

## 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. Answer all five questions:

- (a) Find the resultant of the force system acting on a lamina of equilateral triangle of sides 200 mm. Find also its direction and position w.r.t. point A as shown in the figure. D and E are the mid-points of BC and AC respectively.

[Figure: Equilateral triangular lamina ABC of side 200 mm, A at bottom left, C at bottom right, B at the apex; D is the mid-point of BC and E the mid-point of AC (equal-length tick marks on AE = EC and BD = DC). Forces: 50 kN at B acting along the line CB produced (upwards and to the left, away from C); 60 kN at D acting along the line AD produced (upwards to the right, away from A); 30 kN at C acting horizontally to the right along AC produced; 80 kN acting vertically downwards along the vertical line through B and E (shown below E).]

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- (b) Design two solid circular shafts to transmit 200 HP each without exceeding a shearing stress of 70 MPa. One of these operates at 20 RPM and the other at 20,000 RPM. Give your inference about the final results from the view point of economy. Do you have any other suggestion to improve the economy further?

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- (c) A body is immersed in an air stream with an ambient velocity of 40 m/s at a pressure of  $98.07 \text{ kN/m}^2$  and a mass density of  $1.20 \text{ kg/m}^3$ . If the velocity of the immersed body is 80 m/s at some point, determine the pressure at that point.

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- (d) A 2.5 cm diameter water jet strikes a stationary plate held at right angles to the jet. The jet exerts a force of 784.53 N on the plate. Determine the discharge. Assume the mass unit weight of water as  $10 \text{ kN/m}^3$ .

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- (e) A pelton wheel has a mean bucket speed of 10 m/s and is supplied with water at a discharge of  $0.8 \text{ m}^3/\text{s}$  under a head of 40 m. If the bucket deflects the jet through an angle of  $150^\circ$ , find the power and efficiency of the turbine. Consider the coefficient of velocity as 0.96.

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2. (a) Draw free body diagram (FBD) of the whole system as shown in the figure. Neglecting self-weight of its parts AB, BC, AC and D, draw FBDs of individual parts also. The wheel at D is frictionless.

[Figure: Triangular frame ABC: vertical member AB (B at top), inclined member BC running down from B to C, and horizontal member AC. A rests on a roller support; C is a hinged (pin) support at the same level. A frictionless wheel (pulley) D is pinned on member AC near A. A rope is attached at E on AB, a little above A, runs horizontally to the top of the wheel D, passes round the wheel and hangs vertically down from it carrying a block of weight W. No dimensions are given.]

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- (b) For the semicircular simply supported member shown in the figure, find the value of bending moment as a function of  $\theta$ , and also draw its bending moment diagram.

[Figure: Semicircular arch member of radius  $R$  with centre  $O$ ; ends  $A$  (hinged support, left) and  $B$  (roller support, right) on the horizontal diameter  $AOB$ . A vertical downward load  $P$  acts at point  $C$  on the arch located at a horizontal distance  $R/2$  to the right of the crown (vertical dashed line through  $O$ ). A radius  $R$  is drawn from  $O$  to a general point on the left half of the arch, making angle  $\theta$  with  $OA$ .]

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- (c)(i) The wind velocities were measured above a smooth plane ground surface at 2 m and 4 m heights as 2 and 2.3 m/s respectively. Compute the shear velocity. Assume Karman's constant as 0.40 and kinematic viscosity of air as 0.145 centi stoke. What is the velocity at 8 m above the ground surface? Calculate the probable laminar sublayer thickness.

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- (c)(ii) Distinguish between surface and form drags due to a fluid flow. Estimate the bending moment at the base of a 30 m smoke stack 2 m in diameter during a 100 km per hour wind. Assume the mass density of the air as  $1.24 \text{ kg/m}^3$  and the kinematic viscosity as 0.15 centi stoke.

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3. (a) What is the maximum height  $x$  of a step in the figure so that a force  $P$  will roll a cylinder of radius  $R$  weighing  $W$  over the step with no slippage at all. The coefficient of static friction is  $\mu_s$ .

[Figure: Cylinder of radius  $R$  resting on a horizontal floor against a step of height  $x$  (step to the right of the cylinder). A horizontal force  $P$  acts to the right at the top of the cylinder. The vertical diameter is marked  $R + R$ .]

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- (b) A shallow river has a width of 1200 m and conveys a discharge of  $2830 \text{ m}^3/\text{s}$  at a mean velocity of 0.90 m/s. It is proposed to construct a river model to a horizontal scale of 1 : 800 and a vertical scale of 1 : 40. If Manning's  $n$  for the river bed material is 0.025, what should be its value in the model? Verify whether the flow in the model is turbulent. Assume kinematic viscosity as 1.1 centi stoke.

