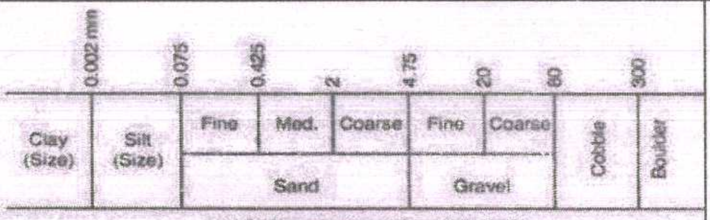
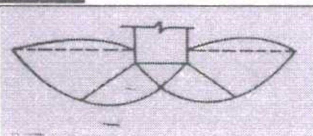
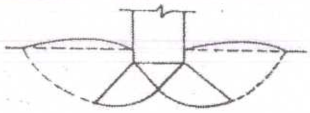
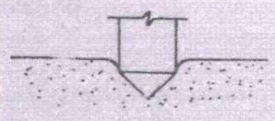
SCHEME OF EVALUATION

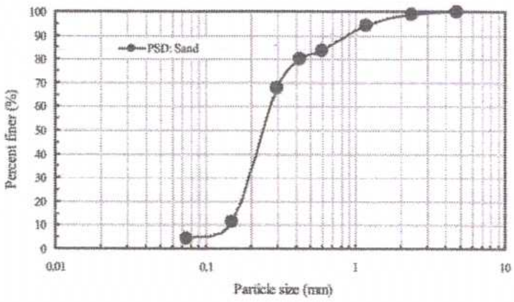
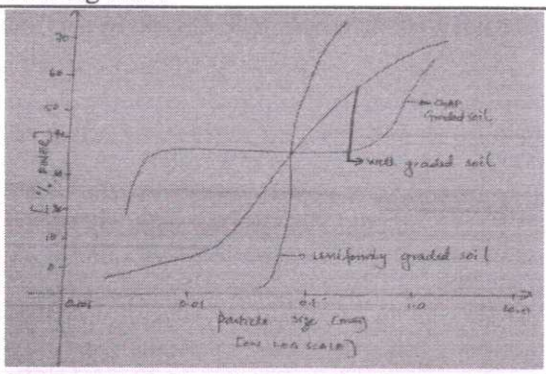
(Scoring Indicators)

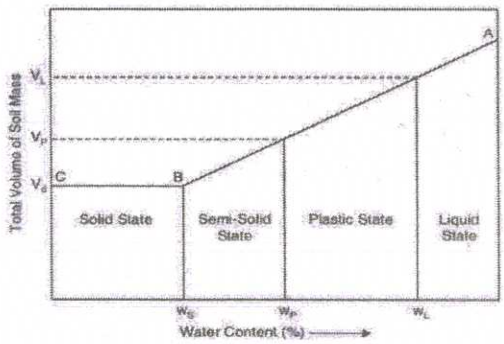
REVISION : 2015		COURSE CODE : 5013		
GEOTECHNICAL ENGINEERING				
Q. No.	SCORING INDICATOR	SPLITUP SCORE	SUB TOTAL	TOTAL
I.	**PART A**			
1	 (d) I.S. Classification (IS : 1498-1970)	2	2	
2	**Effective stress** is the pressure transmitted from soil particle to soil particle to soil particle through their point of contact in soil mass. It is represented by **σ' = σ - u**	1		
	Neutral stress is the pressure transmitted through the pore fluid.It is expressed as **u = γw * h**	1	2	
3	**Darcy's Law :** For Laminar flow conditions in a homogeneous soil, the rate of flow (v) or discharge (q) is proportional to hydraulic gradient (i).	1 1/2		
	v α i v = ki where k is coefficient of permeability	1/2	2	
4	Following parameters are found from N value ; Cohesive soil : Unconfined compressive strength	1		
	Cohensionless soil : Angle of shearing resistance and relative density	1	2	
5	1. Two columns are close to each other so that their induvidual isolated footings overlap.	1		
	2. If the property line is too close, providing isolated footing may lead to eccentric loading. Combined footing by combining the column to adjascent column is prefered.	1	2	10
II.	**PART B**			
1	Water content w = Ww/ Ws w = (Vw * γw)/(Vs * γs)………………………………(1)	1		
	We know Specific gravity of solids , G = γs/γw So, γs = G * γw ……………………………………(2)	1		
	Degree of saturation, S = Vw/Vv So , Vw = S*Vv ……………………………………(3)	1		
	(S*Vv*γw)/(Vs*G*γw) w = (S*Vv)/(G*Vs) ………………………………..(4)	1		

