Engineering Services (Main)
Examination, 2024

SGSE–T–CVL

CIVIL ENGINEERING

PAPER—II

Time Allowed : Three Hours	Maximum Marks : 300

QUESTION PAPER SPECIFIC INSTRUCTIONS

Please read each of the following instructions carefully before attempting questions

There are **EIGHT** questions divided in **TWO** Sections.

Candidate has to attempt **FIVE** questions in all.

Question Nos. **1** and **5** are compulsory and out of the remaining, **THREE** are to be attempted choosing at least **ONE** question from each Section.

The number of marks carried by a question/part is indicated against it.

Wherever any assumptions are made for answering a question, they must be clearly indicated.

Diagrams/Figures, wherever required, shall be drawn in the space provided for answering the questions itself.

Unless otherwise mentioned, symbols and notations have their usual standard meanings.

Attempts of questions shall be counted in sequential order. Unless struck off, attempt of a question shall be counted even if attempted partly.

Any page or portion of the page left blank in the Question-cum-Answer (QCA) Booklet must be clearly struck off.

Answers must be written in **ENGLISH** only.

SECTION—A

1. *(a)* A rectangular plate of 0·50 m × 0·50 m dimensions and weighing 500 N slides down an inclined plane making 30° angle with the horizontal. The velocity of the plate is 1·75 m/s. If the 2 mm gap between the plate and the inclined surface is filled with lubricating oil, find the viscosity of oil and express it in units of poise as well as N-s/m^2. Assume the plate as frictionless. 12

(b) The following is the set of observed data for successive 15 minutes period of 105 minutes storm in a catchment :

Duration (min)	15	30	45	60	75	90	105
Rainfall (cm/hr)	2·0	2·0	8·0	7·0	1·25	1·25	4·5

If the value of ϕ-index is 3·0 cm/hr, estimate the net runoff, the total rainfall and the value of W-index. 12

(c) A hydraulic turbine has an output of 6600 kW when it works under a head of 25 m and runs at 100 r.p.m. What is the type of the turbine? What would be its speed and what power will it develop when working under a head of 16 m? 12

(d) A large stream flowing through an industrialised area is the only source of raw water for the community water supply. The stream water is consistently turbid, has hardness in excess of 300 mg/L as $CaCO_3$ and has refractory organics that are known precursor of trihalomethanes. Draw a schematic diagram of a treatment plant that could render this water potable. Identify all the units. State their purpose, show points of chemical addition and identify all the chemicals. 12

(e) For BOD analysis, 30 mL of treated wastewater sample with DO of zero was mixed with 270 mL of dilution water with DO of 10 mg/L. The 5th and 6th days being holidays, the lab was closed. The final DO was measured as 4 mg/L on the 7th day. It was also found that the incubator was set at 30 °C. Assuming the BOD reaction rate constant as 0·23 day^{-1} at 20 °C and the temperature coefficient as 1·047, determine the 5-day, 20 °C BOD of the sample. 12

2. *(a)* Treated wastewater having a peak flow rate of 12000 m^3/day, BOD_5 of 30 mg/L, DO concentration of 1 mg/L and temperature of 27 °C is discharged in a stream. Before getting mixed with the wastewater, the stream has a minimum flow rate of 0·4 m^3/s, BOD_5 of 4 mg/L, DO concentration of 7 mg/L and temperature of 25 °C. After instantaneous and complete mixing, the velocity of the mixed flow is 0·2 m/s. For the mixed flow, the BOD reaction rate constant is 0·2 day^{-1} and the reaeration constant is 0·4 day^{-1} at 20 °C. Estimate the initial oxygen deficit and DO after two days of flow. Take temperature coefficient for BOD reaction rate constant as 1·047 and for stream reaeration rate constant as 1·016. Take equilibrium concentration of DO for water after mixing as 8·3 mg/L. 20

(b) (i) For a hydraulic jump in a rectangular channel, the velocity and depth after the jump are known to be 0·80 m/s and 1·75 m respectively. Calculate the depth before jump, the energy loss and the power dissipated per metre width. 15

(ii) What do you mean by diversion headworks? Distinguish clearly between a weir and a barrage. 5

(c) (i) A water treatment plant in a city of 100000 population supplies water at the rate of 150 lpcd. Two equal capacity circular settling tanks are to be provided to settle flocculent suspension through Type–II settling. Design the tanks. Take SOR as 20 m^3/m^2-d and water depth of 3·5 m. Leave sludge zone of 0·5 m and keep inlet and outlet zones equal to the side water depth. Calculate the weir loading. Draw the sketch of the tank showing all the zones and dimensions. 12

(ii) In an ideal granular media filter, the entire depth of the filter media should contribute to the retention and removal of solids, ensuring longer filter runs, less head loss and greater filtration rates. Why will the single media filters fail to achieve this? How can the mixed media filter approach an ideal filter in performance? 8

