

**Engineering Services (Main)
Examination, 2026**

वियोज्य **DETACHABLE**

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.

Questions No. **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.

Diagrams/Figures, wherever required, shall be drawn in the space provided for answering the question itself.

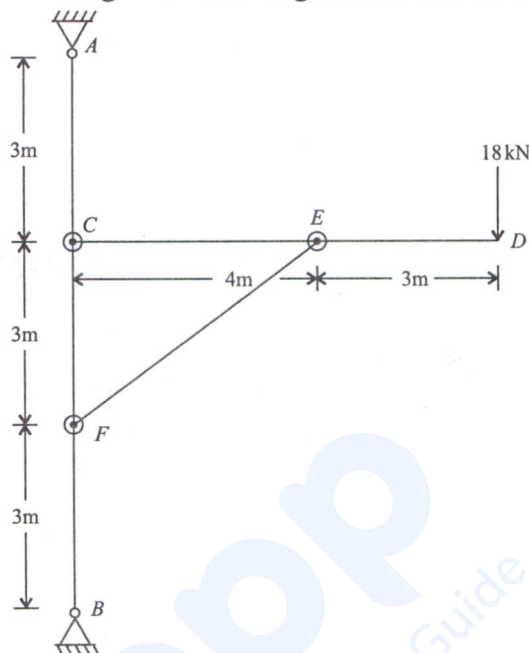
Unless otherwise mentioned, symbols and notations have their usual standard meanings.

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.

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

- 1.(a) *AB*, a vertical post of a crane as shown in figure, is hinged at *A* and *B*. The horizontal arm *CD* is hinged to *AB* at *C* and supported by the strut *EF* which is hinged at *E* and *F*. Draw the bending moment diagram for *AB* and *CD*.



- 1.(b) Explain Fibre Reinforced Plastics (FRPs). Draw a comparison between different type of FRPs based on their composition, engineering properties and their civil engineering applications. 12
- 1.(c) There are two circular beams of same length, same material and of same weight. One of these is solid with diameter D and the other one is hollow with outer diameter D_o and inner diameter D_i . Show that the ratio of section modulus of solid beam to that of the hollow beam is $\left(\frac{DD_o}{D_o^2 + D_i^2} \right)$. 12
- 1.(d) What are the different types of failure of black bolts ? Explain with sketches. 12
- 1.(e) A short column of a 4 m effective height is subjected to an ultimate load of 1500 kN. The column is of 400 mm diameter. The column is reinforced by 6 bars of 20 mm ϕ of Fe-415 grade. If M-30 concrete is used, obtain the ultimate moment carrying capacity of the column. The nominal cover to the longitudinal bar is 40 mm. 12

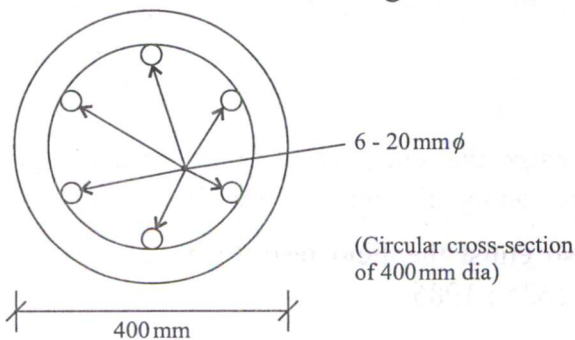
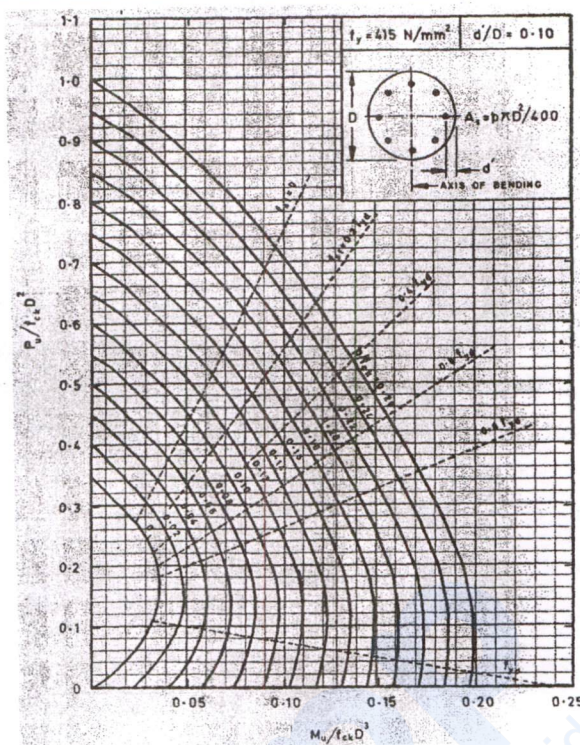
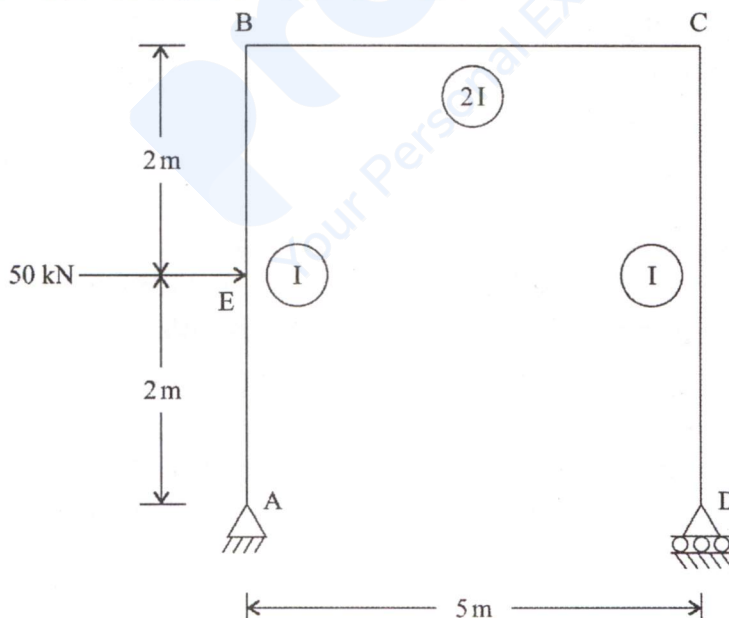


Chart 56 COMPRESSION WITH BENDING – Circular Section



- 2.(a) Determine the horizontal displacement of support D of the frame shown in figure. Take $E = 200 \text{ GPa}$ and $I = 300 \times 10^{-6} \text{ m}^4$.



