

# ESE (Mains), 2022

## Civil Paper-II

### SECTION 'A'

1. (a) (i) Name any six tools for cutting and dressing stones.
- (ii) What are the impurities in lime and how do they affect the cementing properties?

4+8=12

1. (b) A short column of 3 m effective height is subjected to an ultimate load of 1400 kN. Cross section of the column is  $300 \times 600$  mm. The reinforced concrete column consists of 8 longitudinal reinforcing bars of 20 mm diameter as shown. M25 grade concrete and Fe500 grade are used. Obtain its ultimate moment carrying capacity only about its major axis. Effective cover to the longitudinal reinforcing bars is 60 mm.

12

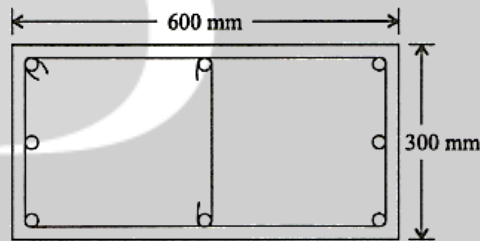


Chart 49 COMPRESSION WITH BENDING—Rectangular Section—Reinforcement Distributed Equally on Four Sides

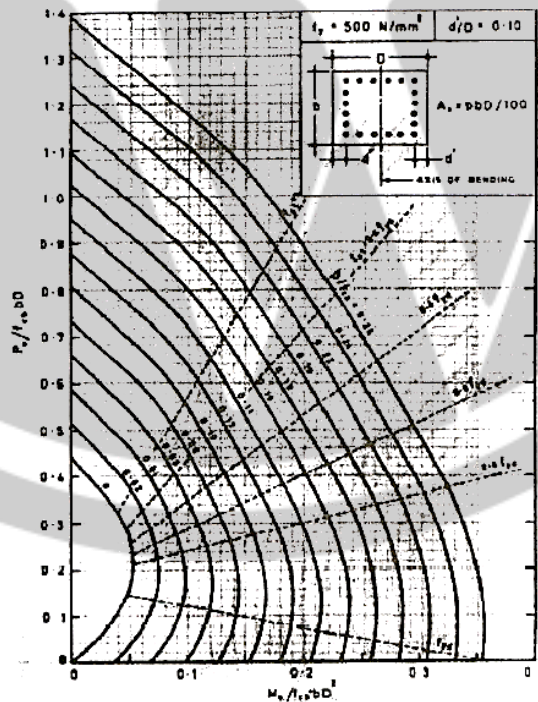
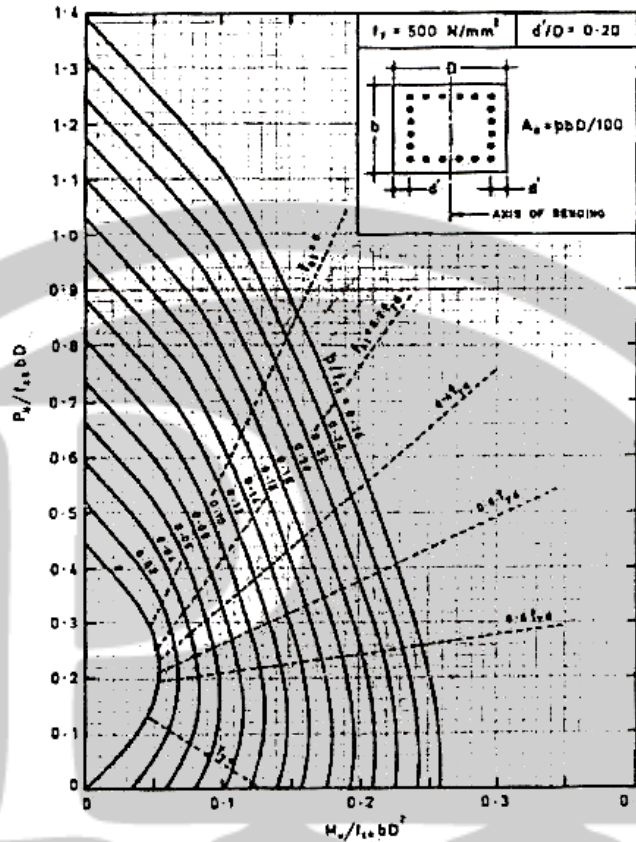


Chart 50 COMPRESSION WITH BENDING—Rectangular Section—Reinforcement Distributed Equally on Four Sides



1. (c) A simply supported post-tensioned concrete beam of 10 m span, 230 mm wide and 400 mm deep is prestressed with a straight cable, having cross sectional area 385 mm<sup>2</sup>, located at 60 mm from the soffit of the beam subjected to an initial stress of 1200 N/mm<sup>2</sup>. Using M50 grade concrete and the following data, estimate the percentage loss of prestress.

$$E_c = 500\sqrt{f_{ck}}$$

Modulus of Elasticity of steel =  $2.1 \times 10^5$  N/mm<sup>2</sup>

Relaxation of stress in steel = 4.5%

Shrinkage strain of concrete = 0.0003

Creep coefficient of concrete = 1.6

Friction coefficient for wave effect = 0.0025 per metre

Slip at anchorage = 2 mm

Loss of prestress due to friction =  $p_0/(\mu\alpha + kx)$ .

