

CIVIL ENGINEERING

(Paper I)

Time Allowed : Three Hours
Maximum Marks : 250

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, any 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.

Word limit in questions, wherever specified, should be adhered to.

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 Booklet must be clearly struck off.

SECTION 'A'

1. (a) A rod AB 6 m long is held against sliding by a string AD. The rod weighs 10 kN. Determine the tension in the string AD assuming that all surfaces are smooth. 10
 [Figure: Rod AB, 6 m long, with its lower end A on a smooth horizontal floor, inclined at 60° to the floor; the rod rests against the smooth top corner C of a vertical step/wall CD of height 4 m (C at the top, D at the foot on the floor), its upper end B projecting above C; a horizontal string AD (tension T) along the floor connects A to D]
- (b) The global stiffness matrix of a structure contains rigid body displacements. Describe how to modify it to account for nodes having zero displacements. Give two approaches. 10
- (c) Draw the B.M. diagram for the beam shown in figure when support B settles by 10 mm, using moment distribution method. 10
 [Figure: Continuous beam ABCD (no external loads shown): hinged support at A, roller supports at B, C and D; spans AB = 5 m, BC = 4 m, CD = 6 m; EI = Constant, $I=200 \times 10^{-6} \text{ m}^4$, $E=200 \text{ GPa}$]
- (d) The ground water movement at a site takes place through a soil zone comprised of 3 m thick sand with coefficient of permeability 0.01 cm/s (in both directions) overlain by 1 m thick fine gravel with coefficient of permeability 0.1 cm/s (in both directions). Determine the coefficient of permeabilities applicable for horizontal and vertical ground water movements through the layer. 10
- (e) At the entry of the pump intake the velocity v varies inversely as the square of the radial distance r from inlet to suction pipe. The velocity is found to be 0.8 ms^{-1} at a radial distance of 1.5 m. Compute the acceleration of flow at radial distances of 0.5 m and at 1.25 m, from the inlet assuming the stream-lines to be radial. 10
2. (a) Material for an earthfill was available from three different borrow pits/sites. In the compacted state the fill measured $1.0 \times 10^5 \text{ m}^3$ at a void ratio of 0.75. The corresponding in-situ void ratio and cost (cost of material and transportation) of the material for three sites are as follows: 15

Borrow site	Void ratio	Total cost per cubic meter
1	0.8	Rs. 200
2	1.15	Rs. 180
3	1.25	Rs. 175

Determine the most economical site for the above earthfill work.
- (b) Two wheels, placed at a distance of 2.5 m apart, with a load of 200 kN on each of them, are moving on a simply supported girder (I-section) of span 6.0 m. The top and bottom flanges of the I-section are of $200 \times 200 \text{ mm}$ and the size of web plate is $800 \times 6 \text{ mm}$. If 20

the allowable bending compressive, bending tensile and average shear stresses are 110 MPa, 165 MPa and 100 MPa respectively, check the adequacy of the section against bending and shear stresses, self weight of the girder may be neglected.

- (c) In order to predict lift and drag forces on a scale model of an aircraft during a section of operational envelope, involves sea level flight at 100 ms^{-1} , where the speed of sound may be taken as 340 ms^{-1} . It is proposed to utilise cryogenic wind tunnel with Nitrogen at 5 atmosphere of pressure and a temperature of -90°C ($\rho=7.7 \text{ kg m}^{-3}$, viscosity $1.2 \times 10^{-5} \text{ Ns}$ for nitrogen). The speed of sound in nitrogen at this temperature is 295 ms^{-1} . Determine the wind tunnel flow velocity, the scale of model to ensure full dynamic similarity and, the ratio of forces acting on the model and prototype. Mass density of air 1.2 kg m^{-3} and viscosity $1.8 \times 10^{-5} \text{ Ns}$.

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3. (a) Determine the slope at A, vertical deflections at B and mid span using the moment-area theorem. Take $EI = \text{Const}$.

