

CIVIL ENGINEERING (Paper I)

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, 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.

SECTION 'A'

1. (a) Compare the moments of resistance for a given maximum bending stress of a beam of square section placed (i) with two sides vertical and (ii) with a diagonal vertical. The bending in each case is parallel to vertical plane. 12
- (b) Three bodies A, B and C of masses 50 kg, 30 kg and 20 kg respectively are under a force of 5 kN as shown. Calculate the force transferred between A and B, B and C. Assume all are frictionless surfaces. 12

[Figure: Three blocks resting side by side in contact on a horizontal frictionless (hatched) surface, from left to right: A (largest), B (smaller), C (smallest); a horizontal force of 5 kN acts towards the right on the left face of A, pushing the three blocks]
- (c) A two-hinged parabolic arch of span 50 m and rise 5 m is under no external load. If the left support yields horizontally by 0.5 mm (outward) and the temperature rises by 10 °C, calculate the horizontal thrust developed and draw the bending moment diagram assuming secant variation. Take $EI=1 \times 10^{12}$ kN-mm², $\alpha=10 \times 10^{-7}/^\circ\text{C}$. 12
- (d) A pipeline carrying oil of specific gravity 0.8 changes in diameter from 300 mm at position A to 500 mm diameter at position B, which is 5 m at a higher level. If the pressure at A is 19.62 N/cm² and at B is 14.91 N/cm², and the discharge is 0.2 m³/s, determine the loss of head and the direction of the flow. 12
- (e) An expression for the velocity distribution in the boundary layer flow on a flat plate is given as
$$u/U = a + b\eta + c\eta^2$$
 where $\eta = y/\delta$, and a , b and c are constants. u and U are velocities at y and δ respectively. y is the distance measured normal to the plate and δ is boundary layer thickness. Value of $u=U$ when $y=\delta$. Sketch the boundary layer thickness growth along the flat plate and velocity distribution in the boundary layer. Find the ratio of boundary layer thickness to displacement thickness. 12
2. (a) Analyse the continuous beam as shown by moment distribution method. Draw the bending moment diagram. Assume $EI = \text{constant}$. 15

[Figure: Continuous beam, total length 11 m, from left to right: fixed support at the left end; point load 20 kN at 2 m from the fixed end; a pinned support 3 m further on (5 m from the fixed end); span of 4 m to a second pinned support, this span carrying a uniformly distributed load of 3 kN/m over its full length; overhang of 2 m beyond the second support with a point load of 20 kN at its free end. Dimensions: 2 m, 3 m, 4 m, 2 m]
- (b) A cantilever beam of cross-section 50 mm × 100 mm is subjected to a compressive force parallel to the longitudinal axis of the beam at the free end. The point of application of the load is at 10 mm above the bottom surface on the vertical centroidal axis. The span of the 15

beam is 4 m. Calculate the maximum stresses in the beam.

- (c) Water is flowing at a critical depth of flow = 1.4 m in a channel shown in the figure below. Estimate the discharge and specific energy in the channel.

[Figure: Channel section captioned “Triangular channel”, drawn as a triangle with its apex at the top: horizontal base line 2.4 m wide at the bottom, the two sloping sides converging upwards to an apex above the water surface; side slope marked 0.5 (horizontal) : 1 (vertical); water surface (▽) shown 1.4 m above the base]

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- (d) The difference in water surface levels in two tanks is 15 m and distance between them is 600 m. Two pipes of diameters 30 cm and 20 cm, and each having equal length, are connected to these tanks. Find the discharge through the pipes when they are connected appropriately in (i) series and (ii) parallel. The coefficient of friction = 0.04 for each pipe. Use $h_f = fLV^2/2gd$. Find the ratio of discharges when the pipes are in parallel to when the pipes are in series.

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3. (a) Determine the plastic moment capacity of the frame as shown. Assume $EI = \text{constant}$.

