

## 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.

Question Nos. 1 and 5 are compulsory and out of the remaining, 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.

**SECTION—A**

1. (a) (i) Explain the types of glazing used for the clay products. 6
- (ii) What are the causes and remedies of efflorescence in bricks? 6
- (b) Explain the specific reasons for the following : 6+6=12
- (i) For prestressed concrete, the Code recommends to use high tensile steel and high strength of concrete.
- (ii) Helically reinforced circular columns have better compressive strength than that of similar columns with lateral ties.
- (c) The rafter member of a truss consists of two angles ISA 75×75×8 placed (back-to-back) both sides of the gusset of thickness 10 mm. It carries factored axial compressive force of 200 kN. Determine the number of 16 mm diameter, 4.6 grade ordinary bolts for the joint. Assume E250 grade of steel and the cross-sectional area in the threaded part for 16 mm diameter bolt is 157 mm<sup>2</sup>. Use  $K_b = 0.49$ ,  $\gamma_{mb} = 1.25$ . Use limit state method of design. 12
- (d) A bar specimen of 38 mm diameter was subjected to a pull of 98 kN during a tensile test. The extension on a gauge length of 200 mm was measured to be 0.092 mm and the change in diameter of 0.0048 mm. Determine the Poisson's ratio, modulus of elasticity, modulus of rigidity and bulk modulus of the material of bar specimen. 12
- (e) (i) With the help of neat sketch of a typical grading curve, describe the term 'gap-graded aggregate' and the adverse effects of using such type of aggregates in concrete. 6
- (ii) How is PPC different from OPC on the basis of their ingredients? Describe the advantages of using PPC in comparison to OPC. 6

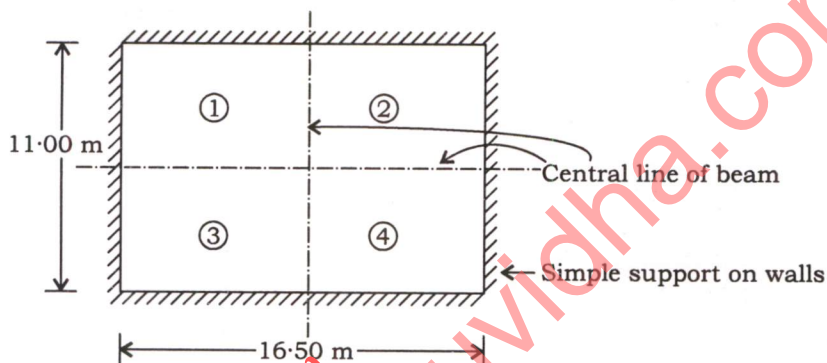
2. (a) A room of effective span  $16.50\text{ m} \times 11.00\text{ m}$  is surrounded by brick walls. In order to lay the RCC slab over it, the room is divided in four equal panels by providing two central beams. The slab is simply supported on all the four walls as shown in the figure below. Using limit state design, determine and provide main reinforcement in a single panel, using  $12\text{ mm}$  diameter steel bars of Fe-415 grade. Consider the grade of concrete as M-20. Draw the reinforcement detail of a panel. Use the following additional data :

Total factored load on slab (dead load + live load) =  $16\text{ kN/m}^2$

Thickness of slab =  $175\text{ mm}$

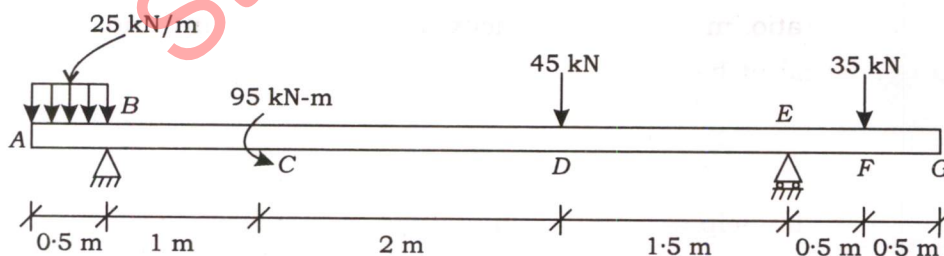
Effective depth of slab =  $150\text{ mm}$

Note : Refer Annex D of IS 456 : 2000 for finding the moments at different locations. The Annex is reproduced at Page Nos. 11 and 12.



