

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.*

*Questions no. **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.

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.

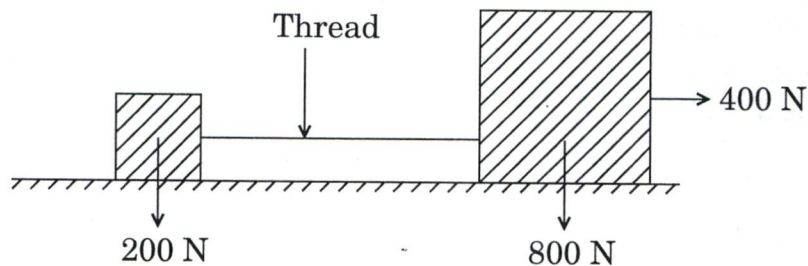
*Answers must be written in **ENGLISH** only.*

SECTION A

Q1. (a) What is D'Alembert's principle ?

Two weights 800 N and 200 N are connected by a thread and move along a rough horizontal plane under the action of a force of 400 N applied to the 800 N weight as shown in the figure below. The coefficient of friction between the sliding surfaces of the weights and the plane is 0.3. Determine the acceleration of the weights and tension in the thread using D'Alembert's principle. (Take $g = 9.81 \text{ m/s}^2$)

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(b) A compound stanchion is made up of two ISMC 250 placed back-to-back as shown in the figure below with a gap between the adjacent flat surfaces. Two $36 \text{ cm} \times 1.2 \text{ cm}$ plates are rivetted to the flanges, so as to form a symmetrical box section. Determine the amount of gap if the column is to carry maximum load. Properties of ISMC 250 are :

$$\text{Area} = 38.67 \text{ cm}^2$$

$$\text{Maximum Moment of Inertia} = 3816.8 \text{ cm}^4$$

$$\text{Minimum Moment of Inertia} = 219.1 \text{ cm}^4$$

$$\text{Distance of the centroid from the back} = 2.30 \text{ cm}$$

If the effective length of the stanchion is 8.5 m, calculate the safe maximum load, the working stress being interpolated from the following table.

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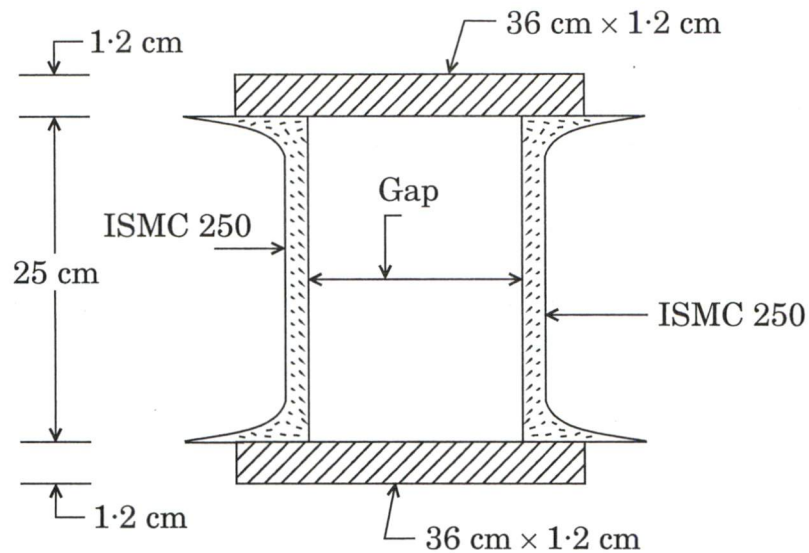


Table :

$\frac{l}{r}$	20	40	60	80	100	120	140
Working stress (N/mm ²)	124	120	113	101	84	67	53

- (c) What do you mean by plastic hinge and plastic moment ? Determine the shape factor of a triangular section.

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- (d) A single riveted lap joint is used to connect 12 mm thick plates. If 20 mm diameter rivets are used at 50 mm gauge, calculate the strength of joint and joint efficiency. Use : $f_y = 260 \text{ N/mm}^2$, and power driven field rivets.