12

1. (d) A cable is suspended from the points (1) and (2) which are 90 m apart horizontally and are at different levels, the point (1) being 5.50 m vertically higher than the point (2) and the lowest point in the cable is 11 m below point (1). The cable is subjected to a UDL of 35 kN/m over the horizontal span. Determine the horizontal and vertical reactions at each end and also the maximum tension in the cable.

12

1. (e) It is quite common to replace/partially substitute, cement with flyash. However, all the concretes made by cement substituted by flyash may not be used for all the applications. Specify some applications where using flyash concrete is useful and the applications where we should avoid using flyash products and provide reasons. 12
2. (a) The floor of a hall is 9 m × 12 m to the centre of supports. The beams are spaced at 3 m centre to centre. Thickness of the floor slab is 150 mm. Live load on the floor is 3 kN/m<sup>2</sup>. Load due to floor finish and plaster being 1.5 kN/m<sup>2</sup>, design one intermediate T-beam for flexure and shear as per Limit State Design. Sketch the reinforcement details. Density of concrete is 25 kN/m<sup>3</sup>. Assume an effective cover to the main reinforcement is 50 mm. Width of rib = 300 mm.

$$\text{Effective width of Flange } b_f = \frac{l_0}{6} + b_w + 6D_f$$

$$\text{For Fe500, } \left( \frac{x_u, \max}{d} \right) = 0.46$$

$$\text{Strength of shear reinforcement } V_{us} = \frac{0.87 f_y A_{s_v} .d}{S_v}$$

$\frac{100A_s}{bd}$	Design shear strength of concrete $\tau_c$ N/mm <sup>2</sup> .
0.75	0.57
1.00	0.64
1.25	0.70
1.50	0.74

### ANNEX G (Clause 38.1)

#### MOMENTS OF RESISTANCE FOR RECTANGULAR AND T-SECTIONS

G-0 The moments of resistance of rectangular and T-section based on the assumptions of 38.1 are given in this annex.

#### G-1 RECTANGULAR SECTIONS

##### G-1.1 Sections Without Compression

##### Reinforcement

The moment of resistance of rectangular sections without compression reinforcement should be obtained as follows :

- (a) Determine the depth of neutral axis from the following equation :

$$\frac{x_u}{d} = \frac{0.87 f_y A_{st}}{0.36 f_{ck} b.d}$$

- (b) If the value of  $x_u/d$  is less than the limiting value (see Note below 38.1) calculate the moment of resistance by the following expression :

$$M_u = 0.87 f_y A_{st} d \left( 1 - \frac{A_{st} f_y}{b d f_{ck}} \right)$$

- (c) If the value of  $x_u/d$  is equal to the limiting value, the moment of resistance of the section is given by the following expression :

$$M_{u,Hm} = 0.36 \frac{x_{u,max}}{d} \left( 1 - 0.42 \frac{x_{u,max}}{d} \right) b d^2 f_{ck}$$

exceeds the limiting value,  $M_u$ ,  $M_m$  compression reinforcement may be obtained from the following equation :

$$M_u - M_{u,Hm} = f_{an} (d - d')$$

where

$M_u$ ,  $M_{u,Hm}$ ,  $f_{an}$   $d$  are same as in G- 1.1,

$f_{ts}$  = design stress in compression reinforcement corresponding to a strain of

$$0.0035 \frac{(x_{u,max} - d^0)}{x_{u,max}}$$

where

$x_{u,max}$  at the limiting value of  $x_u$  from 38.1.

$A_u$  = area of compression reinforcement, and

$d'$  = depth of compression reinforcement from compression face.

The total area of the total tensile reinforcement shall be obtained from the following equation :

$$A_u = A_{a1} + A_{a2}$$

where

$A_u$  = area of the total tensile reinforcement,

$A_{a1}$  = area of the tensile reinforcement for a singly reinforced section for  $M_u$ , un'

$$A_{a2} = A_{ac} f_{ac} / 0.87 f_y.$$

- (d) If  $x_u/d$  is greater than the limiting value, the section should be redesigned.

