GATE – CIVIL ENGINEERING

REINFORCED CEMENT CONCRETE (RCC)

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Design for Bond & Development Length

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Development Length of Bars

The development length L_d is given by

$$L_d = \frac{\phi \sigma_s}{4\tau_{bd}}$$

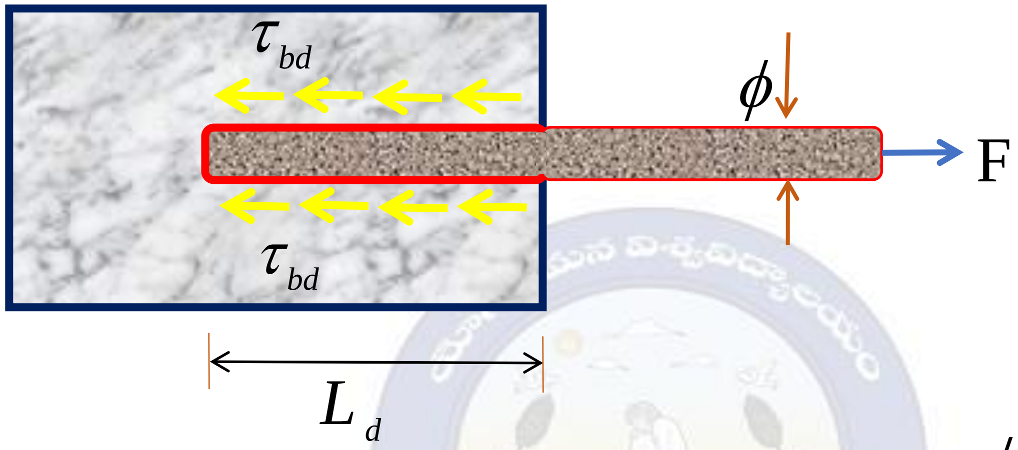
Where

ϕ = nominal diameter of the bar,

σ_s = stress in bar at the section considered at design load, and

τ_{bd} = design bond stress

- The development length includes anchorage values of hooks in tension reinforcement.
- For bars of sections other than circular, the development length should be sufficient to develop the stress in the bar by bond.



When the steel reinforcement fails, $F = \sigma_s . A_s = 0.87 . f_y . \frac{\pi . \phi^2}{4}$

When the bond between concrete and steel fails, $F = \tau_{bd} . \pi . \phi . L_d$

Safe magnitude of F = least of above two values.

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Design bond stress in limit state method for plain bars in tension shall be as below:

Grade of concrete	M20	M25	M30	M35	M40 and above
Design bond stress, τ_{bd}, N/mm^2	1.2	1.4	1.5	1.7	1.9

- For deformed bars, these values shall be increased by 60 percent.
- For bars in compression, the values of bond stress for bars in tension shall be increased by 25 percent.

Bars bundled in contact

The development length of each bar of bundled bars shall be that for the individual bar, increased by 10 percent for two bars in contact, 20 percent for three bars in contact and 33 percent for four bars in contact.

Anchoring Reinforcing Bars

Anchoring bars in tension

a. Deformed bars may be used without end anchorages provided development length requirement is satisfied. Hooks should normally be provided for plain bars in tension.

b. Bends and hooks — Bends and hooks shall conform to IS 2502

1. Bends: The anchorage value of bend shall be taken as 4 times the diameter of the bar for each 45^0 bend subject to a maximum of 16 times the diameter of the bar.
2. Hooks: The anchorage value of a standard U-type hook shall be equal to 16 times the diameter of the bar.

Bearing stresses at bends

The bearing stress in concrete for bends and hooks described in IS 2502 need not be checked. The bearing stress inside a bend in any other bend shall be calculated as given below:

$$\text{Bearing stress} = \frac{F_{bt}}{r\phi}$$

where

F_{bt} = tensile force due to design loads in a bar or group of bars

r = internal radius of the bend, and

ϕ = size of the bar or, in bundle, the size of bar of equivalent area

For limit stale method of design, this stress shall not exceed $\dfrac{1.5\,f_{ck}}{1+2\phi/a}$ where f_{ck} is the characteristic cube strength of concrete and a, for a particular bar or group of bars in contact shall be taken as the centre to centre distance between bars or groups of bars perpendicular to the plane of the bend; for a bar or group of bars adjacent to the face of the member a shall be taken as the cover plus size of bar (ϕ).

