cm. the results obtained from this test will be helpful in increasing the bearing capacity of foundations, Decreasing the undesirable settlement of structures, Control undesirable volume changes, Reduction in hydraulic conductivity, Increasing the stability of slopes and so on.

APPARATUS REQUIRED:

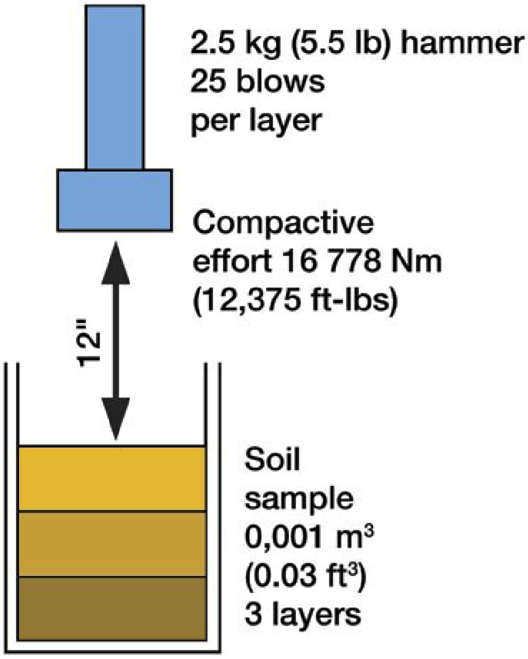
1. Proctor mould having a capacity of 944 cc with an internal diameter of 10.2 cm and a height of 11.6 cm. The mould shall have a detachable collar assembly and a detachable base plate.
2. Rammer: A mechanical operated metal rammer having a 5.08 cm

diameter face and a weight of 2.5 kg. The rammer shall be equipped with a suitable arrangement to control the height of drop to a free fall of 30 cm.

3. Sample extruder, mixing tools such as mixing pan, spoon, towel, and spatula.
4. A balance of 15 kg capacity, Sensitive balance, Straight edge, Graduated cylinder, Moisture tins.

PROCEDURE:

1. Take a representative oven-dried sample, approximately 5 kg in the given pan. Thoroughly mix the sample with sufficient water to dampen it with approximate water content of 4-6 %.
2. Weigh the proctor mould without base plate and collar. Fix the collar and base plate. Place the soil in the Proctor mould and compact it in 3 layers giving 25 blows per layer with the 2.5 kg rammer falling through. The blows shall be distributed uniformly over the surface of each layer.
3. Remove the collar; trim the compacted soil even with the top of mould using a straight edge and weigh.
4. Divide the weight of the compacted specimen by 944 cc and record the result as the bulkdensity ρ_{bulk}.
5. Remove the sample from mould and slice vertically through and obtain a small sample for water content.
6. Thoroughly break up the remainder of the material until it will pass a no.4 sieve as judged by the eye. Add water in sufficient amounts to increase the moisture content of the soil sample by one or two percentage points and repeat the above procedure for each increment of water added. Continue this series of determination until there is either a decrease or no change in the wet unit weight of the compacted soil.



Source : civilblog.org

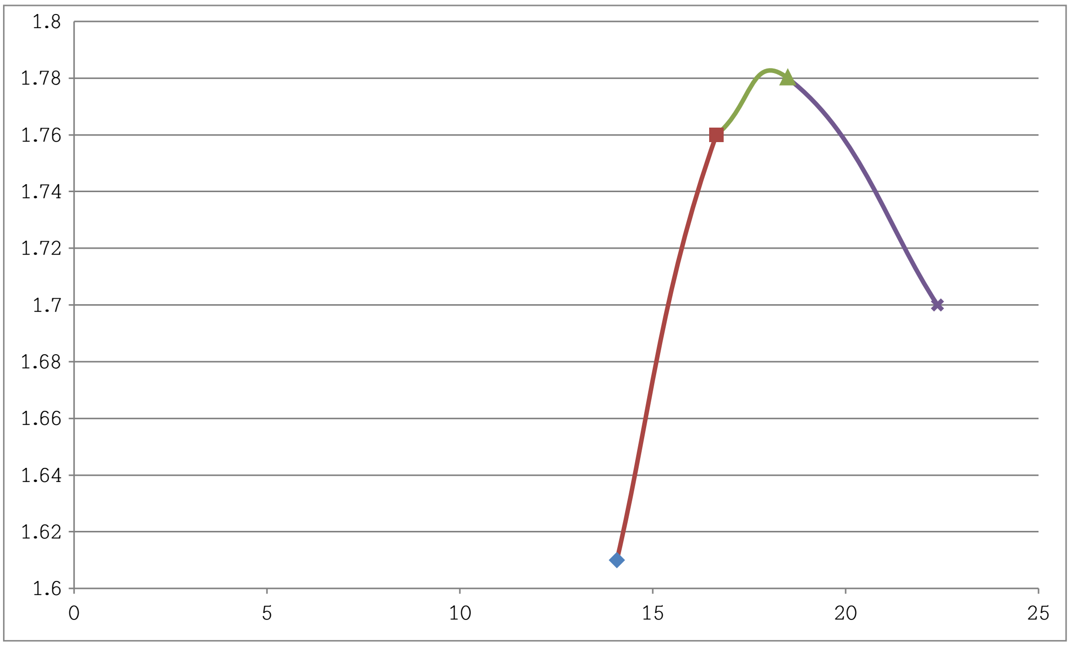
OBSERVATIONS:

S2

Mould Diameter 12 cm, Height 10 cm, Volume 942 cc, Weight 4540 gm

Determination No	1	2	3	4
Average moisture content w%	8%	12%	16%	20%
Wt of mould + compacted soil	6270	6470	6530	6500
Wt of compacted soil W (gm)	1730	1930	1990	1960

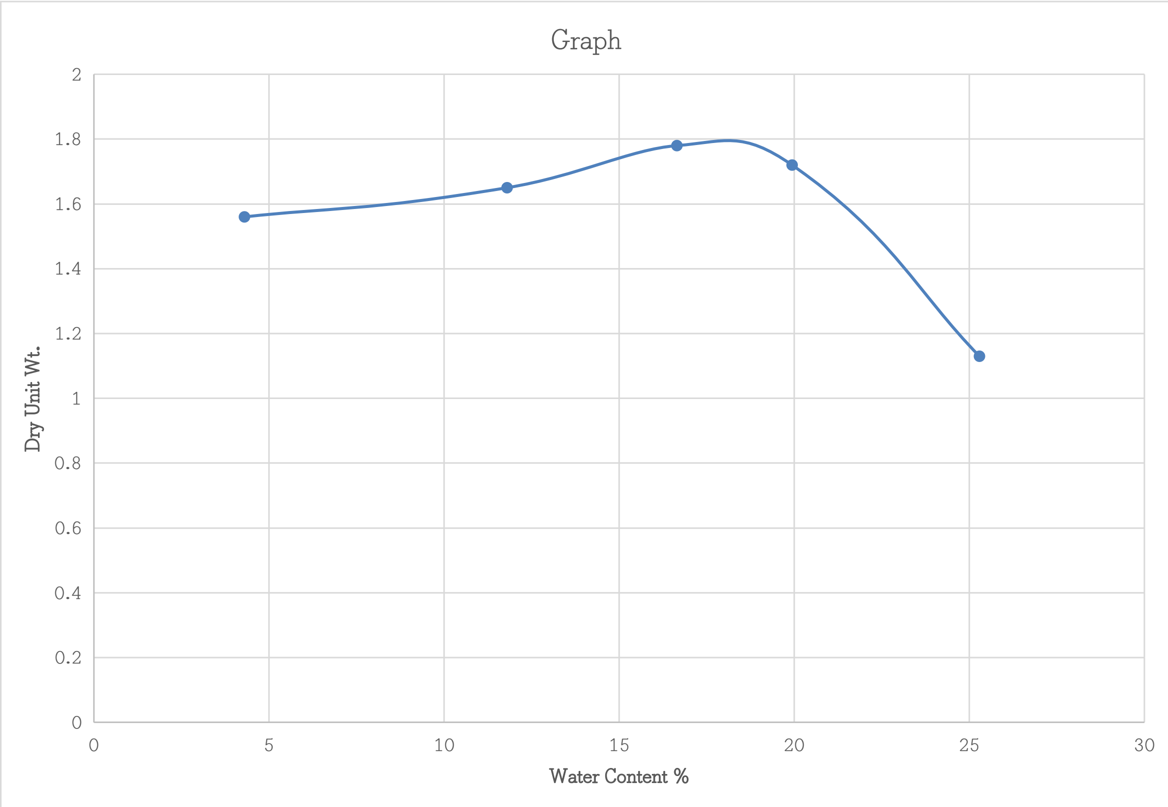
Bulk density (gm/cm^3)	1.84	2.05	2.11	2.08
Water Content				
Container No.	63	65	22	3
Wt. of container (gm) W_c	18.430	18.184	19.172	18.558
Wt. of container + wet soil (gm) W_1	51.368	48.830	63.972	68.191
Wt. of container + dry soil (gm) W_2	47.305	44.455	56.977	59.115
Water content w = $\frac{W_2 - W_1}{W_1 - W_c} \times 100$	14.07	16.65	18.50	22.38
Dry Density = $\frac{\rho_{bulk}}{1 + w}$	1.61	1.76	1.78	1.70