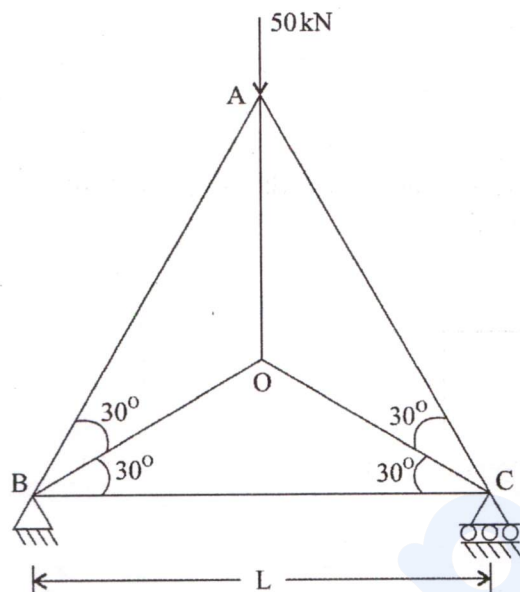
20

- 2.(b)(i) Discuss the classification of building lime based on IS 712 : 1973 specifically mentioning different classes, their names and uses in construction.

Also enlist the field tests to be carried out on building lime as recommended by IS 1624 : 1986.

10

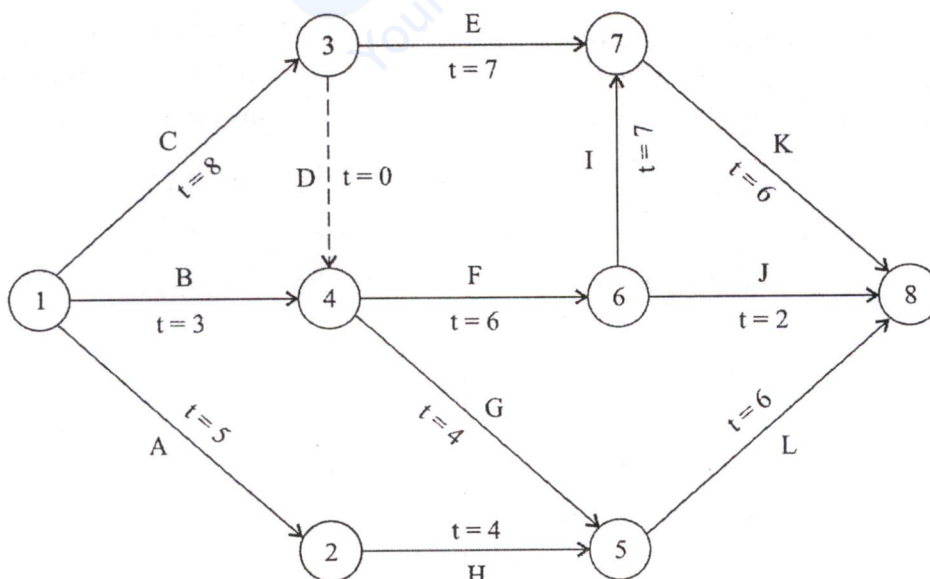
- 3.(b) Determine the member forces in the truss as shown in the figure. The members in tension have a cross-sectional area a and the members in compression have a cross-sectional area $2a$. Take $E = \text{constant}$.



20

- 3.(c) The network of a certain project is shown in figure given below, with the estimated duration of various activities. Determine the following :

- Earliest event time and latest event time.
- Earliest and latest start and finish times of each activity.
- Total and free floats for each activity.
- Critical path for the network.



20

- 4.(a) The floor plan of a building is as shown in figure below. The floor load consists of a live load of 5 kN/m^2 and dead load of 2 kN/m^2 (excluding self weight). Design the slab thickness and reinforcement required at the various critical sections. Use Fe-500 steel and M-20 concrete. Assume that the structure is subjected to mild exposure conditions.

20

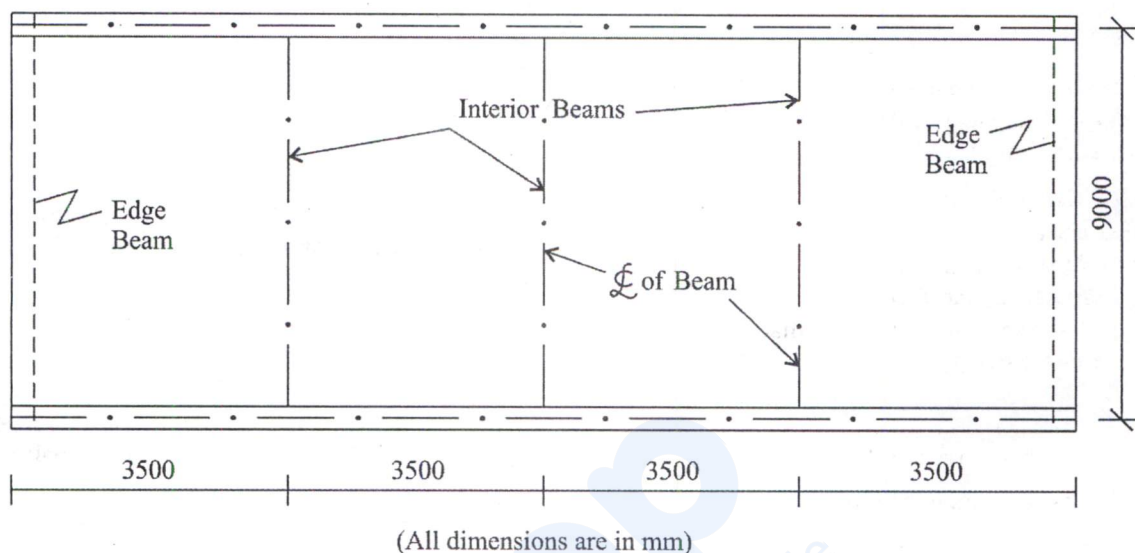


Table 12 Bending Moment Coefficients
(Clause 22.5.1)

Type of Load	Span Moments		Support Moments	
	Near Middle of End Span	At Middle of Interior Span	At Support Next to the End Support	At Other Interior Supports
(1)	(2)	(3)	(4)	(5)
Dead load and imposed load (fixed)	$+\frac{1}{12}$	$+\frac{1}{16}$	$-\frac{1}{10}$	$-\frac{1}{12}$
Imposed load (not fixed)	$+\frac{1}{10}$	$+\frac{1}{12}$	$-\frac{1}{9}$	$-\frac{1}{9}$

NOTE — For obtaining the bending moment, the coefficient shall be multiplied by the total design load and effective span.