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Positive moment reinforcement

a. At least one-third the positive moment reinforcement in simple members and one-fourth the positive moment reinforcement in continuous members shall extend along the same face of the member into the support, to a length equal to $L_d/3$.

b. At simple supports and at points of inflection, positive moment tension reinforcement shall be limited to a diameter such that

$$L_d \ngtr \frac{M_1}{V} + L_0$$

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Where

M_1 = moment of resistance of the section assuming all reinforcement at the section to be stressed to f_d ;

$f_d = 0.87 f_y$ in the case of limit state design and me permissible stress in the case of working stress design;

V = shear force at the section due to design loads;

L_0 = sum of the anchorage beyond the centre of the support and the equivalent anchorage value of any hook or mechanical anchorage at simple support; and at a point of inflection,

L_0 is limited to the effective depth of the members or ,whichever is greater; and

ϕ = diameter of bar.

The value of M_1/V in the above expression may be increased by 30 percent when the ends of the reinforcement are confined by a compressive reaction.

Negative moment reinforcement

At least one-third of the total reinforcement provided for negative moment at the support shall extend beyond the point of inflection for a distance not less than the effective depth of the member of 12ϕ or one-sixteenth of the clear span whichever is greater.

Curtailment of bundled bars

Bars in a bundle shall terminate at different points spaced apart by not less than 40 times the bar diameter except for bundles stopping at a support.

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Lap splices

a) Lap splices shall not be used for larger than 36 mm; for larger diameters, bars may be welded ; in cases where welding is not practicable, lapping of bars larger than 36 mm may be permitted, in which case additional spirals should be provided around the lapped bars.

b) Lap splices shall be considered as staggered if the centre to centre distance of the splices is not less than 1.3 times the lap length calculated as described in (c).

c) Lap length including anchorage value of hooks for bars in flexural tension shall be L_d or 30ϕ whichever is greater and for direct tension shall be $2L_d$ or 30ϕ whichever is greater. The straight length of the lap shall not be less than 15ϕ or 200 mm. The following provisions shall also apply:

Design for Bond & Development Length

PREVIOUS GATE QUESTIONS

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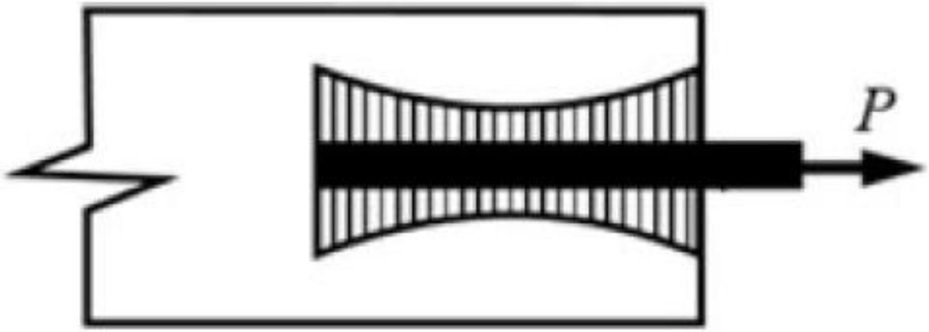
1. A reinforcing steel bar, partially embedded in concrete, is subjected to a tensile force P. The figure that appropriately represents the distribution of the magnitude of bond stress (represented as hatched region), along the embedded length of the bar, is
GATE CE 2020

a.