3. (a) (i) Design a tube well for the following data :

Yield required = 0·10 m^3/s
Radius of circle of influence = 200 m
Coefficient of permeability = 60 m/day
Drawdown = 6 m
Thickness of confined aquifer = 30 m 15

(ii) Describe briefly the various methods adopted as anti-waterlogging measures. 5

(b) (i) Design an irrigation channel in alluvial soil according to Lacey's silt theory for the following data :

Full supply discharge = 10 m^3/s
Lacey's silt factor = 0·9
Side slopes of channel = $\frac{1}{2}$ (H) : 1 (V) 15

(ii) What is gravity dam? Enumerate the various forces acting on gravity dam. 5

(c) (i) A settling column analysis is run to determine the settling characteristics of sludge from an activated sludge reactor with the following results :

Concentration of MLSS (mg/L) :	1000	2000	3000	4000	5000	6000
Settling velocity (m/hr) :	2·8	1·4	0·4	0·2	0·1	0·06

The flow to the secondary clarifier is 4200 m^3/day with MLSS concentration of 2000 mg/L. Determine the required diameter of the clarifier for a preselected solid flux rate of 2·5 kg/m^2-hr. Check the area requirement for the clarification function also. 12

(ii) Why do the conventional channel type horizontal flow grit chambers require the velocity control devices? What are the common velocity control devices that are used? What advantages the aerated grit chamber has over the conventional grit chamber? 8

4. (a) (i) A kite weighing 12·26 N has an effective area of 0·9 m^2. The tension in the kite string is 32·37 N when the string makes an angle of 45° with the horizontal. For a wind of 32 km/hr, what are the coefficients of lift and drag if the kite assumes an angle of 8° with the horizontal? Take specific weight of air as 11·801 N/m^3. 10

(ii) A 1·25 m diameter pipe has to be provided to convey oil of specific gravity 0·85 and kinematic viscosity of 2·75 centistokes at a velocity of 1·25 m/s. In order to model the flow, if a 120 mm diameter pipe is used to convey water of kinematic viscosity 1·0 centistokes, what should be the velocity and the discharge in the model? 10

(b) A city of 1 million population generates 0·45 kg per capita per day of MSW. Collection trucks of capacity 4·5 metric tonnes averaging two trips per day at 75% capacity operate all the days in a week to transfer the waste to centralised processing and landfill site. How many trucks per day will be required to transfer the waste? If about 45% waste is recycled, what is the mass of MSW entering the landfill? If the density of the waste is 280 kg/m^3, what is the volume of MSW? Determine the area required for the landfill with the projected life of 30 years, if the density of the compacted waste is 450 kg/m^3 and the maximum height of the landfill is limited to 15 m. Neglect the volume of cover. 20

(c) (i) Explain the following characteristic terms for biological organisms based on their carbon and energy sources :

(I) Phototrophs

(II) Chemotrophs

(III) Autotrophs

(IV) Heterotrophs

Arrange the following organisms according to their trophic levels giving your reasoning :

(A) Chemoheterotrophs

(B) Photoheterotrophs

(C) Photoautotrophs

(D) Chemoautotrophs 10

(ii) The ambient air concentration of carbon monoxide was reported as 4 mg/m^3 at the temperature of 25 °C and pressure of 103·193 kPa. What will be the concentration in ppm at STP? 10

SECTION—B

5. *(a)* A field vane shear test was carried out on a deep-seated soft clay layer. The vane was 11·25 cm high and 7·5 cm across the blades. The equivalent torque recorded at the torque head at failure was 800 kg-cm. The vane was then rotated very rapidly in order to completely remould the soil. It was found that the remoulded soil can be sheared by applying a torque of 400 kg-cm. Compute the shear strength of the soil in the undisturbed and remoulded states and its sensitivity. 12

(b) A 2·5 m wide strip footing is founded at a depth of 2·0 m below the ground level in a homogeneous pure clay bed. The unit cohesion of clay is 35 kPa. Due to seasonal fluctuations of water table from peak summer (fully dry soil) to peak monsoon (fully saturated soil), compute the change in the net ultimate bearing capacity as per Terzaghi's theory. 12

(c) Design the thickness of a flexible pavement for the design life of 15 years having two-lane single carriageway 7·0 m wide and present traffic of 800 commercial vehicles per day (CVPD). Out of total 800 CVPD, 300 have vehicle damage factor (VDF) of 2·5 and 500 have VDF of 3·0. The planning and construction period is 2 years and annual vehicle growth rate is 7·5%. Design the flexible pavement from the data given below if the effective CBR of the subgrade is 9%. Assume any missing data suitably :

Design traffic	*Wearing course* (mm)	*Binder course* (mm)	*Base* (mm)	*Sub-base* (mm)
5 msa	25 SDBC	50 DBM	250	150
10 msa	40 BC	50 DBM	250	200
20 msa	40 BC	80 DBM	250	200
30 msa	40 BC	95 DBM	250	200