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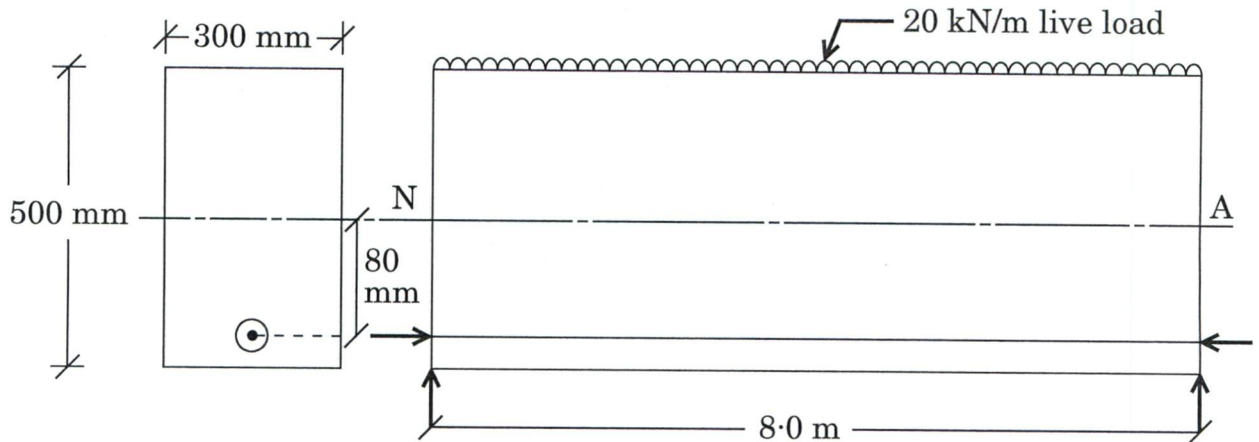
Permissible stress in single shear = 80 N/mm^2

Permissible stress in bearings = 250 N/mm^2

Permissible stress in axial tension in plates = $0.6 f_y$.

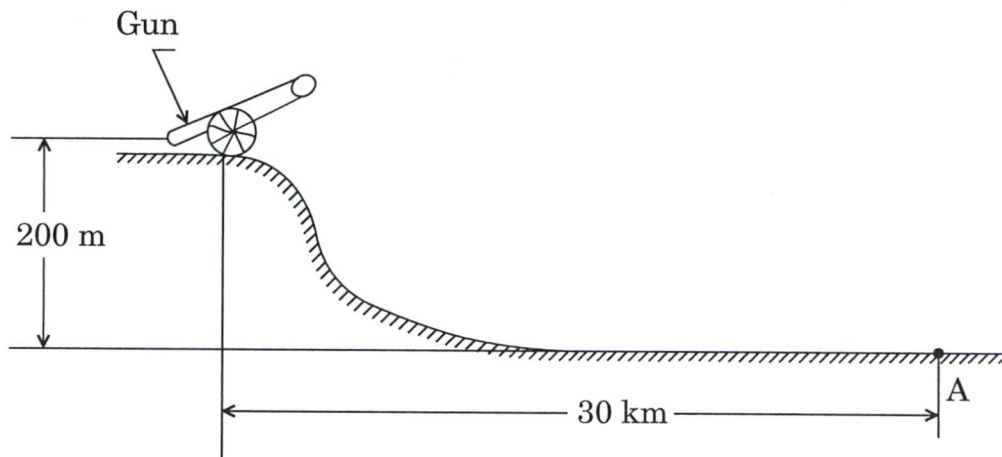
- (e) A rectangular beam of size 300×500 mm is used over an effective span of 8.0 m. It supports a live load of 20 kN/m. A straight tendon is provided at an eccentricity of 80 mm below the centroid of the section. Calculate the minimum prestress required for no tension at live load at mid span. Unit weight of concrete : 24 kN/m^3 .

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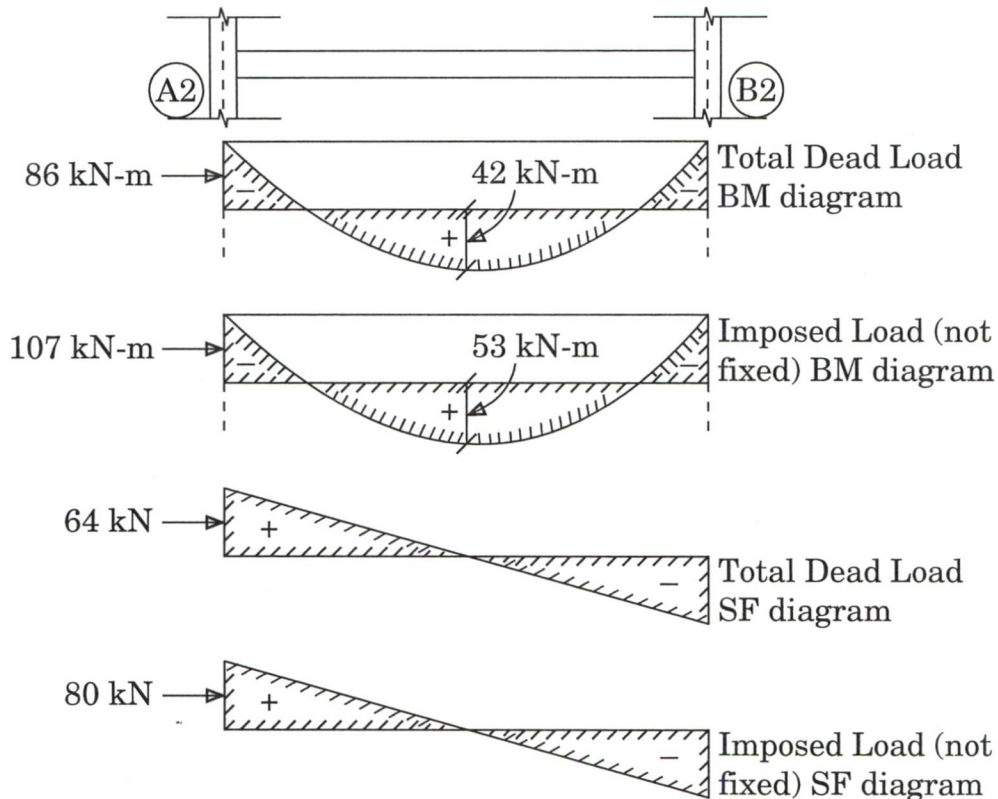
- Q2.** (a) A gun emplacement on a cliff is as shown in the figure below. The muzzle velocity is 1000 m/s. At what angle must the gun point be in order to hit a target at A? Neglect friction. (Take $g = 9.81 \text{ m/s}^2$)