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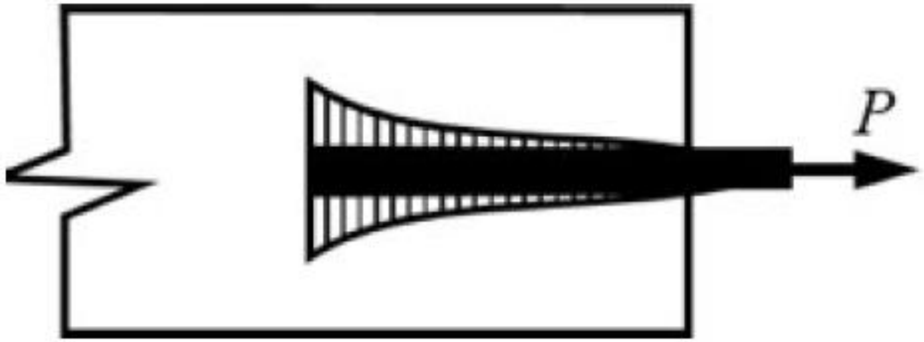
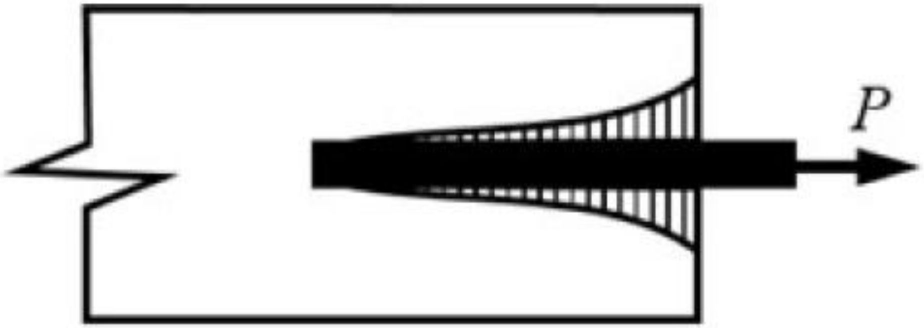
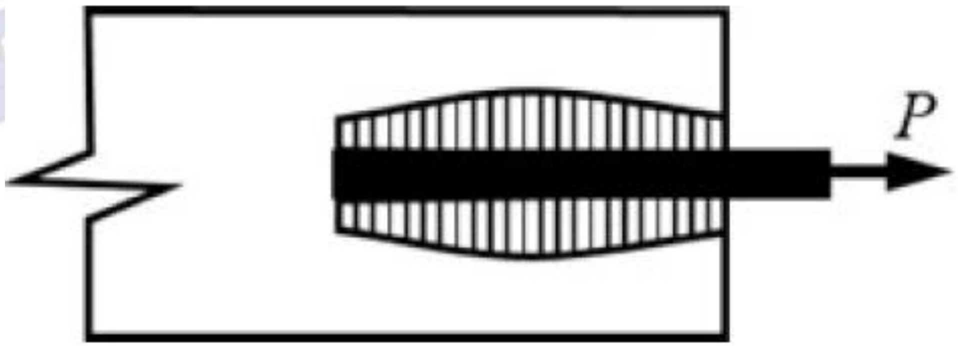


c.



d.



1.c

The actual distribution of band stress along the embedded length of the bar varies parabollically with zero stress at the tip and maximum at the surface of the concrete as shown in fig c. For calculation purpose, it is assumed as uniform through the embedded length of bar.

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02. The development length of a deformed reinforcement bar can be expressed as $\left(\frac{1}{k}\right)\left(\frac{\phi\sigma_s}{\tau bd}\right)$ From the IS: 456-2000, the value of k can be calculated as …..

CE1 2015

Ans. 6.4

Development length, $L_d = \frac{\phi\sigma_s}{4.\tau_{bd}}$

For deformed bars τ_{bd} increased by 60%

$$L_d = \frac{\phi.\sigma_s}{4\times1.6\tau_{bd}} = \frac{1}{6.4}.\frac{\phi.\sigma_s}{\tau_{bd}}$$

Therefore, $k = 6.4$

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03. As per IS:456-2000 for M20 grade concrete and plain bars in tension the design bond stress τ_{bd} = 1.2 MPa. Further, IS 456:2000 permits this design bond stress value to be increased by 60% for HYSD bars. The stress in the HYSD reinforcing steel bars in tension, σ_s = 360 MPa. Find the required development length, L_d , for HYSD bars in terms of the bar diameter,ϕ. 2013

Ans. 46.875 ϕ

Grade of concrete : M20

Bond stress, τ_{bd} = 1.2 N/mm^2

Bond stress τ_{bd} increases by 60% for HYSD bars.

Stress in HYSD reinforcing steel bar in tension, σ_s=360MPa

Development length, $L_d = \dfrac{\phi\sigma_s}{4.\tau_{bd}} = \dfrac{\varphi.360}{4\times1.2\times1.6}$ =46.875 ϕ