S3

Mould Diameter ………… cm, Height ………… cm, Volume 942 cc, Weight of mould 3.770 kg

Determination No	1	2	3	4	5
Average moisture content w%	5%	10%	15%	20%	25%
Wt of mould + compacted soil	*5320*	*5490*	*5710*	*5720*	*5110*
Wt of compacted soil W (gm)	1550	1720	1940	1950	1340
Bulk density (gm/cm^3)	1.64	1.82	2.05	2.07	1.42
Dry Density $= \frac{\rho_{bulk}}{1 + w}$	1.56	1.65	1.78	1.72	1.13
Water Content					
Container No.	36	62	68	46	51
Wt. of container (gm) W_c	18.708	18.430	18.451	18.763	18.823
Wt. of container + wet soil (gm) W_1	27.629	41.038	42.862	59.049	40.301
Wt. of container + dry soil (gm) W_2	27.261	38.647	39.377	52.350	35.965
Water content w = $\frac{W_1 - W_2}{W_2 - W_c} \times 100$	4.30%	11.8%	16.65%	19.94%	25.29%



RESULTS:

GENERAL REMARKS:

The peak point of the compaction curve: The peak point of the compaction curve is the point with the maximum dry density dry density d max. Corresponding to the maximum dry density d max is a water content known as the optimum water content (also known as the optimum moisture content, OMC). Note that the maximum dry density is only a maximum for a specific compactive effort and method of compaction. This does not necessarily reflect the maximum dry density that can be obtained in the field.

Zero air voids curve: The curve represents the fully saturated condition (S = 100 %). (It cannot be reached by compaction).

TRIAXIAL TEST

Need and Scope:

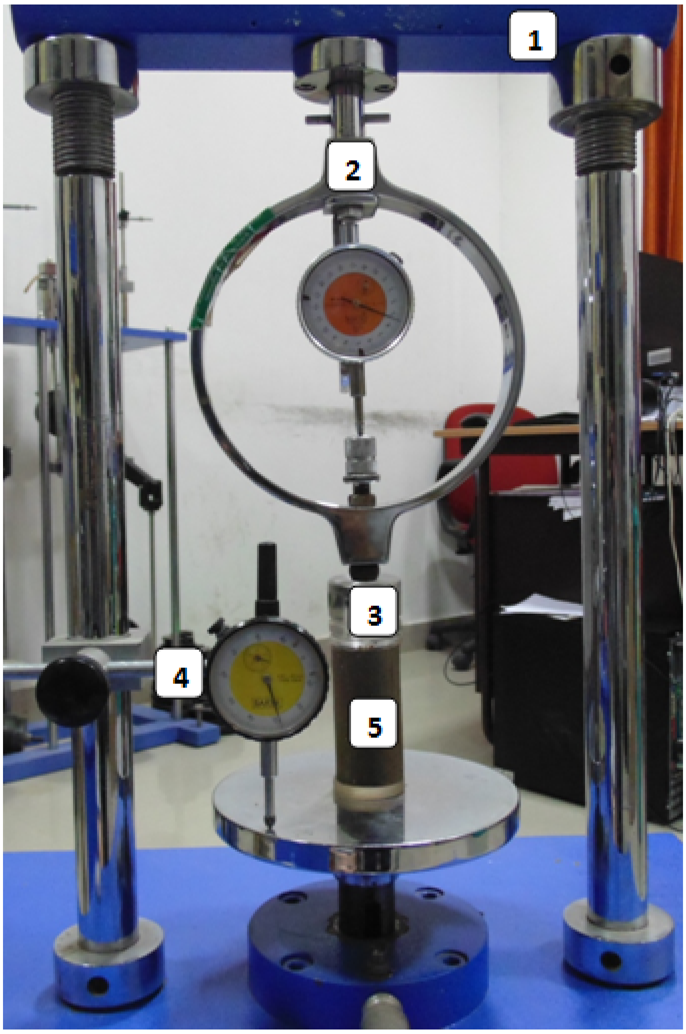
It is not always possible to conduct the bearing capacity test in the field. Sometimes it is cheaper to take the undisturbed soil sample and test its strength in the laboratory. Also to choose the best material for the embankment, one has to conduct strength tests on the samples selected. Under these conditions it is easy to perform the Unconfined Compression (UC) test on undisturbed or remolded soil sample.

Concept:

An Unconfined compression test is also known as uniaxial compression tests, is special case of a triaxial test, where confining pressure is zero. UC test does not require the sophisticated triaxial setup and is simpler and quicker test to perform as compared to triaxial test. In this test, a cylinder of soil without lateral support is tested to failure in simple compression, at a constant rate of strain. The compressive load per unit area required to fail the specimen as called Unconfined compressive strength of the soil.