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- (b) Design a beam A2-B2 by Limit State method of Design; for flexure at A2 and at mid span and for shear at A2 only. Sketch the section and all reinforcement at A2 only.

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Following are the design considerations :

- (i) Limit state of collapse : Flexure and Shear
- (ii) Grade of concrete : M 20
- (iii) Grade of reinforcing bars : Fe 415
- (iv) Beam width : 300 mm
- (v) Framed structure
- (vi) Nominal cover to reinforcement : 25 mm
- (vii) Load combination : Only Dead Load and Imposed Load (not fixed)
- (viii) Partial safety factor for Dead Load and Imposed Load : 1.5 each
- (ix) Minimum overall depth of beam required is : 700 mm as per site requirement
- (x) Total depth calculated shall be rounded off to next multiplier of 10 mm.

- (xi) Largest depth shall be used and provided.
- (xii) Use 20 mm diameter bar for flexural reinforcement and 8 mm diameter for shear reinforcement.
- (xiii) Spacing of shear reinforcement shall be rounded off to lower 10 mm multiplier.
- (xiv) $\tau_{\max} = 2.8 \text{ N/mm}^2$
- (xv)
$$V_{us} = \frac{0.87 f_y \cdot A_{sv} d}{s_v}$$
- (xvi)
$$\frac{M_{u, \lim}}{bd^2} = 0.1389 f_{ck}$$
- (xvii) Percentage reinforcement p_t for M 20 and Fe 415 shall be :

$\frac{M_u}{bd^2}$	1.04	1.10	1.50	1.80	2.0	2.12	2.22	2.30
$p_t \%$	0.311	0.327	0.460	0.565	0.640	0.678	0.717	0.757

- (xviii) Design shear strength of concrete τ_c shall be :

$\tau_c \text{ N/mm}^2$	0.51	0.55	0.57	0.60	0.62
$p_t \%$	0.60	0.70	0.80	0.90	1.00

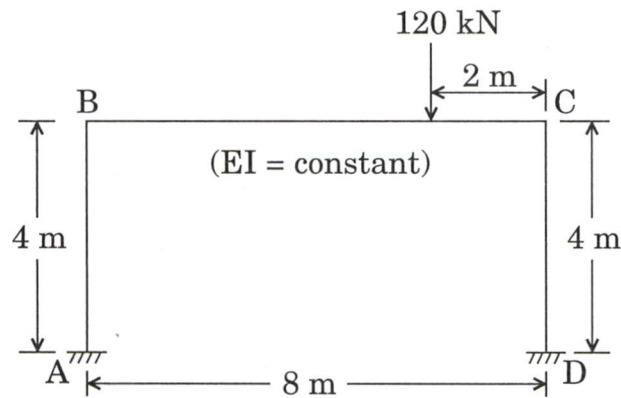
- (xix) Minimum shear reinforcement
$$\frac{A_{sv}}{(b)(s_v)} \geq \frac{0.40}{0.87 f_y}$$

- (c) Design a single angle section for a member of a roof truss to carry a tension of 195.00 kN. Following parameters may be used :

$f_y = 260 \text{ N/mm}^2$, $\sigma_{at} = 0.6 (f_y)$, Rivet diameter = 18.0 mm,
 ISA : 70 × 70 × 10, $A = 1300 \text{ mm}^2$, ISA : 80 × 80 × 12, $A = 1780 \text{ mm}^2$,
 ISA : 90 × 90 × 12, $A = 2020 \text{ mm}^2$.