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- (c)(i) A 900 mm diameter steel pipe conveys a discharge of  $1.5 \text{ m}^3/\text{s}$ . The wall thickness of the pipe is 10 mm and the elastic modulus of the pipe material is  $20.7 \times 10^{10} \text{ N/m}^2$  and the bulk modulus of water is  $21.09 \times 10^8 \text{ N/m}^2$ . Determine the increase in pressure if the valve at the end of the 3.5 km long pipe is closed in (i) 3.5 sec and (ii) 10.0 sec. Assume the mass density of the water as  $1000 \text{ N/m}^3$ .

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- (c)(ii) Following are the monthly inflow, Evaporation and rainfall data and the contemplated demand for a proposed reservoir of a hydropower project:

| Month                            | Jan | Feb | Mar | April | May | June | July | Aug | Sept | Oct | Nov | Dec |
|----------------------------------|-----|-----|-----|-------|-----|------|------|-----|------|-----|-----|-----|
| Monthly Inflow ( $\text{Mm}^3$ ) | 50  | 40  | 30  | 25    | 20  | 30   | 200  | 225 | 150  | 90  | 70  | 60  |
| Monthly Evaporation (cm)         | 6   | 8   | 13  | 17    | 22  | 22   | 14   | 11  | 13   | 12  | 7   | 5   |
| Monthly Rainfall (cm)            | 1   | 0   | 0   | 0     | 0   | 19   | 43   | 39  | 22   | 6   | 2   | 1   |
| Monthly demand ( $\text{Mm}^3$ ) | 70  | 75  | 80  | 85    | 130 | 120  | 25   | 25  | 40   | 45  | 50  | 60  |

The average reservoir area is  $30 \text{ km}^2$ . Estimate the storage that is necessary to meet the demand.

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4. (a) Two equal cylinders,  $E$  and  $F$ , each weighing 1000 N are placed in a box as shown in the figure. Neglecting friction between the cylinders and the box, estimate reactions at  $A$ ,  $B$  and  $C$ .

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[Figure: Rectangular box with vertical side walls and a horizontal bottom. Cylinder E (lower, left) touches the left wall at A and the bottom at B; cylinder F (upper, right) rests on E and touches the right wall at C. The line joining the centres of E and F is inclined at  $45^\circ$  to the horizontal. No other dimensions are given.]

- (b) For the beam shown in the figure, compute the deflection of end B by force method. [Figure: Beam AB of length  $l$ , fixed at end A; end B rests on a spring of stiffness  $K$ . A uniformly distributed load  $W/\text{length}$  acts over the whole length.  $EI = \text{Const.}$ ] 15
- (c)(i) It is required to choose a suitable turbine for hydropower generation for the following data: Available head = 300 m and discharge =  $6.25 \text{ m}^3/\text{s}$ . A runner speed of 200 rpm and maximum overall efficiency of 85% can be adopted. Determine the diameter of the runner. Assume the specific weight of water as  $10,000 \text{ N/m}^3$ . 12
- (c)(ii) A discharge of  $1.0 \text{ m}^3/\text{s}$  is to be pumped to a height of 40 m using centrifugal pumps of specific speed  $N_s$  of 50. The pumps run at 1500 rpm and have an overall efficiency of 75%. Determine the number and arrangement of pumps. 13

### SECTION 'B'

5. Answer all five parts:

- (a) A built-up column consists of three ISWB 450 @ 0.794 kN per m connected effectively to act as one column. (See above figure.) Determine the safe load carrying capacity of built-up section if the unsupported length of column is 4.25 m. Properties of ISWB 450 @ 0.794 kg per m. Area =  $101.15 \text{ sq cm}$   $I_{xx} = 35057.6 \text{ cm}^4$   $I_{yy} = 1706.7 \text{ cm}^4$   $t_w$  = thickness of web = 9.2 mm;  $f_y = 250 \text{ M.Pa}$  = yield stress.

[Figure: Built-up column section of three ISWB 450: two ISWB sections placed upright (webs vertical, flanges horizontal) at the left and right, and a third ISWB placed between them with its web horizontal along the x-x axis and its flanges vertical, the flanges of the middle section bearing against the webs of the outer sections. Axis x-x is horizontal through the centroid; y-y axes are marked through the webs of the two outer sections. No dimensions are given.]

| Slenderness ratio                                                      | 10  | 20  | 30  | 40  | 50  | 60  | 70  |
|------------------------------------------------------------------------|-----|-----|-----|-----|-----|-----|-----|
| Permissible stress in axial compression in M.Pa<br>$f_y = 250$<br>M.Pa | 150 | 148 | 145 | 139 | 132 | 122 | 112 |