Table 13 Shear for Coefficients
(Clauses 22.5.1 and 22.5.2)

Type of Load	At End Support	At Support Next to the End Support		At All Other Interior Supports
		Outer Side	Inner Side	
(1)	(2)	(3)	(4)	(5)
Dead load and imposed load (fixed)	0.4	0.6	0.55	0.5
Imposed load (not fixed)	0.45	0.6	0.6	0.6

NOTE — For obtaining the shear force, the coefficient shall be multiplied by the total design load.

22.6 Critical Sections for Moment and Shear

22.6.1 For monolithic construction, the moments computed at the face of the supports shall be used in the design of the members at those sections. For non-monolithic construction the design of the member shall be done keeping in view 22.2.

22.6.2 Critical Section for Shear

The shears computed at the face of the support shall be used in the design of the member at that section except as in 22.6.2.1.

22.6.2.1 When the reaction in the direction of the applied shear introduces compression into the end region of the member, sections located at a distance less than d from the face of the support may be designed for the same shear as that computed at distance d (see Fig. 2).

NOTE—The above clauses are applicable for beams generally carrying uniformly distributed load or where the principal load is located farther than $2d$ from the face of the support.

22.7 Redistribution of Moments

Redistribution of moments may be done in accordance with 37.1.1 for limit state method and in accordance with B-1.2 for working stress method. However, where simplified analysis using coefficients is adopted, redistribution of moments shall not be done.

IS 456 : 2000

23 BEAMS

23.0 Effective Depth

Effective depth of a beam is the distance between the centroid of the area of tension reinforcement and the maximum compression fibre, excluding the thickness of finishing material not placed monolithically with the member and the thickness of any concrete provided to allow for wear. This will not apply to deep beams.

23.1 T-Beams and L-Beams

23.1.1 General

A slab which is assumed to act as a compression flange of a T-beam or L-beam shall satisfy the following:

- The slab shall be cast integrally with the web, or the web and the slab shall be effectively bonded together in any other manner; and
- If the main reinforcement of the slab is parallel to the beam, transverse reinforcement shall be provided as in Fig. 3; such reinforcement shall not be less than 60 percent of the main reinforcement at mid span of the slab.

23.1.2 Effective Width of Flange

In the absence of more accurate determination, the effective width of flange may be taken as the following

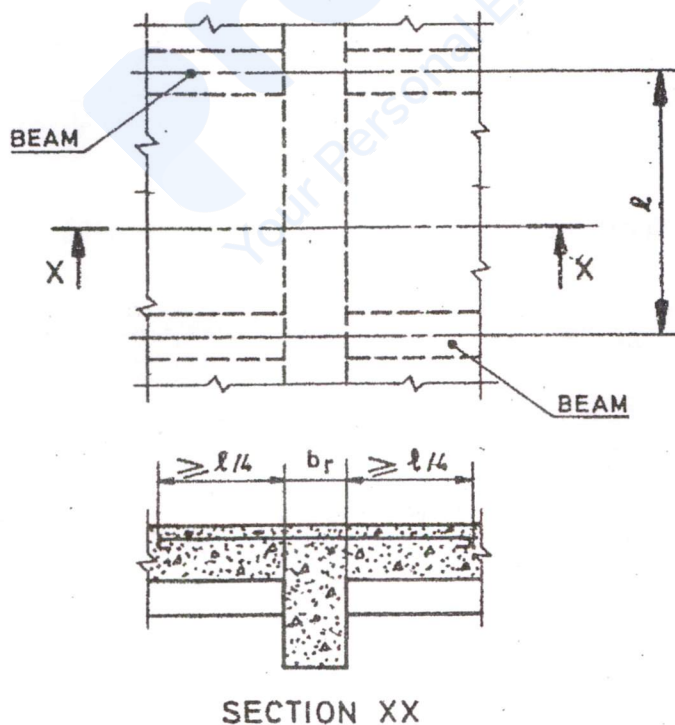
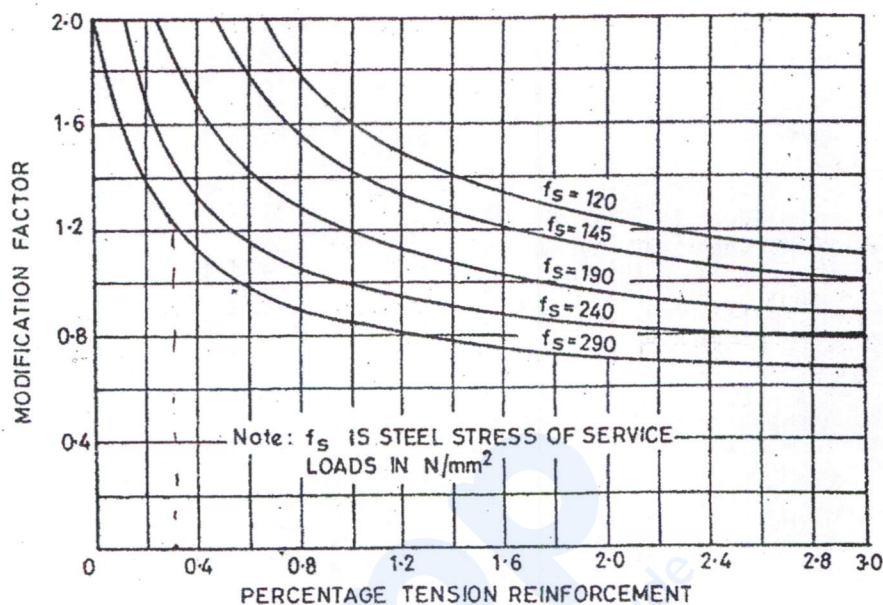


FIG. 3 TRANSVERSE REINFORCEMENT IN FLANGE OF T-BEAM WHEN MAIN REINFORCEMENT OF SLAB IS PARALLEL TO THE BEAM

- e) For flanged beams, the values of (a) or (b) be modified as per Fig. 6 and the reinforcement percentage for use in Fig. 4 and 5 should be based

on area of section equal to $b_f d$.