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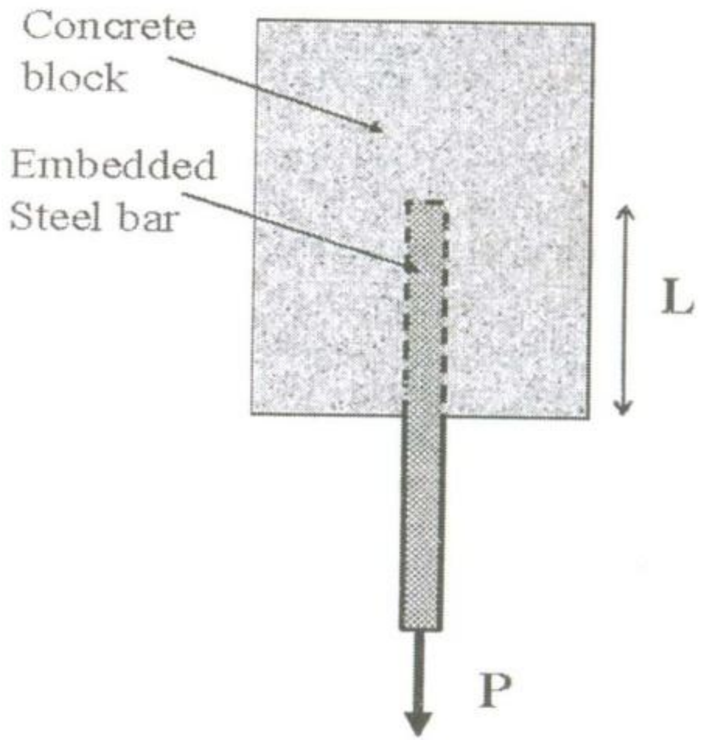
04. Consider a bar of diameter 'D' embedded in a large concrete block as shown in the adjoining figure, with a pull out force P being applied. Let σ_b and σ_{st} be the bond strength (between the bar and concrete) and the tensile strength of the bar, respectively. If the block is held in position and it is assumed that the material of the block does not fail, which of the following options represents the maximum value of P? 2011



a. Maximum of $\left(\frac{\pi}{4}D^2\sigma_b\right)$ and $\left(\pi DL\sigma_{st}\right)$

b. Maximum of $\left(\frac{\pi}{4}D^2\sigma_{st}\right)$ and $\left(\pi DL\sigma_b\right)$

c. Minimum of $\left(\frac{\pi}{4}D^2\sigma_{st}\right)$ and $\left(\pi DL\sigma_b\right)$

d. Minimum of $\left(\frac{\pi}{4}D^2\sigma_b\right)$ and $\left(\pi DL\sigma_{st}\right)$

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Ans. c

Maximum pull out force is obtained from

i. Tensile failure of the reinforced bar, $P = \left(\frac{\pi}{4} D^2 \sigma_{st} \right)$

ii. Bond failure between concrete and steel, $P = \left(\pi D L \sigma_b \right)$

The maximum value of P is the minimum of (i) and (ii).

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05. In the design of a reinforced concrete beam the requirement for bond is not getting satisfied. The economical option to satisfy the requirement for bond is by

2008

a. bundling of bars

b. providing smaller diameter bars more in number

c. providing larger diameter bars less in number

d. providing same diameter bars more in number

Ans. b

The economical option to satisfy the requirement for bond in RCC beams is by providing more number of smaller diameter bars so that the surface area of steel reinforcement in contact with concrete increases and thereby bond stress decreases.

$$\tau_{bd} = \frac{V}{(\Sigma O).z}$$

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06. If a beam is likely to fail due to high bonding stresses, then its bond strength can be increased most economically by

a. Providing vertical stirrups

b. Increasing the depth of the beam

c. Using smaller diameter bars in correspondingly more numbers

d. Using higher diameter bars by reducing their numbers

Ans. c

07. The bond between steel and concrete is mainly due to

1.Mechanical resistance 2.Pure adhesive resistance 3.Frictional resistance

a.1 and 2 only b. 1 and 3 only c. 2 and 3 only **d.** 1, 2 and 3

Ans. d

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08. Splicing of rebars in RCC beams can be done at a section where

a. bending moment is zero

b. bending moment is less than half of the maximum bending moment in beam

c. bending moment is maximum

d. shear force is zero

Ans. b

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09. The appropriate expression in assessing development length is

$$\textbf{a.}\ L_d = \frac{\phi\sigma_s}{4\tau_{bd}} \quad \text{b.}\ L_d = \frac{\phi\sigma_{bc}}{\tau_{bd}} \quad \text{c.}\ L_d = \frac{\sigma_s}{4\tau_{bd}} \quad \text{d.}\ L_d = \frac{\phi\sigma_s}{8\tau_{bd}}$$