- Q3.** (a) Analyse the frame shown in the figure below by column analogy method and draw bending moment diagram. (Take $EI = \text{constant}$)

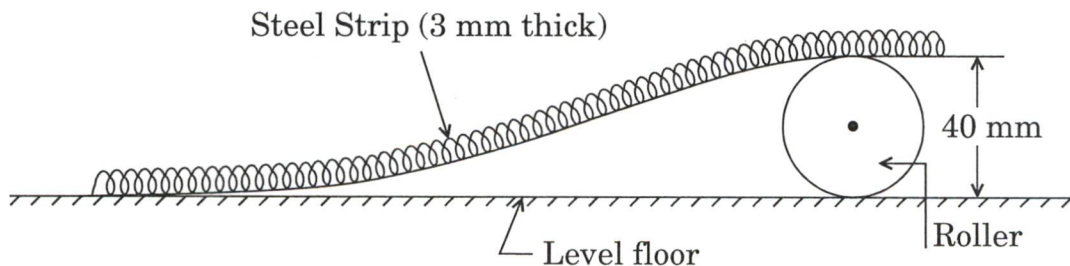
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- (b) A long strip of steel of uniform width and 3 mm thickness is laid on a level floor, but passes over a 40 mm diameter roller lying on the floor, at one point, as shown in the figure below.

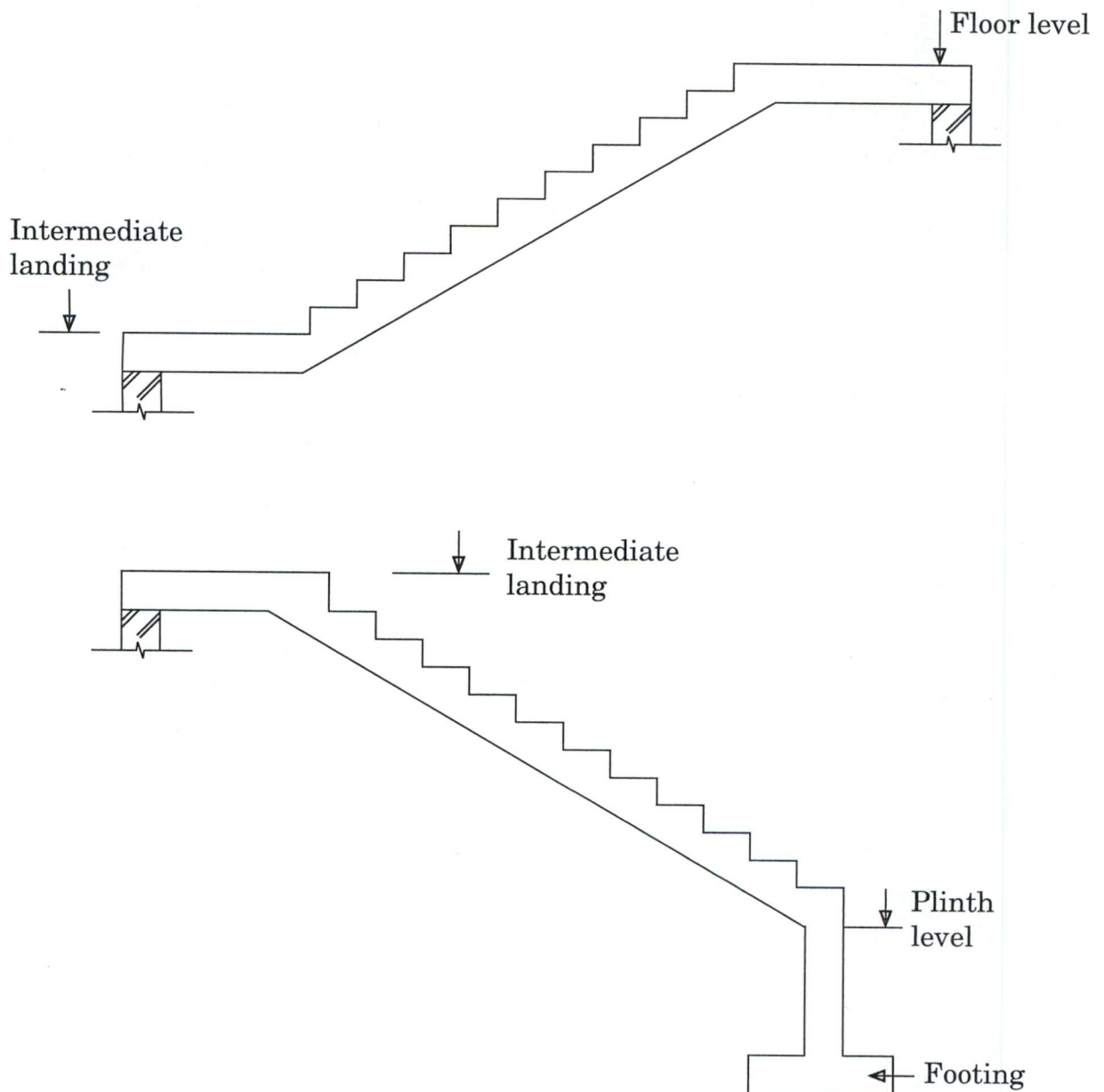
For what distance on either side of the roller will the strip be clear off the floor and what will be the maximum bending stress induced? Take weight of steel as $7.8 \times 10^{-5} \text{ N/mm}^3$ and E for steel as $2 \times 10^5 \text{ N/mm}^2$.