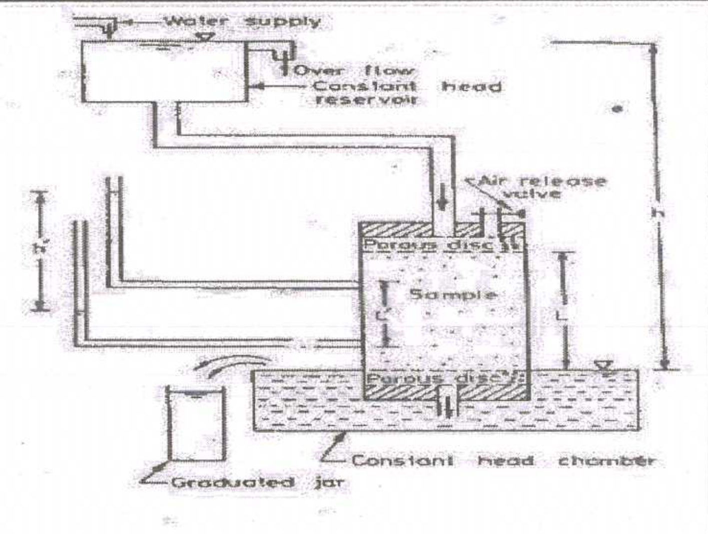
	But Void ratio e = Vv/Vs Vv=e*Vs ……………………………………………(5)	1	
	Substituting (5) in (4) and rearranging , e = (w*G)/S	1	6
2	1. First measure the internal diameter (Di) and height (H) of the core so that the volume (V) of the steel core can be determined.		
	2.Take note of the weight (W1) of the core by using physical balance.	1	
	3. Take the apparatus to the site and the soil at the site to be tested, should be levelled and cleaned.		
	4. Then fix the dolly on the core and start pressing the core in the soil. The ramming is done till only 15 mm of the dolly remains above the soil	1	
	5. After that remove the soil surrounding the core so that it can be pulled off easily.Then remove the dolly from the apparatus and the protruding soil sample is to be flushed by using a straight edge blade.		
	6. Note the weight of the soil including the core (W2). Calculate field density by the equation γ = (W2-W1)/V	2	
	7.After take representative sample for moisture content determination of soil. Moisture content (w) is determined by oven dring method.		
	8. Dry density is calculated by the equation, γd = γ / (1+w)	2	6
3	**Smooth Wheel Rollers** 1 . Has two wheels in rear and one wheel in front which are of drum shape. 2. Useful for finishing operations after compaction and for compacting granular base course of highways. 3. Not effective for compaction of deep layer of soil.	2	
	Pneumatic Tyred Roller 1. Has 9-11 tyres in two axles spaced in such a way that it gives maximum coverage. 2. Compaction by the contact pressure between soil and tyre. 3. Contact pressure depends on area of contact and inflation pressure. 4. Best equipment for light use.	2	
	Sheep Foot Rollers 1. Has hollow drum with small projections. 2. Compacts soil by kneading action. 3. Useful for compaction of cohesive soils. 4. At first, projections penetrate to the soil and compacts lower potion. In successive passes middle and top are compacted.	2	6

4	**Free Water :** Free water moves in pores of soil under the influence of gravity. The flow is similar to laminar flow in pipes		
	Held water : The water which is retained in pores of water and cannot move under the influence of gravity is called held water. It is of three types	1 1/2	
	1. Structural water : It is the chemically combined water in the crystal structure of the mineral of the soil. This water cannot be removed without breaking the structure of the mineral.	1 1/2	
	2. Adsorbed water : The water held by electrochemical forces existing on the soil surface is adsorbed water. Adsorbed water is also known as hygroscopic water. Adsorbed water is important for clayey soil. For sandy soil adsorbed water is zero.	1 1/2	
	3. Cappilary water : Water held in interstices of soil due to cappillary forces is called cappillary water. The inter connected voids in the soil mass acts as cappillary tubes of varying diameters and water rises through these voids by adhesion, cohesion and surface tension.	1 1/2	6
5	***(Can be given full 6 marks if atleast 6 points are noted)***		
	Its through reconnaissance that a geotechnical engineer plans and decides what type of investigation has to be carried out at the specific site.		
	The following information is obtained through a reconnaissance;		
	1. General topography of the site, the existence of drainage ditches and dumps of debris and sanitary fills.		
	2. Existence of settlement cracks in the structure already built near the site.		
	3. Evidence of land slides, creep of slopes and shrinkage cracks.		
	4. Stratification of soil as observed from deep cuts near the site.		
	5. Location of high flood marks in nearby buildings and bridges.		
	6. Depth of ground water table as observed from wells.		
	7. Existence of springs and swamps.		
	8. The drainage pattern existing at the site.		
	9. Type of vegetation existing at the site. The type of vegetation gives a clue to the nature of the soil.		
	10. Existance of underground water mains, power conduits etc. at the site.		
	11. In addition, Engineer study geological maps, Arial photographs, and blue prints of existing buildings to get an overall information about the area.	6	6