20

- (b) Explain the mechanism of alkali-aggregate reaction in concrete. How can it be controlled? 20
- (c) Draw the bending moment and shearing force diagrams for the overhanging beam loaded as shown in the figure below. Determine the positions of maximum bending moment, maximum shearing force and locate the locations of zero bending moment : 20



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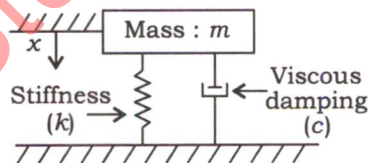
3. (a) (i) What is gel-space ratio? How is it estimated? Discuss its effect on the strength of concrete. 10
- (ii) What are the factors affecting durability of concrete? 10

(b) A rectangular beam of size 300 mm × 600 mm is used over a simply supported effective span of 7 m. The beam supports a live load of 12 kN/m. A straight tendon is provided at an eccentricity of 100 mm below the centroid of the beam section. Find the minimum prestressing force required for no tension condition at mid-span under live load. Also, show the stress distribution under self-weight only at mid-span and at the ends of the member. 20

(c) A uniformly distributed load of 45 kN/m longer than the span rolls over a simply supported girder of 35 m span. Using influence line diagram for shear force and bending moment, determine the maximum shear force and maximum bending moment at a section 14 m from left-hand support. 20

4. (a) (i) For the vibrating system shown in the figure below, determine the following parameters :

- (1) Natural frequency of the vibrating system
- (2) Critical damping of the vibrating system
- (3) Damping ratio
- (4) Damped natural frequency of the vibrating system



$$m = 10 \text{ kg}$$

$$k = 2400 \text{ N/m}$$

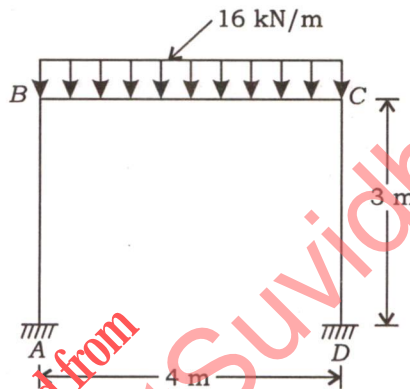
$$c = 77 \text{ N-s/m}$$

10

(ii) A short braced reinforced concrete column has unsupported length of 3.5 m and size of 300 mm × 360 mm. Verify the applicability of simplified formula of  $P_u$  (i.e., ultimate load-carrying capacity of a short axially loaded column) as given in the Code. Also, determine the design moments due to minimum eccentricity to be considered for this case if the column is subjected to an ultimate axial load of 1600 kN. 10

- (b) (i) What are the factors affecting rheological properties of concrete? 10
- (ii) How are the properties of concrete affected by seawater and industrial wastewater, if they are used for making the concrete? 10

- (c) Analyze the portal frame shown in the figure below by moment distribution method. The frame is fixed at *A* and *D*, and has rigid joints at *B* and *C*. Draw the bending moment diagram and sketch the deflected shape of the structure. Take  $EI$  as constant :



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5. (a) (i) Describe the mechanical properties of ceramics. 6

- (ii) Explain roller-compacted concrete. What are the advantages of roller-compacted concrete? 6

- (b) A steel cable of 12 mm diameter is stretched across two poles 80 m apart. If the central dip is 1.10 m at normal temperature, determine the stress intensity in the cable. Also, determine the change in temperature necessary to raise the stress to 80 MPa. Take unit weight of steel  $\gamma = 78 \text{ kN/m}^3$  and  $\alpha = 12 \times 10^{-6} / ^\circ\text{C}$ . 12

- (c) A T-beam is continuous over a span of 10 m. The sectional parameters of the beam are as below :

Width of web = 250 mm

Width of flange = 1100 mm

Effective depth of beam = 460 mm

Area of steel in tension =  $1800 \text{ mm}^2$

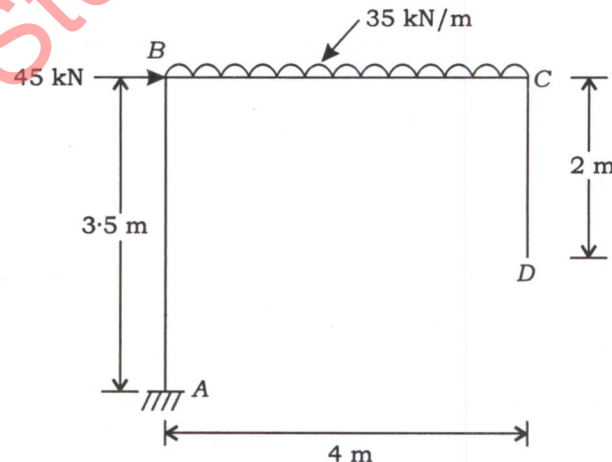
Area of steel in compression =  $1000 \text{ mm}^2$

