SUB-SOIL INVESTIGATION

- *Investigation Stage*
- *Depth of Exploration*
- *Methods of Exploration*
- *Field Permeability Tests*
- *Bearing Capacity Tests*

Introduction

The earth crust is heterogeneous and consists of soil and rock and accumulation of mineral grains cemented or not cemented. To the engineer engaged in design and construction of structural foundations and earth works, the identification of weak zones, presence of unreliable materials below the foundation are the major tasks.

All the defects have to be identified during the investigation stage itself so that, remedial measures can be initiated in time. Any defect if identified after the investigation stage or subsequent construction stage becomes un economical and some times the remedial measures can not be attempted. Therefore, a construction management plan has to be evaluated.

The construction management plan can be evaluated in the following stages:

1. Investigation stage,
2. Design stage,
3. Construction stage,
4. Maintenance stage.

1. INVESTIGATION STAGE:

a. The defects if identified during investigation stage and remedial measures taken before the design stage will prove economical for safe completion of a project.

b. The defects if identified at the design stage will be a bit costlier to take remedial measures because the design has to be modified.

c. Identification of a defect during construction stage becomes much more un economical because investigation is to be done for remedial measures, re-design and some times reconstruction of the structure.

d. At maintenance stage any defect, if identified becomes much more costly and sometimes leads to dismantling of the structure.

A. The objective of site investigation is to provide reliable, specific and detailed information about the sub-soil conditions which may be required for a safe and economic design and execution of project. An exploration of the region likely to be affected by the proposed structure should yield precise information about the following :

i. Extent of the soil or rock formation

ii. Nature and engineering properties of the soils or rock,

iii. Location of Ground water.

DEPTH OF EXPLORATION:

Exploration in general, should be carried out to a depth upto which the increase in pressure due to structural loading is likely to cause perceptible settlement or shear failure. Such a depth is known as the significant depth which depends upon the type of structure, its weight, size, shape disposition of the loaded area and soil profile and its properties.

It is generally safe to assume the significant depth upto a level at which net increase in vertical pressure becomes less than 10% of the initial over burden pressure. Alternatively a pressure bulb bounded by an isobar of 1/5 to 1/10 of the surface, loading intensity is some time assumed to define the minimum depth of exploration. This depth may be assumed to be equal to 11/2 to 2 times the width of a loaded area.

A. Depth of exploration – Guidelines :

1. Isolated spread footing → 1.5 tmes the width of footing,

2. Adjacent footing 1.5 times the length,

3. Pile foundation 1.5 times the width of structure,

4. Base of retaining wall 1.5 times base width or 1.5 times of exposed height of face wall which ever is greater

5. Floating foundation	depth of construction
6. Dams	a) 0.50 times the bottom width or earth dam
	b) 2 times the height for concrete dams less than 30 mts high
	c) Upto bed rock
7. Roads, cuts, fills	a) 1 mt where little cut or fill is required
	b) 1 mt below formation level in cuts
	c) 1xB deep cuts equal to bottom width(B)
	d) 2 mts below ground in fill sections or equal to height of fill which ever is greater.

A. Number and disposition of Pits and borings :

To reveal any major changes in thickness, depth and properties of the strata affected:

1. For compact building sites covering an area of 0.4 hectare **-** 5 bore holes or pits.
2. For smaller & less important - 1 bore hole or pit in center
3. Larger areas................................... 100 mts c/c one bore hole or pit
4. Dam sites.. 50 mts spacing along the top line of U/S face and 2 bore holes in either abutment base.
5. Road ....c/c 100 mts to 500 mts.

METHODS OF SITE EXPLORATION :

1. Open excavation
2. Borings
3. Sub-Surface soundings
4. Geophysical methods

1. (a) Open Excavation:

Test pits and trenches: Soil can be inspected in their natural condition. Undisturbed and disturbed samples can be collected as per convenience using sampling tubes and core cutters. This is generally considered suitable for shallow depths of excavation say upto 3 meters.