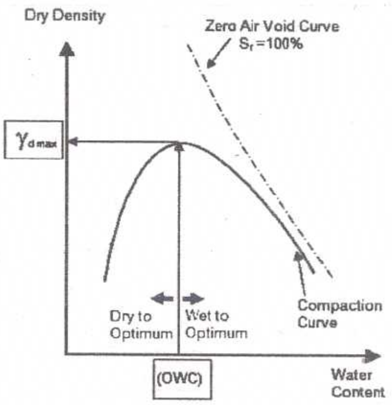
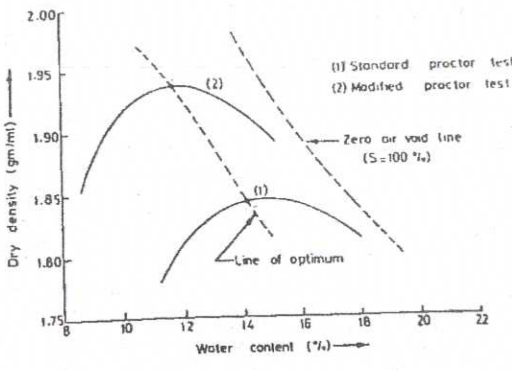
6	*(Any two shall be answered for full credit : total 2*3 = 6 marks)*			
	<u>General Shear Failure</u>			
	 (a) GENERAL SHEAR FAILURE			
	General shear failure takes place on dense sand or stiff clay.			
	Failure nature is charachterised by distinctive heave of soil on both sides.			
	<u>Local Shear Failure</u>			
	 (b) LOCAL SHEAR FAILURE			
	Local shear failure takes place on medium dense sand or clay of medium consistency			
	Heave is observed only when there is substantial settlement			
	<u>Punching Shear Failure</u>			
	 (c) PUNCHING SHEAR FAILURE			
	Punching shear failure takes place on loose sand or soft clay.			
	No heave. But vertical movement of the footing takes place.	6	6	
7	1. The dead load from each column, including the weight of the footing is calculated. 2. The maximum live load to which each footing is subjected is determined. 3. The ratio of maximum live load to maximum dead load is calculated. 4. The footing that has the largest live load to dead load ratio is taken as the governing footing. 5. The area of governing footing (Ag) is calculated by, **Ag = (DL+LL) / Allowable Bearing Capacity** 6. The service loads for all footings are determined. 7. The design bearing capacity (qd) of all the footings, except the governing footing is determined as, **qd = Service Load for Governing Footing / Ag** 8. The area of other footings is determined as, **A= Service Load for that Footing / qd**	6	6	30

	PART C			
III a)	 	1 1/2		
	Particle size distribution curve or gradation curve represents the distribution of particles of different sizes in the soil mass. It has percentage finer on y axis and particle size marked on x axis on a log scale.	1 1/2		
	 	1 1/2		
	Gap Graded Soil : The soil in which some intermediate particles are missing is called gap graded soil.	1 1/2		
	Well Graded Soil : A flat S curve represents soil which contains particles of different sizes in good proportion. Such a soil is called well graded soil.	1 1/2		
	Uniformly Graded Soil : A steep curve which indicates the soil containing particles of same size. Such soils are called uniform soils.	1 1/2	9	
III b)	**Dry Density :** $\gamma d=$ $\gamma/(1+w) = 22/(1+0.12) = 19.64$ kN/m^3	2		
	Void Ratio : $\gamma d=$ $(G\gamma_w)/(1+e)$ $e =$ $\{(G\gamma_w)/\gamma d\} - 1 = \{(2.7*10)/19.64\}-1 = 0.375$	2		
	Degree of Saturation : $e =$ $(wG)/S$ $S =$ $wG/e = (0.12*2.7)/0.375 = 0.864 = 86.4\%$	2	6	15
IV a)	**Residual Soil :** The soil which resides at or near parent rock with out getting transported is called residual soil. **Transported Soil :** Transported soil gets transported by agents like wind, water, glacier and gravity and get deposited away from parent rocks. Eg : Aeolian soil, Alluvial soil, Colluvial soil etc.	2	2	

