Model Answer: Winter-2019

Subject: Geotechnical Engineering | **Sub. Code: 22404**

Important Instructions to Examiners

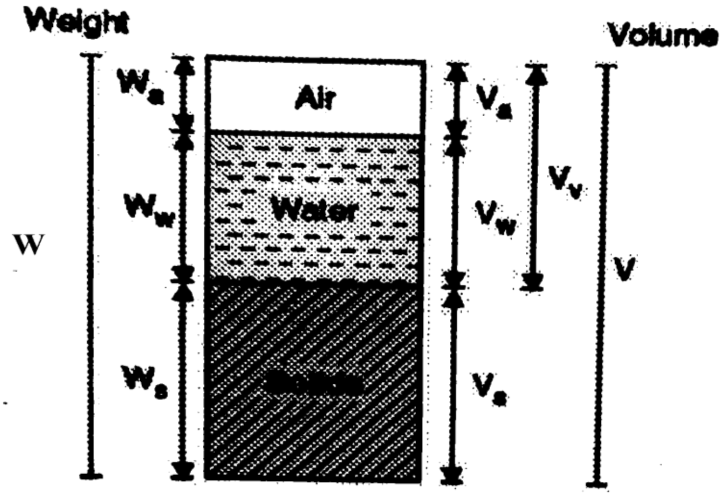
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more importance. (Not applicable for subject English and Communication Skills.)
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by the candidate and those in the model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and the model answer.
6) In case of some questions credit may be given by judgment on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

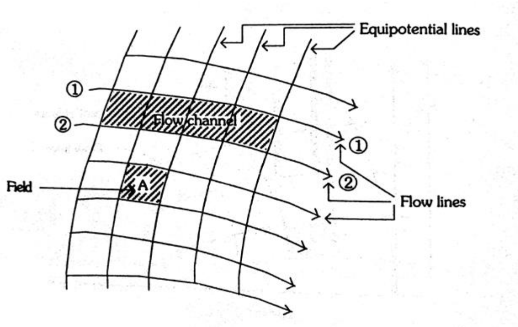
Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.1		**Attempt any FIVE of the following:**		**10**
	(a)	**Define soil as per I.S.**		
	Ans.	**Definition of soil as per IS:2809-1972:** Soil is the sediment or other unconsolidated accumulation of solid particles produced by physical and chemical disintegration of rock	**2**	**2**
	(b)	**Define a Rock and state one type of it.**		
	Ans.	**Rock:** It is the aggregate of minerals, called as rock.	**1**	
		Types of Rock: 1. Igneous rock 2. Sedimentary rock 3. Metamorphic rock	**1 (any one)**	**2**
	(c)	**Define voids ratio and porosity.**		
	Ans.	**Voids ratio:** It is the ratio of volume of voids to volume of solids called as voids ratio.	**1**	
		Porosity: It is the ratio of volume of voids to the total volume of soil; called as porosity.	**1**	**2**

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.1	(d)	**Define: (i) Water content (ii) Plasticity index**		
	Ans.	**(i) Water content:** It is the ratio of weight of water to weight of soil solids, measured in percentage, called as water content.	1	
		(ii) Plasticity Index: It is numerical difference between liquid limit and plastic limit values of one particular soil, called as plasticity index.	1	2
	(e)	**Enlist any two the methods of soil stabilization.**		
	Ans.	**Methods of soil stabilization:** 1. Mechanical stabilization 2. Cement stabilization 3. Lime stabilization 4. Bitumen stabilization 5. Fly ash stabilization 6. Chemical stabilization 7. Stabilization by heating 8. Stabilization by freezing 9. Stabilization by grouting	**1 each (any two)**	2
	(f)	**State relation between e, S and W, G.**		
	Ans.	**Relation between e, S and W, G:** S. e = W. G **OR** S = (W. G) / e	2	2
	(g)	**Define soil exploration.**		
	Ans.	**Soil exploration:** It is the technique of acquiring the information of subsoil before the proposed construction work; is known as soil exploration.	2	2