Ans. a

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10. The development length in compression for a 20 mm diameter deformed bar of grade *Fe415* embedded in concrete of grade *M25*, whose design bond stress is 1.40 N/mm^2, is

a. 1489 mm b. 1289 mm c. 806 mm **d.** 645 mm

Ans. d

$$\phi = 20\,mm \qquad f_y = 415\,N/mm^2 \qquad f_{ck} = 25\,N/mm^2$$

$$\tau_{bd} = 1.40\,N/mm^2$$

$$L_d = \frac{\phi\sigma_S}{4\tau_{bd}} = \frac{20\times0.87\times415}{4\times1.4\times1.6\times1.25} = 644.7\text{mm}$$

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11. Lap length of reinforcement in compression shall not be less than

a. 10ϕ **b.** 30ϕ c. 20ϕ d. 15ϕ

Ans. b

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12. Match List-I with List-II and select the correct answer using the code given below the lists:

List –I	List-II
A. $\frac{V_u}{bd}$	1. Modulus of rapture
B. $0.7\sqrt{f_{ck}}$	2. Development length
C. $5000\sqrt{f_{ck}}$	3. Nominal shear stress
D. $\phi.\sigma_s / 4\tau_{bd}$	4. Hook anchorage value
	5. Modulus of concrete

a. A3 B1 C5 D2   b. A2 B1 C4 D3   c. A3 B5 C1 D4   d. A2 B4 C1 D3

Ans. a

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13. What is the anchorage value of a standard hook of a reinforcement bar of diameter *D*?

a. *4D* b. *8D* c. *12D* **d.** *16D*

Ans. d

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14. What is the bond stress acting parallel to the reinforcement on the interface between bar and concrete?

a. Shear stress b. Local stress c. Flexural stress d. Bearing stress

Ans. a

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15. When HYSD bars are used in place of mild steel bars in beam, the bond strength

a. does not change **b.** increases c. decreases d. becomes zero

Ans. b

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16. Which one of the following is the correct expression to estimate the development length of deformed reinforcing bar as per IS code in limit state design?

a. $\dfrac{\phi.\sigma_s}{4.5\tau_{bd}}$ b. $\dfrac{\phi.\sigma_s}{5\tau_{bd}}$ **c.** $\dfrac{\phi.\sigma_s}{4\tau_{bd}}$ d. $\dfrac{\phi.\sigma_s}{8\tau_{bd}}$

where ϕ is diameter of reinforcing bar, σ_s is the stress in the bar at a section and τ_{bd} is bond stress.

Ans. c

17. The distance between theoretical cut-off point and actual cut-out point in respect of the curtailment of reinforcement of reinforced concrete beams should not be less than

a. Development length

b. 12 × dia. of bar or effective depth whichever is greater

c. 24 × dia. of bar or effective depth whichever is greater

d. 30 × dia. of bar or effective depth whichever is greater

Ans. b

18. In a reinforced concrete member, the best way to ensure adequate bond is

a. to provide minimum number of large diameter bars

b. to provide large number of smaller diameter bars

c. to increase the cover for reinforcement

d. to provide additional stirrups

Ans. b

19. In limit state design, permissible bond stress in the case of deformed bars is more than that in plain bars by

a. 60% b. 50% c. 40% d. 25%

Ans. a

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Design of Columns

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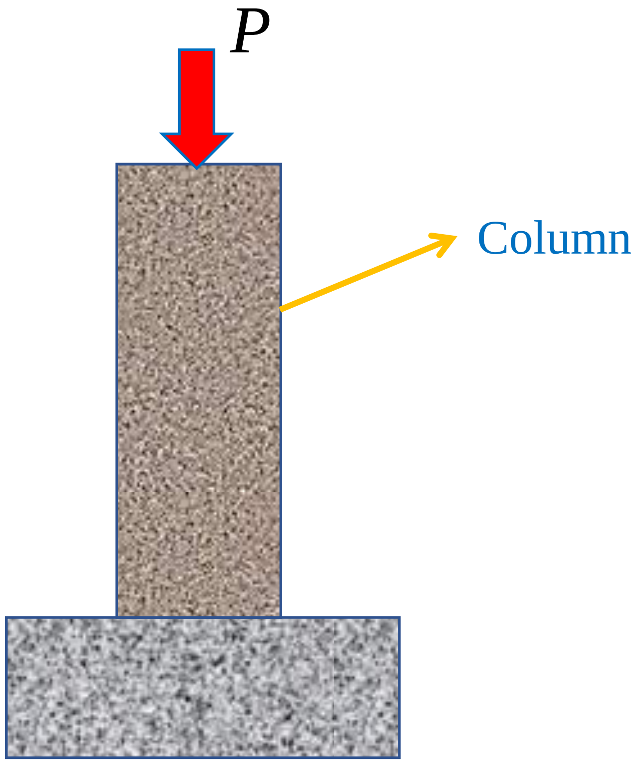
Introduction

- Column is a compression member
- Compression members are structural elements primarily subjected to axial compressive forces and hence, their design is guided by considerations of strength and buckling.