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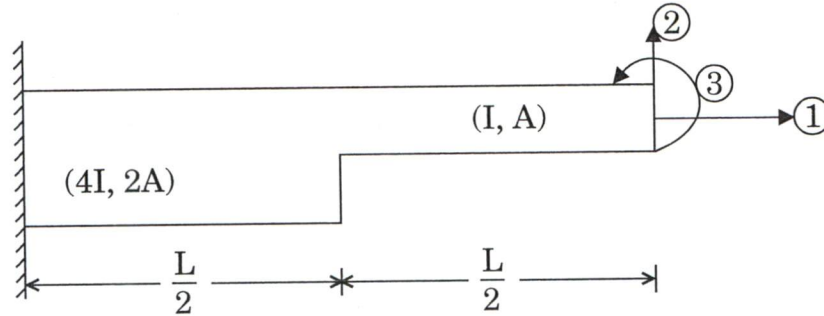


- (c) A staircase as shown in the figure below is supported at ends of flight. Sketch the details of all the main reinforcement and distribution reinforcements. Also mark the tentative position of development and lap length. (Note : Given figure may be used for sketching the reinforcement details)

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- Q4.** (a) Generate the flexibility matrix for the structure with coordinates as shown in the figure below. (Take $E = \text{constant}$)



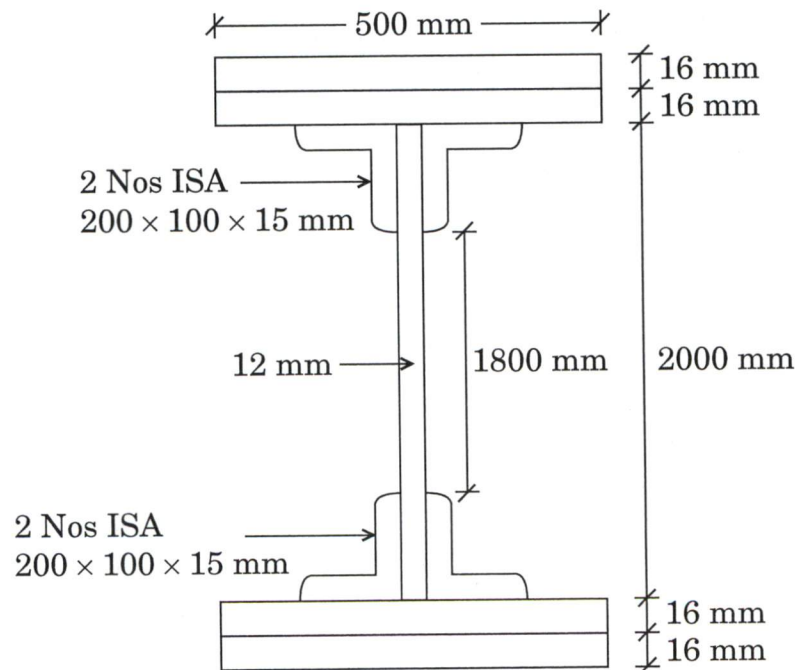
Also mention the relative merits and demerits of force and displacement methods.

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- (b) A steel plate girder simply supported at two ends has an effective span of 20 m. The girder has been fabricated as shown in the figure below. Total uniformly distributed load (dead load + live load + impact load) on the girder is 150 kN/m.

Calculate stresses in compression and tension flange and check the shear stresses.