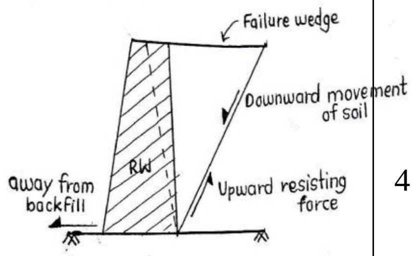
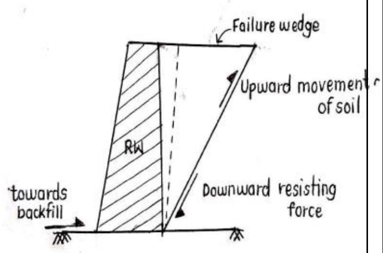
Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.2		**Attempt any THREE of the following:**		12
	(a)	**Write step by step procedure for determination of specific gravity by pycnometer bottle.**		
	Ans.	**Procedure for determination of specific gravity by pycnometer bottle:** 1. Clean the pycnometer bottle and dry it. Take the weight of empty pycnometer with conical cap as ‘W_1’ gm. 2. Oven dry the given soil sample passing through 4.75 mm and retained on 75 micron IS sieve, in oven at temperature 105-1100C for 24 hours to get dry soil. 3. Place this soil sample about 150-200 gm. in the pycnometer and take its weight as ‘W2’ gm. 4. Now add the distilled water to half of height of pycnometer and stirrer it using glass rod, so that entrapped air will be removed from soil. Fill the distilled water up to top of conical cap using pipette. Take the weight of pycnometer filled with distilled water as ‘W3’ gm. 5. Remove all content from the pycnometer bottle. Wash and clean it with water. 6. Fill the pycnometer bottle with distilled water only up to top of conical cap. Take the weight of pycnometer completely filled with water as W4 gm. 7. Calculate the specific gravity G of given soil as, as $G = (W_2 - W_1) / ((W_4 - W_1) – (W_3 - W_2))$ 8. Repeat all above steps two more times to calculate average specific gravity of given soil sample.	4	4
	(b)	**The density of soil sample is 2000 kg/m^3 and its water content is 16 %. Determine its dry density, voids ratio, porosity and degree of saturation.**		
	Ans.	Given: γ = 2000 kg/m$^3 = 2 gm/cc$, w = 16 % = 0.16, Calculate: $\gamma_d, e, \eta, S = ?$ *To* find dry density γ_d, $\gamma_d = \frac{\gamma}{1 + w}$ $\gamma_d = \frac{2}{1 + 0.16}$ $\boxed{\gamma_d = 1.724 \text{ gm/cc}}$	1	

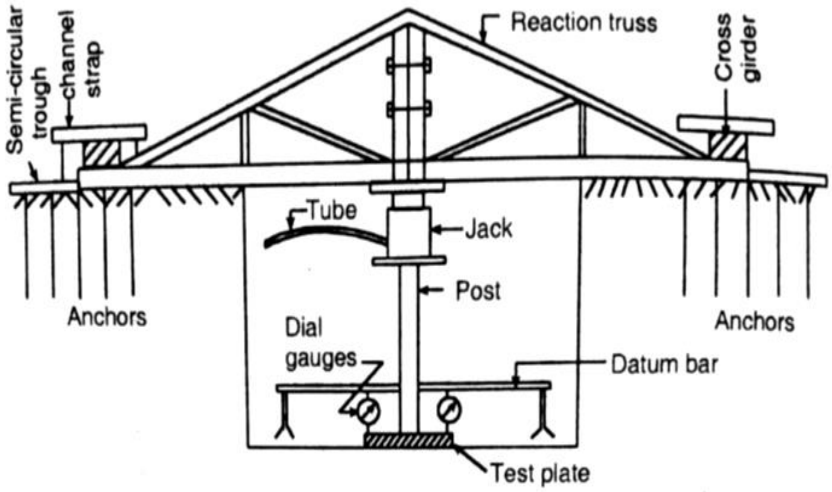
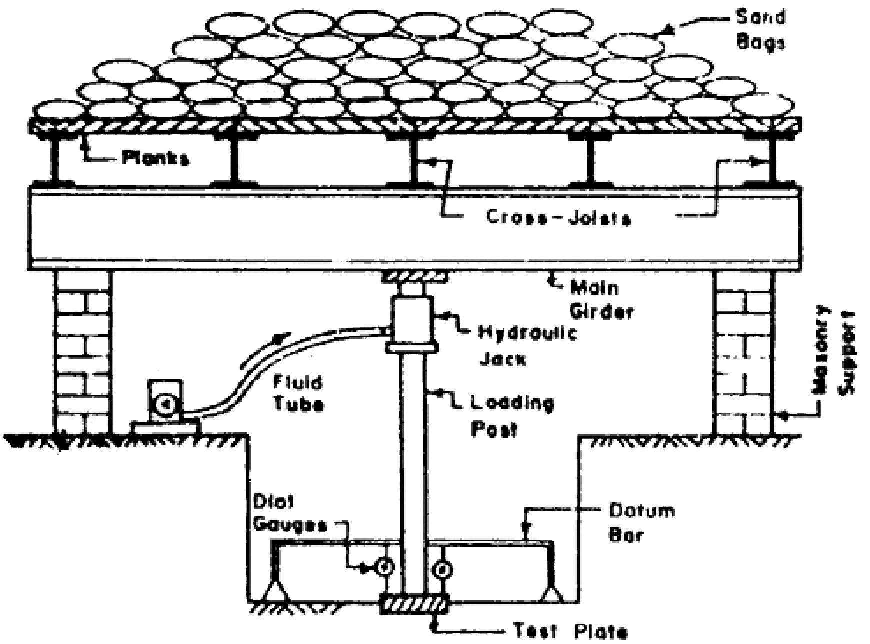
Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.2	**(b)** **Ans.**	*To* find coids ratio e, Assume specific gravity G = 2.7 Density of water $\gamma_w = 1 gm/cc$ $\gamma_d = \frac{\gamma_w \times G}{1 + e}$ $1.724 = \frac{1 \times 2.7}{1 + e}$ $\boxed{e = 0.566}$	1	**12**
		To find porosity η, $\eta = \frac{e}{1 + e}$ $\eta = \frac{0.566}{1 + 0.566}$ $\eta = 0.3614$ $\eta = 0.3614 \times 100$ $\boxed{\eta = 36.14\ \%}$	1	
		To find degree of saturation S, $S = \frac{w \times G}{e}$ $S = \frac{0.16 \times 2.7}{0.566}$ $S = 0.7632$ $S = 0.7632 \times 100$ $\boxed{S = 76.32\ \%}$	1	4