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Slenderness Ratio (λ):

- Design of columns mainly depends on the slenderness ratio of the column.
- Slenderness ratio of the column is the geometrical property of the compression member (Column) which is related to the ratio of its effective length L_{eff} and radius of gyration $r_{\min}$

$$\lambda = \frac{L_{eff}}{r_{\min}}$$

- For RCC, slenderness ratio can be written as $\lambda = \frac{L_{eff}}{b}$

- L_{eff} – effective length of the column
- b – least lateral dimension

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Compression members

Pedestal

$$\frac{L_{eff}}{b} < 3.0$$

Columns

Short Columns

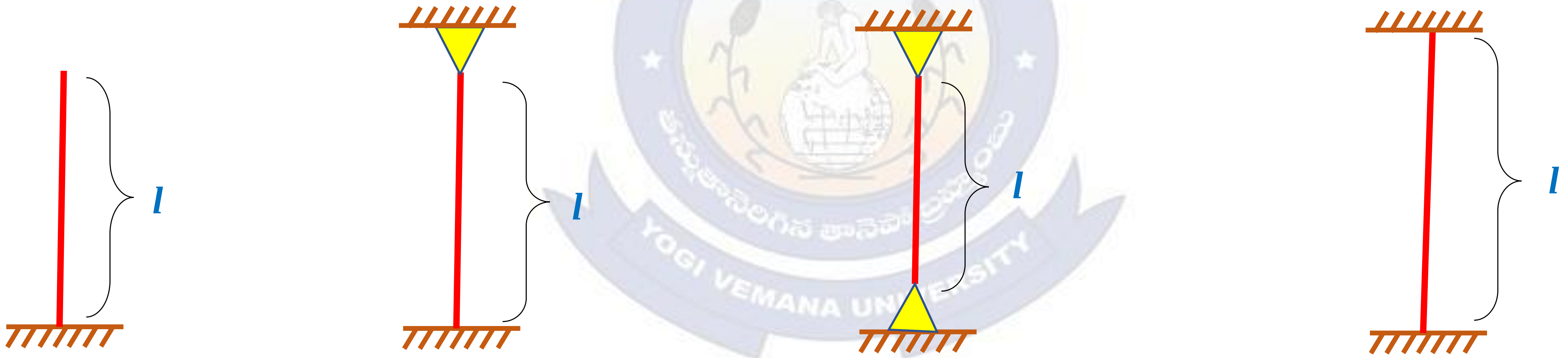
$$\frac{L_{eff}}{b} = 3.0 \text{ to } 12$$

Long Columns

$$\frac{L_{eff}}{b} = 12 \text{ to } 60$$

Effective length:

- The vertical distance between the points of inflection of the compression member in the buckled configuration in a plane is termed as effective length L_{eff} of that compression member in that plane.
- The effective length is different from the unsupported length l of the member, though it depends on the unsupported length and the type of end restraints.



$L_{eff} = 2 \times l$

$L_{eff} = \frac{l}{\sqrt{2}}$ or $0.8l$

$L_{eff} = l$

$L_{eff} = \frac{l}{2}$ or $0.65l$

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Minimum eccentricity:

$$e_{\min} = \frac{L}{500} + \frac{b}{30} \qquad \text{min of } 20\text{mm}$$

L – Unsupported length

b – Least Lateral dimension

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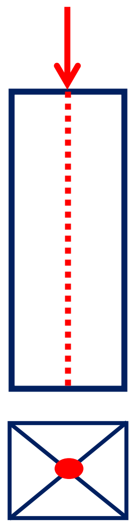
Short axially loaded columns:

- Practically apply the load is difficult, but IS 456-2000 given little consideration as long as eccentricity of the column can be treated as axially loaded column only.