IV b)	 CONSISTENCY LIMITS	1 1/2	
	Liquid Limit (w_l) : Water content at which soil changes from liquid state to plastic state is liquid limit	1 1/2	
	Plastic Limit (w_p) : Water content at which the soil starts behaving as a plastic material is called plastic limit.	1 1/2	
	Shrinkage limit (w_s) : Maximum water content at which reduction of water content will not cause a decrease in volume of soil mass is called shrinkage limit.	1 1/2	6
IV c)	1. About 120 gm of air-dried soil from thoroughly mixed portion of material passing 425 micron I.S sieve is to be obtained.		
	2. Distilled water is mixed to the soil thus obtained in a mixing disc to form uniform paste. The paste shall have a consistency that would require 30 to 35 drops of cup to cause closer of standard groove for 12 mm length.		
	3. For clayey soil leave it for 24 hours prior to test to ensure distribution of Moisture throughout the soil mass.		
	4. The soil should then be remixed thoroughly before the test. A portion of the paste is placed in the cup of Mechanical Liquid Limit device and spread into portion with few strokes of spatula as possible.	1	
	5. The soil is placed in the cup of Casagrande's apparatus and a groove is made using standard grooving tool (Indian Standard/ Casagrande's Grooving Tool for Clayey soils and ASTM Grooving Tool for sandy soils) along the diameter through the centre line.	1 1/2	
	6. 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 12 mm by flow only.	1	
	7. The number of blows required to cause the groove close for about 12 mm shall be recorded.	1	
	8. A representative portion of soil is taken from the cup for water content determination by oven drying method.		
	9. Repeat the test with different moisture contents at least three more times for blows between 15 and 35.	1	

	10. A graph is plotted between water content in y axis and number of blows in x axis. The water content corresponding to 25 blows is the liqid limit of soil.	1 1/2	7	15
V a)	 Fig. Constant Head Permeameter	4		

	1. Soil specimen of length 'L' is kept in a mould between two porous discs.			
	2. Water is allowed to flow through the sample from a reservoir designed to keep the water level constant.			
	3. The sample is placed in a constant head chamber which also has its water level maintained constant.			
	4. The level difference between the water levels in reservoir and the chamber is the head causing flow 'h'.			
	5. Water which passes through the soil sample spills over the chamber and is collected in a graduated cylinder.			
	6. The quantity of water collected 'Q' in time 't' is noted.	2		
	7. k is calculated by following equation : $q = \frac{Q}{t} = k\,i\,A$; $k = \frac{Q}{t}\frac{1}{iA}$; $\therefore \boxed{k = \frac{QL}{Aht}}$ k : Coefficient of permeability (cm/s) A : Cross sectional area of the soil sample (cm^2) q : Discharge per unit time (cm^3/s) Q : Quantity of water collected (cm^3) in jar in time t (s) i : Hydraulic gradient = h/L	1		
	8. Due to settling of finer particles at ends permeability at ends will be different from middle.			
	9. To measure permeability at middle, two piezometers are placed at middle at a distance of L'.			
	10. The head difference between the piezometers is h'.			
	11. Accurate value of k can be obtained by substituting i = h'/L' in the above equation.	2	9	

V b)	k= (aL/At) ln (h_1/h_2)	1		
	A = (π/4) * 4* 4 =12.57 cm^2	1		
	$1.09*10^{-3}$ = {(1*18)/(12.57*t)}ln (1/0.4) So, t = 1204 seconds (*Near values can be given full credit*)	4	6	15
VI a)	**<u>1. WATER CONTENT</u>** Upto OMC dry density increases as water lubricates soil particles and move to a densely packed state. Beyond OMC, dry density decreases when water content increases. Air voids attains a constant volume and hence cannot be decreased further leading to the increase in volume and thus the dry density decreases 	2		
	<u>2.AMOUNT OF COMPACTION</u> Increasing compactive effort ; a) Increases maximum dry density b) Decreases OMC However the effect on dry density while compacting decreases as water content increases. 	2		
	<u>3. TYPE OF SOIL</u> Coarse grained soils can be compacted to higher density than fine grained soil. Well graded soil attains higher dry density than poorly graded soil.			

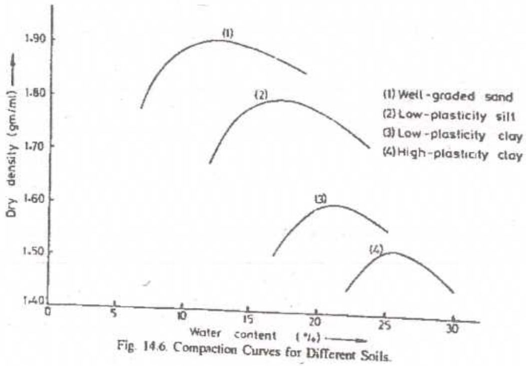


Fig. 14.6. Compaction Curves for Different Soils.

2

4. METHOD OF COMPACTION

The dry density achieved depends on method of compaction.

Methods of compaction can be by ;

a) Kneading action

b) Dynamic action

Different compaction gives different compaction curve and different line of optimums.