(b) Boring methods :

i. **Auger borings**

a) **Post hole auger:** Samples collected are generally in undisturbed condition and useful for identification.

b) **Helical auger:** - Samples collected are generally in disturbed condition and useful for identification.

ii. **Shell boring -** Can be used for deep boring; contains a shell with cutting edge or teeth at lower end suitable for soils.

iii. **Wash boring :** Fast and simple method for advancing the hole in all types of soils. Water is forced under pressure through the drill rod which is alternatively raised and dropped. Samples collected are valueless.

iv. **Percussion boring:** Used for quick advancing of the hole. Foundation however gets disturbed.

v. **Rotary Boring:** will have core barrel and diamond drill bit; rock cores can be collected.

UNDISTURBED SAMPLING:

Undisturbed samples are required to determine shear parameters, consolidation tests, permeability tests and computation of bearing capacity for foundation strata.

INSITU TESTING:

I. Insitu permeability tests :-

a) Open trench (Japanese method)

b) Open end method

c) Packers method

II. Plate bearing test: - IS 1888

III. Insitu shear test

IV. Standard penetration test.

Procedure for the determination of permeability (Insitu) (Japanese Method):-

1. Scrap all the top loose material at the desired area to an extent of 6' x 6'
2. Make a trench of bottom dimensions 4' x 2' and 1' deep with side slopes 1:1. The trench may be excavated with vertical sides if the soil permits.
3. Have a can calibrated to 1/10 gallons from which water can be sent in to the trench.
4. Fillup the trench with water to a depth of 3'' from the top and go on feeding water into the trench so that level is maintained at the depth of 3'' from the top surface.

5. Record the water intake every one hour.
6. Experiment is to be repeated till the water intake is steady. Say for a period of 4 hours.
7. Extend the pit to dimensions 4' x 4' at the bottom by cutting an extra width of 1 ft on either end of the shorter sides of the trench.
8. Feed the trench with water as in the previous case maintaining the water level in the pit 3" from the top.
9. Measure the intake every hour for period of 2 hours (at least).
10. Determine the extra amount of water required to maintain the level in the pit after it has been extended.
11. If the extra amount of water is 1/100 gallon per hour the permeability is 1 ft/year.
12. If the extra amount of water is 1/10 gallon per hour, the permeability is 10ft/year.
13. If the extra amount of water is 1 gallon per hour - the permeability is 100ft/year.

    (One gallon = 4536 cc) or 4.536 lts

FIELD PERMEABILITY TEST :

Two types of bore hole permeability tests are in use. When compared to laboratory tests, insitu tests are reliable.

$= K = \frac{q}{5.5rh}$

a. Pumping in test,

b. Pumping out test.

Pumping test is further sub-divided into:

a) Open end Method:

An Open end pipe is sunk in the strata and the soil is taken out upto the bottom. Clean water is added through metering system to maintain gravity flow under constant head.

Permeability m/s

where h = difference in head of water (gravity + pressure)

r = radius of casing pipe

q = constant rate of flow.

b) Packers Method : $K = \frac{q}{2\pi Lh}\log\left(\frac{L}{r}\right)\ for\ L \geq 10\,r$ and

$$K = \frac{q}{2\pi Lh}\sin^{-1}\left(\frac{L}{2r}\right) for\ 10r > L \geq r$$

Where q = Constant rate of flow into bore hole

L = Length of test hole

r = radius of bore hole

h = differential head of water

BEARING CAPACITY:

A) Un disturbed soil samples are collected at the location of foundation by core cutters and seamless beveled edge sampling tubes.

Field dry density and field moisture contents are determined.

Shear parameters are also determined in the laboratory.

If $\varnothing > 36°$, general shear failure of the strata occurs

If , Local shear failure of the strata occurs

Bearing capacity factors are taken from the tables. The IS code method for computation for Bearing capacity is given in IS: 6403-81.

The ultimate net bearing capcity of strip footing is given in the following equation.

1. For General shear failure: For Local shear failure:

Where = q_u = ultimate bearing capacity

= bearing capacity factors.

C = Cohesion

= Angle of internal friction

=

= Density of soil

d = Depth of foundation from Ground level

B = Breadth of footing

Bearing Capacity from Plate Bearing test (IS: 1888-76): -

Plate load test is a field test to determine ultimate bearing capacity of soil and probable settlement under a given loading. The test essentially consists of loading a 25 mm thick rigid plate at the foundation level and determining the settlements corresponding to each load increment.

The ultimate bearing capacity is then taken as the load at which the plate starts sinking at a rapid rate.

The test pit is made 5 times the width of the plate Bp

When the load is applied to the plate, it sinks or settles. The settlement of the plate is measured with the help of sensitive dial guages.