Experimental Setup:

1. Loading frame of capacity of 2 t, with constant rate of movement.
2. Proving ring of 0.01 kg sensitivity for soft soils; 0.05 kg for stiff soils.
3. Frictionless end plates of 76 mm diameter (Perspex plate with silicon grease coating).
4. Dial gauge (0.01 mm accuracy)
5. Soil sample of 38 mm diameter & 76 mm length



Specimen Preparation:

a)Undisturbed Specimen(UDS):

1. Note down the sample number, bore hole number and the depth at which the sample was taken.
2. Remove the protective cover (paraffin wax) from the sampling tube.
3. Place the sampling tube (38 mm dia) extractor and push the plunger till a small length of sample moves out.
4. Trim the projected sample using a wire saw, and push the plunger until a 76 mm long sample comes out.
5. Cutout this sample carefully and hold it on the split sampler so that it does not fall.

6. Take about 10 to 15 g of soil from the tube for water content determination.
7. Note the container number and take the net weight of the sample and the container.
8. Measure the diameter at top, middle, and bottom of the sample. Find the average and record the same.
9. Measure the length and weight of the sample and record.

b) Remoulded Specimen(R):

1. For the desired water content and the dry density, calculate the weight of the dry soil Ws required for preparing a specimen of 38 mm diameter and 76 mm long.
2. Add required quantity of water W_w to this soil.

   $W_w = W_s \times W/100$ gm
3. Mix the soil thoroughly with water.
4. Place the wet soil in a tight thick polythene bag in a humidity chamber.
5. After 24 hours take the soil from the humidity chamber and place the soil in a constant volume mould, having an internal height of 76 mm and internal diameter of 38 mm.
6. Place the lubricated mould with plungers in position in the load frame.
7. Apply the compressive load till the specimen is compacted to a height of 76 mm.
8. Eject the specimen from the constant volume mould.
9. Record the correct height, weight and diameter of the specimen.

Experimental procedure (IS 2720 Part 10):

1. Take two frictionless bearing plates of 38 mm diameter.
2. Place the specimen on the base plate of the load frame (sandwiched between the end plates).

3. Place a hardened steel ball on the bearing plate.
4. Adjust the center line of the specimen such that the proving ring and the steel ball are in the same line.
5. Fix a dial gauge to measure the vertical compression of the specimen.
6. Adjust the gear position on the load frame to give suitable vertical displacement.
7. Start applying the load and record the readings of the proving ring dial and compression dial for every 5 mm compression.
8. In UC test, the commonly used loading rate is 1.25 mm/min. For harder specimens 1.5 mm/min or 2.25 mm/min can also be used.
9. Continue loading till failure is complete, and then draw the sketch of the failure pattern in the specimen.

Observation Sheet:

Sample no:__________________________Depth/Location:_______________________

Weight of Sample:______________________ In-situ density: ______________________

Diameter:__________________________

Area:___________________________

Initial Water Content:____________________ Deformation rate:___________________

Least count of dial gauge:__________________ Proving ring constant: __________________

0.5

Dial gauge reading	Proving ring reading	Stress (N/mm^2)	Dial gauge reading	Proving ring reading	Stress (N/mm^2)

0	0		1000	105	
100	17		1100	112	
200	34		1200	117	
300	48		1300	120	
400	59		1400	127	
500	68		1500	130	
600	76		1600	132	
700	83		1700	132	
800	93		1800		
900	97		1900		

1.0

Dial gauge reading	Proving ring reading	Stress (N/mm^2)	Dial gauge reading	Proving ring reading	Stress (N/mm^2)
0	0		1000	116	
100	44		1100	111	
200	58		1200	117	
300	71		1300		

400	73		1400		
500	78		1500		
600	90		1600		
700	97		1700		
800	105		1800		
900	111		1900		

1.5

Dial gauge reading	Proving ring reading	Stress (N/mm^2)	Dial gauge reading	Proving ring reading	Stress (N/mm^2)
0	0		1000	107	
100	41		1100		
200	56		1200		
300	70		1300		
400	82		1400		
500	94		1500		
600	104		1600		
700	112		1700		

800	115		1800		
900	101		1900		

Calculations:

1. Axial stress = (Proving ring reading x Proving ring constant) / A_{corr}
2. $A_{corr} = A_0/(1-□)$; A_0 is initial cross-sectional area of the soil specimen, □ is the axial strain at that point of loading.
3. Maximum axial stress is obtained, which is also considered to be the failure point of the specimen.
4. Repeat the test 3 times. Find the average value of maximum axial stress obtained in all three UC tests.
5. Unconfined compression strength of the soil, q_u = average value of maximum axial stress of three tests
6. Shear strength of the soil (cohesion, c) = $q_u/2$
7. Sensitivity = (q_u for undisturbed sample)/ (q_u for remoulded sample).