Use M-20 grade of concrete and Fe-415 grade of steel. Estimate the safety of the beam for deflection control using the empirical method given in the Code IS 456 : 2000. The corresponding graphs are reproduced at Page Nos. 13–15. 12

- (d) A single angle ISA  $100 \times 100 \times 10$  is connected to a gusset plate of thickness 10 mm by weld along two parallel edges. The size of weld (fillet) is 6 mm. The member is subjected to an axial compressive load of 150 kN (factored). Find the weld length along two parallel edges. Assume E250 grade of steel and shop welded. For ISA  $100 \times 100 \times 10$ ,  $c_y = c_z = 27.6 \text{ mm}$ . Use limit state method. 12

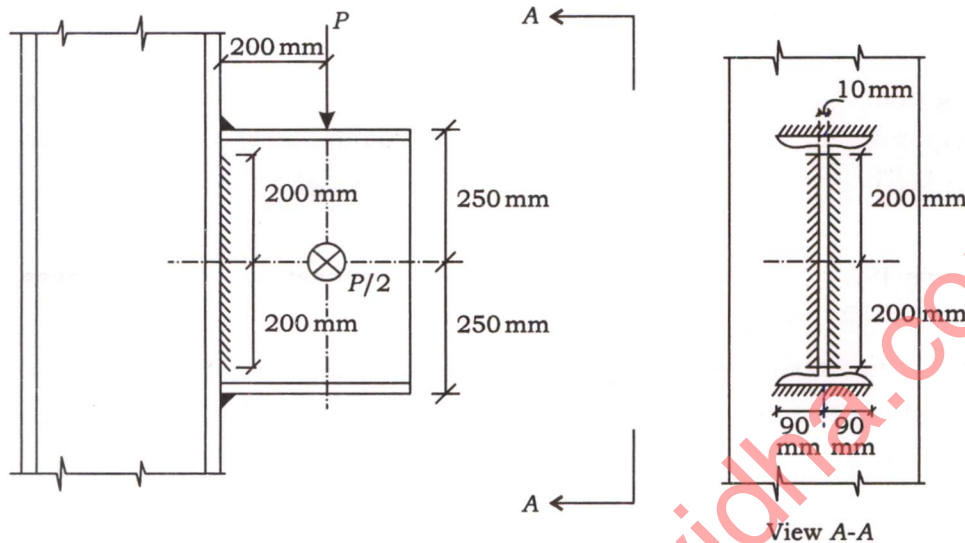
- (e) Determine the maximum principal stress developed in a cylindrical shaft 10 cm in diameter, subjected to a BM of 3.0 kN-m and twisting moment of 4.50 kN-m. If the yield stress of the shaft material is  $230 \text{ MN/m}^2$ , determine the factor of safety according to the maximum shearing stress theory of failure. 12

6. (a) Determine the vertical and horizontal deflections at the free end of the frame shown in the figure below. Take  $EI = 12 \times 10^4 \text{ kN-m}^2$  :



20

- (b) A cantilever beam (ISMB 500) is connected to the flange of the column (ISHB 450) by fillet weld of size 5 mm. The beam is subjected to a vertical load  $P$  and a horizontal load  $P/2$  at a distance of 200 mm from the flange of the column as shown in the figure below. Find the factored  $P$  that can be applied for the joint. Assume E250 grade of steel, site weld. Given,  $f_e = \sqrt{f_a^2 + 3q^2}$ . Use limit state method. Assume that the beam section is safe :



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- (c) The following table gives the details of various activities of a construction project :

Activity	Optimistic time (months)	Most likely time (months)	Pessimistic time (months)
1-2	2	2	8
1-3	2	5	8
1-4	3	3	9
2-5	2	2	4
3-5	3	6	15
4-6	3	6	9
5-6	4	7	16
6-7	2	2	2

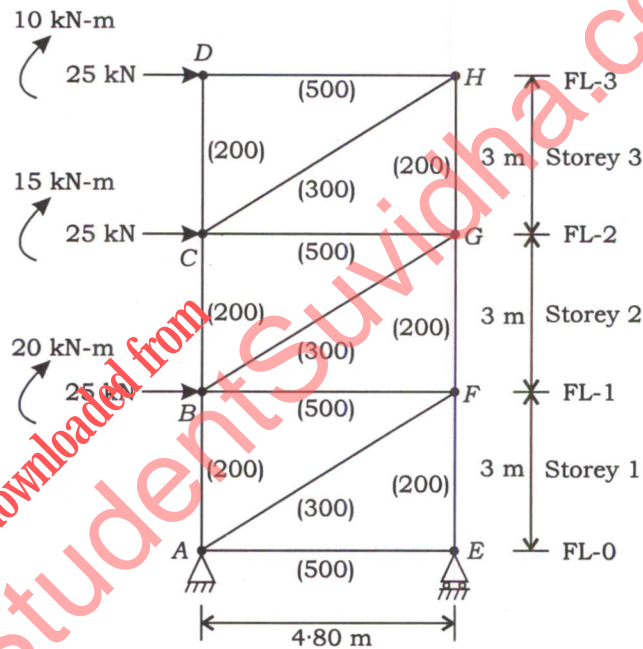
- (i) Draw the network for the project.
- (ii) Find the expected duration and variance of each activity.