[Figure: Portal frame with columns of unequal height: left column 4 m high, right column 6 m high, both with fixed bases (bases at different levels, the right base 2 m lower); horizontal beam 4 m long joining the column tops; horizontal load 20 kN acting to the right at the top of the left column (beam level); vertical load 50 kN on the beam at 2 m from the right column (mid-span)]

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- (b) Draw the bending moment and shear force diagram of the beam as shown. $EI = \text{constant}$.

[Figure: Beam AEBFCFD, total length 10 m: A fixed (left end); E at 1 m from A carrying point load 2 kN; B at 3 m from A is an internal hinge; BC = 4 m carrying a uniformly distributed load of 4 kN/m over its length; C is an internal hinge; F at 1 m from D carrying point load 2 kN; CD = 3 m; D fixed (right end)]

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- (c) Derive Euler’s equation of motion along a streamline for an ideal fluid flow stating clearly the assumptions. Explain how this is integrated to get Bernoulli’s equation along a streamline. How is this equation modified while applying in practice? Draw a relevant sketch pertaining to Bernoulli’s equation components for flow in an upward inclined converging pipe.

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- (d) An inward reaction turbine has an external diameter 1.2 m and breadth 0.3 m. If the velocity of flow at inlet is 3 m/s, find the mass of the water passing through the turbine per second. Assume 15 percent of the area of flow is blocked by blade thickness. If the speed of the runner is 240 r.p.m. and guide blade angle at inlet is 15° to the wheel tangent, draw inlet velocity triangle and find– (i) the runner vane angle at inlet; (ii) the velocity of the wheel at inlet; (iii) the absolute velocity of water leaving the guide blade; (iv) the relative velocity of water entering the runner vane.

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4. (a) Calculate the maximum load P that can be applied on the frame as shown. Yield stress = 320 MPa and $E=210 \text{ GPa}$.

[Figure: Two-member frame ACB: A is a pinned support on the left; member AC rises from A at 60° to the horizontal to joint C; member CB descends from C to a pinned support B on the right, inclined at 30° to the horizontal (B lies below the level of A); C is 4 m above the horizontal (dashed) line through A; vertical load P applied downward at C. Cross-section of the members (“C/S of the members”): hollow rectangular box section, outer dimensions 50 mm wide $\times$ 60 mm deep, inner dimensions 40 mm wide $\times$ 50 mm deep]

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- (b) Draw the influence line diagram for forces in the members ①, ② and ③ of the truss as shown assuming loads are moving on the bottom chord.

[Figure: Pratt-type truss, span 6 @ 2 m = 12 m, height 2 m; bottom chord L0–L6 with 7 joints at 2 m spacing, top chord U1–U5 over L1–L5; inclined end posts L0–U1 and U5–L6; verticals at U1–L1, U2–L2, U3–L3, U4–L4, U5–L5; diagonals U1–L2, L2–U3, U3–L4, L4–U5; hinged support at L0 (left), roller support at L6 (right). Member ① is the top chord U2–U3, member ② is the diagonal L2–U3, member ③ is the vertical U2–L2]

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- (c) A jet of water of diameter 100 mm strikes a curved vane at its centre with a velocity of 15 m/s. The curved vane is moving with a velocity of 7 m/s in the direction of the jet. The jet is deflected through an angle of 160° . Assuming the vane is smooth, find– (i) the force exerted on the vane in the direction of the jet; (ii) the power of the jet; (iii) the efficiency. A series of vanes are attached to a rotating wheel such that jet always strikes the vane. Find (i), (ii) and (iii) of the above case for this situation also.

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- (d) A liquid of specific gravity 1.6 is flowing upwards at the rate of $0.1 \text{ m}^3/\text{s}$ through a vertical venturi meter with an inlet diameter of 0.3 m and throat diameter of 0.15 m. The coefficient

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of discharge is 0.98. The vertical distance between the pressure tapings is 0.5 m. (i) Find the difference in readings of the two pressure gauges, which are connected to the two pressure tapings. (ii) Find the difference in levels of mercury columns of the differential manometer connected to the tapings in place of pressure gauges. (iii) Sketch the arrangement showing the details.