Graphs:

1. Axial stress versus Axial strain relationship

Example

The UC test has been performed at loading rate of 1.25mm/min on specimen of 38 mm dia & 76 mm ht.

Results:

Unconfined Compressive Strength (q_u) = 267 kPa

Cohesion (c) = 133 kPa

Internal friction angle (□) = 0 deg

General Remarks

• Minimum three samples should be tested; correlation can be made between unconfined strength and field SPT value N.
• Up to 6% strain the readings may be taken at every 1/2 min (30 sec).
• UC test is recommended for cohesive soils, or which can stand without lateral support.

Theory:

In UC test, a cylindrical soil specimen of standard size (normally 38 mm dia & 76 mm ht) is loaded axially monotonically under compression till failure at a constant strain rate / deformation rate in a loading frame. Since soil specimen is not kept laterally confined, it is termed as Unconfined Compression test. The axial/vertical compressive stress is the major principal stress and other two principal stresses are considered to be zero.

Since soil specimens are kept unconfined, these tests cannot be performed on soils which cannot stand without lateral support. These tests are performed only on cohesive soils in undisturbed or remoulded conditions. A loading frame with proving ring and a dial gauge to measure axial load and axial deformation, respectively. Maximum axial stress (compressive stress) causing failure is obtained from stress-strain plot and is defined as unconfined compressive strength of soil. When failure point on the curve is not defined, the stress corresponding to 20% axial strain is used to represent the strength values. During the test, No drainage of water from the sample takes place; and to maintain same water content of the sample, the test is run at a fast strain rate. Failure plane is not predetermined and takes place along the weakest plane.

Mohr circle of stresses at failure in unconfined compression test and loading conditions are given below:

STANDARD PENETRATION TEST

The Standard Penetration Test (SPT) is widely used to determine the in-situ properties of soil. The test is especially suited for cohesion-less soils as the correlation between the SPT value and φ is now well established. In India this test is widely used for all types of soil. The test was introduced in 1902 and remains today as the most common in-situ test worldwide. The procedures for the SPT are detailed in IS 2131:1981.

The test consists of driving a split spoon sampler (Figure 1.1) into the soil through a borehole 55 to 100 mm in diameter at the desired depth. It is done by a hammer weighing 63.5 kg dropping onto a drill rod from a height of 750 mm. The number of blows N required to produce a penetration of 300 mm is regarded as the penetration resistance. To avoid seating errors, the blows for the first 150 mm of penetration are not taken into account; those required to increase the penetration from 150 mm to 450 mm constitute the N-value. The operation of SPT is shown in Figure 1.2.

It is important to point out that several factors contribute to the variation of the standard penetration number „N" at a given depth for similar soil profiles. Among these factors are the SPT hammer efficiency, borehole diameter, sampling method, rod length, water table and overburden pressure important. The most two common types of SPT hammers used in the field are the safety hammer and donut hammer. They are usually dropped using a rope with two wraps around a pulley. The configurations of the hammers are shown in Figure 1.3.

Usually SPT is conducted at every 1.5 m or 2 m depth or at the change of stratum. In hard formations, the testing is discontinued if N value is found to be over 100 and it is termed refusal.