2

5. ADMIXTURES

Compaction characteristics can be improved by using admixtures.

Lime, cement and bitumen are most commonly used admixtures.

1 | 9

VI b)

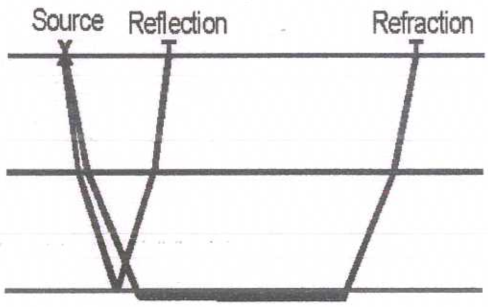
PARTICULARS	STANDARD PROCTOR TEST	MODIFIED PROCTOR TEST
As Per BIS	Light Compaction	Heavy Compaction
Rammer Weight	2.6 kg	4.89 kg
Drop Height	310 mm	450 mm
No. of Layers	3	5
No. of Blows per Layer	25	25
Illustration		

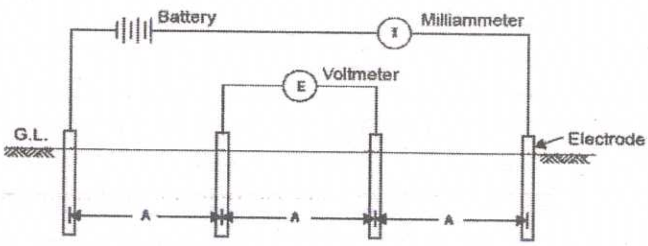
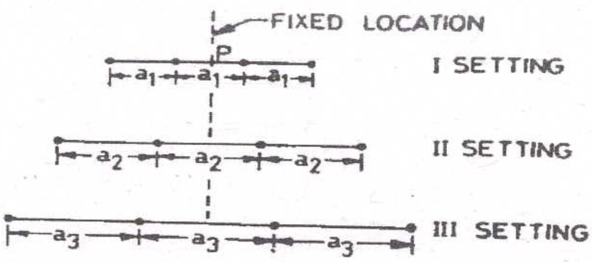
6 | 6 | 15

VII a)

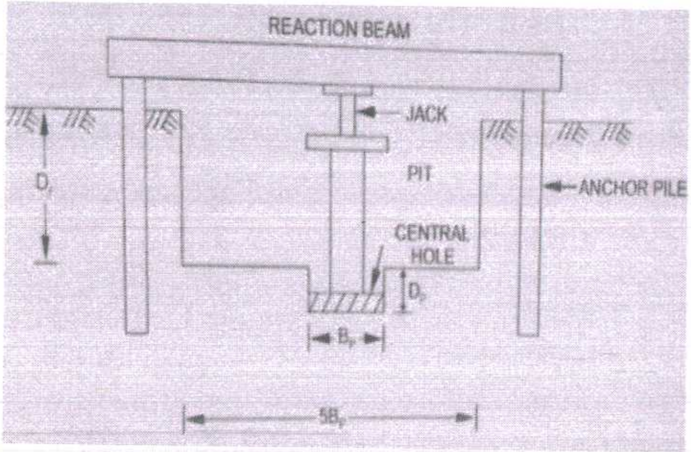
(For any six points full credit can be given)

1. To select type and depth of foundation for a given structure.
2. To determine the bearing capacity of soil.
3. To estimate the probable maximum and differential settlements.
4. To establish the ground water level and to determine the properties of water.
5. To predict lateral earth pressure against retaining walls and abutments.

	6. To select suitable construction technique. 7. To predict and solve potential foundation problems. 8. To ascertain the suitability of the soil as construction material. 9. To investigate the safety on the existing structures and to suggest the remedial measures.	6	6		
VII b)	**1. Seismic Methods** • Principle : o Elastic shock waves have different velocities in different materials. o At the interface of two different materials, the waves get partially reflected and partially refracted. • The shock waves are created by hammer blows. • Geophones are located at different intervals on soil surface. • Assumed that velocity at different layers increases as depth increases. • This velocities at different layers are calculated by plotting distance v/s time plot and taking the reciprocal of respective slopes. Different soil has different velocities and the soil is identified from the velocity measured.  The depth of each stratum is calculated by equations.	3			
	2. ELECTRICAL RESISTIVITY METHODS • Principle : o Electrical resistivity of a conductor (ρ) Is expressed as, $\rho = RA/L$ R : electrical resistance in ohms A : area of cross section of the conductor (cm2) L : length of the conductor (cm) • The resistivity of any material depends upon the type material, water content in it and many other factors. • So the value of resistivity gives an idea about the material				