12

(d) Calculate the speed restriction for a 2° curve on a broad-gauge section with maximum permissible speed of 100 km/hr. Due to space restrictions, the length of transition curve is limited to 50 m and superelevation provided is 60 mm. 12

(e) The following staff readings were taken with a level :

1·255, 1·950, 2·450, 3·100, 3·900, 1·215, 1·795, 2·800, 3·500, 0·560, 1·210, 1·900, 2·955

The level was shifted after the 5th and 9th reading, and the 7th reading was taken to a benchmark of RL 120·00 m. Arrange the data in tabular form and find the reduced level of all the points by rise and fall method. Also apply the usual checks for calculations. 12

6. *(a)* *(i)* Two straights AB and BC are to be connected by a 2° simple circular curve. Two points P and Q are selected on AB and BC respectively and the following observations are done in the field :

$\angle APQ = 130°$ Length $PQ = 120$ m

$\angle CPQ = 120°$ Chainage of point $P = 1700$ m

Calculate the chainages of intersection and all other important points in the curve. Assume the standard chord length of 20 m. 10

(ii) Explain the various sources of errors and their corrections in positioning with Global Positioning System (GPS). 10

(b) *(i)* A greenfield airport is proposed at an elevation of 250 m above mean sea level (m.s.l.). The monthly average of the maximum daily temperature at the proposed site is 45 °C during the hottest month of the year. During the same month, the average daily temperature is 35 °C. The maximum difference in elevation is 6·0 m along the proposed runway of basic length 2000 m. Calculate the actual length of runway to be provided. 15

(ii) What are the various considerations in the selection of the site for a harbour? 5

(c) A concrete driven pile of 20 m length and 1 m × 1 m in cross-section is fully embedded in sand having unit weight, $\gamma = 18$ kN/m^3 and $\phi' = 30°$. Estimate the ultimate load Q_u which the pile can take and mention the contributions from point load (tip load Q_p using Meyerhof's method) and frictional resistance Q_s. Consider $N_q^* = 55$ (for $\phi' = 30°$), $\delta' = 0{\cdot}8\phi'$, $K = 1{\cdot}8\,(1 - \sin\phi')$, $L_{cr} = 15D$. 20

7. *(a)* An infinite soil slope is having a slope angle as 25°. The soil properties are $c' = 26$ kN/m^2, $\phi' = 20°$, $e = 0{\cdot}71$ and $G = 2{\cdot}65$. Given $\gamma_w = 10$ kN/m^3. Find out the critical height of the slope considering stability number which represents cohesion and $F_\phi = 1{\cdot}0$, for cases (i) soil slope is dry and (ii) soil slope is submerged. 20

(b) A smooth rigid vertical retaining wall of height 7·0 m supports two layers of horizontal backfill. Top layer 1 is of 2·0 m depth having $\phi = 20°$, $c = 15$ kN/m^2 and $\gamma = 15$ kN/m^3. Bottom layer 2 is pure sand with $\phi = 30°$ and $\gamma = 17$ kN/m^3. Mention the practical depth of tensile crack. Also draw active earth pressure diagram and compute the total active thrust on the wall. Assume that the entire soil layers are dry. 20

(c) *(i)* What is meant by wear of rails? How is it measured? Explain the methods adopted to reduce wear of rails. 10

(ii) What is 'mucking' in the construction of tunnels? Explain the various techniques for haulage of muck from the tunnel. 10

8. *(a)* Estimate the traffic density and theoretical capacity of six-lane expressway at a stream speed of 80 km/hr. The average reaction time is 0·75 s and the average length of vehicle is 5 m. 10

(b) List all the major methods of ground modifications (ground improvement) in *(i)* cohesive soil and *(ii)* cohesionless soil. 10

(c) A building is proposed to be constructed on a thick silty clay deposit. The maximum vertical load on a column is 5000 kN. Using Boussinesq's stress distribution, calculate the minimum depth of soil exploration required for the foundation design. Note that as per De Beer's recommendation, the vertical additional stress should be less than or equal to 10% of the effective vertical stress. Take unit weight, γ, of soil as 18 kN/m^3 and γ_w = 10 kN/m^3. 20

(d) *(i)* A survey line *OPQR* running in the east direction has a lake between points *P* and *Q*; *P* and *Q* are intervisible but it is not possible to measure its length in the field. A traverse *PABCQ* was run around the lake and the following measurements were done in the field :

Line	*Length* (m)	*Bearing*
PA	160	N 15° E
AB	300	N 45° E
BC	200	N 60° E
CQ	—	S 30° E

Calculate the lengths of the lines *CQ* and *QP*. 10

(ii) Enlist the various geological challenges need to be considered for construction of tunnels in the Himalayan region. 10

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