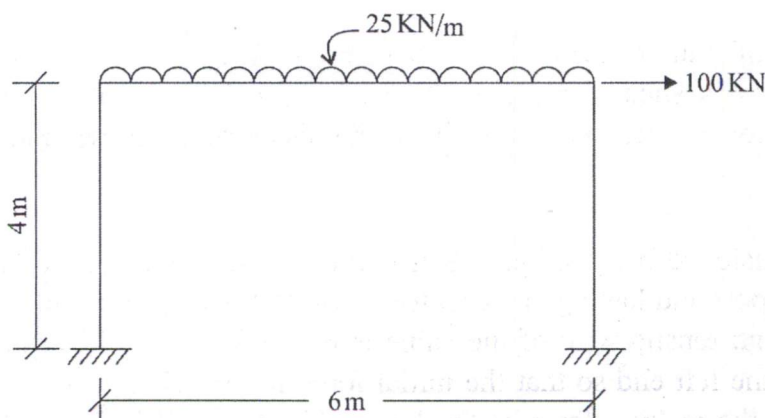
NOTE—When deflections are required to be calculated, the method given in Annex C may be used.



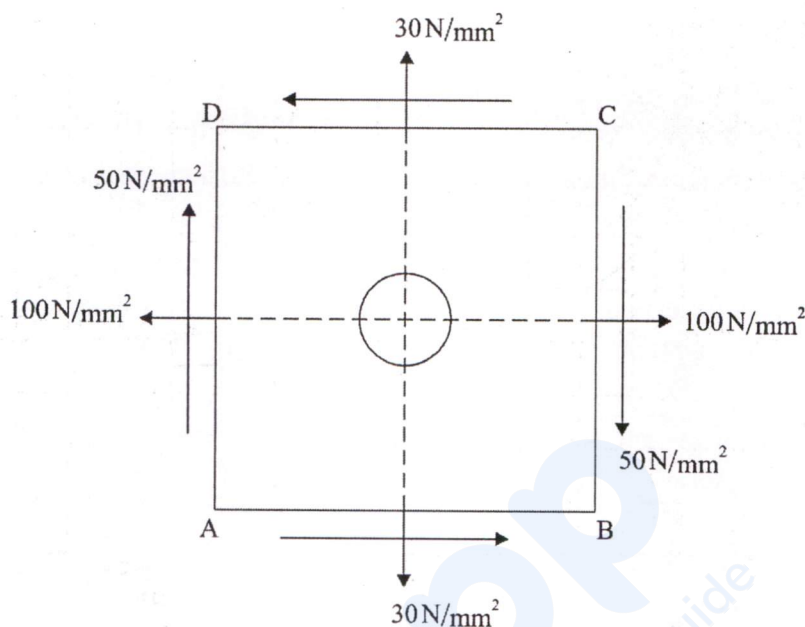
$$f_s = 0.58 f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

FIG. 4 MODIFICATION FACTOR FOR TENSION REINFORCEMENT

- 4.(b) Determine the plastic moment capacity for the frame of uniform cross-section shown in figure below under applied factored load.



- 4.(c) A circle of 60 mm is marked on a mild steel plate prior to the application of stresses on the plate. The plate is stressed as shown in figure. Find the lengths of the major and minor axes of an ellipse formed as a result of the deformation of the circle marked. Take $E = 2 \times 10^5 \text{ N/mm}^2$ and Poisson's ratio, $\mu = 0.25$



20

SECTION 'B'

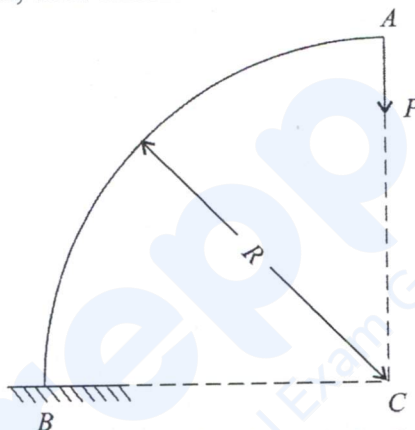
- 5.(a) Design a bolted connection for double angle member ISA $100 \times 100 \times 10$ in a truss connected on either side of a 10 mm thick gusset plate. The length of the member is 2.5 m. Use 16 mm dia bolt of grade 4.6. Assume net area at threads is 0.85 times area at shank. $\gamma_{mb} = 1.25$, $K_b = 0.6$. The factored loads in the member are 175 kN (Compression) and 150 kN (Tension). 12
- 5.(b) What is preservation of timber? Explain various methods of preservation of timber. 12
- 5.(c) A beam of square section is used with one diagonal horizontal. The beam is subjected to a shear force F at a section. Find the maximum shear stress in the cross-section of the beam and draw the shear stress distribution diagram for the section. 12
- 5.(d) A post tensioned beam of span 8 m is pre-stressed by a parabolic cable, concentric at the support and having an eccentricity of 240 mm at midspan. The cross-sectional area of high tensile wire of the cable is 600 mm^2 . The wires are stressed by using a jack at the left end so that the initial force in the cable at the right end is 260 kN. Calculate the jacking force at the left end and the total losses of stress in wires.

Assume :

Coefficient of curvature effect	=	0.55	
Coefficient for wave effect	=	0.003/m	
Relaxation of steel stress	=	4%	
Shrinkage of concrete	=	0.0002	
Creep coefficient	=	2.2	
Anchorage slip at jacking end	=	3 mm	
$E_s = 210 \text{ kN/mm}^2$ and E_c	=	35 kN/mm^2	
Size of beam	=	$250 \times 750 \text{ mm (b} \times \text{D)}$	12

5.(e) Discuss various safety measures to be taken for workers while working at height. 12

6.(a) A cantilever has a quadrantal shape as shown in figure with a radius of curvature of R . It carries a vertical downward load P at its free end A , while its other end is fixed. If EI is constant, find horizontal and vertical deflection of the free end A .