Values of Safe bearing capacities according to IS: 1904 - 1986 (Reaffirmed 1995)

	Description	**Safe bearing capacity in T/M^2**
1.	Very soft clay which can be penetrated several inches with the thumb	5
2.	Soft clay indented with moderate thumb pressure	10
3.	Fine sand loose and dry	10
4.	B.C. soil or other shrinkable soil or expansive clay in dry condition (50% saturation)	15
5.	Moist clay and sandy clay mixture which can be indented with a strong thumb pressure	15
6.	Fine sand, silt (dry lump easily pulvorised by fingers)	15
7.	Medium clay readily indented with a thumb nail	25
8.	Loose gravel or sand gravel mixture Loose coarse to medium sand dry	25
9.	Medium sand compact and dry	25
10.	Soft shale hard or stiff clay in deep bed - dry	45
11.	Coarse sand compact and dry	45
12.	Gravel, sand and gravel compact and offering high resistance to penetration when excavated by tools	45

Bearing Capacity by Standard Penetration test:

Standard Penetration tests are conducted using split spoon sampler as per IS: 2131-1981. The SP is generally conducted in sandy and completely weathered rock strata till 45 cm penetration with number or blows recorded for every 15 cm penetration. The first 15 cm penetration is neglected and the blows for last 30 cm penetration is added and taken as SPT Value.

The SPT is continued untill either 45 cm has been penetrated or 'N' value or 100 blows has been applied, whichever is earlier in the clayey strata.

When drilling of sampler is not possible, the soil samples obtained in the SPT sampler are carefully packed in polythene bags for testing in the laboratory.

Computation of Net Bearing capacity as per IS: 6403-1981

SBC =

Where, q_{nu} = Net ultimate capacity

q_{nu} = Net Safe bearing capacity

C = Cohesion

$\varnothing$ = Angle of internal friction

q = Over burden pressure

B = Breadth of foundation

W = Water table correction factor

Bearing capacity factors

Shape factors

For stone footing shape factor =

For rectangular footing factor =

$= S_q = 1 + 0.2xB/L$

$S_\gamma = 1 - 0.4xB/L =$

Inclination factors:

$i_c = i_q = (1 - \frac{\propto}{90})^2$

$i\gamma = (1 - \frac{\propto}{\varphi})^2$

Where á = inclinaiton of load with vertical in degrees

For square footing = $S_c = 1.0, S_q = 1.2, S_\gamma = 0.8$

For Circular footing = $S_c = 1.3, S_q = 1.2, S_\gamma = 0.6$

Depth factors: d_c, d_γ

Pressure testing holes:

1. After grouting is completed, holes as required shall be water tested. In all grout holes when abnormal gain or loss of water is observed, hole pressure has to be tested.

2. Procedure for water pressure testing :

   a) The hole drilled for testing shall be isolated by sealing off with double packer attatched to a perforated steel pipe and lowered into the hole.

   b) If stage drilling method is used, a single packer shall be used.

   c) Water shall then be pumped into the section to be tested under pressure and periods specified here in -

      i) The time, pressure and quantities of water used for testing section of hole shall be recorded.

      ii) The lengths of test section shall be measured parallel to the direction of hole.

      iii) Hole shall be tested in 2 to 5 meters section

      iv) The pressure testing apparatus shall be periodically callibrated.

$d_q = d_\gamma = 1$ for $\varnothing < 10$

   d) The pressure test shall be performed in one continuous operation using the following pressures times :

Sl. No.	Pressure (P)	Psi	Elapsed time (in mts)
1	1/3	P	5
2.	2/3	P	5
3.	--	P	10
4.	2/3	P	5
5.	1/3	P	5

   The pressure P shall be determined depending on geological conditions and on the depth of upper package. However this pressure need not exceed 10 kg/cm^2 at the gauge. After 4 or 5 times the valve shall be closed and pressure drop observed and recorded for a minimum period of 3 minutes in each instance.

   e) A desirable degree of impermeability is considered to exist when the leakage obtained by applying water test to section of a hole drilled is less than 2 Lugeons (L) (ie)

   2 lugeons = two litres / Metre/ Minute of hole tested when pressure of 10 kg/cm^2 at the gauge point is applied for a period of 10 minutes.