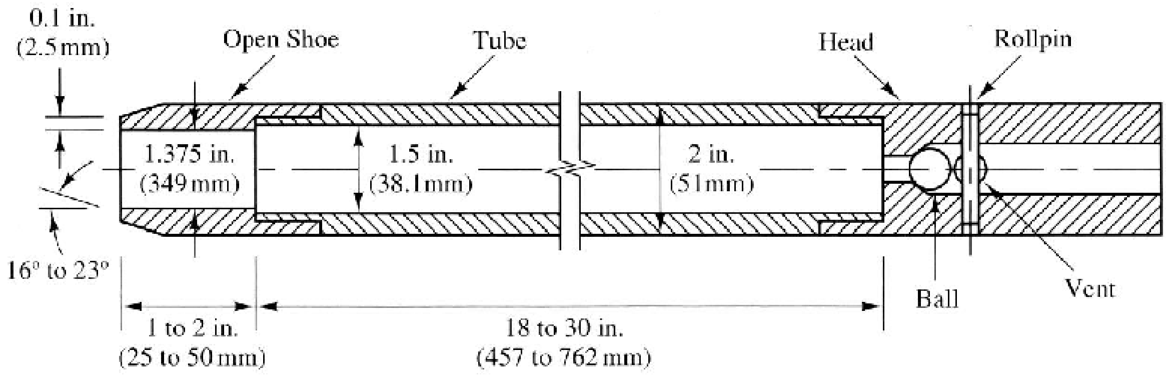


Figure 1.1 Schematic diagram of split spoon sampler

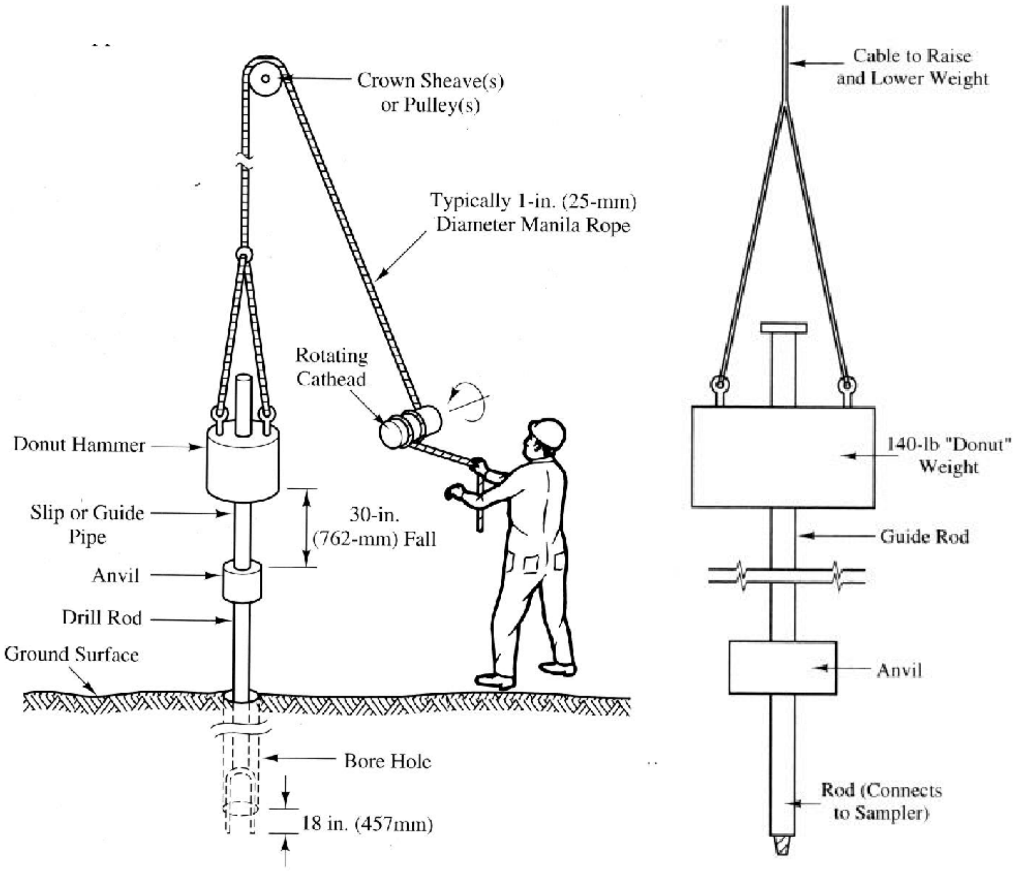


Figure 1.2 Demonstration of standard penetration test with donut hammer

1.3 Termination of Standard Penetration Test (SPT)

The test can be terminated if the following three conditions appear in the field.

A total of 50 blows have been applied during any one of the three 6-in. (150 mm) increments.

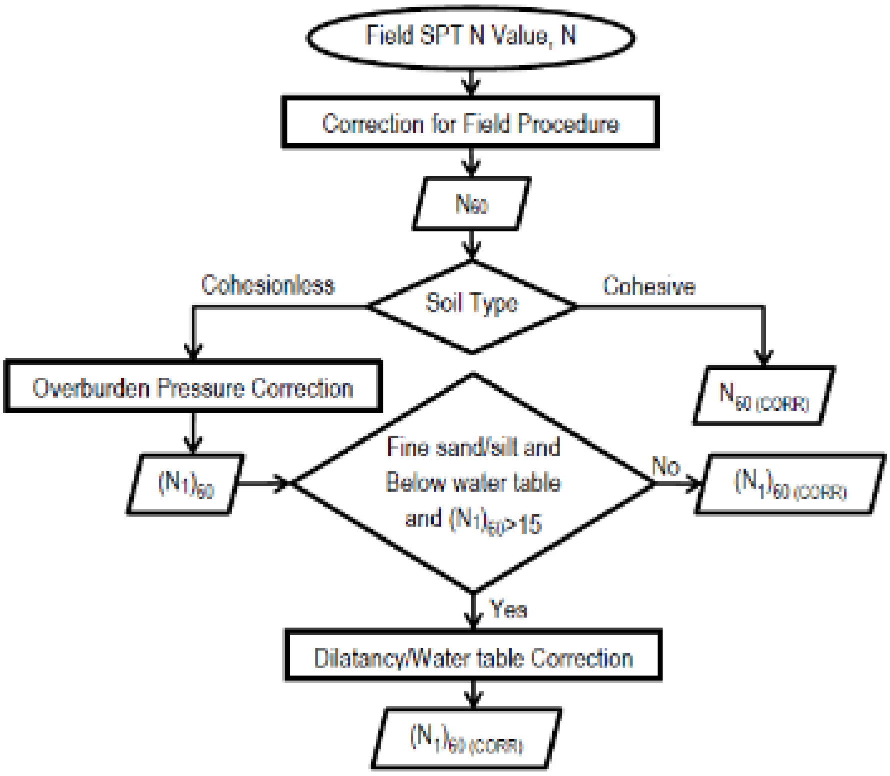
A total of 100 blows have been applied.