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.2	(c)	**Explain soil as three phase system with labelled sketch.**		12
	Ans.	**Soil as three phase system**: 1. As natural soil contains solid soil particles and water and air present in its voids such complex nature of soil sample is difficult to analyze its physical properties Hence it is simplified and presented in its equivalent 3 phase diagram as shown in figure below. 2. Depending upon three phase diagram of soil its is classified in three categories- 1. Dry soil 2. Partially saturated soil 3. Fully saturated soil. 3. However if we take a dry soil mass, the voids are filled with air only. In case of perfectly saturated soil the voids are filled completely with water. In case of partially saturated soil, both air and water are present in the voids.	3	
		 **Figure.: Three Phase System of Soil**	1	4
	(d)	**Explain the importance of geology in civil Engineering Construction.**		
	Ans.	**Importance of geology in civil engineering construction:** 1. Geology is essential to know the nature if substrata and hence helpful to decide the depth of foundation for important structures. 2. Geology is also required to know the properties of rock beneath the earth surface which becomes beneficial to design earthquake resistance structures. 3. It is important to find the most suitable site for dams, bridges etc 4. Geology plays vital role in groundwater survey and related recharging process. 5. It is significant in tunnel excavation projects as it provides information of rock strata and its engineering properties. 6. It is also important to excavate raw materials for stone crushing plant to manufacture aggregates.	**1 each (any four)**	4

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.3		**Attempt any THREE of the following:**		12
	(a)	**Define flow net and state its characteristics with neat sketch.**		
	Ans.	**Definition of flow net:** It is the grid network formed due to intersection of flow (stream) lines and equipotential lines, called as flow net.	1	
		Characteristics of flow net: 1. The flow lines and equipotential lines in the flow net intersects each other orthogonally 2. The area or field formed due to intersection of these lines is approximately square 3. The quantity of water flowing through each channel is almost same. 4. Smaller dimensions of the field indicate greater hydraulic gradient and more velocity of flow. 5. The potential drop between two adjacent equipotential lines is same.	1 each (any two)	
		 **Figure: Flow net**	1	4
	(b)	**State any four assumptions made in Terzaghi's analysis if bearing capacity of soil.**		
	Ans.	**Assumptions of Terzaghi's bearing capacity failure theory:** 1. Soil behaves like ideally plastic material. 2. Soil is homogeneous, isotropic and its shear strength is represented by Coloumb's equation. 3. The total load on footing is vertical and uniformly distributed. 4. The footing is long enough with $L/B = \infty$. 5. The shear strength above base of footing is neglected and taken as uniform surcharge γ_{Df}. 6. The elastic zones developed has straight boundaries inclined at $\psi = \phi$.	1 each (any four)	4

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.3	(c)	**Differentiate between active and passive earth pressure.**		
	Ans.	**Difference between active and passive earth pressure:**	1 each	4