- (b) Draw the bending moment diagram and shear force for the beam as shown in the figure. [Figure: Beam ADBC: hinged support at A, roller support at B, overhang BC. AD = 2 m, DB = 2 m, BC = 2 m. Point load 10 kN at D; uniformly distributed load 2 kN/m over the overhang BC.] 10
- (c) What will be the gross and net safe bearing pressure of sand having  $\phi = 36^\circ$  and effective unit weight of  $18 \text{ kN/m}^3$  under (i) 1 m wide strip footing (ii) a square footing of 1 m size? Assume the footings are placed at a depth of 1 m below ground surface and the water table is at a great depth. Also, assume a factor of safety of 3.0. Use Terzaghi's theory. Given  $\phi = 36^\circ$ ,  $N_q = 47$  and  $N_y = 43$ . 10
- (d) In a variable head permeability test the initial ( $t=0$ ) hydraulic head is 45 cm and it drops 1 cm in 5 minutes. Calculate the time required for the head to drop further by 10 cm i.e. from 44 cm to 34 cm. 10
- (e) In unconfined compression test, a soil sample fails at  $160 \text{ kN/m}^2$  stress. The failure plane makes an angle of  $50^\circ$  with the horizontal. Calculate the values of cohesion and angle of internal friction of the soil. 10
6. (a) A simply supported I beam (ISMB 350) is to carry an imposed load of  $20 \text{ kN/m}$ . The beam ends are resting on 250 mm thick walls with bearing plates (smooth) with clear span of 6.25 m. The beam is laterally restrained and is made of MILD STEEL. The beam supports a floor slab. Check the beam section against bending, shear and deflection. The 20

section properties of ISMB 350 are:  $I_{xx} = 13630.6 \times 10^4 \text{ mm}^4$ ; Weight = 524 N per m  $t_w$  = Thickness of web = 8.1 mm; Area = 6671 sq mm  $D$  = Depth of the beam = 350 mm Assume allowable bending stress, allowable shear stress as per code.

- (b) A masonry retaining wall has to retain sand with a unit weight of  $15 \text{ kN/m}^3$ . Angle of internal friction  $30^\circ$ . Assume sand to be dry and the height retained is 4.2 m. The top width of the wall is 300 mm. Bottom width is 2100 mm. Check whether the resultant of the forces is within the middle third of the base. Calculate the stability factors of the wall. The back of the wall adjoining the soil is vertical. The top level of sand is horizontal. Unit of weight of masonry is  $24 \text{ kN/m}^3$ . 15
- (c) For sub-soil conditions shown in the figure draw total, effective and neutral stress diagram up to a depth of 8 m. Neglect capillary rise. Take  $\gamma_w = 10 \text{ kN/m}^3$ .  
[Figure: Soil profile below ground level (G.L.): Sand layer 5 m thick, with  $e=0.6$ ,  $G=2.65$ ; water table at 3 m below G.L. (3 m of sand above and 2 m of sand below the water table). Below the sand, a Clay layer 3 m thick with  $\omega=45\%$ ,  $G=2.7$ . Total depth shown 8 m.] 15
7. (a) A slab is reinforced with 10 mm diameter bars at 200 mm c/c located at an effective depth of 125 mm. M 20 concrete and Fe 415 steel are used. Find the Moment of resistance of the slab using either working stress method or limit state of strength (ultimate limit state of stress) method as per I.S. code. (I.S. codes are not applied during examination). What shall be the overall depth of slab? Modular ratio is 13.33. 20
- (b) A 30 cm diameter concrete pile, is driven to a depth of 20 m in a deep deposit of clay having unconfined compressive strength of  $90 \text{ kN/m}^2$ . What is the design carrying capacity of pile? Assume adhesion factor = 0.8 and factor of safety = 3. 15
- (c) A point load of 200 kN acts on the surface of a homogenous soil mass of large extent. Find the stress intensity (i) at a depth of 10 m directly under the load. (ii) at a horizontal distance of 5 m and depth of 10 m. Use Boussinesq equation. 15
8. (a) A prestressed concrete beam of 300 mm wide  $\times$  500 mm overall depth is prestressed with a net force of 750 kN at an eccentricity of 100 mm below from the centroid of gross section. The effective simply supported span of beam is 7 m. It is subjected to an imposed load of 20 kN per metre in addition to the dead load. Evaluate the stresses at top and bottom fibres at the centre of span due to effect of prestress, dead load and live load. Unit weight of prestressed beam is 24 kN per m. Calculation of equivalent area of concrete is not necessary. 15
- (b) Analyse the continuous beam by moment-distribution method and draw the bending moment diagram showing salient values.  
[Figure: Continuous beam AEBCD: fixed support at A; simple (hinged) supports at B and C; overhang CD. AB = 5 m, BC = 4 m, CD = 1 m. Point load 20 kN at E, 2 m from A; uniformly distributed load 5 kN/m over span BC; point load 20 kN at the free end D. EI = Constant.] 20
- (c) A normally consolidated clay has a compression index = 0.2. Initial void ratio of this clay layer is 0.9 and thickness = 3 m. If the initial soil stress is  $10 \text{ kN/m}^2$ , how high can the stress become before the ultimate settlement is 2 cm? 15