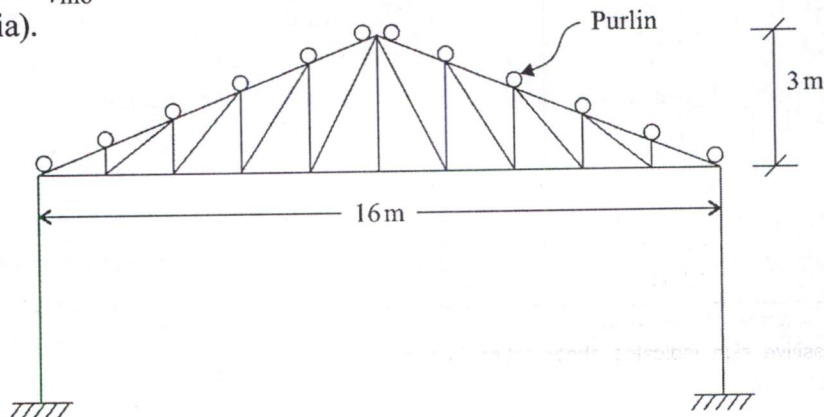


20

6.(b) A factory shed is to be constructed using pitched roof trusses supported on R.C. columns. The spacing of the truss is 5 m. Purlins are placed at the nodes (Refer figure below). Design the purlins with circular hollow section for the unfactored loading as follows :

Dead load = 180 N/m
Live load = 920 N/m
Wind load = 2080 N/m (suction)

Assume E250 grade steel. Apply limit state method of design. Assume sections are compact. $\gamma_{mo} = 1.1$. Draw also the connection with the rafter (100 mm Nominal bore dia).



Given :

Nominal bore dia. (mm)	Outer dia. (mm)	Thickness (mm)	Moment of Inertia (cm ⁴)	Plastic section Modulus (cm ³)
50	60.3	3.6	25.9	11.6
65	76.1	3.6	54.0	19.0
80	88.9	4.0	96.4	28.8
90	101.6	4.0	146.3	38.1
100	114.3	4.5	234.3	54.3

20

- 6.(c) Design a circular water tank of capacity 350 m³ resting on ground. The base of wall is fixed with base slab. Height of Tank is restricted to 3.4 m including free board of 300 mm. The materials used are M-30 concrete and Fe-500 steel. Use IS-3370 (Part IV) method. Adopt working stress design approach. Use wall thickness of 200 mm. Show details of reinforcement.

20

Table Shear at the Base of Cylindrical Wall				
Shear $V = \text{coefficient} \times \begin{cases} \gamma_w H^2 \\ \rho H \\ M/H \end{cases}$				
H^2/Dt	Triangular load, fixed base	Rectangular load, fixed base	Triangular or rectangular load, hinged base	Moment at edge
0.4	+0.436	+0.755	+0.245	-1.58
0.8	+0.374	+0.552	+0.234	-1.75
1.2	+0.339	+0.460	+0.220	-2.00
1.6	+0.317	+0.407	+0.204	-2.28
2.0	+0.299	+0.370	+0.189	-2.57
3.0	+0.262	+0.310	+0.158	-3.18
4.0	+0.236	+0.271	+0.137	-3.68
5.0	+0.213	+0.243	+0.121	-4.10
6.0	+0.197	+0.222	+0.110	-4.49
8.0	+0.174	+0.193	+0.096	-5.18
10.0	+0.158	+0.172	+0.087	-5.81
12.0	+0.145	+0.158	+0.079	-6.38
14.0	+0.135	+0.147	+0.073	-6.88
16.0	+0.127	+0.137	+0.068	-7.36

- Notes: 1. γ_w Density of the liquid
2. Positive sign indicates shear acting inward.

Table Hoop Tension in Cylindrical Walls Fixed at Base and Free at Top
(IS: 3370-1967, Part IV)
Hoop tension $T = (\text{Coefficient}) \times (\gamma_w H r)$

H^2/Dt	Coefficients at point									
	0.0H	0.1H	0.2H	0.3H	0.4H	0.5H	0.6H	0.7H	0.8H	0.9H
0.4	+0.149	+0.134	+0.120	+0.101	+0.082	+0.066	+0.049	+0.029	+0.014	+0.004
0.8	+0.263	+0.239	+0.215	+0.190	+0.160	+0.130	+0.096	+0.063	+0.034	+0.010
1.2	+0.283	+0.271	+0.254	+0.234	+0.209	+0.180	+0.142	+0.099	+0.054	+0.016
1.6	+0.265	+0.268	+0.268	+0.266	+0.250	+0.226	+0.185	+0.134	+0.075	+0.023
2.0	+0.234	+0.251	+0.273	+0.285	+0.285	+0.274	+0.232	+0.172	+0.104	+0.031
3.0	+0.134	+0.203	+0.267	+0.322	+0.357	+0.362	+0.330	+0.262	+0.157	+0.052
4.0	+0.067	+0.164	+0.256	+0.339	+0.403	+0.429	+0.409	+0.334	+0.210	+0.073
5.0	+0.025	+0.137	+0.245	+0.346	+0.428	+0.477	+0.469	+0.398	+0.259	+0.092
6.0	+0.018	+0.119	+0.234	+0.344	+0.441	+0.504	+0.514	+0.447	+0.301	+0.112
8.0	-0.011	+0.104	+0.218	+0.335	+0.443	+0.534	+0.575	+0.530	+0.381	+0.151
10.0	-0.011	+0.098	+0.208	+0.323	+0.437	+0.542	+0.608	+0.589	+0.440	+0.179
12.0	-0.005	+0.097	+0.202	+0.312	+0.429	+0.543	+0.628	+0.633	+0.494	+0.211
14.0	-0.002	+0.098	+0.200	+0.306	+0.420	+0.539	+0.639	+0.666	+0.541	+0.241
16.0	-0.000	+0.099	+0.199	+0.304	+0.412	+0.531	+0.641	+0.687	+0.582	+0.265

Note: Positive sign indicates tension.