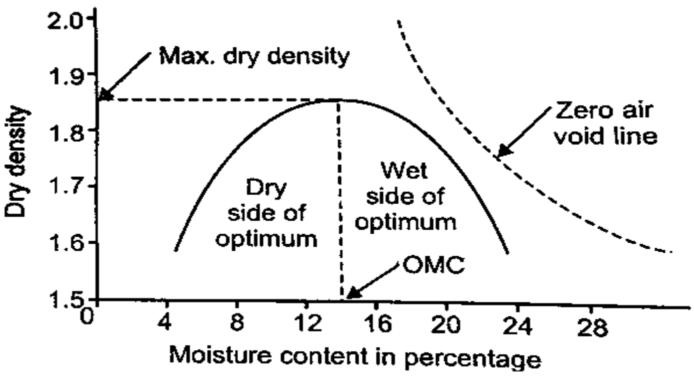
	Active Earth Pressure		**Passive Earth Pressure**
1	The pressure exerted by backfill soil on retaining wall, is called as active earth pressure.	1	The pressure exerted by retaining wall on soil is known as passive earth pressure.
2	It is developed due to movement of wall away from backfill	2	It is developed due to movement of wall towards backfill.
3	Active earth pressure should be less for stability of retaining structures.	3	Passive earth pressure should be more to ensure stability of retaining structures.
4	 Fig : Active Earth Pressure	4	 Fig. : Passive Earth Pressure

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.3	(d) Ans.	**Draw a neat labelled sketch of plate load test set up for determination of field bearing capacity.**  **Figure: Plate Load Test using Reaction Truss Loading** **OR**  **Figure: Plate Load Test using Gravity Loading** ***(Note: 2 marks for sketch and 2 marks for label.)***	4	4

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.4		**Attempt any THREE of the following:**		12
	(a)	**Calculate active earth pressure and passive earth pressure at depth of 9 m in dry cohesionless soil with an angle of internal friction of 30^0 and unit weight of 17 kN/m^3.**		
	Ans.	Given: H = 9 m, $\phi = 30^0$, $\gamma = 17\ KN/m^3$, Calculate: P_a *and* P_p = ?		
		To find coefiicient active earth pressure K_a, $K_a = \frac{1 - \sin\phi}{1 + \sin\phi}$, $K_a = \frac{1 - \sin 30^0}{1 + \sin 30^0}$, $\boxed{K_a = 0.333}$	1	
		Active earth pressure P_a, $P_a = K_a \times \gamma \times H$, $P_a = 0.333 \times 17 \times 9$, $\boxed{P_a = 50.949\ kN/m^2}$	1	
		To find coefiicient passive earth pressure K_p, $K_p = \frac{1 + \sin\phi}{1 - \sin\phi}$, $K_p = \frac{1 + \sin 30^0}{1 - \sin 30^0}$, $\boxed{K_p = 3}$	1	
		Passive earth pressure P_p, $P_p = K_p \times \gamma \times H$, $P_p = 3 \times 17 \times 9$, $\boxed{P_p = 459\ kN/m^2}$	1	4

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.4	(b)	**Differentiate between compaction and consolidation with four points.**		
	Ans.	**Difference between compaction and consolidation:**	1 each (any four)	4

Sr. No.	Compaction	Consolidation
1	Instant compression of soil under dynamic load is called compaction.	Gradual compression of soil under steady load is called consolidation.
2	It is fast process.	It is very slow process.
3	It is artificial process.	It is natural process.
4	It is done to improve soil properties like bearing capacity, shear strength, impermeability etc.	It takes place due to structural load which does not improve soil properties.
5	Settlement is prevented due to compaction.	Settlement takes place due to consolidation.
6	Compaction is done before construction of structure.	Consolidation takes place after construction of structure.
7	Pore water pressure is not important in compaction.	Pore water pressure is very important in compaction.
8	Compaction does not go indefinitely.	Consolidation goes indefinitely.

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.4	(c)	**Explain standard proctor test to determine MDD and OMC of soil.**		
	Ans.	**Procedure of Standard Proctor Test:** 1. Measure the diameter and height of proctor mould to calculate its volume V in cm^3. Take the empty weight of the mould (without collar and base plate) as W_1 gm. 2. Apply a thin film of grease to inside of mould. Fix the mould to the base plate with the help of wing nuts, place collar on the mould. 3. Take about 5 Kg. of de-aired soil passing through sieve 20 mm in tray. Fill the soil in mould in three equal layers by giving 25 using hammer of 2.6 kg through dropping height 310 mm. Remove the mould and excess soil from top of mould. 4. Take the weight of mould filled with compacted soil as W_2 gm. 5. Calculate the bulk density $\gamma = (W_2 - W_1) / V$ in gm/cc 6. Take the representative soil sample from mould and determine its water content as w % using oven drying method. 7. Calculate dry density γ_d = (bulk density) / (1 + w) in gm/cc. 8. Repeat all above steps by increasing water in soil and determine γ_d and w % for each trial. 9. Plot the compaction curve as water content v/s. dry density to find maximum value of dry density as MDD and corresponding water as OMC.	3	
		 **Figure: Compaction curve to find OMC and MDD of Soil.**	1	4