In the above equations,

$x_u$  = depth of neutral axis,

$d$  = effective depth,

$f_y$  = characteristic strength of reinforcement,

$A_{at}$  = area of tension reinforcement,

$f_{ck}$  = characteristic compressive strength of concrete,

$b$  = width of the compression face,

$M_{u, use}$  = limiting moment of resistance of a section without compression reinforcement, and

$x_{u, mx}$  = limiting value of  $x_u$  from 39.1.

## G-1.2 Section with Compression Reinforcement

Where the ultimate moment of resistance of section

G-2.2.1 When the ratio  $D_r/d$  exceeds 0.2, the moment of resistance of the section may be calculated by the following equation:

$$M_u = 0.36 \frac{x_{u,max}}{d} \left( 1 - 0.42 \frac{x_{u,max}}{d} \right) f_{ak} b_w d^2 + 0.45 f_{ck} (b_f - b_w) y_r \left( d - \frac{y_r}{2} \right)$$

## G-2 FLANGED SECTION

G-2.1 For  $x_u < D_r$ , the moment of resistance may be calculated from the equation given in G-1.1.

G-2.2 The limiting value of the moment of resistance of the section may be obtained by the following equation when the ratio  $D_1/d$  does not exceed 0.2 :

$$M_u = 0.36 \frac{x_{u, \max}}{d} \left( 1 - 0.42 \frac{x_{u, \max}}{d} \right) f_{ck} b_w d^2 + 0.45 f_{ck} (b_f - b_w) D_t \left( d - \frac{D_t}{2} \right)$$

where

$M_u$ ,  $x_{u, \max}$ ,  $d$  and  $f_t$  are same as in G-1.1,

$b_f$  = breadth of the compression face/flange,

$b_w$  = breadth of the web, and

$D_t$  = thickness of the flange.

G-2.2.1 When the ratio  $D_1/d$  exceeds 0.2, the moment of resistance of the section may be calculated by the following equation :

$$M_u = 0.36 \frac{x_{u, \max}}{d} \left( 1 - 0.42 \frac{x_{u, \max}}{d} \right) f_{ck} b_w d^2 + 0.45 f_{ck} (b_f - b_w) y_t \left( d - \frac{y_t}{2} \right)$$

where  $y_t = (0.15 x_u + 0.65 D_1)$ , but not greater than  $D_1$ , and the other symbols are same as in G-1.1 and G-2.2.

G-2.3 For  $x_{u, \max} > x_u > D_1$ , the moment of resistance may be calculated by the equations given in G-2.2 when  $D_1/x_u$  does not exceed 0.43 and G-2.2.1 when  $D_1/x_u$  exceeds 0.43; in both cases substituting  $x_a$ , by  $x_u$ .

2. (b) Determine the proportion of aggregates required to give a suitable grading based on their fineness moduli. Assume the following gradings of aggregates :

IS sieve designation (mm)	Aggregate size associated with percentage passing IS sieve (mm)		
	40	20	10
40	90	—	—
20	10	90	—
10	02	10	90
4.75	—	03	20

How, fineness modulus affect the characteristics of concrete? What is the optimum value of FM for fine aggregates?

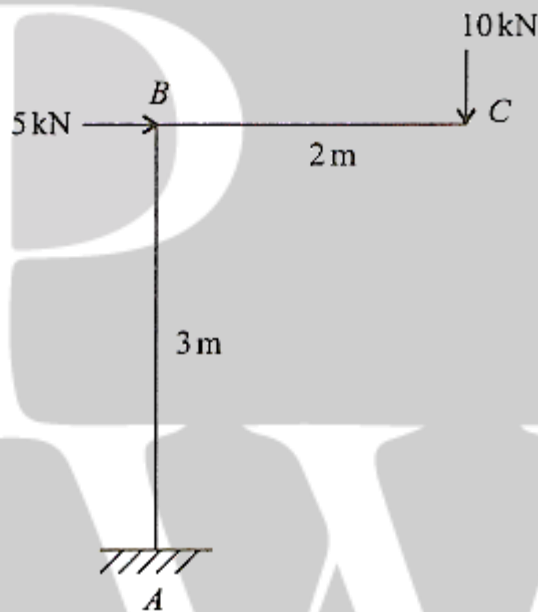
2. (c) A continuous beam ABC consists of two spans AB and BC of length 15.50 m and 11.50 respectively. The span AB carries a UDL of 28 kN/m and span BC carries a point load of 100 kN at 8 m from support B. EI is constant for both the span. The end supports A and C are fixed, while support B is simply supported. Determine the support moments and reactions. And also draw the shear force and bending moment diagrams.
3. (a) (i) Classify the bricks based on the physical and mechanical properties. Indicate the properties of first class bricks. Which are the applications where first class bricks are highly recommended and other classes of bricks should not be used?  
(ii) Discuss the scale of sampling for physical characteristics of bricks. Indicate its importance.
3. (b) A prestressed concrete beam, 300×800 mm, is simply supported over an effective span of 12 m. It is

prestressed with a cable whose eccentricity varies linearly from 50 mm at the supports to 250 mm at  $\left(\frac{1}{3}\right)^{\text{rd}}$  span points from either support. Effective prestress in the cable is 900 kN. Determine,

- (i) Net deflection due to prestress and self weight
- (ii) Central concentrated load required to cause a maximum downward deflection of  $\left(\frac{\text{Span}}{400}\right)$ .