$$P_u = P_c + P_{sc}$$

$$P_u = 0.4 f_{ck} A_c + 0.67 f_y A_{sc}$$

- To avoid sudden crushing problem of column, the permissible stresses are $\left(\dfrac{f_{ck}}{2.5}, \dfrac{f_y}{1.5}\right)$



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LIMIT STATE OF COLLAPSE: COMPRESSION

Assumptions

In addition to the assumptions for flexure, the following shall be assumed:

a) The maximum compressive strain in concrete in axial compression is taken as 0.002.

b) The maximum compressive strain at the highly compressed extreme fibre in concrete subjected to axial compression and bending and when there is no tension on the section shall be 0.0035 minus 0.75 times the strain at the least compressed extreme fibre.

Short Axially Loaded Members in Compression

The member shall be designed by considering the assumptions given in 39.1 and the minimum eccentricity. When the minimum eccentricity as per 25.4 does not exceed 0.05 times the lateral dimension, the members may be designed by the following equation:

$$P_u = 0.4\, f_{ck}.A_c + 0.67\, f_y.A_{sc}$$

where

P_u=axial load on the member

f_{ck}=characteristic compressive strength of the concrete

A_c=Area of concrete

f_y=characteristic strength of the compression reinforcement, and

A_{sc}=area of longitudinal reinforcement for columns

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Compression Members with Helical Reinforcement

The strength of compression members with helical reinforcement satisfying the requirement shall be taken as 1.05 times the strength of similar member with lateral ties.

$$\frac{\text{Volume of helical reinforcement}}{\text{Volume of core}} \nless 0.36\left(\frac{A_g}{A_c}-1\right)\frac{f_{ck}}{f_y}$$

A_g=gross area of the section,

A_c=area of the core of the helically reinforced column measured to the outside diameter of the helix,

f_{ck}=characteristic compressive strength of the concrete, and

f_y=characteristic strength of the helical reinforcement but not exceeding 415 N/mm^2.

Members Subjected to Combined Axial Load and Biaxial Bending

The resistance of a member subjected to axial force and biaxial bending shall be obtained to satisfy the equilibrium of load and moments about two axes. Alternatively such members may be designed by the following equation:

$$\left[\frac{M_{ux}}{M_{ux1}}\right]^{\alpha_n} + \left[\frac{M_{uy}}{M_{uy1}}\right]^{\alpha_n} \leq 1.0$$

Where

M_{ux}, M_{uy}=moments about x and y axes due to design loads,

M_{ux1}, M_{uy1}=maximum uniaxial moment capacity for an axial load of P_u bending about x and y axes respectively

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α_n is related to $\dfrac{P_u}{P_{uz}}$

where $P_{uz} = 0.45 f_{ck}.A_c + 0.75 f_y.A_{sc}$

For values of $\dfrac{P_u}{P_{uz}}$ = 0.2 to 0.8, the values of α_n vary linearly from 1.0 to 2.0. For values less than 0.2, α_n is 1.0; for values greater than 0.8, α_n is 2.0.

Slender Compression Members

The design of slender compression members shall be based on the forces and the moments determined from an analysis of the structure, including the effect of deflections on moments and forces. The additional moments M_{ax} and M_{ay} shall be calculated by the following formulae:

$$M_{ax} = \frac{P_u D}{2000}\left\{\frac{l_{ex}}{D}\right\}^2 \qquad M_{ay} = \frac{P_u b}{2000}\left\{\frac{l_{ey}}{b}\right\}^2$$

Where

P_u=axial load on the member, l_{ex}=effective length in respect of the major axis,
l_{ey}=effective length in respect of the minor axis,
D=depth of the cross-section at right angles to the major axis b=width of the member

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The values given by equation may be multiplied by the following factor:

$$k = \frac{P_{uz} - P_u}{P_{uz} - P_b} \leq 1$$

P_u=axial load on compression member,

P_{uz}=as defined in 39.6, and

P_b=axial load corresponding to the condition of maximum compressive strain of 0.0035 in concrete and tensile strain of 0.002 in outer most layer of tension steel.

Longitudinal reinforcement

a. The cross-sectional area of longitudinal reinforcement, shall be not less than 0.8 percent not more than 6 percent of the gross cross sectional area of the column.