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.4	(d)	**Explain determination of coefficient of permeability by constant head method.**		
	Ans.	**Procedure of determination of coefficient of permeability by constant head method:** 1. Take 2.5 Kg air dried soil sample passing through 9.5mm IS sieve. Add the water in soil equals to its optimum moisture content (OMC) to get required density. 2. Apply grease to inside surface of mould, base plate and collar. Clamp the base plate with extension collar. Fill the prepared soil sample in permeameter in three different layers. Compact each layer using 25 blows using rammer. Remove the collar and trim the excess soil for mould. Remove compaction base plate. Cover the soil with filter paper and porous stones on both sides. 3. Place the mould assembly in the drainage base. Fix the top cap on it using rubber sealing gasket. 4. Connect the inlet nozzle of permeameter to outlet of constant head water tank. Close the air vent of mould. Open outlet of permeameter and allow water to flow in the bottom water tank. Wait for some time to establish steady flow. 5. Measure head causing flow 'h'. Collect quantity of water (Q) in the measuring cylinder for suitable time interval (t). 6. Calculate the coefficient of permeability of soil as $K = \frac{Q \times L}{A \times h \times t}$ cm/s. 7. Repeat all above steps two more times to get average coefficient of permeability of given soil sample.	4	4

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.4	(e)	**A sample of soil 10 cm height and 50 cm² in c/s area water flows through the soil under a constant head of 80 cm. Water collected in 9 minutes is 450 C.C. Find the coefficient of permeability.**		
	Ans.	*Given*: L = 10 cm, $A = 50cm^2$, h = 80 cm, t = 9 min.=540 sec., $Q = 450\ cc$ *Calculate*: K=?		
		Coefficient of permeability by constant head method, $K = \frac{Q \times L}{A \times h \times t}$	1	
		$K = \frac{450 \times 10}{50 \times 80 \times 540}$	1	
		$\boxed{K = 2.083 \times 10^{-3} cm/s}$	2	4

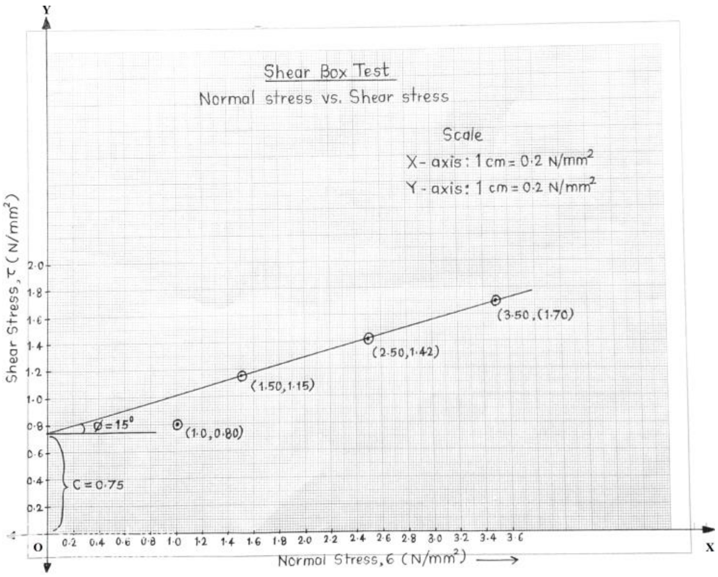
Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.5		**Attempt any TWO of the following:**		12
	(a)	**(i) Explain field applications of geotechnical engineering.**		
	Ans.	**Field applications of Geotechnical Engineering:** 1. **Design of foundation for various civil structures:** As foundation resting on soil carries load of any particular structure, geotechnical engineering is applicable to design such stable foundations for various loads. 2. **Design of pavement for various types of roads:** Layers of pavement made up of sand, gravel is laid on sub grade soil can be designed in terms of thickness, load carrying capacity using geotechnical engineering. 3. **Design of earth retaining structures:** Geotechnical engineering is also applicable to design and construct earth retaining structures like retaining wall and sheet pile useful for hill roads, landslides. 4. **Design of water retaining structures:** Geotechnical is very much applicable for easy and safe design and execution and maintenance of earthen dam, weir, barrage etc. 5. **Design of underground structures:** Underground pipelines i.e. water supply and sewage lines require geotechnical engineers for effective work. It is also significant in safe excavation of proposed alignment.	**1 each (any four)**	
		(ii) State two civil engineering situations where knowledge of geotechnical engineering is used. **Civil engineering situations where knowledge of Geo-Technical Engineering (GTE) is used:** 1. Geo-Technical Engineering knowledge is required to find most suitable site for proposed construction work. 2. GTE knowledge is also useful to find the suitability of available soil for planned construction activity. 3. GTE knowledge is useful to design and construction of foundation for various structures like building by knowing bearing capacity, shear strength of soil. 4. It is also helpful for design and construction of pavement for various roads by knowing properties sub grade soil, pavement layers like compaction, bulk and dry density etc. 5. GTE concepts are essential to design and construction of earth retaining structures i.e. retaining wall, sheet pile by studying earth pressure theory. 6. GTE theories are beneficial in design and construction of water retaining structures i.e. dam, weir etc. by determining permeability, shear strength etc. 7. GTE test procedures are necessary in design and construction of abutments of bridge by testing shears strength, earth pressure etc. 8. It plays vital role in design construction of underground structures i.e. pipeline, tunnels etc. by knowing soil erosion, slope stability.	**1 each (any two)**	6