Use M40 grade concrete. Derive only the expressions for deflections due to prestress.  $E_c = 5000 \sqrt{f_{ck}}$ . Density of concrete = 25 kN/m<sup>3</sup>. 20

3. (c) Determine the vertical and horizontal deflections at the free end of the frame shown in figure. Support A is fixed, B is rigid joint and point C is free. Moment of inertia of BC = I and BA = 2I, E = 210 GPa and I = 300 × 10<sup>-6</sup> m<sup>4</sup>. Use Unit Load Method. 20



4. (a) A simply supported one way slab 178 mm thick having an effective span of 4.88 m is reinforced with 12 mm diameter rebars at 125 mm center to center. The nominal concrete cover to the main reinforcement is 20 mm. The slab is subjected to a live load of 4 kN/m<sup>2</sup> and surface finish of 1.2 kN/m<sup>2</sup>. Use M25 concrete and Fe500 grade steel. Compute only the short-term deflection and deflection due to shrinkage. Shrinkage strain is 0.0003. Density of concrete is 25 kN/m<sup>3</sup>.

$$E_c = 5000 \sqrt{f_{ck}}, E_s = 2 \times 10^5 \text{ MPa}$$

$$P_t = \frac{100A_{st}}{bd}; P_c = \frac{100A_{sc}}{bd}.$$

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### ANNEX C

(Clauses 22.3.2, 23.2.1 and 42.1)

#### C-1 TOTAL DEFLECTION

C-1.1 The total deflection shall be taken as the sum of the short-term deflection determined in accordance with C-2 and the long-term deflection, in accordance with C-3 and C-4.

#### C-2 SHORT-TERM DEFLECTION

C-2.1 The short-term deflection may be calculated by the usual methods for elastic deflections using the short-



term modulus of elasticity of concrete,  $E_c$  and an effective moment of inertia  $I_{eff}$  given by the following equation:

$$I_{eff} = \frac{I_r}{1.2 - \frac{M_r}{M} \frac{z}{d} \left(1 - \frac{x}{d}\right) \frac{b_w}{b}}; \text{ but}$$

$$I_r \leq I_{eff} \leq I_{gr}$$

where

$I_t$  = moment of inertia of the cracked section,

$M_r$  = cracking moment, equal to  $\frac{f_{cr} I_{gr}}{y_t}$  where

$f_{cr}$  is the modulus of rupture of concrete,  $I_{gr}$  is the moment of inertia of the gross section about the centroidal axis, neglecting the reinforcement, and  $y_t$  is the distance from centroidal axis of gross section, neglecting the reinforcement, to extreme fibre in tension,

$M$  = maximum moment under service loads,

$z$  = lever arm,

$x$  = depth of neutral axis,

$d$  = effective depth,

$b_w$  = breadth of web, and

$b$  = breadth of compression face.

For continuous beams, deflection shall be calculated using the value of  $I_r$ ,  $I_{gt}$  and  $M_t$  modified by the following equation :

$$X_e = k_1 \left[ \frac{X_1 + X_2}{2} \right] + (1 - k_1) X_e$$

where

$X_e$  = modified value of  $X$ ,

$X_1, X_2$  = values of  $X$  at the supports,

$X_e$  = value of  $X$  at mid span,

$k_1$  = coefficient given in Table 25, and

$X$  = value of  $I_r$ ,  $I_s$  or  $M_r$  as appropriate.

### C-3 DEFLECTION DUE TO SHRINKAGE

C-3.1 The deflection due to shrinkage  $a_a$  may be computed from the following equation :

$$a_{cs} = k_3 \Psi_{cs} l^2$$

where

$k_3$  is a constant depending upon the support conditions,

0.5 for cantilevers,

0.125 for simply supported members,

0.086 for members continuous at one end,

and

0.063 for fully continuous members.