	In soil electrical resistivity is calculated by two methods. i.Electrical Profiling Method ii.Electrical Sounding Method.	2		
	i.Electrical Profiling Method • Four electrodes are spaced at constant spacing and are driven into the ground. Two outer electrodes : Current Electrodes Two inner electrodes : Potential Electrodes • DC current is applied at the current electrodes. • Voltage drop between inner electrodes is measured using voltmeter and resistivity is calculated as, $\rho = 2\pi aV/I$ (I = current supplied, a = electrode spacing and v = voltage drop.) 	2		
	ii.Electrical Sounding Method • In this method the spacing between the electrodes are increased about a fixed point in different steps (setting) as shown in the figure. • In each setting the spacing of electrode will be equal to the depth of soil at which the investigation is carried out. • Resistivity at each of this depth is calculated by the method as described in the electrical profiling method. • The resistivity values gives an idea about the type of soil as seen in the table in previous section. • By the sounding method we will be able to study the variation of the soil strata at different depths. 	2	9	15

VIII a)



3

Conducted to estimate allowable bearing pressure of soil in field.

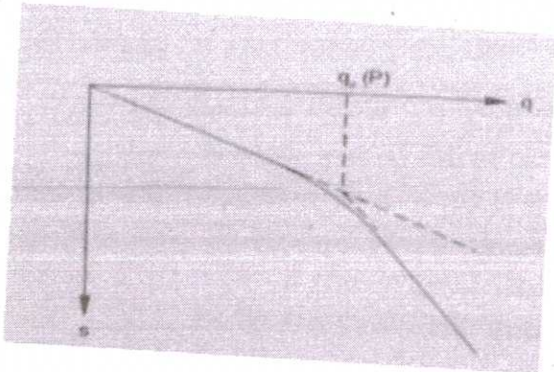
1. A pit of size 5Bp x 5Bp is excavated in soil to a depth equal to the depth of foundation (Df). (Bp is the width of the plate. Usually steel plates of area 0.3 m square and 25 mm thickness are used).

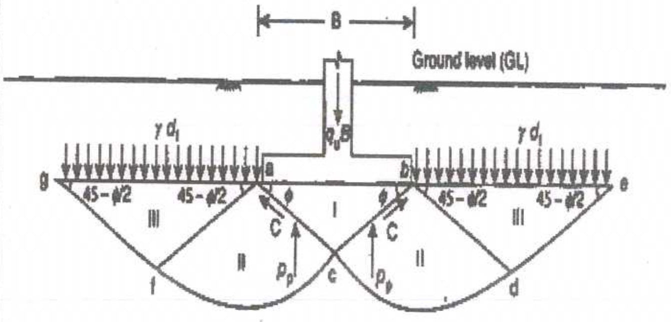
2. A central hole of size Bp x Bp is excavated in the pit. The depth of the pit (Dp) is obtained by the following relation ;

$$D_p/B_p = D_f/B_f$$

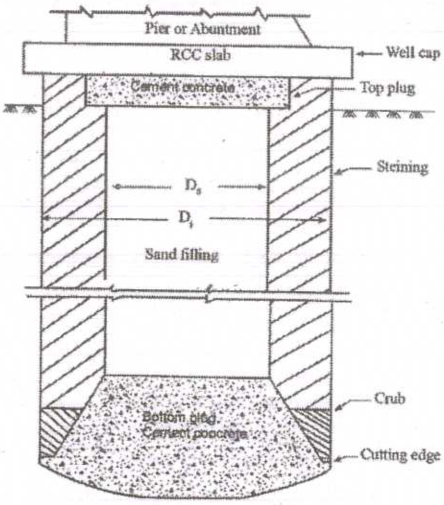
$$Dp = Bp * (Df/Bf)$$

3. Plate is placed on the central hole and load is applied by means of a hydraulic jack.
4. The reaction to jack is provided by a reaction beam.
5. A seating load of 7 kN/m2 is initially applied and released after sometime.
6. Then the loads are applied at an increment of 20% of estimated safe load or 1/10th of ultimate load.
7. Settlements are recorded after 1,5,10,20,40,60 minutes and further after an interval of one hour.
8. The observations are taken until the rate of settlement become 0.2mm per hour for clayey soils.
9. Test is conducted till a settlement of 25 mm is reached or until failure for sandy soils.
10. The results are plotted (load-settlement plot) in a log-log plot or natural plot.
11. In log-log plot, the ultimate load (qu) is represented by a break. If break is not well defined, then load corresponding to a settlement of 1/5th of Bp is taken as qu.
12. In natural plot, qu is obtained from intersection of the tangents as shown.