SECTION 'B'

5. (a) A reinforced concrete rectangular section of size 300 mm × 600 mm (effective depth) is reinforced with three bars of 20 mm dia. Determine the safe uniformly distributed working load that the beam can carry over a simply supported effective span of 5 m. Do not ignore self-weight of the beam. Concrete used is M 20 grade and steel used is Fe 415. Use limit state method. 12
- (b) A short reinforced concrete column of size 300 mm × 300 mm is reinforced with four HYSD bars of Fe 415 having 20 mm dia. Concrete used is M 20. Determine the safe working load that the column can carry. If the load is doubled and steel amount is kept the same, find the required section of square column. Use limit state method. 12
- (c) Which law controls the wet analysis? Give assumptions and limitations of the law. 12
- (d) What is quicksand phenomenon? How does it happen and how is it remedied? 12
- (e) What is earth pressure at rest? Explain it considering active and passive pressure. 12
6. (a) The following figure shows the flight of staircase of a hospital building which is simply supported on two walls at two ends. Assume suitable live load, finish load and other dead loads: For the given data– (i) find at which section, the maximum moment will occur; (ii) find the total steel and give total number of bars of particular dia to be provided in the flight; (iii) find the nominal shear stress at critical section; (iv) show the detailing of reinforcement at A without any curtailment of main longitudinal bars. No need to apply deflection check. Use limit state method. 15
- [Figure: Staircase flight (elevation): upper landing 1.2 m long resting at its left end on a 230 mm wall; going of 8 @ 250 mm (tread) with rise = 150 mm, the waist slab sloping down to the right; lower landing 1 m long resting at its right end on a 230 mm wall; total vertical rise between the landings 1.2 m; width of flight = 1.5 m; the junction of the upper landing and the sloping waist slab is circled and marked "Detail A"]
- (b) The following figure shows the plan of slab of a framed building. It consists of several panels with different edge conditions: Assume: DL on slabs = 6 kN/m²; IL on slabs = 3 kN/m². The positive and negative short-span and long-span factored moments are given in the table for three panels: From the given moments, work out positive and negative bending moment coefficients, and indicate for which edge condition and for which long-span to short-span ratio, they are applicable. 15
- [Figure: Plan of a slab with columns at the grid intersections; bays 5.5 m and 4 m in one direction and 5 m and 5 m in the other; the left and top edges are the outer (discontinuous) edges of the floor, the right and bottom edges are shown with break lines (slab continues). Top-left panel (5.5 m × 5 m) is S₁; in the next row, the 5.5 m × 5 m panel is S₂ (below S₁, along the left edge) and the 4 m × 5 m panel is S₃ (interior)]
- | Slab | Short-span (+)ve moment (kN-m per m width) | Short-span (–)ve moment (kN-m per m width) | Long-span (+)ve moment (kN-m per m width) | Long-span (–)ve moment (kN-m per m width) |
|----------------|--|--|---|---|
| S ₁ | 13.5 | 17.9 | 11.8 | 15.86 |
| S ₂ | 10.8 | 14.5 | 9.46 | 12.5 |
| S ₃ | 7.34 | 9.72 | 5.18 | 6.91 |
- (c) The dry unit weight γ_d of a soil having 15% moisture content is 18.5 kN/m³. Find the bulk unit weight γ , saturated unit weight γ_{sat} and submerged unit weight γ' . Assume $G=2.7$. 15
- (d) What are the shear strength parameters? How are they determined? The following data are obtained from a series of drained shear box tests on 36 cm² sample of silty clay. Plot the graph for effective shear strength parameters. Give the value of attraction (Janbu): 15
- | Normal stress (kN/m ²) | 20 | 40 | 60 |
|------------------------------------|----|----|----|
| | | | |

