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# UPSC IFS (M)

**Previous Year Paper**  
**(Civil Engineering) Paper-I**  
**27 Nov, 2024 Shift 1**



CIVIL ENGINEERING

Paper—I

Time Allowed : Three Hours

Maximum Marks : 200

**QUESTION PAPER SPECIFIC INSTRUCTIONS**

**Please read each of the following instructions carefully  
before attempting questions**

There are EIGHT questions in all, out of which FIVE are to be attempted.

Question Nos. **1** and **5** are compulsory. Out of the remaining SIX questions, THREE are to be attempted selecting at least ONE question from each of the two Sections A and B.

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.

All questions carry equal marks. The number of marks carried by a question/part is indicated against it.

Answers must be written in ENGLISH only.

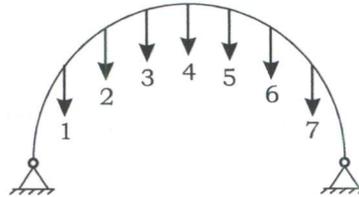
Unless otherwise mentioned, symbols and notations have their usual standard meanings.

Assume suitable data, if necessary, and indicate the same clearly.

Neat sketches may be drawn, wherever required.

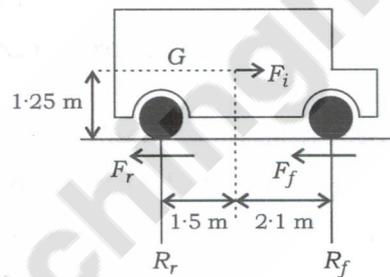
**SECTION—A**

1. (a) A two-hinged parabolic arch, whose section varies such that the moment of inertia of the section is proportional to the secant of the slope of the arch axis, has a span of 120 m and a rise of 18 m. The load is transmitted to the arch by means of seven suspenders placed 12.5 m apart. Each suspender transmits a force of 60 kN. Find the horizontal reaction  $H$  :



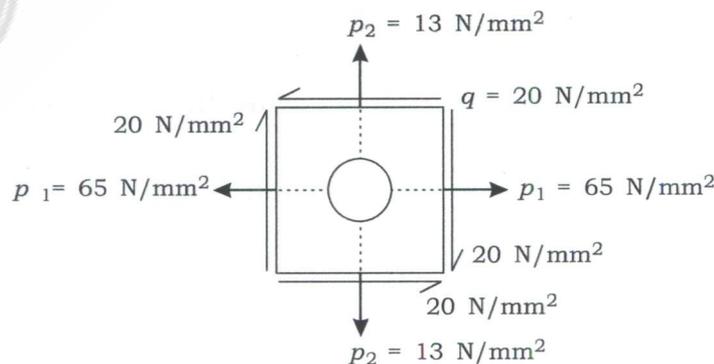
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- (b) A vehicle weighing 40 kN as shown in the figure and moving at a velocity of 80 km/hr is stopped by applying brakes, so that it skids to stop over a distance of 60 m. Determine the coefficient of friction and the reactions on each wheel while the car is skidding :



8

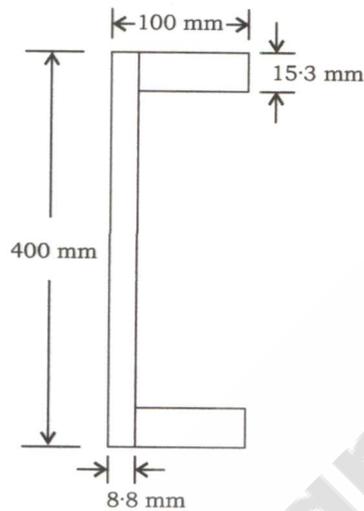
- (c) A mild steel plate is stressed as shown in the figure. Before stressing, a circle of 300 mm diameter is drawn on the plate. Determine the length and direction of the major and minor axis of the ellipse into which the circle deforms after stressing. Poisson's ratio = 0.3, stressing Poisson's ratio = 0.3, modulus of elasticity = 20 kN/mm<sup>2</sup> :



8

- (d) A rectangular beam 200 mm wide by 300 mm deep, spanning over 6.0 m is prestressed by a straight cable carrying an effective prestressing force 300 kN located at an eccentricity of 50 mm. The beam supports a live load of 6.0 kN/m. Calculate the resultant stress distribution for the central cross-section of the beam. The density of concrete is  $25 \text{ kN/m}^3$ .
- (e) Determine the plastic section modulus about the stronger axes of ISMC 400 @ 501 N/m having the following section :