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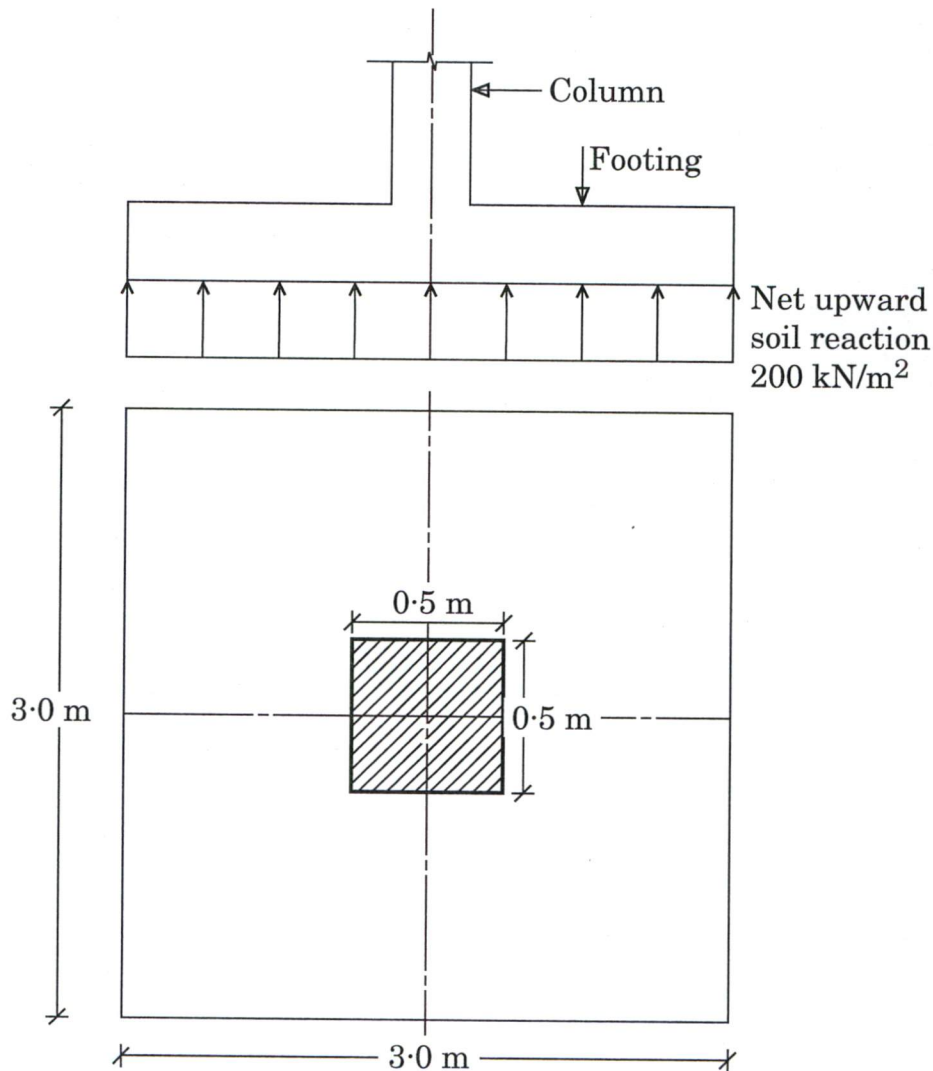
Following parameters may be used :

- (i) $f_y = 260 \text{ N/mm}^2$
- (ii) Permissible stress in compression flange = 160 N/mm^2

- (iii) Net flange area provided in tension flange = 24642 mm^2
- (iv) Gross flange area provided in compression flange = 28556 mm^2
- (v) Moment of inertia of the complete section

$$I_{X-X} = 5736642.2 \times 10^4 \text{ mm}^4$$
- (vi) Permissible shear stress = 104 N/mm^2

(c)



A square column of size $500 \times 500 \text{ mm}$ is transferring load to the square footing as shown in the figure above. Net upward soil reaction of 200 kN/m^2 is acting on the footing. Design the footing for flexure, one way shear and two way shear. Also sketch the section and all the reinforcements.

Following design considerations shall be used :

- (i) Client has requested for minimum thickness of 840 mm and minimum 0.20% reinforcement of *effective depth* $\times$ *length of footing*.
- (ii) Grade of concrete : M 20
- (iii) Grade of reinforcing bars : Fe 415
- (iv) Nominal cover to reinforcement : 75 mm
- (v) Diameter of reinforcement : 12 mm
- (vi) $M_{u, \text{lim}} = 0.1389 f_{ck} b d^2$
- (vii) Total depth calculated shall be rounded off to next multiplier of 10 mm
- (viii) Largest depth shall be used and provided
- (ix) Percentage reinforcement p_t for M 20 and Fe 415 shall be :

$\frac{M_u}{b d^2}$	0.40	0.45	0.70	1.00	1.30	1.50
p_t	0.114	0.128	0.203	0.295	0.392	0.460

- (x) Spacing of reinforcement shall be rounded off to lower 10 mm multiplier.
- (xi) Two way shear strength $Z_c = 0.25 \sqrt{f_{ck}}$
- (xii) Shear strength of concrete based on percentage reinforcement :