(iii) What is the expected project length?

(iv) What is the probability that the project will be completed at least 3 months earlier than expected?

(v) What will be the time required for 95% probability of its completion? 20

7. (a) Determine the forces in the member of the braced frame as shown in the figure below. Also, determine the drift due to shear in each storey. Areas of diagonals and horizontal girders are shown in brackets and they are in  $\text{mm}^2$ . Take  $E = 205 \text{ kN/mm}^2$  :



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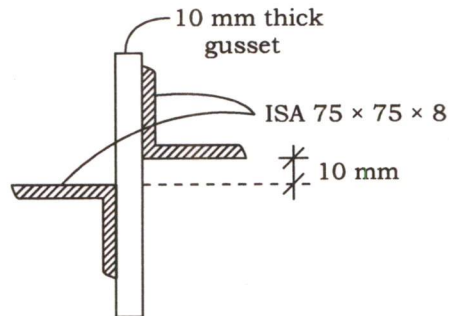
- (b) A member of a transmission tower is composed of two angles ISA  $75 \times 75 \times 8$  in star configuration as shown in the figure below. The angles are tack welded by a gusset plate of thickness 10 mm suitably. Find the axial compressive load-carrying capacity of the member under dead and live load condition. The nodal length of the member is 3 m. Assume  $K = 0.85$  and E250 grade of steel. The properties of ISA  $75 \times 75 \times 8$  are as follows :

$$A = 1140 \text{ mm}^2, \quad I_{yy} = I_{zz} = 59 \text{ cm}^4, \quad c_y = c_z = 21.4 \text{ mm}, \quad r_{uu} = 28.8 \text{ mm}, \\ r_{vv} = 14.5 \text{ mm}$$



Given :

$\frac{KL}{r}$	60	70	80	90	100	110	120	130
$f_{cr}$ (MPa)	168	152	136	121	107	94.6	83.7	74.3



Use limit state method.

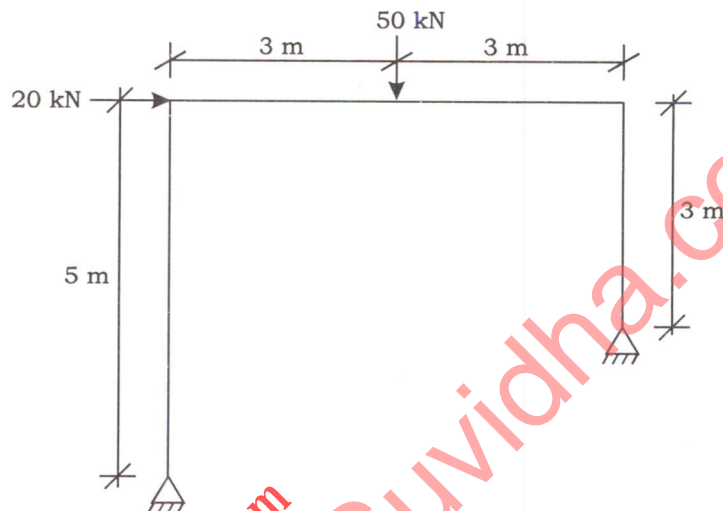
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- (c) (i) What are the precautions to be taken for labour safety during formwork construction? 10
- (ii) Discuss the parameters influencing the degree of compaction achieved by a vibratory roller. 10
8. (a) (i) A mass of 1000 kg is placed at the free end of a cantilever beam of span 3 m. Assume that the beam is massless compared to applied mass. The flexural rigidity of the beam is  $10^3 \text{ kN-m}^2$ . Determine the natural time period of the system. (Assume  $g = 10 \text{ m/s}^2$ ) 10
- (ii) A trapezoidal combined footing supports two columns of sizes 450 mm x 450 mm and 550 mm x 550 mm carrying service load of 750 kN and 1250 kN respectively. The CG of smaller column lies at 0.45 m from the property line. The centre-to-centre distance of two columns is 4.4 m. The total length of footing is to be restricted to 5.6 m. Determine and show the layout plan of the above footing. Consider safe bearing capacity of soil = 155 kN/m<sup>2</sup>. 10

- (b) Find the designed plastic moment for the portal frame as shown in the figure below under collapse condition for the factored (applied) loads. Assume that the frame has uniform cross-section. Also, find the minimum section required for the frame for E250 grade of steel.