Table Tension in Circular Ring Wall, Hinged Base, Free Top and Subjected to Triangular Load

$$\text{Tension } T = \text{Coefficient} \times \gamma_w H r$$

H^2/Dt	Coefficients at point									
	0.0H	0.1H	0.2H	0.3H	0.4H	0.5H	0.6H	0.7H	0.8H	0.9H
0.4	+0.474	+0.440	+0.395	+0.352	+0.308	+0.264	+0.215	+0.165	+0.111	+0.057
0.8	+0.423	+0.402	+0.381	+0.358	+0.330	+0.297	+0.249	+0.202	+0.145	+0.076
1.2	+0.350	+0.355	+0.361	+0.362	+0.358	+0.342	+0.309	+0.256	+0.186	+0.098
1.6	+0.271	+0.303	+0.341	+0.369	+0.385	+0.385	+0.362	+0.314	+0.233	+0.124
2.0	+0.205	+0.260	+0.321	+0.373	+0.411	+0.434	+0.419	+0.369	+0.280	+0.151
3.0	+0.074	+0.179	+0.281	+0.375	+0.449	+0.506	+0.519	+0.479	+0.375	+0.210
4.0	+0.017	+0.137	+0.253	+0.367	+0.469	+0.545	+0.579	+0.553	+0.447	+0.256
5.0	-0.008	+0.114	+0.235	+0.356	+0.469	+0.562	+0.617	+0.606	+0.503	+0.294
6.0	-0.011	+0.103	+0.223	+0.343	+0.463	+0.566	+0.639	+0.643	+0.547	+0.327
8.0	-0.015	+0.096	+0.208	+0.324	+0.443	+0.564	+0.661	+0.697	+0.621	+0.386
10.0	-0.008	+0.095	+0.200	+0.311	+0.428	+0.552	+0.666	+0.730	+0.678	+0.433
12.0	-0.002	+0.097	+0.197	+0.302	+0.417	+0.541	+0.664	+0.750	+0.720	+0.477
14.0	0.000	+0.098	+0.197	+0.299	+0.408	0.531	+0.659	+0.761	+0.752	+0.513
16.0	+0.002	+0.100	+0.198	+0.299	+0.403	+0.521	+0.650	+0.764	+0.776	+0.536

Notes: 1. γ_w is the density of the liquid.

2. Positive sign indicates tension.

Table Bending Moment in Cylindrical Walls Fixed at Base and Free at Top
(IS: 3370-1967, Part IV)
Moment $M = (\text{Coefficient}) \times \gamma_w H^3$

H^2/Dt	Coefficients at point									
	0.1H	0.2H	0.3H	0.4H	0.5H	0.6H	0.7H	0.8H	0.9H	1.0H
0.4	+0.0005	+0.0014	+0.0021	+0.0007	-0.0042	-0.0150	-0.0302	-0.0529	-0.0816	-0.1205
0.8	+0.0011	+0.0037	+0.0063	+0.0080	+0.0070	+0.0023	-0.0068	-0.0224	-0.0465	-0.0795
1.2	+0.0012	+0.0042	+0.0077	+0.0103	+0.0112	+0.0090	+0.0022	-0.0108	-0.0311	-0.0602
1.6	+0.0011	+0.0041	+0.0075	+0.0107	+0.0121	+0.0111	+0.0058	-0.0051	-0.0232	-0.0505
2.0	+0.0010	+0.0035	+0.0068	+0.0099	+0.0120	+0.0115	+0.0075	-0.0021	-0.0185	-0.0436
3.0	+0.0006	+0.0024	+0.0047	+0.0071	+0.0090	+0.0097	+0.0077	+0.0012	-0.0119	-0.0333
4.0	+0.0003	+0.0015	+0.0028	+0.0047	+0.0066	+0.0077	+0.0069	+0.0023	-0.0080	-0.0268
5.0	+0.0002	+0.0008	+0.0016	+0.0029	+0.0046	+0.0059	+0.0059	+0.0028	-0.0058	-0.0222
6.0	+0.0001	+0.0003	+0.0008	+0.0019	+0.0032	+0.0046	+0.0051	+0.0029	-0.0041	-0.0187
8.0	0.0000	+0.0001	+0.0002	+0.0008	+0.0016	+0.0028	+0.0038	+0.0029	-0.0022	-0.0146
10.0	0.0000	+0.0000	+0.0001	+0.0004	+0.0007	+0.0019	+0.0029	+0.0028	-0.0012	-0.0122
12.0	0.0000	-0.0001	+0.0001	+0.0002	+0.0003	+0.0013	+0.0023	+0.0026	-0.0005	-0.0104
14.0	0.0000	0.0000	0.0000	0.0000	0.0001	+0.0008	+0.0019	+0.0023	-0.0001	-0.0090
16.0	0.0000	0.0000	-0.0001	-0.0002	-0.0001	+0.0004	+0.0013	+0.0019	+0.0001	-0.0079

Note: Positive sign indicates tension at the outside face.

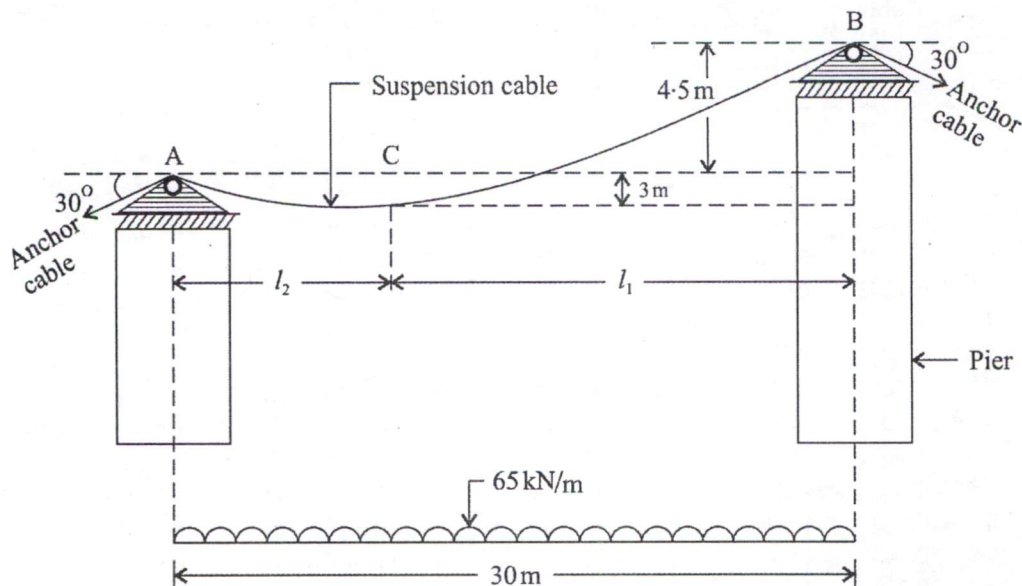
7.(a)(i) A beam of 200 mm × 200 mm section is 4.0 m long and is simply supported at its ends. The beam fails under bending when a point load of 200 kN is applied at the centre of the beam. Find the intensity of the uniformly distributed load which will cause failure of 5.0 m long cantilever of same material having cross-section of 400 mm wide and 500 mm deep. 10

7.(a)(ii) Determine the output of an angle dozer with a blade width = 3.35 m, blade height = 0.855 m, forward speed = 9.4 kmph on a haul road 90 m long consisting of earth and gravel (swell factor = 0.83). The efficiency of dozer is 80% and its working time is 50 min/hr. The job conditions are good and management conditions are fair (Factor for these conditions may be taken as 0.69). 10

7.(b) An unstiffened suspension cable carries a uniformly distributed load of 65 kN/m over a span of 30 m as shown in the figure. The suspension cable is supported on frictionless rollers, fixed to the piers. The anchor cables are inclined at 30° to horizontal. One pier is 4.5 m below the other and the maximum dip of the cable at the lowest point (C) is 3 m below the lower pier. Calculate

(i) the maximum and minimum tension in the cable.