τ_c in N/mm^2	0.33	0.39	0.44	0.48	0.50
p_t in %	0.20	0.30	0.40	0.50	0.60

SECTION B

- Q5. (a) A trapezoidal channel is to be designed to convey $40 \text{ m}^3/\text{second}$ of water at a velocity of $2.0 \text{ m}/\text{second}$. The bed width to depth ratio of the channel is to be 5.0 and the side slopes of the channel cross-section are to be $2 \text{ Horizontal} : 1 \text{ Vertical}$. It will be lined with a material whose Manning's roughness coefficient, $n = 0.025$. Calculate the bed width, depth of flow and slope of the channel. 8
- (b) A run-of-river hydroelectric power station is proposed across a river site where a net head is available on the turbine. The river carries a sustained minimum flow of $20 \text{ m}^3/\text{sec}$ in dry weather and behind the power station sufficient pondage is provided to supply daily peak load of demand of water with a load factor of 71% . Assuming the plant efficiency of 56% , determine the maximum generating capacity of the generator to be installed at the power house. If the daily load pattern indicates 21 hours average load and 3 hours of peak load, determine the value of pondage to be provided to supply the daily demand. 8
- (c) What are the corrections applied to the hydrometer reading while performing sedimentation analysis of a fine grained soil ? Explain. 8
- (d) The liquid limit and plastic limit of a clayey soil are 45% and 32% respectively. The mass specific gravity of a fully saturated specimen of the soil having a water content 34% is 1.96 . On oven drying the mass, specific gravity drops to 1.59 . Determine the specific gravity, shrinkage limit and shrinkage index of the soil. 8
- (e) The soil is to be excavated from a borrow pit for constructing an earth embankment. The bulk density of undisturbed soil is $18.5 \text{ kN}/\text{m}^3$ and its water content is 8.5% . In order to construct a 4.5 m high embankment with 2.5 m top and $1 : 1$ side slopes, determine the quantity of soil required to be excavated per metre length of the embankment. The dry density required in the embankment is $15.4 \text{ kN}/\text{m}^3$ with a water content of 9% . Assume specific gravity of soil solid as 2.66 . What will be the void ratio and degree of saturation of the soil in remoulded state and undisturbed condition ? 8

- Q6.** (a) A square footing of 1.5 m side is located in a homogeneous cohesive soil at a depth of 1.2 m below the ground level. Assuming the soil is soft and there is chance for local shear failure, determine the safe bearing capacity of the footing. The properties of soil are as follows :
Bulk density = 17.5 kN/m^3 , Effective cohesion = 37 kN/m^2 , Effective angle of shearing resistance $\phi = 19^\circ$. The bearing capacity factors for general shear failure are as follows :

ϕ	N_q	N_γ
10°	2.7	1.2
15°	4.4	2.5

Also estimate the maximum safe load taken by the foundation. Assume factor of safety as 2.5. Also the water table is far below the foundation.

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- (b) A tank has a circular orifice of 20 mm diameter in the vertical side near the bottom. The tank contains water to a depth of 1.0 m above the orifice with oil of relative density of 0.8 for a depth of 1.0 m above the water. Acting on the upper surface of the oil is an air pressure of 20 kN/m^2 (gauge). The jet of water issuing from the orifice travels a horizontal distance of 1.5 m from the orifice while falling a vertical distance of 0.156 m. If the coefficient of contraction of the orifice is 0.65, estimate the value of coefficient of velocity and the actual discharge through the orifice. Take $g = 9.81 \text{ m/sec}^2$ and density of water, $\rho = 1000 \text{ kg/m}^3$.

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- (c) A Francis turbine develops 8000 kW at 300 rpm under a net head of 45 m with an overall efficiency of 85%. What would be the speed, discharge and brake power of the same turbine under a net head of 60 m under homologous conditions ? The efficiency can be assumed to be the same at both the operating conditions. Take $g = 9.81 \text{ m/sec}^2$ and density of water, $\rho = 1000 \text{ kg/m}^3$.