Given :

Section	ISMB 125	ISMB 150	ISMB 175	ISMB 200	ISMB 225	ISMB 250	ISMB 300	ISMB 350
Plastic Section Modulus (cm <sup>3</sup> )	81	110	184	255	348	466	651	889



- (c) (i) Explain different types of contract. Discuss the importance of each type of contract. 20
- (ii) On a homogeneous embankment, compacting rollers are used to compact silty clay soil. Determine the quantity of earth compacted if the sheeps-foot roller travels at 4 km/hr, time of rolling is 50 min, length of drum is 2.4 m, number of drums is one, fraction of overlap is 1/8, layer thickness is 0.45 m and number of passes given is 5. 10

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ANNEX D

(Clauses 24.4 and 37.1.2)

SLABS SPANNING IN TWO DIRECTIONS

D-1 RESTRAINED SLABS

D-1.0 When the corners of a slab are prevented from lifting, the slab may be designed as specified in D-1.1 to D-1.11.

D-1.1 The maximum bending moments per unit width in a slab are given by the following equations:

$$M_x = \alpha_x w l_x^2$$

$$M_y = \alpha_y w l_y^2$$

where

$\alpha_x$  and  $\alpha_y$  are coefficients given in Table 26,

$w$  = total design load per unit area,

$M_x, M_y$  = moments on strips of unit width spanning  $l_x$  and  $l_y$  respectively, and

$l_x$  and  $l_y$  = lengths of the shorter span and longer span respectively.

D-1.2 Slabs are considered as divided in each direction into middle strips and edge strips as shown in Fig. 25 the middle strip being three-quarters of the width and each edge strip one-eighth of the width.

D-1.3 The maximum moments calculated as in D-1.1 apply only to the middle strips and no redistribution shall be made.

D-1.4 Tension reinforcement provided at mid-span in the middle strip shall extend in the lower part of the slab to within 0.25  $l$  of a continuous edge, or 0.15  $l$  of a discontinuous edge.

D-1.5 Over the continuous edges of a middle strip, the tension reinforcement shall extend in the upper part of the slab a distance of 0.15  $l$  from the support, and at least 50 percent shall extend a distance of 0.3  $l$ .

D-1.6 At a discontinuous edge, negative moments may arise. They depend on the degree of fixity at the edge of the slab but, in general, tension reinforcement equal to 50 percent of that provided at mid-span extending 0.1  $l$  into the span will be sufficient.

D-1.7 Reinforcement in edge strip, parallel to that edge, shall comply with the minimum given in Section 3 and the requirements for torsion given in D-1.8 to D-1.10.

D-1.8 Torsion reinforcement shall be provided at any corner where the slab is simply supported on both edges meeting at that corner. It shall consist of top and bottom reinforcement, each with layers of bars placed parallel to the sides of the slab and extending from the edges a minimum distance of one-fifth of the shorter span. The area of reinforcement in each of these four layers shall be three-quarters of the area required for the maximum mid-span moment in the slab.

D-1.9 Torsion reinforcement equal to half that described in D-1.8 shall be provided at a corner contained by edges over only one of which the slab is continuous.

D-1.10 Torsion reinforcements need not be provided at any corner contained by edges over both of which the slab is continuous.

D-1.11 Torsion  $l_y/l_x$  is greater than 2, the slabs shall be designed as spanning one way.

D-2 SIMPLY SUPPORTED SLABS

D-2.1 When simply supported slabs do not have adequate provision to resist torsion at corners and to prevent the corners from lifting, the maximum

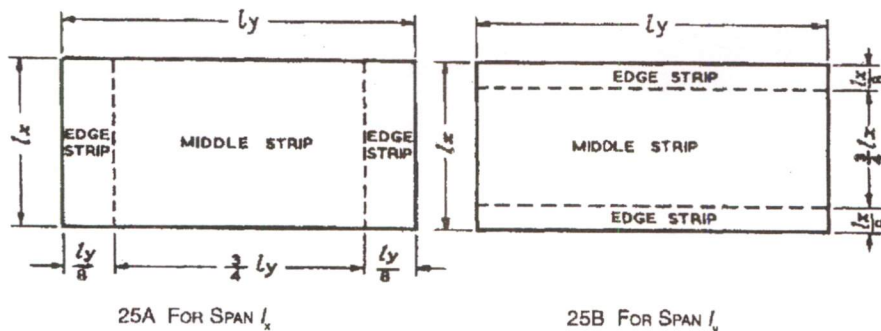


FIG. 25 DIVISION OF SLAB INTO MIDDLE AND EDGE STRIPS

**Table 26 Bending Moment Coefficients for Rectangular Panels Supported on Four Sides with Provision for Torsion at Corners**  
(Clauses D-1.1 and 24.4.1)