		3		
	• The ultimate bearing capacity of proposed foundation $q_u(f)$ can be obtained from the following relations : For Clayey soils, $q_u(f) = q_u(p)$ For sandy soils, $q_u(f) = q_u(p)\,\frac{B_f}{B_p}$ • The settlement of foundation (s_f) for a given intensity of loading can be found from the settlement of plates (s_p) for the same load intensity using the following relations ; For Clayey soils, $s_f = s_p\,\frac{B_f}{B_p}$ For sandy soils, $s_f = s_p\left[\frac{B_f(B_p+0.3)}{B_p(B_f+0.3)}\right]^2$	2	8	
VIII b)	**ASSUMPTIONS** 1. The base of the foundation is rough. 2. The footing is laid at a shallow depth, i.e. Df<= B. 3. The shear strength of the soil above the base of the soil is neglected and soil above is replaced by a uniform surcharge γ*Df. 4. The load on the footing is vertical and is uniformly distributed. 5. The footing is long, i.e. L/B ratio is infinite, where B is the width and L is the length of the footing. 6.The shear strength of soil is governed by Mohr-Coulomb equation.	3		

	TERZAGHIS'S ANALYSIS  Figure 18.2 Failure surface as per Terzaghi's theory. I. ZONE I - Wedge abc behaves as a part of footing itself. II. ZONE II - cbd and caf are Radial shear zones. III. ZONE III - Rankine's Passive Zone, overburden pressure of γD_f acts here.	2		
	TERZAGHIS'S EQUATION $q_u = C'N_C + \ qo\,Nq + 0.5\,\gamma B N_\gamma$ $N_c = \cot\phi'\left[\frac{a^2}{2\cos^2\left(45^0+\frac{\phi'}{2}\right)}-1\right]$ $N_q = \left[\frac{a^2}{2\cos^2\left(45^0+\frac{\phi'}{2}\right)}\right]$ Where $a = e^{\left(\frac{3\pi}{4}-\frac{\phi'}{2}\right)\tan\phi'}$ and $N_r = \frac{1}{2}\left[\frac{K_p}{\cos^2\phi'}-1\right]\tan\phi'$ N_C, N_q, N_γ : Bearing Capacity Factors. ϕ or ϕ' : Angle of Shearing Resistance. q_0 : Overburden pressure, γD_f Kp : Coefficient of passive earth pressure.. B : Width of foundation C' : Cohesion	2	7	15
IX a)	Pile foundation is required ; 1.When strata below the soil is highly compressible and weak. 2.When plan of the structure is irregular and providing shallow foundation may cause differential settlement. 3. To carry structural loads through a deep water body to a hard stratum.			

	4. For resisting horizontal loads due to wind and earthquake in tall structures and retaining structures 5. For transmission towers, offshore structures and other structures subjected to uplift. 6. In collapsible soils and expansive soils.	5	5	
IX b)	**<u>1. Classification based on type of material</u>** Steel pile, concrete pile, Timber piles and composite piles	1 1/2		
	<u>2.Classification based on mode of load transfer</u> a. End Bearing Piles : Transfer the loads to the hard strata through its bottom end. b. Friction Piles : Do not reach the hard stratum. Transfer of the loads is by skin friction between the surface of the pile and soil surrounding. c. Combined End Bearing and Friction Piles : Piles that transfer loads by combined end bearing at the bottom and skin friction on sides.	1 1/2		
	3. **<u>Classification based on installation method</u>** a. Driven Piles : Piles that are driven to the ground by blow of hammer. b. Driven and Cast in-situ Piles: First a casing with closed bottom is driven into the soil and then concrete is poured into the casing.. c. Bored and Cast in-situ Piles: Holes are excavated on the ground and the concrete is poured into the bored hole. d. Screw Piles : Piles are screwed into the soil. e. Jacked Piles : Piles are jacked into the soil by means of a hydraulic jack.	2 1/2		
	<u>4. Classification based on use</u> a.Load Bearing Pile : Piles that transfer loads to the stratum of soil b.Compaction Piles : Driven into the loose soil to increase its density. They increase bearing capacity. c.Tension Piles : Piles are under tension. Used to anchor down structures subjected to uplift and overturning forces d. Sheet Piles : Sheet piles forms a continuous wall which is used for retaining earth or water. e. Fender Piles : Sheet piles used to protect water front structures from impact of ships. f. Anchor Piles : Used provide anchorage for anchored sheet piles.	3		
	<u>5. Classification based on displacement of soil</u> a. Displacement Piles : All driven piles are displacement piles. The soil is displaced laterally while installing the piles. Soil gets densified in this case.			