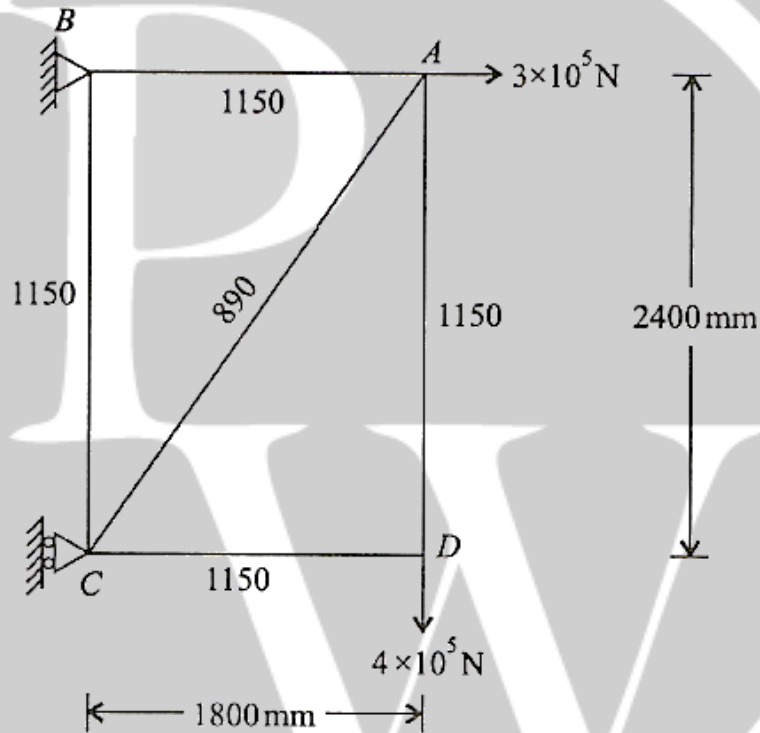
$\Psi_{cs}$  is shrinkage curvature equal to  $k_4 k_4 \frac{\epsilon_{ct}}{D}$

where  $\epsilon_{cs}$  is ultimate shrinkage strain of concrete (see 6.2.4),

$$k_4 = 0.72 \times \frac{P_t - P_c}{\sqrt{P_t}} \leq 1.0 \text{ for } 0.25 \leq P_t - P_c < 1.0$$

$$= 0.65 \times \frac{P_t - P_c}{\sqrt{P_t}} \leq 1.0 \text{ for } P_t - P_c \geq 1.0$$

4. (b) (i) Draw a neat sketch of complete operational sequence of Dry process in making cement. Also indicate the place/equipment/part of plant where the process is taking place.
- (ii) Indicate the advantages of Dry process over the Wet process. 10+10=20
4. (c) Determine the vertical displacement of joint A of the metal truss shown in figure, due to heating from the wall member BC is subjected to an increase in temperature of  $\Delta T = 70^\circ\text{C}$ . Take coefficient of thermal expansion of member  $\alpha = 1.05 \times (10^{-5})/^\circ\text{C}$  and  $E = 210 \times 10^3 \text{ N/mm}^2$ . The cross-sectional area of each member is indicated in the figure in  $\text{mm}^2$ . 20



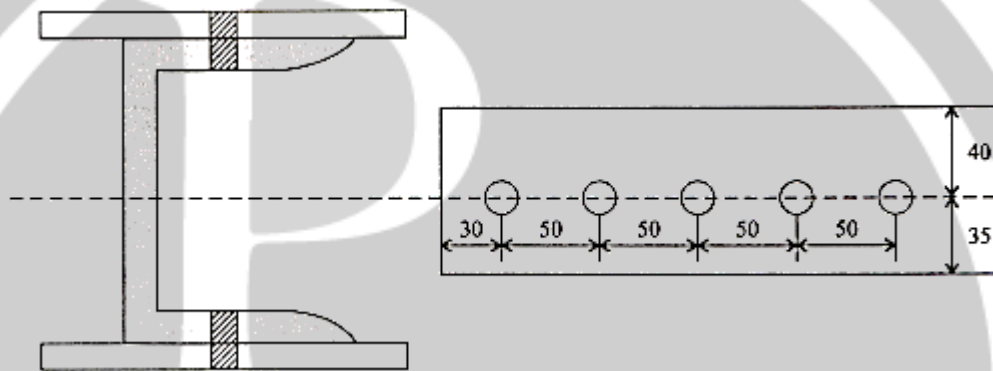


### SECTION 'B'

5. (a) (i) To put large quantity of concrete in short duration with accuracy, which pump should be used and why? Compare it with other available pumps which are used for concreting.  
(ii) What safety measures should be taken in case of placing the concrete using pumps?