8



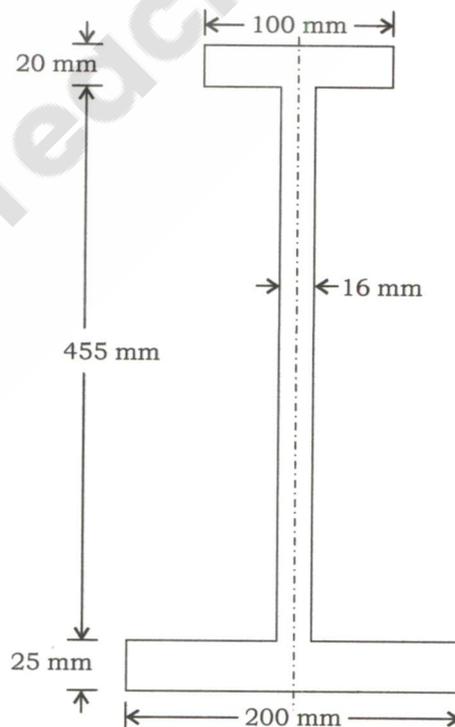
$$h = 400 \text{ mm}, \quad t_w = 8.8 \text{ mm}$$

$$b_f = 100 \text{ mm}, \quad t_f = 15.3 \text{ mm}$$

8

2. (a) Determine the position of centroid and moment of inertia about the base flange for the I-section shown in the figure :

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- (b) Design a cantilever beam, section near support, over a span of 3.0 m, carrying a superimposed load of 20 kN/m. Use working stress method of design.

The following design considerations shall be used :

Grade of concrete = M20

Permissible stress in bending compression,  $\sigma_{cbc} = 7.0 \text{ N/mm}^2$

Grade of steel = Fe415

Permissible tensile strength,  $\sigma_{st}$  or  $\sigma_{sv} = 230 \text{ N/mm}^2$

Diameter of longitudinal reinforcement = 16 mm

Shear stirrups : 2-legged, 8 mm dia, vertical

Width of beam,  $b = 400 \text{ mm}$

Design constants for working stress method of design :

$$m = 13.33 \quad N = 0.2886$$

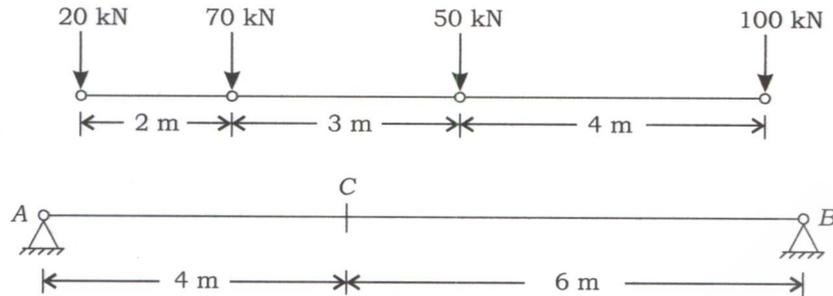
$$j = 0.9038 \quad Q = 0.913$$

Permissible shear stress in concrete, $\tau_c$ , $\text{N/mm}^2$						
$100 \frac{A_s}{bd}$	Grade of concrete					
	M15	M20	M25	M30	M35	M40 and above
(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\leq 0.15$	0.18	0.18	0.19	0.20	0.20	0.20
0.25	0.22	0.22	0.23	0.23	0.23	0.23
0.50	0.29	0.30	0.31	0.31	0.31	0.32
0.75	0.34	0.35	0.36	0.37	0.37	0.38
1.00	0.37	0.39	0.40	0.41	0.42	0.42
1.25	0.40	0.42	0.44	0.45	0.45	0.46
1.50	0.42	0.45	0.46	0.48	0.49	0.49
1.75	0.44	0.47	0.49	0.50	0.52	0.52
2.00	0.44	0.49	0.51	0.53	0.54	0.55
2.25	0.44	0.51	0.53	0.55	0.56	0.57
2.50	0.44	0.51	0.55	0.57	0.58	0.60
2.75	0.44	0.51	0.56	0.58	0.60	0.62
3.00 and above	0.44	0.51	0.57	0.60	0.62	0.63

NOTE :  $A_s$  is that area of longitudinal tension reinforcement which continues at least one effective depth beyond the section being considered except at supports where the full area of tension reinforcement may be used provided the detailing conforms to 26.2.2 and 26.2.3