Case No.	Type of Panel and Moments Considered	Short Span Coefficients $\alpha_x$ (Values of $l_y/l_x$ )								Long Span Coefficients $\alpha_y$ for All Values of $l_y/l_x$
		1.0	1.1	1.2	1.3	1.4	1.5	1.75	2.0	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	<i>Interior Panels:</i>									
	Negative moment at continuous edge	0.032	0.037	0.043	0.047	0.051	0.053	0.060	0.065	0.032
	Positive moment at mid-span	0.024	0.028	0.032	0.036	0.039	0.041	0.045	0.049	0.024
2	<i>One Short Edge Continuous:</i>									
	Negative moment at continuous edge	0.037	0.043	0.048	0.051	0.055	0.057	0.064	0.068	0.037
	Positive moment at mid-span	0.028	0.032	0.036	0.039	0.041	0.044	0.048	0.052	0.028
3	<i>One Long Edge Discontinuous:</i>									
	Negative moment at continuous edge	0.037	0.044	0.052	0.057	0.063	0.067	0.077	0.085	0.037
	Positive moment at mid-span	0.028	0.033	0.039	0.044	0.047	0.051	0.059	0.065	0.028
4	<i>Two Adjacent Edges Discontinuous:</i>									
	Negative moment at continuous edge	0.047	0.053	0.060	0.065	0.071	0.075	0.084	0.091	0.047
	Positive moment at mid-span	0.035	0.040	0.045	0.049	0.053	0.056	0.063	0.069	0.035
5	<i>Two Short Edges Discontinuous:</i>									
	Negative moment at continuous edge	0.045	0.049	0.052	0.056	0.059	0.060	0.065	0.069	—
	Positive moment at mid-span	0.035	0.037	0.040	0.043	0.044	0.045	0.049	0.052	0.035
6	<i>Two Long Edges Discontinuous:</i>									
	Negative moment at continuous edge	—	—	—	—	—	—	—	—	0.045
	Positive moment at mid-span	0.045	0.043	0.051	0.057	0.063	0.068	0.080	0.088	0.035
7	<i>Three Edges Discontinuous (One Long Edge Continuous):</i>									
	Negative moment at continuous edge	0.057	0.064	0.071	0.076	0.080	0.084	0.091	0.097	—
	Positive moment at mid-span	0.043	0.048	0.053	0.057	0.060	0.064	0.069	0.073	0.043
8	<i>Three Edges Discontinuous (One Short Edge Continuous):</i>									
	Negative moment at continuous edge	—	—	—	—	—	—	—	—	0.057
	Positive moment at mid-span	0.043	0.051	0.059	0.065	0.071	0.076	0.087	0.096	0.043
9	<i>Four Edges Discontinuous:</i>									
	Positive moment at mid-span	0.056	0.064	0.072	0.079	0.085	0.089	0.100	0.107	0.056

moments per unit width are given by the following equation:

$$M_x = \alpha_x w l_x^2$$

$$M_y = \alpha_y w l_y^2$$

where

$M_x, M_y, w, l_x, l_y$  are same as those in D-1.1,

and  $\alpha_x$  and  $\alpha_y$  are moment coefficients given in Table 27

**D-2.1.1** At least 50 percent of the tension reinforcement provided at mid-span should extend to the supports. The remaining 50 percent should extend to within 0.1  $l_x$  or 0.1  $l_y$  of the support, as appropriate.

**Table 27 Bending Moment Coefficients for Slabs Spanning in Two Directions at Right Angles, Simply Supported on Four Sides**  
(Clause D-2.1)

$l_y/l_x$	1.0	1.1	1.2	1.3	1.4	1.5	1.75	2.0	2.5	3.0
$\alpha_x$	0.062	0.074	0.084	0.093	0.099	0.104	0.113	0.118	0.122	0.124
$\alpha_y$	0.062	0.061	0.059	0.055	0.051	0.046	0.037	0.029	0.020	0.014