[6+6]

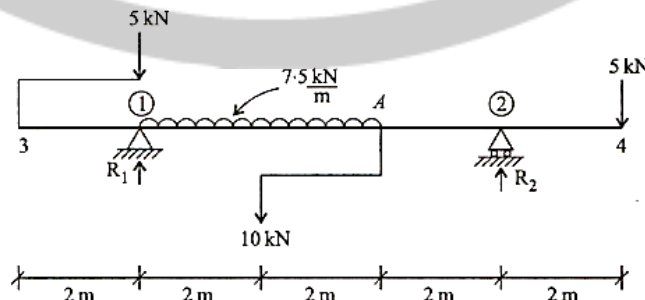
5. (b) Determine the maximum principal stresses and maximum shearing stresses at a point A on the surface of a 25 mm diameter shaft. The shaft is subjected to a torque of 175.93 N-m and axial tension of 31.415 kN. Show the orientation of principal planes and planes of maximum shearing stress with respect to an axis parallel to the axis of the shaft.
5. (c) Determine the tensile strength of an ISMC 175 when it is connected to gusset plates through the two flanges by two rows of 16 mm bolts with a connection length 200 mm as shown in the figure, Use grade Fe 410 steel ( $f_y = 250$  MPa). Also given  $\gamma_{m0} = 1.1$  and  $\gamma_{m1} = 1.25$ .



Properties of ISMC 175 :

$A = 2490 \text{ mm}^2$ ,  $h = 175 \text{ mm}$ ,  $b_f = 75 \text{ mm}$ ,  $t_f = 10.2 \text{ mm}$  and  $t_w = 6 \text{ mm}$ . 12

5. (d) How are the various types of loads estimated for the design of roof truss? 12
5. (e) (i) An axial pull of 45 kN is applied on a steel bar of diameter 13 mm and length of 2500 mm. Determine the change in length, diameter and volume of the steel bar if the Poisson's ratio is 0.25. Use  $E = 200 \times 10^3 \text{ N/mm}^2$ . 6
5. (e) (ii) Determine the value of Poisson's ratio and Modulus of Elasticity, if the modulus of rigidity of a given material is  $50 \times 10^3 \text{ N/mm}^2$  and the bulk modulus is  $80 \times 10^3 \text{ N/mm}^2$ . 6
6. (a) (i) Define determinate and indeterminate structures with suitable examples.  
(ii) Draw the shear force diagram of the beam shown in figure. Supports (1) and (2) are simply supported.  
(iii) Draw the bending moment diagram for the beam shown in figure. 4+8+8=20



6. (b) An upper storey column ISHB 300@577 N/m ( $b_f = 250$  mm,  $t_f = 10.6$  mm) carries a factored load of 1200 kN and a factored moment of 12 kN-m. It is to be spliced with lower storey column ISHB 400@806 N/m ( $b_f = 250$  mm,  $t_f = 12.7$  mm). Design a suitable splice. Given that  $f_y = 250$  MPa,  $\gamma_{m0} = 1.1$ ,  $\gamma_{m1} = 1.25$  and  $\beta_{pk} = (1 - 0.0125 t_{pk})$ . Also sketch connection details. Use bolts of Grade 5.8.

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6. (c) The following table shows the normal, shortest and longest durations for each activity to be completed for the completion of the project. The table also shows the slope (increase/decrease) in cost per unit duration of each activity. The contract includes penalty clause of ₹ 10000/- per unit time and bonus of ₹ 5000/- per unit time for the completion of project with respect to the normal duration of the project. The overhead (indirect) cost per unit time is ₹ 16000/-. Calculate the optimum cost of project completion. The cost (direct) of completing all the eight activities in normal duration is ₹ 650000/-.

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Activity	Normal duration	Milt. duration	Max. duration	Slope ( $\pm$ )
1-2	6	4	6	8000/-
1-3	8	4	11	₹ 4000/- for first 2 unit time and ₹ 9000/-subsequently.
1-4	5	3	6	3000/-
2-4	3	3	3	-
2-5	5	3	9	8000/-
3-6	12	8	14	₹ 8000/- for first 3 unit time and ₹ 20000/-subsequently.
4-6	8	5	10	5000/-
5-6	6	6	6	-

7. (a) A rigid jointed portal frame ABCD has the horizontal beam member BC of length 6 m and moment of inertia  $2I$ . The left vertical column AB of height 6 m and moment of inertia  $2I$  and the right vertical column DC of length 4 m and moment of inertia is  $1.5I$ . The supports A and D are hinged. A uniformly distributed load of 10 kN/m acts on the full length of the beam BC. Analyse the portal and draw the bending moment diagram. The analysis of the frame for a sway load of 1 kN at B in the direction of  $\vec{BC}$  gives the end moment  $M_{BC} = +2$  kN-m and  $M_{CB} = +2.66$  kN-m both clockwise. The B and C are at the same level.