[Figure: Simply supported beam AD of span 6 m, supports at A and D; point loads 20 kN at B (2 m from A) and 20 kN at C (2 m from D); O is the mid-span point between B and C ($BO = OC = 1 \text{ m}$)]

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- (b) Design a section of wall of a water tank on uncracked basis to resist a pull of 60 kN and a bending moment of 7.5 kNm/m width producing tension on the water face. Use M 30 concrete and Fe 415 grade steel. Effective cover = 30 mm; Permissible stress in direct tension in concrete = 1.5 MPa; Permissible stress in bending tension in concrete = 2 MPa; Modular ratio = 9

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- (c) Three pipes are connected as shown in figure. The characteristics of pipe are as follows:

Pipe	D (mm)	L (m)	f
A	150	600	0.020
B	100	480	0.032
C	200	1200	0.024

Determine the flow rate in each pipe. Minor losses may be neglected.

[Figure: Reservoir with water surface at 60.0 m; pipes A and B run in parallel from the reservoir to a junction P at EL 36.00; from P a single pipe C runs down and discharges freely at its outlet at EL 15.00 m]

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4. (a) What is the preconsolidation pressure? Describe a method to determine the preconsolidation pressure.

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- (b) An in-situ vane shear test was conducted at the bottom of a borehole in a soft clayey soil. A torque of 155 N-m was required to shear the soil. The vane was 100 mm diameter and 150 mm long. What was the undrained shear strength, C_u of the soil? Derive the relevant expression relating to torque vane dimension, and undrained shear strength of the soil.

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- (c) A counterfort retaining wall is shown in figure in plan and sectional elevation. It retains dry earth having a density of 19 kN/m^3 and angle of repose of 30° . Design a counterfort in flexure only using the limit state design. Take M 30 grade of concrete and Fe 500 grade steel.

[Figure: (a) PLAN – stem 0.5 m thick along one side; heel slab extending 5 m behind the stem; counterforts 0.5 m thick at right angles to the stem; along the wall the dimensions read 3 m, 0.5 m (counterfort), 6 m (clear spacing, centre line marked), 0.5 m (counterfort), 3 m; section line A–A through a counterfort. (b) SEC A–A – base slab 1 m thick and 5 m + 0.5 m wide (heel 5 m, stem 0.5 m); counterfort of triangular elevation rising from the top of the heel slab at its rear end to the top of the stem; vertical dimensions 1 m (base slab) + 5 m + 1 m, i.e. 7 m overall to the top of the wall; the ground-surface symbol (∇) of the retained earth is drawn on the heel side at the top of the 5 m dimension, i.e. 1 m below the top of the wall]

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SECTION 'B'

5. (a)(i) Determine the diameter of the vertical pipe needed for a flow of a liquid of kinematic viscosity $1.95 \times 10^{-3} \text{ m}^2 \text{ s}^{-1}$ at a Reynolds number of 1500. The constant pressure is maintained throughout its length.

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- (a)(ii) Prototype data of Tidal Channel are as follows: Length of channel = 18 km, Discharge = $250 \text{ m}^3 \text{ s}^{-1}$; Depth = 2.5 m, Width of the channel = 50 m. Model is built with a vertical

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scale of 1 : 50 and a horizontal scale of 1 : 500. Tidal period is 12 hours. Compute the average velocity in ms^{-1} and tidal period in the model.