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.5	**(b)**	**In shear box test, following observations were recorded at the failure of soil specimen.**		

Normal Stress (kg/cm^2)	**1.00**	**1.50**	**2.50**	**3.50**
Shear Stress (kg/cm^2)	**0.80**	**1.15**	**1.42**	**1.70**

Find the value of cohesion C and internal friction ϕ by graphical method.

Ans.



(Marks: 4)

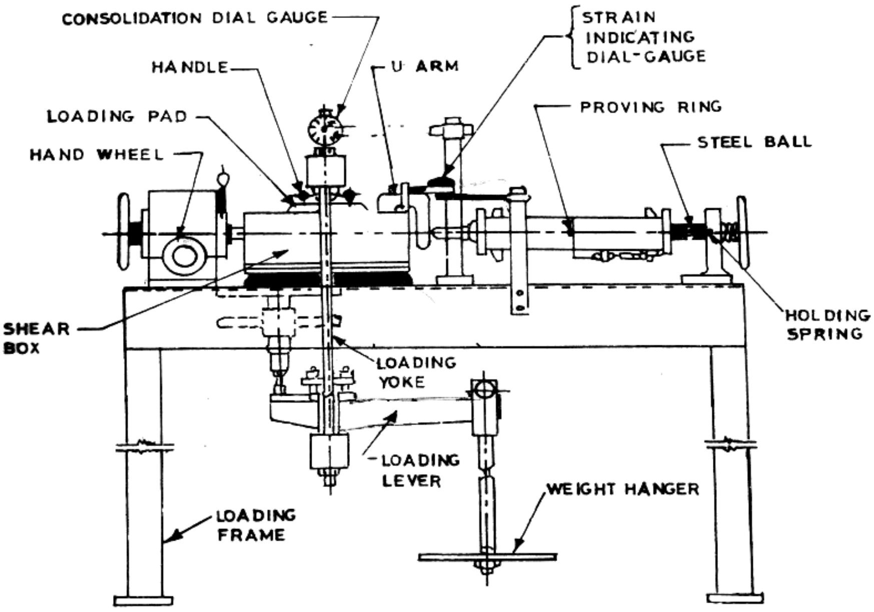
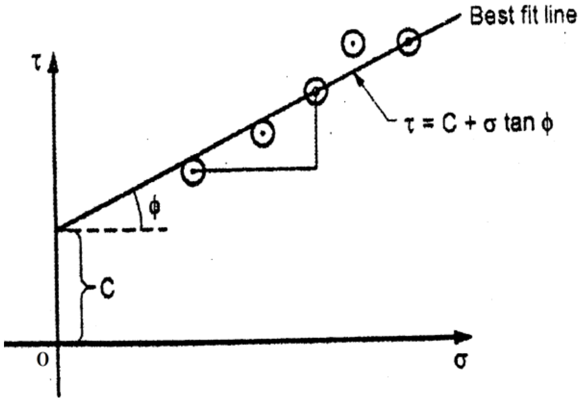
From above graph:

1. Cohesion C = 0.75 N/mm^2 (Marks: 1)
2. Angle of internal friction ϕ = 15^0 (Marks: 1; Total Marks: 6)

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.5	(c)	**A soil sample of volume 160 CC, weights 304 gms, when partially saturated. It weights 269.28 gms, when fully dry specific gravity of soil is 2.64. Determine porosity, voids ratio, water content, and degree of saturation.**		
	Ans.	Given: V = 160 *cc*, W_{wet} = 304 gms, W_{dry} = 269.28 gms, Calculate: $w, e, \eta, S = ?$ *To* find water content *w*, $w = \left(\frac{W_{wet} - W_{dry}}{W_{dry}}\right) \times 100$ $w = \left(\frac{304 - 269.28}{269.28}\right) \times 100$ $\boxed{w = 12.893\ \%}$	1	
		To find dry density γ_d, Assume specific gravity G = 2.7 Density of water $\gamma_w = 1 gm/cc$ $\gamma_d = \frac{W_{dry}}{V}$ $\gamma_d = \frac{269.28}{160}$ $\boxed{\gamma_d = 1.683 \text{ gm/cc}}$	1	
		To find voids ratio e, $\gamma_d = \frac{\gamma_w \times G}{1 + e}$	1	
		$1.683 = \frac{1 \text{ x } 2.64}{1 + e}$ $e = \frac{2.64}{1.683} - 1$ $\boxed{e = 0.568}$	1	