There is no observed advance of the sampler during the application of 10 successive blows of the hammer.

1.4 Correction of Standard Penetration Test (SPT)

The use of SPT correction factor is often confusing. Corrections for field procedures (Energy Correction) are always appropriate, but the overburden pressure correction may or may not be appropriate depending on the procedures by those who developed the analysis method under consideration.

For cohesive soil there is no need for overburden pressure correction (Peck et al.,1974 pp. 114). For cohesionless soil at first overburden pressure correction is made, then if it is fine sand or silt under water table with N value >15, dilatancy correction is made.



1.4.1 Correction of SPT Value for Field Procedures

On the basis of field observations, it appears reasonable to standardize the field SPT number as a function of the input driving energy and its dissipation around the sampler around the surrounding soil. The variations in testing procedures may be at least partially compensated by converting the measured N to N60 as follows (Skempton, 1986)

$$N_{60} = \frac{E_H C_B C_S C_R N}{0.60}$$

Where,

N_{60} = Corrected SPT N-value for field procedures

E_H = Hammer efficiency

C_B = Borehole diameter correction

C_S = Sampler correction

C_R = Rod length correction

N = Measured SPT N-value in field

This correction is to be done irrespective of the type of soil. (Table 1.1)

1.4.2 Correction of SPT Value for Overburden Pressure

In cohesion-less soils, the overburden pressure affects the penetration resistance. For SPT made at shallow levels, the values are usually too low. At a greater depth, the same soil at the same density index would give higher penetration resistance. It was only as late as in 1957 that Gibbs & Holtz (1957) suggested that corrections should be made for field SPT values for depth.

As the correction factor came to be considered only after 1957, all empirical data published before 1957 like those by Terzaghi is for uncorrected values of SPT. Since then a number of investigators have suggested overburden correction. Gibbs & Holtz took standard pressure of 280 kN/m2 (corresponding to a depth of 14 m) and duly made overburden correction for other overburdens. Thornburn suggested a standard pressure of 138 kN/m2 (corresponding to a depth of 7 m). Finally, Peck et. al. (1974) suggested a standard pressure of 100 kN/m2 (Equivalent to 1 tsf or 1 kg/cm2 overburden corresponding to a depth of 5 m). As such, all field SPT values are to be corrected by the correction factor given by them as

$(N_1)_{60} = C_N \times N_{60} \leqslant 2N_{60}$

Where,

C_N = Overburden pressure correction factor

The following relationships are widely used for C_N.

$$C_N = 0.77 \log\left(\frac{2000}{\sigma_0'}\right)$$

Where σ_0' is in kN/m^2 or kPa.

$$C_N = 0.77 \log\left(\frac{20}{\sigma_0'}\right)$$

Where σ_0' is in tsf.

Another overburden correction that is commonly used is due to Bazaraa (1967). It is given by

$$C_N = \frac{4}{1 + 4p} \quad \text{if } p \leq 0.75 \text{ kg/cm}^2$$

$$C_N = \frac{4}{3.15 + 4p} \quad \text{if } p > 0.75 \text{ kg/cm}^2$$

1.4.3 Correction of SPT Value for Water Table

In addition to corrections of overburden, investigators suggested corrections of SPT-value for water table in the case of fine sand or silt below water table. Apparently, high N-values may be observed especially when observed value is higher than 15 due to dilatancy effect. In saturated, fine or silty, dense or very dense sand the N-values may be abnormally great because of the tendency of such materials to dilate during shear under undrained conditions. The pore pressure affects the resistance of the soil and hence the N value. In such cases, following correction is recommended (Terzaghi and Peck, 1948).

$$(N_1)_{60\,(CORR)} = 15 + \frac{1}{2}[(N_1)_{60} - 15] \qquad (1.5)$$

For coarse sand this correction is not required. In applying this correction, overburden correction is applied first and then this diltancy correction is used.