Maximum shear stress, $\tau_{c \max}$ , $\text{N/mm}^2$						
Concrete grade	M15	M20	M25	M30	M35	M40 and above
$\tau_{c \max}$ , $\text{N/mm}^2$	1.6	1.8	1.9	2.2	2.3	2.5

- (c) Determine the maximum possible shear force and moment at point C of the beam shown in the figure, due to a series of concentrated loads moving on the beam from right to left :



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3. (a) A parabolic arch, symmetrical with hinges at centres and ends, carries a point load  $P$  at a distance  $x$  from left support. The arch has a span of 20 m and a rise of 5.0 m. What is the value of  $x$  if the left hinge reaction is inclined with a slope of two vertical on a horizontal?

15

- (b) An interior panel of two-way slab for a room has clear dimensions of 4.0 m  $\times$  5.0 m. The live load on the slab is 2.5 kN/m<sup>2</sup> and finishing as 1.0 kN/m<sup>2</sup>. Design the middle strip of this slab panel using IS code method. Draw the reinforcement also.

The following design considerations shall be used :

Neglect the design of edge strip and corner/torsion reinforcement

Design the middle strip for flexural only

Grade of concrete is M20

Grade of reinforcement is Fe415

$$M_{u \text{ lim}} = 0.138 f_{ck} b d^2$$

$$M_u = 0.697 f_y A_{st} d$$

Minimum cover to reinforcement is 20 mm

Minimum thickness of slab is 120 mm

Use dia of reinforcement as 8 mm

Self-weight of concrete is 25 kN/m<sup>3</sup>

Use limit state method

BM coefficients as per IS 456 : 2000

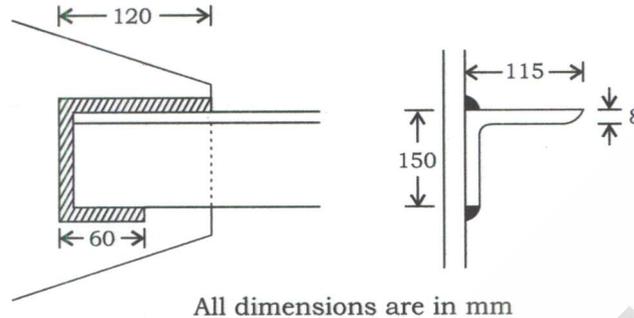
Type of panel and moment considered	Shorter span coefficient $\alpha_x$ (Value of $l_y / l_x$ )				Longer span coefficient $\alpha_y$ for all values of $l_y / l_x$
	1.0	1.1	1.2	1.3	
Inner panel :					
Negative moment at cont. edge	0.032	0.037	0.043	0.047	0.032
Positive moment near mid-span	0.024	0.028	0.032	0.039	0.024

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(c) Compute the tensile strength of an angle section ISA 150 mm × 115 mm × 8 mm of Fe410 grade of steel connected with the gusset plate as shown in the figure, for the following cases :

(i) Gross section yielding

(ii) Net section rupture



The following parameters are to be considered :

For grade Fe410 steel :  $f_u = 410$  MPa,  $f_y = 250$  MPa

Partial safety factor :  $\gamma_{m0} = 1.1$ ,  $\gamma_{m1} = 1.25$

For ISA 150 mm × 115 mm × 8 mm : Gross area  $A_g = 2058$  mm<sup>2</sup>

$$\beta = 1.4 - 0.076 \left( \frac{w}{t} \right) \left( \frac{f_y}{f_u} \right) \left( \frac{b_s}{L_c} \right)$$

$$\beta = \frac{f_u}{f_y} \times \frac{\gamma_{m0}}{\gamma_{m1}}$$

$$T_{dn} = 0.9 \frac{A_{nc} \cdot f_u}{\gamma_{m1}} + \beta \frac{A_{g0} \cdot f_y}{\gamma_{m0}}$$

10

4. (a) An isolated flat footing for a column, 500 mm × 500 mm, is transferring an axial load 1600 kN and uniaxial moment 80 kN-m. Design the flat square footing for flexure and two-way shear by limit state method. Sketch the section and all the reinforcements.