(ii) the horizontal and vertical forces at support A.



20

- 7.(c) Design a combined footing with a strap beam for two reinforced concrete columns 400 mm × 400 mm size spaced 5 m apart and each supporting a factored load of 1000 kN. Assume the safe bearing capacity of soil as 100 kN/m². Maximum length of footing is restricted to 8.0 M. Adopt M-25 concrete and Fe-500 Bars. Nominal cover for foundation shall be considered as 50 mm. Load factor considered is 1.5. Show details of reinforcement.

20

TABLE 3 FLEXURE — REINFORCEMENT PERCENTAGE, p_t FOR SINGLY REINFORCED SECTIONS

$f_{ck} = 25 \text{ N/mm}^2$

M_u/bd^2 , N/mm ²	f_y , N/mm ²					M_u/bd^2 , N/mm ²	f_y , N/mm ²				
	240	250	415	480	500		240	250	415	480	500
0.30	0.146	0.140	0.084	0.073	0.070	2.55	1.415	1.358	0.818	0.708	0.679
0.35	0.171	0.164	0.099	0.085	0.082	2.60	1.448	1.390	0.837	0.724	0.695
0.40	0.195	0.188	0.113	0.098	0.094	2.65	1.482	1.422	0.857	0.741	0.711
0.45	0.220	0.211	0.127	0.110	0.106	2.70	1.515	1.455	0.876	0.758	0.727
0.50	0.245	0.236	0.142	0.123	0.118	2.75	1.549	1.487	0.896	0.775	0.744
0.55	0.271	0.260	0.156	0.135	0.130	2.80	1.584	1.520	0.916	0.792	0.760
0.60	0.296	0.284	0.171	0.148	0.142	2.85	1.618	1.554	0.936	0.809	0.777
0.65	0.321	0.309	0.186	0.161	0.154	2.90	1.653	1.587	0.956	0.827	0.794
0.70	0.347	0.333	0.201	0.174	0.167	2.95	1.689	1.621	0.977	0.844	0.811
0.75	0.373	0.358	0.216	0.186	0.179	3.00	1.724	1.655	0.997	0.862	0.828
0.80	0.399	0.383	0.231	0.199	0.191	3.05	1.760	1.690	1.018	0.880	0.845
0.85	0.425	0.408	0.246	0.212	0.204	3.10	1.797	1.725	1.039	0.898	0.863
0.90	0.451	0.433	0.261	0.225	0.216	3.15	1.834	1.760	1.061	0.917	0.880
0.95	0.477	0.458	0.276	0.239	0.229	3.20	1.871	1.796	1.082	0.936	0.898
1.00	0.504	0.483	0.291	0.252	0.242	3.25	1.909	1.832	1.104	0.954	0.916
1.05	0.530	0.509	0.307	0.265	0.255	3.30	1.947	1.869	1.126	0.973	0.935
1.10	0.557	0.535	0.322	0.279	0.267	3.32	1.962	1.884	1.135	0.981	0.942
1.15	0.584	0.561	0.338	0.292	0.280	3.34	1.978	1.899	1.144	0.989	
1.20	0.611	0.587	0.353	0.306	0.293	3.36	1.993	1.914	1.153		
1.25	0.638	0.613	0.369	0.319	0.306	3.38	2.009	1.929	1.162		
1.30	0.666	0.639	0.385	0.333	0.320	3.40	2.025	1.944	1.171		
1.35	0.693	0.666	0.401	0.347	0.333	3.42	2.040	1.959	1.180		
1.40	0.721	0.692	0.417	0.360	0.346	3.44	2.056	1.974	1.189		
1.45	0.749	0.719	0.433	0.374	0.359	3.46	2.072	1.989			
1.50	0.777	0.746	0.449	0.388	0.373	3.48	2.088	2.005			
1.55	0.805	0.773	0.466	0.403	0.387	3.50	2.104	2.020			
1.60	0.834	0.800	0.482	0.417	0.400	3.52	2.120	2.036			
1.65	0.862	0.828	0.499	0.431	0.414	3.54	2.137	2.051			
1.70	0.891	0.856	0.515	0.446	0.428	3.56	2.153	2.067			
1.75	0.920	0.883	0.532	0.460	0.442	3.58	2.170	2.083			
1.80	0.949	0.911	0.549	0.475	0.456	3.60	2.186	2.099			
1.85	0.979	0.940	0.566	0.489	0.470	3.62	2.203	2.115			
1.90	1.009	0.968	0.583	0.504	0.484	3.64	2.219	2.131			
1.95	1.038	0.997	0.601	0.519	0.498	3.66	2.236	2.147			
2.00	1.068	1.026	0.618	0.534	0.513	3.68	2.253	2.163			
2.05	1.099	1.055	0.635	0.549	0.527	3.70	2.270	2.179			
2.10	1.129	1.084	0.653	0.565	0.542	3.72	2.287	2.196			
2.15	1.160	1.114	0.671	0.580	0.557	3.74	2.304				
2.20	1.191	1.143	0.689	0.596	0.572						
2.25	1.222	1.173	0.707	0.611	0.587						
2.30	1.254	1.204	0.725	0.627	0.602						
2.35	1.285	1.234	0.743	0.643	0.617						
2.40	1.317	1.265	0.762	0.659	0.632						
2.45	1.350	1.295	0.781	0.675	0.648						
2.50	1.382	1.327	0.799	0.691	0.663						

NOTE — Blanks indicate inadmissible reinforcement percentage (see Table E).