- (b) A particle moves on a vertical line with an acceleration $a=3v/v$. At $t = 2$ sec, its displacement is 8 m and velocity is 6 m/s. Determine its displacement, velocity and acceleration at time $t = 4$ sec. a = acceleration and v = velocity. 10
- (c) A horizontal shaft 12 m in length is fixed at its ends. When viewed from its left end, axial couples of 50 kNm clockwise and 75 kNm counterclockwise act at 5 m and 9 m from the left end respectively. Determine the end fixing couples and the position where the shaft suffers no angular twist. 10
- (d) An infinite natural slope with angle of slope 15° (inclination measured from horizontal) has a saturated unit weight of 18 kN/m^3 and an effective angle of internal friction, $\phi=35^\circ$. Determine the factor of safety against failure of the slope (i) when the slope is completely dry or submerged but without seepage, (ii) when seepage occurs at and parallel to the surface of the slope. 10
- (e) Design a welded lap joint to join two plates of size $300 \times 10 \text{ mm}$ and $280 \times 10 \text{ mm}$ in Fe 410 grade steel to mobilise the tensile strength of the plates using field weld. Yield strength of material = 250 MPa; $\gamma_{mo}=1.1$; Partial safety factor for field weld = 1.5
[Figure: Lap joint. Elevation: two plates overlapping, pulled apart by axial force P at each end, with a fillet weld at each end of the overlap. Plan: $280 \times 10 \text{ mm}$ plate (280 mm wide) lapped over the $300 \times 10 \text{ mm}$ plate (300 mm wide); overlap length L ; fillet welds (hatched) on all four sides of the overlap – along both longitudinal edges of the 280 mm plate over the length L and across both transverse ends] 10
6. (a) A beam has a cross-section shown in figure. It is subjected to a vertical shear force of 10 kN at a given section. Determine the shear stress distribution on the section.
[Figure: Symmetrical cross-shaped (+) section: a central vertical web 50 mm wide and 200 mm deep overall, crossed at mid-height by a horizontal flange 250 mm wide (100 mm + 50 mm + 100 mm) and 100 mm deep (50 + 50 about the horizontal centroidal axis); the web projects 50 mm above and 50 mm below the flange (depth dimensions 50 mm, 50, 50, 50)] 15
- (b)(i) A booster pump is installed in the pipeline between two reservoirs. If the energy added by the pump is 20 m, determine the flow rate in the pipeline in $\text{m}^3 \text{s}^{-1}$. Length of the pipeline = 1500 m; Coefficient of friction = 0.02; Diameter of the pipeline = 300 mm; WSEL of A = 200 m WSEL of B = 185 m
[Figure: Reservoir A (water surface 200) on the left connected by a pipeline, with a pump in it, to reservoir B (water surface 185) on the right] 5
- (b)(ii) Compute the shear stress acting on the river bed for the data given: Discharge = $5000 \text{ m}^3 \text{s}^{-1}$, River bed slope = 1 : 2500; Depth of flow = 4.50 m. Assume the river to be wide. 4
- (b)(iii) A hydraulic jump has an energy loss of 9.0 m and the downstream Froude number is 0.12. Determine the initial depth and the discharge intensity. 6
- (c)(i) State the Abram's law on water-cement ratio. 5
- (c)(ii) Name the various grades of ordinary Portland cement. 5
- (c)(iii) Define characteristic strength of reinforcing steel. 5
- (c)(iv) State any five applications of prestressed concrete. 5
7. (a)(i) For the sluice gate shown in Figure, if $C_c=0.98$ and $C_v=0.62$, what is the height of the opening? Given $V_1=2.006 \text{ m s}^{-1}$, $g=9.81 \text{ ms}^{-2}$. Also determine the flow per unit width.
[Figure: Vertical sluice gate in a horizontal channel; upstream depth 2 m with velocity head $V_1^2/2g$ above the water surface; gate opening a ; downstream (contracted) depth 0.8 m with velocity head $V_2^2/2g$; total energy line shown dashed] 5
- (a)(ii) The uniform flow depth is 1.5 m in a trapezoidal channel of bottom width of 20 m with a side slope of 1(V) : 2(H). The bed slope is 1×10^{-4} . Manning roughness coefficient is 0.2. The downstream control raises the water surface by 3 m. Classify the profile. 5