The following design considerations shall be used :

Safe bearing capacity of soil = 200 kN/m<sup>2</sup>

Grade of concrete = M20

Grade of reinforcement = Fe415

Minimum cover to reinforcement = 75 mm

Dia of reinforcement bars = 16 mm

Total depth calculated shall be rounded off to next multiple of 20 mm

Spacing of reinforcement shall be rounded off to lower 10 mm multiple

$$M_{u \text{ lim}} = 0.138 f_{ck} b d^2$$

Minimum footing thickness = 600 mm

$$M_u = 0.697 f_y A_{st} d$$

15

- (b) A column ISHB 300 @ 576.8 N/m is to support a factored load of 1200 kN. The column section is to be spliced at a height of 3.0 m. Design the splice plate and connection using 16 mm dia bolts of 4.6 grade, with the figure.

The following parameters are to be considered :

For grade of steel Fe410 :  $f_u = 410$  MPa,  $f_y = 250$  MPa

For bolt of grade 4.6 :  $f_{ub} = 400$  MPa

Partial safety factor for material :  $v_{m0} = 1.10$ ,  $v_{mb} = 1.25$

Property of ISHB 300 @ 576.8 N/m :  $A = 7485$  mm<sup>2</sup>,

$b_f = 250$  mm,  $t_f = 10.6$  mm

Net area of 16 mm dia bolt,  $A_{nb} = 157$  mm<sup>2</sup>

Strength of bolt in single shear =  $A_{nb} \frac{f_{ub}}{\sqrt{3} v_{mb}}$

Strength of bolt in bearing =  $2.5k_b dt \frac{f_u}{v_{mb}}$

assuming  $k_b = 1.0$

Column section to be machined for complete bearing 15

- (c) Find the stresses in a hollow pipe of internal diameter 250 mm and thickness of metal 25 mm, subjected to an internal fluid pressure of 30 N/mm<sup>2</sup>, by using Lamé's equation for thick pipe. 10

#### SECTION—B

5. (a) A 3.0 m wide rectangular channel is built to bypass a dam so that fish can swim upstream during their migration. During normal conditions when water depth is 1.2 m, the water velocity is 1.5 m/s. Determine the velocity during a flood when the water depth is 2.4 m. 8
- (b) A laminar flow of water is obtained in a laboratory at Reynolds number of 20000 in a horizontal 5 cm diameter pipe. Calculate the head loss in a 10 m section of developed flow, the wall shear stress and the length of the entrance region. Assume density of water as 1000 kg/m<sup>3</sup> and dynamic viscosity of water as  $1 \times 10^{-3}$  N-s/m<sup>2</sup>. 8
- (c) In a laboratory, two soils are tested for the consistency limits. The test results are as follows :

	Soil A	Soil B
Liquid limit	40%	58%
Plastic limit	20%	22%
Flow index	10	6
Natural water content	38%	52%

On the basis of the results obtained, comment on the following :

- (i) Which soil has greater plasticity?
  - (ii) Which soil is more compressible?
  - (iii) Which soil has better shear strength at the plastic limit?
  - (iv) Could organic matter be present in these soil? 8
- (d) Determine the coefficient of permeability of the uniform sands having spherical grains and a void ratio of 0.85. The viscosity of water is  $10^{-3}$  N-s/cm<sup>2</sup>. The  $D_{10}$  value of the sand is 0.2 cm. Assume the composite shape factor as 0.0027. 8
- (e) In order to purchase sampling tubes, the market survey is carried out and the following samplers are available :

	Tube A	Tube B	Tube C
Outer diameter (mm)	75.0	111.0	50.0
Inner diameter (mm)	72.0	108.0	36.0
Length of tube (mm)	750	750	750

Out of these three, which sampler will be suitable to procure the undisturbed soil samples from a borehole? 8

6. (a) In a triaxial apparatus, a test is performed on normally consolidated clay under consolidated undrained condition. The sample is consolidated under a cell pressure of 200 kN/m<sup>2</sup> and failed at an additional axial pressure of 160 kN/m<sup>2</sup>. The pore pressure at failure was 80 kN/m<sup>2</sup>. Determine the shear strength parameters both in terms of total and effective stresses. What will be the ratio of major principal stress to minor principal stress? Also find the value of  $A_f$ . Assume that the soil sample was fully saturated. 15
- (b) A reaction turbine 500 mm in diameter, when running at 600 r.p.m., developed brake power of 195 kW when the flow was 0.74 m<sup>3</sup>/s. The pressure head at entrance to the turbine was 27.90 m and elevation of the turbine casing above tailwater level was 1.91 m. The water entered the turbine with a velocity of 3.66 m/s. Calculate (i) the effective head, (ii) the efficiency, (iii) the speed expected under a head of 68.6 m and (iv) the break power and discharge under the 68.6 m head. Assume density of water,  $\rho = 1000$  kg/m<sup>3</sup>. 15
- (c) A vertical cut is made through a homogeneous and isotropic soil mass, the properties of which are given below :

$$\text{Cohesion} = 19 \text{ kN/m}^2$$

$$\text{Angle of shearing resistance} = 20^\circ$$

$$\text{Density} = 17 \text{ kN/m}^3$$

Determine the safe depth of the vertical cut by using Culmann's method. Also verify the safe depth by Taylor's stability method. Assume the factor of safety as 2.0.