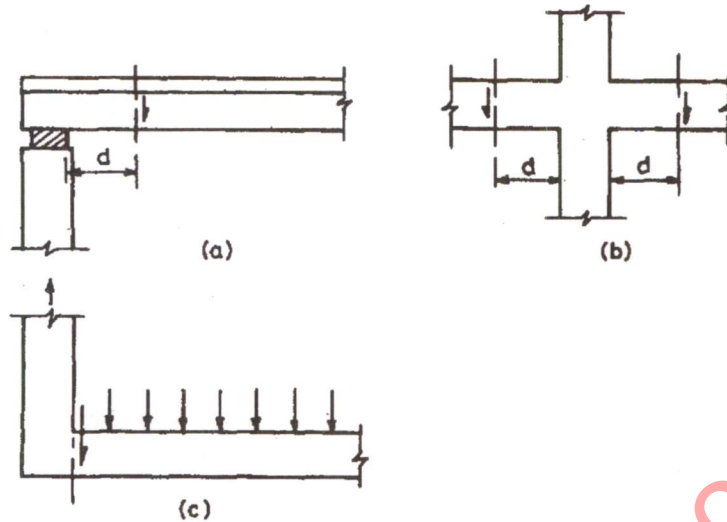


FIG. 2. TYPICAL SUPPORT CONDITIONS FOR LOCATING FACTORED SHEAR FORCE

but in no case greater than the breadth of the web plus half the sum of the clear distances to the adjacent beams on either side.

- a) For T-beams,  $b_f = \frac{l_0}{6} + b_w + 6 D_f$
- b) For L-beams,  $b_f = \frac{l_0}{12} + b_w + 3 D_f$
- c) For isolated beams, the effective flange width shall be obtained as below but in no case greater than the actual width:

$$\text{T-beam, } b_f = \frac{l_0}{\left(\frac{l_0}{b}\right) + 4} + b_w$$

$$\text{L-beam, } b_f = \frac{0.5 l_0}{\left(\frac{l_0}{b}\right) + 4} + b_w$$

where

- $b_f$  = effective width of flange,
- $l_0$  = distance between points of zero moments in the beam,
- $b_w$  = breadth of the web,
- $D_f$  = thickness of flange, and
- $b$  = actual width of the flange.

NOTE — For continuous beams and frames, ' $l_0$ ' may be assumed as 0.7 times the effective span.

### 23.2 Control of Deflection

The deflection of a structure or part thereof shall not adversely affect the appearance or efficiency of the

structure or finishes or partitions. The deflection shall generally be limited to the following:

- a) The final deflection due to all loads including the effects of temperature, creep and shrinkage and measured from the as-cast level of the supports of floors, roofs and all other horizontal members, should not normally exceed span/250.
- b) The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

23.2.1 The vertical deflection limits may generally be assumed to be satisfied provided that the span to depth ratios are not greater than the values obtained as below:

- a) Basic values of span to effective depth ratios for spans up to 10 m:

Cantilever	7
Simply supported	20
Continuous	26

- b) For spans above 10 m, the values in (a) may be multiplied by 10/span in metres, except for cantilever in which case deflection calculations should be made.
- c) Depending on the area and the stress of steel for tension reinforcement, the values in (a) or (b) shall be modified by multiplying with the modification factor obtained as per Fig. 4.
- d) Depending on the area of compression reinforcement, the value of span to depth ratio be further modified by multiplying with the modification factor obtained as per Fig. 5.

For Question No. 5 (c)

IS 456 : 2000

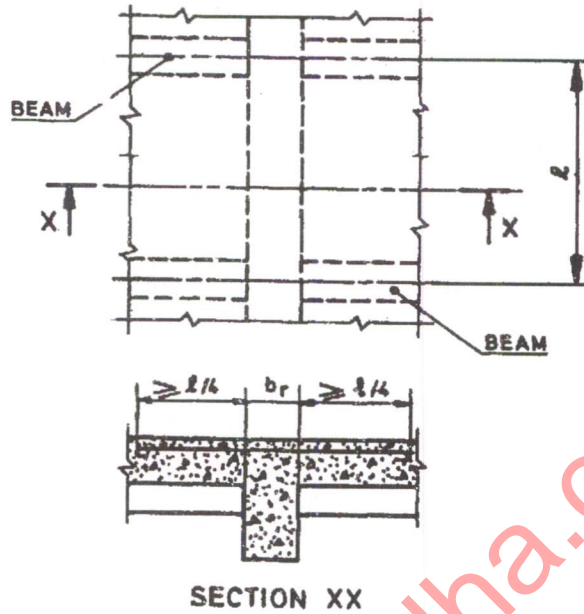


FIG. 3 TRANSVERSE REINFORCEMENT IN FLANGE OF T-BEAM WHEN MAIN REINFORCEMENT OF SLAB IS PARALLEL TO THE BEAM

- 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.