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.5	(c) Ans.	*To* find porosity η, $\eta = \frac{e}{1+e}$ $\eta = \frac{0.568}{1+0.568}$ $\eta = 0.3622$ $\eta = 0.3622 \times 100$ $\boxed{\eta = 36.22\ \%}$	1	
		To find degree of saturation S, $S = \frac{w \times G}{e}$ $S = \frac{0.1289 \times 2.64}{0.568}$ $S = 0.5992$ $S = 0.5992 \times 100$ $\boxed{S = 59.92\ \%}$	1	6

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.6		**Attempt any TWO of the following:**		**12**
	(a)	**Explain with figure laboratory determination of shear strength of soil with direct shear test.**		
	Ans.	**Procedure for Direct Shear Test:** 1. Take 2.5 Kg air dried soil sample passing through 4.75 mm and retained on 2.36mm IS sieve. 2. Measure the internal dimensions of the shear box. Fix the upper part of the box to the lower part using the locking screws. Attach the base plate to the lower part. 3. For performing a UU test, Plain toothed grids (without perforations) are used at the top and bottom faces of samples. Place the porous stone over the grid plate. 4. Weigh the shear box with base plate, grid plate and porous stone. Place the soil specimen in the box. Tamp it directly in the shear box at the required density. 5. When the soil in the top half of the shear box is filled, weigh the box with soil specimen. Weigh the box inside the box contained and fix the loading pad on the box. Mount the box contained on the loading frame. 6. Bring the upper half of the box in contact with the proving ring. Check the contact by giving a slight movement. 7. Mount the loading yoke on the ball placed on the loading pad. Mount the dial gauge on the loading yoke to record the vertical displacement and another dial gauge on the container to record the horizontal displacement. 8. Place the slotted weights of 0.5 N/mm^2 on the loading yoke to apply a normal stress. Note the reading of the vertical displacement dial gauge. 9. Remove the locking screws. Using the spacing screws, raise the upper part slightly above the lower part such that the gap is slightly larger than the maximum particle size. Remove the spacing screws. 10. Apply the horizontal shear load at a constant rate of strain of 0.2mm/minute till shear failure of soil. Record the reading of the proving ring, the vertical displacement dial gauge and the horizontal displacement dial gauge at regular time intervals to know the shear stress at failure. 11. Repeat the test on identical specimens under the normal stresses of 1.0, 1.5, 2.0 N/mm^2 etc. Plot the graph by taking the value Normal Stress as abscissa and the maximum shearing stress as ordinate to find shear strength of soil.	4	

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.6	(a)	 **Figure: Direct Shear Test Apparatus**	1	
		 **Figure: Graph of Normal stress vs. Shear stress**	1	6

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.6	(b)	**The following are the test results of standard compaction test performed on a sample of soil:**		

Water content %	5	10	15	20	25	30
Bulk density (gm/cc)	1.77	1.98	2.10	2.18	2.16	2.12

Plot the water content dry density curve and obtain the optimum water content (OMC) and its maximum dry density (MDD).

Ans.

Calculation of Dry density for each observation:

For obs. no. 1; $\gamma_d = \left(\frac{\gamma}{1+w}\right) = \left(\frac{1.77}{1+\left(\frac{5}{100}\right)}\right) = 1.68 \text{ gm/cc}$

For obs. no. 2; $\gamma_d = \left(\frac{\gamma}{1+w}\right) = \left(\frac{1.98}{1+\left(\frac{10}{100}\right)}\right) = 1.80 \text{ gm/cc}$

For obs. no. 3; $\gamma_d = \left(\frac{\gamma}{1+w}\right) = \left(\frac{2.10}{1+\left(\frac{15}{100}\right)}\right) = 1.82 \text{ gm/cc}$