Taylor's stability chart

Angle at shearing resistance →	10°	15°	20°
Inclination ↓			
90°	0.218	0.199	0.182

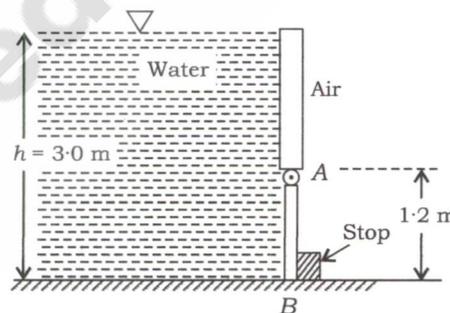
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7. (a) The velocity potential for a certain inviscid, incompressible flow field is given by the equation  $\phi = -9 \cdot 8x^2y + 3 \cdot 28y^3$ , where  $\phi$  has the units of  $m^2/s$ , and  $x$  and  $y$  are the coordinates in meters. Determine the pressure difference in kilopascal between a point with coordinates  $x = 0.3$  m,  $y = 0.6$  m and another point with coordinates  $x = 1.2$  m,  $y = 1.2$  m. Assume that elevation changes are negligible and fluid is water with its density as  $1000 \text{ kg/m}^3$ .

15

(b) Water is filled in one side of the gate AB as shown in the figure. The gate is 1.5 m wide into the paper, hinged at A, and restrained by a stop at B. If the density of water is  $1000 \text{ kg/m}^3$ , depth of water is 3.0 m and weight of the gate is negligible, answer the following :

- (i) What would be the force on stop B?
- (ii) What would be the reactions at A?



10

(c) Two plate load tests on a sandy soil at the site were performed and the following results were obtained :

Size of plate	Load	Settlement
0.30 m × 0.30 m	50 kN	25 mm
0.60 m × 0.60 m	50 kN	15 mm

- (i) Determine the deformation modulus of the soil. Assume Poisson's ratio as 0.3.

- (ii) If there are two columns, one of size 3 m × 3 m, carrying a load of 3000 kN and the other of size 3.5 m × 3.5 m, carrying a load of 4500 kN, determine the differential settlement. The columns are separated by 8 m.

Assume that the influence factor for the square footing is 1.12 and the footing is rigid.

Also check the differential settlement as per IS code. 15

8. (a) (i) What are the desirable characteristics of grouts? 8  
 (ii) Estimate the quantity of cement required for permeation grouting in gravel, having porosity of 0.4. The water-cement ratio of grout mix is 6 : 1. Assume that 60% of the void space gets filled with the grout slurry. The specific gravity of cement is 3.14. 7

- (b) A 5 m wide rectangular channel with its bottom slope ( $S_0$ ) = -0.001 conveys flow at a rate of  $Q = 30 \text{ m}^3/\text{s}$ . If at a given location, the depth is  $y_1 = 2.0 \text{ m}$  and downstream of that location the depth is  $y_2 = 1.8 \text{ m}$ , and Manning's coefficient is  $n = 0.02$ , answer the following :

- (i) What is the distance between locations 1 and 2?  
 (ii) What type of water surface profile exists in the reach? Why? 15

- (c) A porous round pipe with diameter  $D = 60 \text{ mm}$  carries water. The inlet velocity of water is uniform with  $V_1 = 7.0 \text{ m/s}$ . Water flows radially and axisymmetrically outward through the porous walls with velocity distribution

$$v = V_0 \left[ 1 - \left( \frac{x}{L} \right)^2 \right]$$

where  $V_0 = 0.03 \text{ m/s}$  and  $L = 0.950 \text{ m}$ . What would be the mass flow rate inside the pipe at a distance  $x = L$ ? Assume that the density of water is  $1000 \text{ kg/m}^3$  and water flow is steady. 10

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