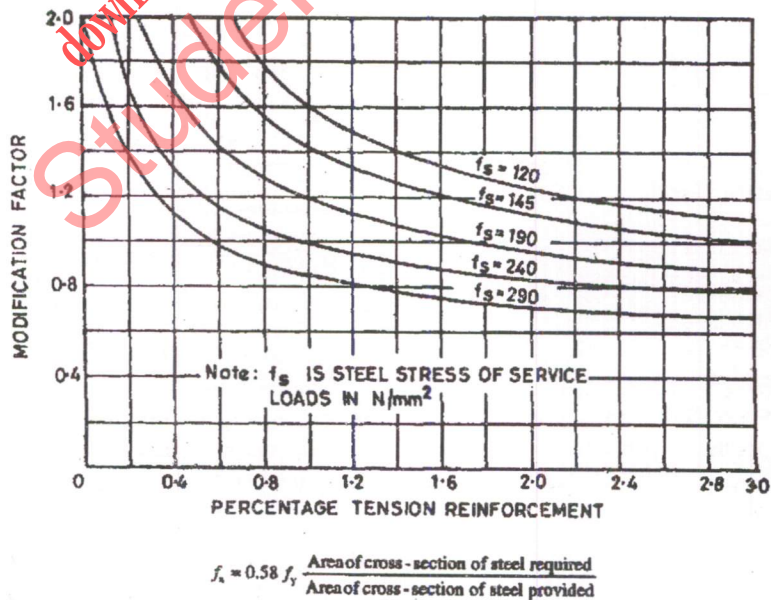


FIG. 4 MODIFICATION FACTOR FOR TENSION REINFORCEMENT

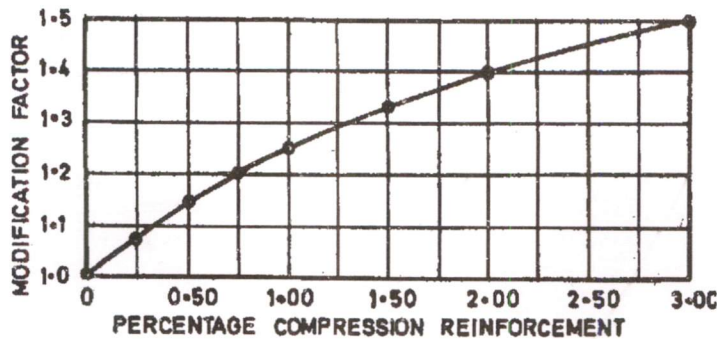


FIG. 5 MODIFICATION FACTOR FOR COMPRESSION REINFORCEMENT

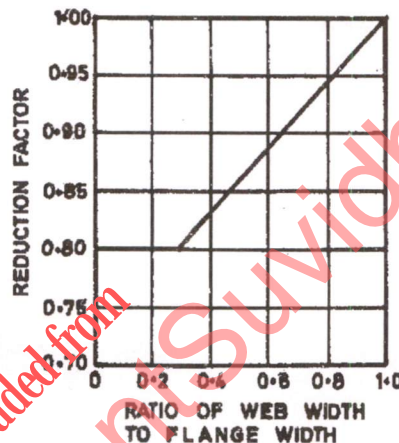


FIG. 6 REDUCTION FACTORS FOR RATIOS OF SPAN TO EFFECTIVE DEPTH FOR FLANGED BEAMS

**23.3 Slenderness Limits for Beams to Ensure Lateral Stability**

A simply supported or continuous beam shall be so proportioned that the clear distance between the lateral restraints does not exceed  $60 b$  or  $\frac{250 b^2}{d}$  whichever is less, where  $d$  is the effective depth of the beam and  $b$  the breadth of the compression face midway between the lateral restraints.

For a cantilever, the clear distance from the free end of the cantilever to the lateral restraint shall not exceed  $25 b$  or  $\frac{100 b^2}{d}$  whichever is less.

**24 SOLID SLABS**

**24.1 General**

The provisions of 23.2 for beams apply to slabs also.

**NOTES**

- For slabs spanning in two directions, the shorter of the two spans should be used for calculating the span to effective depth ratios.
- For two-way slabs of shorter spans (up to 3.5 m) with mild steel reinforcement, the span to overall depth ratios given below may generally be assumed to satisfy vertical deflection limits for loading class up to 3 kN/m<sup>2</sup>.
 

Simply supported slabs	35
Continuous slabs	40

For high strength deformed bars of grade Fe 415, the values given above should be multiplied by 0.8.

**24.2 Slabs Continuous Over Supports**

Slabs spanning in one direction and continuous over supports shall be designed according to the provisions applicable to continuous beams.

**24.3 Slabs Monolithic with Supports**

Bending moments in slabs (except flat slabs) constructed monolithically with the supports shall be calculated by taking such slabs either as continuous over supports and

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