- (a)(iii) Following data are given for a rectangular channel: Width = 9 m, $n = 0.017$, $S_0 = 1:4000$; D/S depth is 6.80 m, U/S depth is 3.6865 m; Discharge $48.748 \text{ m}^3 \text{ s}^{-1}$. Using single step method compute the length of profile. 5
- (b) A pile group consists of nine friction piles driven into a deep layer of clay soil. The diameter of each pile is 0.4 m, the embedded length is 12 m and center to center spacing of the piles is 1.2 m. The soil has cohesion, $c = 50 \text{ kN/m}^2$, unit weight, $\gamma = 18 \text{ kN/m}^3$. Determine (i) the block capacity of the pile group using a factor of safety = 3.0, (ii) group capacity based on individual pile failure criterion and (iii) design capacity of the pile group. (Assume adhesion factor $\alpha = 0.8$) 20
- (c) A radial flow turbine has the following dimensions: Outer periphery radius $r_1 = 0.5 \text{ m}$; Inner periphery radius $r_2 = 0.3 \text{ m}$. The angle made by the relative velocity at the inlet is $(\beta_1) = 80^\circ$. The width of the flow passage between the two sides of the turbine is 0.25 m. The flow of $4 \text{ m}^3 \text{ s}^{-1}$ goes through the turbine when the speed is 300 rpm. Find the blade angle β_2 such that water exit radially. Find the torque exerted by the water in the turbine and the power thus developed. Find the head utilised by the runner and the power resulting therefrom. Assume no shock at the entrance and blades are of negligible thickness. 15
8. (a) For the earth retaining structure shown in the figure, determine the total active thrust on the wall, and the point of application of the thrust above the base of the wall. Given $H = 5 \text{ m}$, $\phi = 30^\circ$, $C = 0$, $\beta = 90^\circ$, $h_w = 2.0 \text{ m}$, $\gamma_{sat} = 18 \text{ kN/m}^3$, $\gamma_{bulk} = 17 \text{ kN/m}^3$ (above water table), $q = 250 \text{ kN/m}^2$.
[Figure: Vertical wall of height $H = 5 \text{ m}$ with vertical back face ($\beta = 90^\circ$) retaining horizontal backfill ($\phi = 30^\circ$, $C = 0$); uniform surcharge $q = 250 \text{ kN/m}^2$ on the backfill surface; water table at $h_w = 2.0 \text{ m}$ above the base of the wall; $\gamma_{bulk} = 17 \text{ kN/m}^3$ above the water table, $\gamma_{sat} = 18 \text{ kN/m}^3$ below it] 15
- (b) For the truss shown in fig. draw the influence lines for force in members U_3L_3 , U_3L_2 and L_2L_3 . The load moves on the bottom chord.
[Figure: Parallel-chord truss of 6 panels @ 5 m (span 30 m), height 5 m; bottom chord L_0-L_6 , top chord U_1-U_7 with U_1 above L_0 , U_2 above L_1 , ..., U_7 above L_6 ; verticals at every panel point; diagonals U_1L_1 , U_2L_2 , U_3L_3 (sloping down towards the centre) and L_3U_5 , L_4U_6 , L_5U_7 ; hinged support at L_0 , roller support at L_6] 15
- (c) A bracket connection shown in figure, consists of a joist cutting welded to the flange of a column by shop fillet welds 8 mm on flanges and 6 mm on the web. Determine the safe service load 'W', the bracket can support at a distance of 200 mm from the face of the column if the steel grade is Fe 410. Partial factor of safety on shop weld = 1.25; Yield strength of steel = 250 MPa
[Figure: Side elevation: joist cutting welded to the face of the column flange, load W at 200 mm from the column face; 6 mm fillet welds on both sides of the web over a depth of 200 mm; 8 mm fillet welds along the flanges. End view: joist cutting 250 mm deep with flanges 150 mm wide, welded to a column flange 250 mm wide] 20