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7. (b) Design a welded plate girder 24 m in span and laterally restrained throughout. It has to support a uniform load of 100 kN/m throughout the span, exclusive of self weight. Design the girder cross section without intermediate transverse stiffeners. The steel for the flange and web plates is of grade Fe410 ( $\mu = 0.30$  and  $E = 2 \times 10^5$  MPa). Given that partial safety factor,  $\gamma_{m0} = 1.5$  (for site welding) and  $\gamma_{m0} = 1.25$  (for shop welding) and  $\lambda_{w0} = 1.2$ .

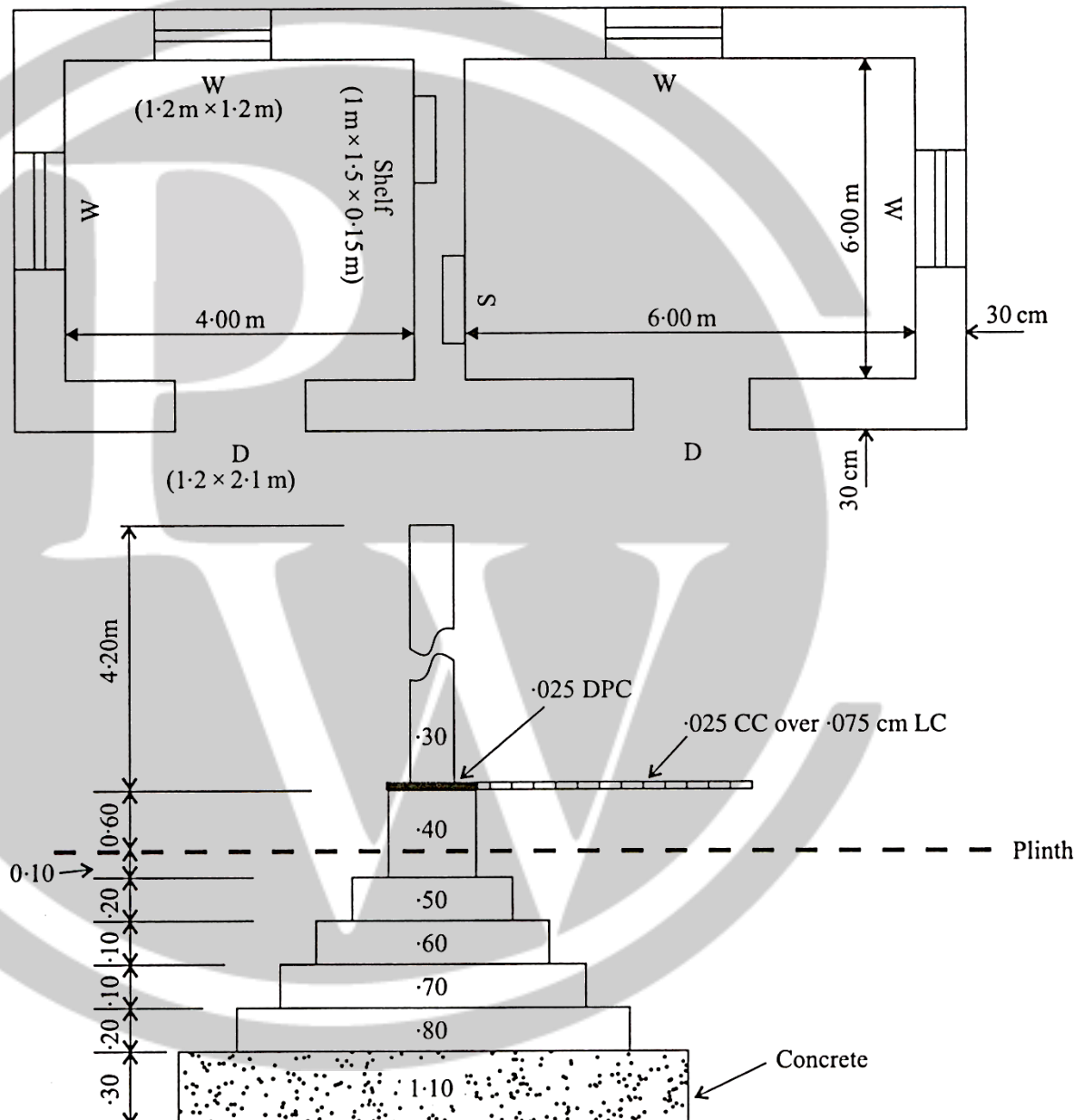
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7. (c) Estimate the following quantities for the given structure (plan and section):  
(i) Earthwork in excavation in foundation