1.5 Correlations between SPT N values and Different Parameters of Soil

The SPT has been used to correlate different soil parameters i.e., unit weight γ, relative density Dr, angle of internal friction φ and undrained compressive strength qu. It has also been used to estimate the bearing capacity of foundations and for estimating the stress-strain modulus.

Terzaghi and Peck give the following correlation (Table 1.2 and Table 1.3) between SPT value and other soil parameters.

Linear relationships of above correlation with average values can be very helpful in analytical problems. Some of the correlations are given below.

Correlation with unconfined compressive strength of cohesive soil shown in Equation (1.6 is a modified form of Terzaghi & Peck's (1967) relationship. This correlation was initially with field N-value (BNBC 2015 Eq. 6.D.7). Correlation with angle of internal friction of cohesion-less soil shown in Equation (1.7 was originally in a graphical representation by Peck et. al 1974.

Observation Table

S. No.	Depth	No. of Blows
1.	150 mm	4
2.	300 mm	25
3.	450 mm	63

*

(a) Correction for Overburden Pressure

N = 59

$P = \square \times D_f = 0.0023$ kg/cc x 230 cm = 0.529 kg/cm^2

$$C_N = \frac{4}{1 + 4p} = \frac{4}{1 + 4(0 \cdot 529)} = 1.28$$

$N' = N \times C_N = 59 \times 1.28 = 75.73$

(b) Correction for Dilatancy

$N'' = 15 + 0.5(N' - 15) = 15 + 0.5(75.73 - 15) = 45.365$

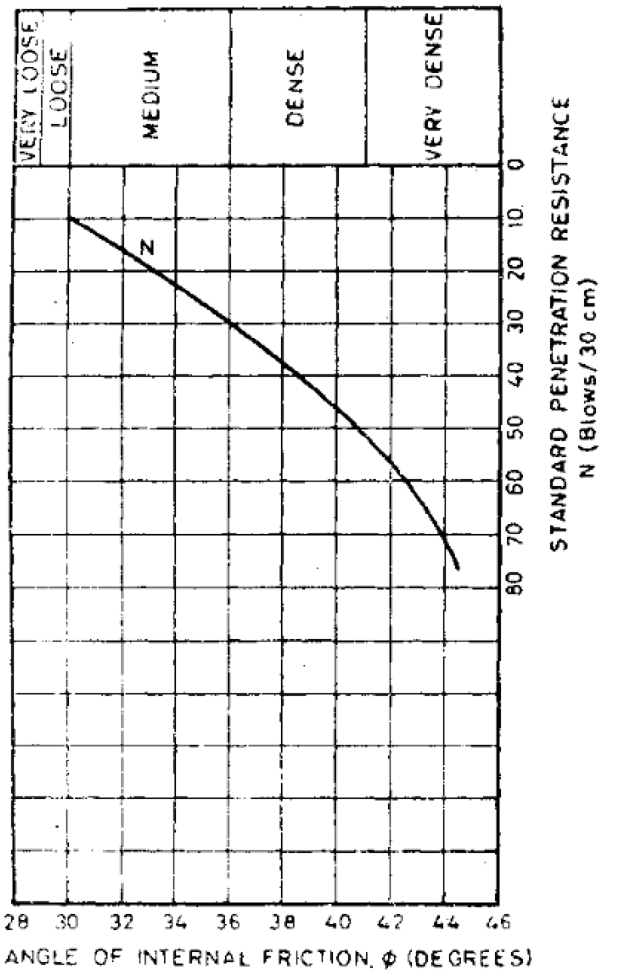


FIG. 1 RELATIONSHIP BETWEEN ϕ AND N

by this graph, we can find $\varphi = 40^{\circ}$

In case of general shear failure ultimate bearing capacity of a shallow foundation following equation may be used

$q_{nu} = cN_c s_c d_c i_c + q(N_q-1)s_q d_q i_q + 0.5\gamma B N_\gamma s_\gamma d_\gamma i_\gamma W'$

In this equation, q_{nu} refers to the net ultimate bearing capacity. N_c, N_q and N_γ are bearing capacity factors which are given by Vesic equations as

$N_c = (N_q-1) \cot \varphi$

$N_q = e^{\pi \tan\varphi}.\tan^2(45+\varphi/2)$

$N_\gamma = 2(N_q+1) \tan \varphi$

q_{nu} = cx 75.31 x 1.3 x 1.49 + 5.29 (64.2-1)1.2 x 1.24 + 0.5 x 2.3 x 2 x 109.41 x 0.6 x 1.24

= 684.702

assuming B = 2 m, taking c = 0, q = D_f x ▯ = 2.3 x 2.3 = 5.29

taking FOS = 3

q_{safe} (sbc) = 684.708/3 = 228.234

DESIGN OF FOUNDATION

RESULTS AND DISCUSSIONS

CONCLUSIONS

REFERENCES