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- Q7.** (a) The gross weight of a pile is 2 tons. Determine its safe load carrying capacity using modified Hiley's formula as per IS 2911 (Part 1) – 1964. 15
- The data given are :
- Weight of hammer = 2.5 tons
- Height of free fall = 90 cm
- Hammer efficiency = 75%
- Length of pile = 20 m
- Diameter of pile = 30 cm
- Coefficient of restitution = 0.56
- Average penetration under last five blows = 10 mm
- Assume factor of safety = 2.5.
- (b) A square flexible footing of size 2.5 m × 2.5 m carries a total load of 500 kN (including self-weight of the footing). The footing rests on a coarse grained sand layer having modulus of elasticity of 45 MN/m² and Poisson's ratio of 0.35. Determine the probable immediate settlement below the centre and below any one corner of the footing. The influence factor I_f is given below : 10
- I_f (corner) = 0.56
- I_f (centre) = 1.12
- (c) An exhaust fan is to be selected to ventilate a bathroom whose dimensions are 2.5 m × 2.5 m × 3.0 m. The air velocity is not to exceed 7.5 m/sec to minimize vibration and noise. If the combined efficiency of the fan-motor unit of an exhaust fan is 50 percent and if the fan is to replace the entire volume of air in 10 minutes, determine the following : 15
- (i) The required electric power input (in watts) to be supplied to the exhaust fan,
- (ii) The diameter of the fan casing, and
- (iii) The pressure difference across the fan.
- (Assume the air density to be 1.2 kg/m³ and clearly write all assumptions.)

Q8. (a) (i) Explain how the factor of safety is estimated for the slope of an embankment in sudden drawdown condition in full reservoir level.

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(ii) What is the total active force per metre length of the retaining wall as shown in the figure ? Where will this force act ? The properties of soil are as below :

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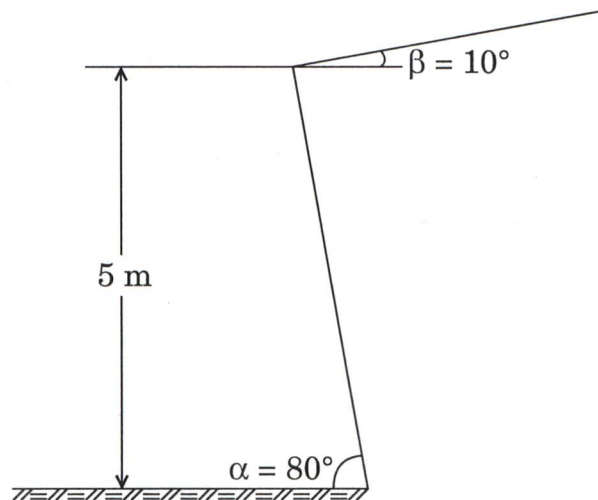
Angle of shearing resistance $\phi = 30^\circ$

Angle of wall friction $\delta = \frac{2}{3} \phi$

Angle of surcharge $\beta = 10^\circ$

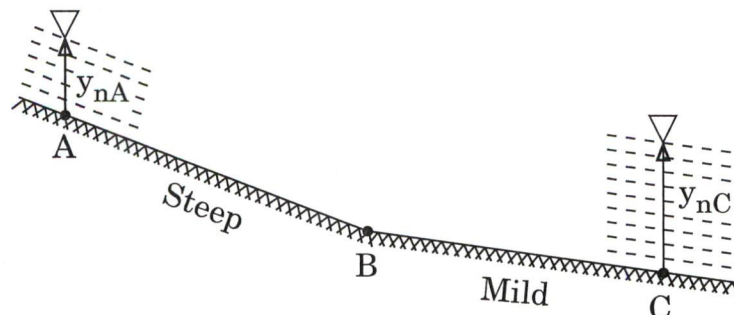
Angle of batter $\alpha = 80^\circ$

Bulk density of soil retained = 17 kN/m^3



Use Coulomb's Equation.

(b) A very long rectangular channel has normal flow conditions at locations A and C, and a change in the bottom slope occurs at location B as shown in the figure below.



If the depth of water at A, $y_{nA} = 1.0$ m, the depth of water at C, $y_{nC} = 1.8$ m and the discharge per unit width of the channel, $q = 6.0$ m³/sec/m, answer the following :

- (i) Somewhere between locations A and C, a hydraulic jump will take place. Explain why this statement is true.
- (ii) Classify and sketch the two possible water surface profiles that exist between A and C.
- (iii) With appropriate explanation, determine whether the jump will occur upstream of location B, or downstream of location B. Show the necessary calculation.

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- (c) The electrical transmission towers, 10 m high, are fixed 500 m apart to 16 cables, each 2 cm in diameter. If a 100 km per hour wind is blowing transversely across the cables, calculate the total drag force offered by all the cables. Also, determine whether the cables are subjected to self-induced vibrations and, if so, calculate the frequency of vortex shedding. Assume density of air, $\rho = 1.2$ kg/m³, Dynamic viscosity of air, $\mu_{\text{air}} = 1.7 \times 10^{-5}$ N.sec/m², Drag coefficient $c_d = 0.95$ for $10^3 < \text{Re} < 10^4$, and $c_d = 1.2$ for $10^4 < \text{Re} < 10^5$. Also, assume that there is no interference between the wires.

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