	b. Non-displacement Piles : Bored piles are non displacement piles. As the soil is removed by boring before the installation of the pile, here there is no movement of the soil in lateral direction and hence the name non displacement piles.	1 1/2	10	15
X a)	 Fig 1 Parts of a Well Foundation	4		
	Cutting edge To facilitate sinking of well. **Well curb** Tapered portion of well above the cutting edge. **Steining** * Walls of the well. * Made of brick masonry , stone masonry, PCC or RCC. * Designed to resist the imposed loads, * Should be heavy to overcome frictional resistance while sinking. **Bottom plug** * Base of the well. * After well sunk to its final position plug is formed by concreting. * To transmit loads from the well to the soil. Shape of bulb to provide arch action. **Sand Filling** * The well is partly or fully filled with sand. * Purpose is to provide stability to the well by increasing its weight. * Not a an integral part of structural well as sand does not transfer load. **Well Cap** * RC slab at the top of well. * Transmits the load of superstructure to the well. **Top Plug**			

* Top plug is formed by concreting at the top of the well.
* Not required if well cap is provided.
* However generally provided as a precaution. 4 8

X b) *(Full credit can be given if atleast 5 methods are briefly explained)*

1. Regulation of Grabbing

* At initial stages, higher side is grabbed more by controlling dredging.
* At later stages if well is tilted, a hole is made in the steining on the higher side and the rope of grab is pulled through the hook.

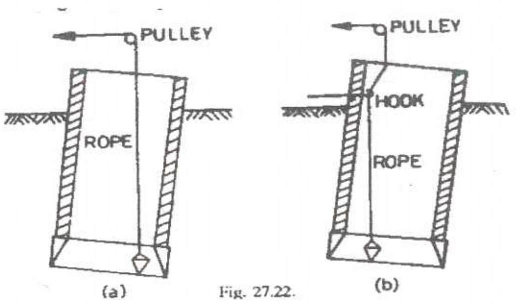


Fig. 27.22.

2. Eccentric Loading

* To provide greater sinking effect on higher side, eccentric loading is provided by adjusting kentledge.
* An additional platform is constructed on higher side for this purpose.
* As sinking progresses heavier loads are applied eccentrically to rectify the tilt.

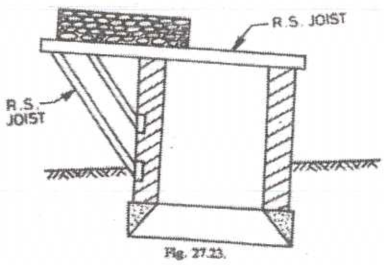


Fig. 27.23.

3. Water Jetting

To reduce side friction on higher side, water jets can be applied.

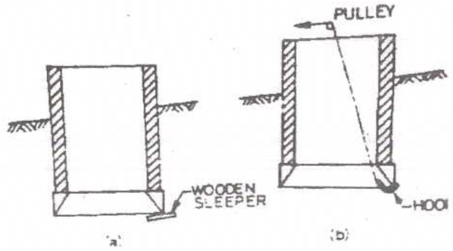
4. Excavation Under Cutting Edge

* If some hard strata remains below the cutting edge, the well does not straighten up.
* If dewatering of the well is possible, open excavation can be done under cutting edge.
* If dewatering is not possible, divers can be sent to loosen the strata.

5. Inserting Wooden Sleeper under Cutting Edge

* Wooden sleepers are provided below cutting edge on lower side to avoid further tilt.

* A hook can be inserted and can be pulled by a rope to keep the well straight.



6. Pulling the Well

* In early stages, the well can be pulled to higher side by using steel ropes.
* Vertical sleepers are provided to distribute pressure uniformly over steining.

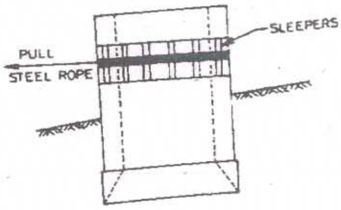


Fig. 27.25

7. Strutting the Well

Well is strutted on tilted side with suitable wooden logs to prevent further tilt.
Sleepers provided to distribute loads to the steining.

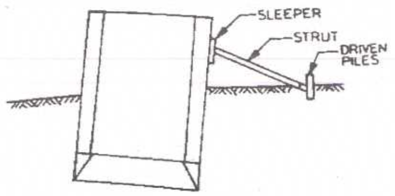


Fig 27.26

8. Pushing the Wells by Jacks

The tilt can be rectified by pushing the well with a suitable arrangement through mechanical or hydraulic jacks.

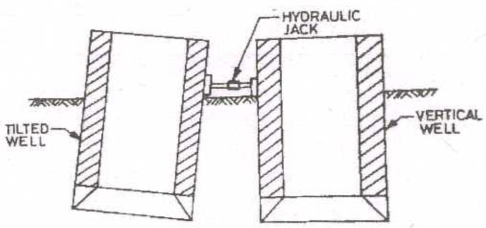


Fig. 27.27.

		7	7	15