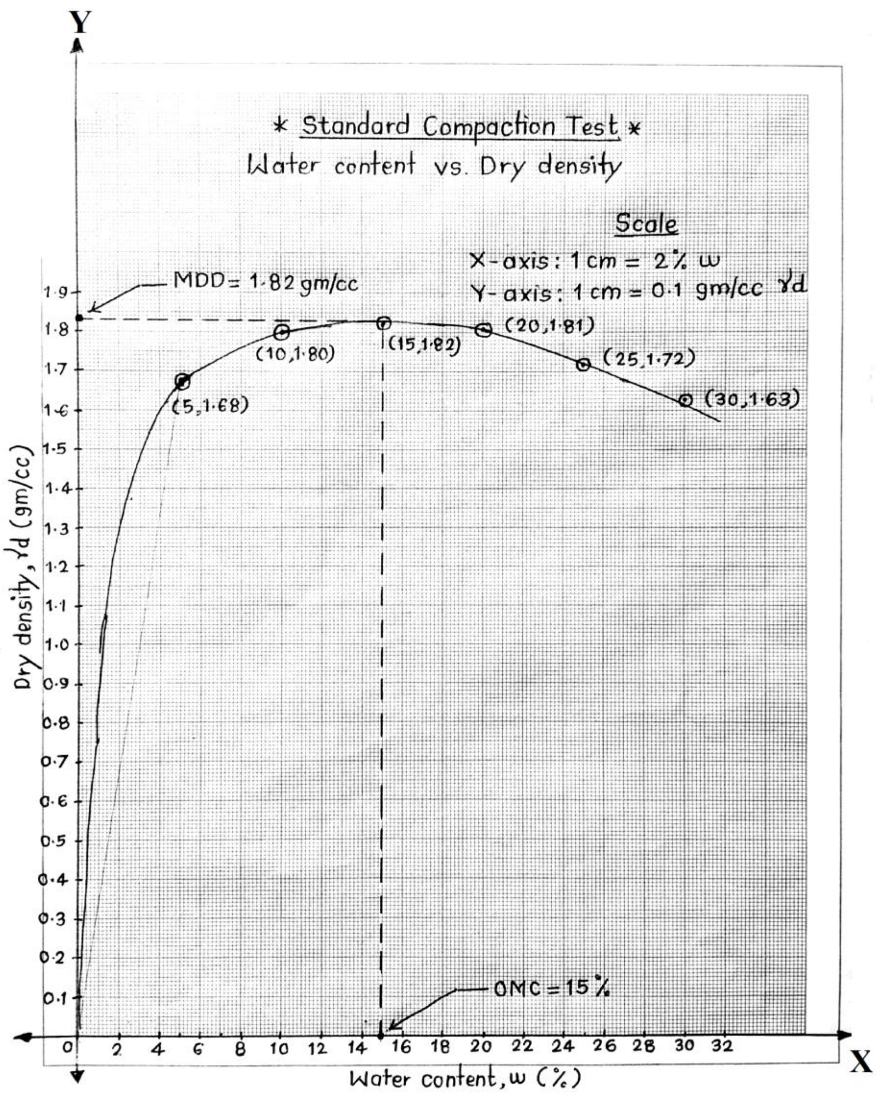
For obs. no. 4; $\gamma_d = \left(\frac{\gamma}{1+w}\right) = \left(\frac{2.18}{1+\left(\frac{20}{100}\right)}\right) = 1.81 \text{ gm/cc}$

For obs. no. 5; $\gamma_d = \left(\frac{\gamma}{1+w}\right) = \left(\frac{2.16}{1+\left(\frac{25}{100}\right)}\right) = 1.72 \text{ gm/cc}$

For obs. no. 6; $\gamma_d = \left(\frac{\gamma}{1+w}\right) = \left(\frac{2.12}{1+\left(\frac{30}{100}\right)}\right) = 1.63 \text{ gm/cc}$

(Marks: 2)

Water content %	5	10	15	20	25	30
Dry density (gm/cc)	1.68	1.80	1.82	1.81	1.72	1.63

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.6	(b)	**Compaction Curve : Water Content-Dry Density Curve:**  **From above graph:** 1. Optimum Moisture Content (OMC) = 15 %. 2. Maximum Dry Density (MDD) = 1.82 gm/cc.	2 1 1	6

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q.6	(c)	**State field methods of compactions. Explain suitability of various compaction equipments.**		
	Ans.	**Field methods of compactions:** 1. Compaction by rolling 2. Compaction by ramming 3. Compaction by tamping 4. Compaction by vibration	½ each	
		Suitability of various compaction equipments. 1. **Smooth wheel roller:** It is suitable only for fine grained cohesive soil i.e. black cotton soil used for plinth filling, earthen dam, abutment of bridge, etc. 2. **Sheep foot roller:** These rollers are best suitable for compaction of cohesion less soils i.e. sandy soils used for sub grade or base course of road pavement. 3. **Pneumatic tyred roller:** Pneumatic tyred rollers are effective for compacting both cohesive as well as cohesion less soils. It is useful for mega projects of road, dam and bridge sites. 4. **Rammer:** Dropping weight type, internal combustion type and pneumatic type rammers are used to compact all types of soil used for light to medium structure i.e. for plinth filling, PCC etc. 5. **Tamping rod:** Tamping rod is used to compact coarse grained cohesion less soils of lesser thickness for less important construction work. 6. **Vibratory compactor:** Dropping weight type and pulsating hydraulic type vibrators compacts soil particles of sub grades and base course of both flexible and rigid pavement. It is also suitable for compacting granular soils with no fines.	1 each (any four)	6