TABLE 61 SHEAR — DESIGN SHEAR STRENGTH OF CONCRETE, τ_c N/mm²

P_t	f_{ck} , N/mm ²					
	15	20	25	30	35	40
0.20	0.32	0.33	0.33	0.33	0.34	0.34
0.30	0.38	0.39	0.39	0.40	0.40	0.41
0.40	0.43	0.44	0.45	0.45	0.46	0.46
0.50	0.46	0.48	0.49	0.50	0.50	0.51
0.60	0.50	0.51	0.53	0.54	0.54	0.55
0.70	0.53	0.55	0.56	0.57	0.58	0.59
0.80	0.55	0.57	0.59	0.60	0.61	0.62
0.90	0.57	0.60	0.62	0.63	0.64	0.65
1.00	0.60	0.62	0.64	0.66	0.67	0.68
1.10	0.62	0.64	0.66	0.68	0.69	0.70
1.20	0.63	0.66	0.69	0.70	0.72	0.73
1.30	0.65	0.68	0.71	0.72	0.74	0.75
1.40	0.67	0.70	0.72	0.74	0.76	0.77
1.50	0.68	0.72	0.74	0.76	0.78	0.79
1.60	0.69	0.73	0.76	0.78	0.80	0.81
1.70	0.71	0.75	0.77	0.80	0.81	0.83
1.80	0.71	0.76	0.79	0.81	0.83	0.85
1.90	0.71	0.77	0.80	0.83	0.85	0.86
2.00	0.71	0.79	0.82	0.84	0.86	0.88
2.10	0.71	0.80	0.83	0.86	0.88	0.90
2.20	0.71	0.81	0.84	0.87	0.89	0.91
2.30	0.71	0.82	0.86	0.88	0.91	0.93
2.40	0.71	0.82	0.87	0.90	0.92	0.94
2.50	0.71	0.82	0.88	0.91	0.93	0.95
2.60	0.71	0.82	0.89	0.92	0.94	0.97
2.70	0.71	0.82	0.90	0.93	0.96	0.98
2.80	0.71	0.82	0.91	0.94	0.97	0.99
2.90	0.71	0.82	0.92	0.95	0.98	1.00
3.00	0.71	0.82	0.92	0.96	0.99	1.01

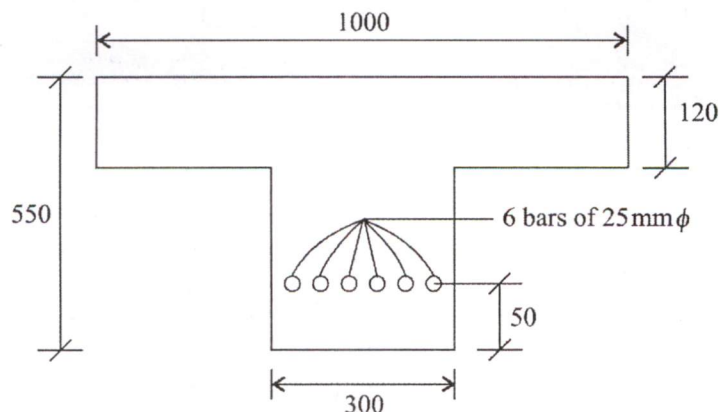
- 8.(a) A built up column of effective length 5 m consists of two ISMC 250 (back to back). The sections are laced. Find the spacing of the sections for maximum axial compressive load capacity. Also design the single lacing system using bars connected to the channels by weld (shop). Draw the lacing system also. For ISMC 250, $A = 38.67 \text{ cm}^2$, $I_{xx} = 3817 \text{ cm}^4$, $I_{yy} = 219 \text{ cm}^4$, $C_{yy} = 2.3 \text{ cm}$. Assume lacing bars are at 50° with the vertical.

Given :

$\frac{KL}{r}$	40	50	60	70	80	90	100	110	120
f_{cd} (MPa)	198	183	168	152	136	121	107	95	84

20

- 8.(b)(i) Discuss the important features of common post tensioned systems in prestressed concrete. 10
- 8.(b)(ii) Calculate the moment of resistance of a T-beam as shown in figure given below. The grade of concrete is M-25 and Grade of steel is Fe-500.



(All Dimensions are in mm)

10

ANNEX G
(Clause 38.1)

MOMENTS OF RESISTANCE FOR RECTANGULAR AND T-SECTIONS

G-0 The moments of resistance of rectangular and T-sections 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 :

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

- 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_{st} = area of tension reinforcement,
 f_{ck} = characteristic compressive strength of concrete,
 b = width of the compression face,
 $M_{u,lim}$ = limiting moment of resistance of a section without compression reinforcement, and
 $x_{u,max}$ = limiting value of x_u from 39.1.

G-1.2 Section with Compression Reinforcement

Where the ultimate moment of resistance of section exceeds the limiting value, $M_{u,lim}$ compression reinforcement may be obtained from the following equation :

$$M_u - M_{u,lim} = f_{sc} A_{sc} (d - d')$$

where

- $M_u, M_{u,lim}, d$ are same as in G-1.1,
 f_{sc} = design stress in compression reinforcement corresponding to a strain of

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

where

- $x_{u,max}$ = the limiting value of x_u from 38.1,
 A_{sc} = area of compression reinforcement, and
 d' = depth of compression reinforcement from compression face.

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

$$A_{st} = A_{st1} + A_{st2}$$

where

- A_{st} = area of the total tensile reinforcement,
 A_{st1} = area of the tensile reinforcement for a singly reinforced section for $M_{u,lim}$, and
 $A_{st2} = A_{sc} f_{sc} / 0.87 f_y$.

G-2 FLANGED SECTION

G-2.1 For $x_u < D_f$, 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_f/d does not exceed 0.2 :

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

where

- $M_u, x_{u,max}, d$ and f_{ck} are same as in G-1.1,
 b_f = breadth of the compression face/flare,
 b_w = breadth of the web, and
 D_f = thickness of the flange.

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

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

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

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

- 8.(c) A hollow marine propeller shaft turning at 120 rpm is required to propel a vessel at 16 m/s at the expense of 6500 kW of shaft power. The efficiency of the propeller is 70%. The ratio of the outer diameter to inner diameter of the shaft is $\frac{2}{3}$. If the direct stress due to thrust is not to exceed 10 N/mm², calculate the following :

- (i) Outer and inner diameter of the shaft
(ii) Maximum shearing stress due to torque