(ii) Concrete in foundation

(iii) Brick work in super structure

All windows, doors and shelves have the dimensions  $(1.2 \text{ m} \times 1.2 \text{ m})$ ,  $(1.2 \text{ m} \times 2.1 \text{ m})$  and  $(1 \text{ m} \times 1.5 \text{ m} \times 0.15 \text{ m})$  respectively. All dimensions are in m, if not mentioned. 20



8. (a) Two wheel loads of  $8000 \text{ N}$  and  $4000 \text{ N}$  at a fixed distance of  $2000 \text{ mm}$ , cross a beam of  $20 \text{ m}$  span. Draw the influence line diagram for bending moment and shear force for a point  $8 \text{ m}$  from the left side and also determine the maximum bending moment and shear force at that point. Also evaluate the absolute maximum bending moment due to the given loading system. The loads cross the beam from left to right. 20

8. (b) A simply supported beam of 6 m span carries a udl of 70 kN/m including its self weight. The available section is ISMB 450. Cover plates of 8 mm thick may be provided, if required, only on the top flange. Design the steel beam and check for shear and deflection.

Take  $\gamma_f = 1.5$ ;  $\gamma_{m0} = 1.1$ . Assume that the section is plastic,  $f_y = 250$  MPa

Sectional area of ISMB 450;  $a = 9227 \text{ mm}^2$

Width of flange = 150 mm

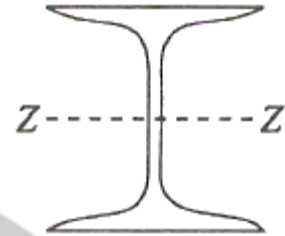
Thickness of flange = 17.4 mm

Thickness of web = 9.4 mm

Moment of inertia  $I_{zz} = 30390.8 \text{ cm}^4$

Radius at root = 15 mm

Plastic Modulus  $Z_{pz} = 1533.4 \text{ cm}^3$ .



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### 8.4 Shear

The factored design shear force,  $V$ , in a beam due to external actions shall satisfy

$$V \leq V_d$$

where

$V_d$  = design strength

$$= V_n / \gamma_{m0}$$

where

$\gamma_{m0}$  = partial safety factor against shear failure (see 5.4.1).

The nominal shear strength of a cross-section,  $V_n$ , may be governed by plastic shear resistance (see 8.4.1) or strength of the web as governed by shear buckling (see 8.4.2).

8.4.1 The nominal plastic shear resistance under pure shear is given by:

$$V_n = V_p$$

where

$$V_p = \frac{A_v F_{yw}}{\sqrt{3}}$$

$A_v$  = shear area, and

$f_{yw}$  = yield strength of the web.

8.4.1.1 The shear area may be calculated as given below:

I and channel sections:

Major Axis Bending:

Hot-Rolled —  $h t_w$

Welded —  $d t_w$

Minor Axis Bending:

Hot-Rolled or Welded —  $2b t_f$

Rectangular hollow sections of uniform thickness:

Loaded parallel to depth ( $h$ ) —  $Ah/(b + h)$

Loaded parallel to width ( $b$ ) —  $A b/(b + h)$

Circular hollow tubes of uniform thickness —  $2 A/\pi$

Plates and solid bars — A

where

A = cross-section area,

b = overall breadth of tubular section, breadth of I-section flanges,

d = clear depth of the web between flanges,

h = overall depth of the section,

t<sub>f</sub> = thickness of the flange, and

t<sub>w</sub> = thickness of the web.

NOTE — Fastener holes need not be accounted for in plastic design shear strength calculation provided that:

$$A_{vn} \geq (f_y/f_v) (\gamma_{m1}/\gamma_{m0}) A_v/0.9$$

If A<sub>vn</sub> does not satisfy the above condition, the effective shear area may be taken as that satisfying the above limit. Block shear failure criteria may be verified at the end connections. Section 9 may be referred to for design strength under combined high shear and bending.

#### 8.4.2 Resistance to Shear Buckling

8.4.2.1 Resistance to shear buckling shall be verified as specified, when

d/t<sub>w</sub> > 67ε for a web without stiffeners, and

$$> 67\epsilon \sqrt{\frac{K_v}{5.35}} \text{ for a web with stiffeners V5.35}$$

where

K<sub>v</sub> = shear buckling coefficient (see 8.4.2.2), and

$$\epsilon = \sqrt{250/f_y}$$

8. (c) Calculate the hourly tire cost that should be part of machine operating cost if a set of tires can be expected to last 5000 hr. Tires cost ₹ 40000/- (per set of four). Tire repair cost is estimated to average 16% of the straight-line tire depreciation. The machine has a service life of 4 yr and operates 2500 hr per year. The discount rate is 8%. Compare both the cases, i.e., without time value and with time value of money.