Maximum shear stress (kN/m^2)	19.5	28.6	38.0
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7. (a) A prestressed concrete beam section is 250 mm wide and 300 mm deep. The initial prestress force is 450 kN at an eccentricity of 60 mm as shown below. The beam has a span of 5.75 m and has to carry an imposed load of 7.5 kN/m. Analyse the beam section for the stresses produced at mid-span before and after the application of imposed load. Allow a loss of prestress of 15%. Assume unit weight of concrete as 24 kN/m^3 .
[Figure: Rectangular beam section 250 mm wide $\times$ 300 mm deep; centroidal axis at 150 mm from the top; prestressing tendon 60 mm below the centroidal axis, i.e. 90 mm above the bottom] 15
- (b) The figure shown below gives the cross-section of a cantilever retaining wall which is retaining 6 m of earthfill having a unit weight of 16 kN/m^3 . The coefficient of active earth pressure is 0.33. The resultant of all the forces lies in the middle-third of the base. The wall is safe against sliding and overturning. The eccentricity is given as 0.47 m: Find the base pressures and design the heel slab for the maximum moment only by limit state method. Find the design shear at critical section. Use M 20 concrete and Fe 415 steel. Safe bearing capacity of soil is 180 kN/m^2 .
[Figure: Cantilever retaining wall section: vertical stem 0.35 m thick; base slab 3 m wide and 0.4 m thick, with toe projection 1 m (left, in front of the stem) and heel projection 1.65 m (right, under the backfill); backfill on the right level with the top of the stem, 6 m above the underside of the base; ground level in front (left) 1.5 m above the underside of the base] 15
- (c) In laboratory test on a clay sample of thickness 25 mm drained at top only, 50% consolidation occurred in 11 minutes. Find the time required for the corresponding clay layer in field, 2 m thick and drained at top only, to undergo 70% consolidation. Assume $T_{v_{50}} = 0.197$ and $T_{v_{70}} = 0.405$. 15
- (d) Using Terzaghi's theory, determine the ultimate bearing capacity of a strip footing 1.5 m wide resting on a saturated clay ($C_u = 20 \text{ kN/m}^2$, $\phi_n = 0$ and $\gamma_{sat} = 20 \text{ kN/m}^3$) at a depth of 2 m below the ground level. The water table is also at a depth of 2 m from the ground level. If the water table rises by 1 m, calculate the percentage reduction in the ultimate bearing capacity. 15
8. (a) A tension member 0.9 m long has to resist a service dead load of 20 kN and service live load of 60 kN. Design a rectangular flat bar of standard structural steel of grade Fe 410. Assume that the member is connected by one line of 16 mm diameter bolts of grade 4.6. Use limit state method. Given: Partial safety factor for material, $\gamma_{m_0} = 1.1$ and $\gamma_{m_1} = 1.25$. Partial safety factor for dead load and live load, $\gamma_f = 1.5$. 15
- (b) A joist cutting is used as bracket to support a factored load of 200 kN. It is welded to column flange as shown in the figure given below. Find the size of fillet weld. Grade of steel is Fe 410. Use partial safety factor for shop weld, $\gamma_{mw} = 1.25$. While calculating the moment of inertia, ignore the moment of inertia of the flange weld about its own axis. Use limit state method.
[Figure: Bracket made from a cut ISMB 400 (tapered joist cutting) welded to the flange of an ISHB 450 column. Factored load 200 kN acts vertically on the top flange of the bracket at 170 mm from the column flange face. Welds: 120 mm long weld along the top flange, 120 mm long weld along the bottom flange, and 320 mm long welds along the web (vertical). "View of weld from XX": two horizontal flange welds each 120 mm long, 400 mm apart (top to bottom), and two vertical web welds each 320 mm long between them] 15
- (c) What is standard penetration test? What corrections are applied for the test? Name the other penetration tests giving the positive features of the tests. 15
- (d) What type of foundations be provided for successful performance of constructed low-rise structure on expansive soil? 15