The use of 6 percent reinforcement may involve practical difficulties in placing and compacting of concrete; hence lower percentage is recommended. Where bars from the column below have to be lapped with those in the column under consideration. The percentage of steel shall usually not exceed 4 percent.

b. In any column that has a larger cross-sectional area than that required to support the load, the minimum percentage of steel shall be based upon the area of concrete required to resist the direct stress and not upon the actual area.

c. The minimum number of longitudinal bars provided in a column shall be four in rectangular columns and six in circular columns.

d. The bars shall not be less than 12 mm in diameter.

e. A reinforced concrete column having helical reinforcement shall have at least six bars of longitudinal reinforcement within the helical reinforcement.

f. In a helically reinforced column, the longitudinal bars shall be in contact with the helical reinforcement and equidistant around its inner circumference.

g. Spacing of longitudinal bars measured along the periphery of the column shall not exceed 300 mm.

h. In case of pedestals in which the longitudinal reinforcement is not taken in account in strength calculations, nominal longitudinal reinforcement not less than 0.15 percent of the cross-sectional area shall be provided.

Transverse reinforcement

1. Pitch : The pitch of transverse reinforcement shall be not more than the least of the following
   - i. The least lateral dimension of the compression members;
   - ii. Sixteen times the smallest diameter of the longitudinal reinforcement bar to be tied
   - iii. 300 mm.
2. Diameter: The diameter of the polygonal links or lateral ties shall be not less than one-fourth of the diameter of the largest longitudinal bar, and in no case less than 6 mm.

Helical reinforcement

1. Pitch: not more than 75 mm,

   nor more than one-sixth of the core diameter of the column

   nor less than 25 mm

   nor less than three times the diameter of the steel bar forming the helix.

2) The diameter of the helical reinforcement shall be in accordance with lateral ties

Design of Columns

PREVIOUS GATE QUESTIONS

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01. A structural member subjected to compression, has both translation and rotation restrained at one end, while only translation is restrained at the other end. As per IS 456:2000, the effective length factor recommended for design is CE2 2018

a. 0.50 b. 0.65 c. 0.70 **d.** 0.80

Ans. d

Compression member:

One end: Both translation and rotation restrained (Fixed)

Other end: only translation is restrained (Hinge)

As per IS: 456-2000, the effective length recommended for design is $l_e = 0.80L$

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02. An RCC short column (with lateral ties) of rectangular cross section of 250mmx300mm is reinforced with four numbers of 16 mm diameter longitudinal bars. The grades of steel and concrete are Fe415 and M20 respectively. Neglect eccentricity effect. Considering limit state of collapse in compression (IS:456-2000), the axial load carrying capacity of the column (in kN, up to one decimal place), is… CE1 2018

Ans. **815.0 to 830.0**

Size of short RCC column = 250 × 300 mm

Area of steel reinforcement, A_{sc} = 4x201mm^2

Grade of steel : Fe 415, f_y= 415 N/mm^2

Grade of concrete: M20, f_{ck}= 20 N/mm^2

Since the effect of eccentricity is neglected, the load carrying capacity of axially loaded short column is

$$P_u = 0.4\ f_{ck}.A_c + 0.67\ f_y.A_{sc}$$

$$P_u = 0.4 \times 20 \times (250 \times 300 - 4 \times 201) + 0.67 \times 415 \times 4 \times 201$$

$$= 593.57 + 223.55 = 817.12\,kN$$

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03. A column of size 450 mm x 600 mm has unsupported length of 3.0 m and is braced against side sway in both directions. According to IS 456: 2000, the minimum eccentricities (in mm) with respect to major and minor principal axes are:

CE2 2015

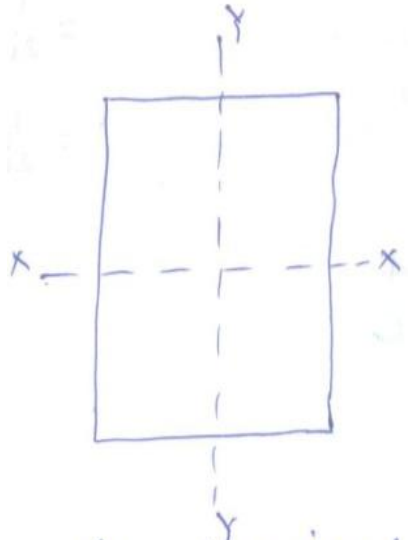
a. 20.0 and 20.0 **b**. 26.0 and 21.0 c. 26.0 and 20.0 d. 21.0 and 15.0

Ans. b

Size of column: 450 mm × 600 mm Unsupported length, l = 3.0 m

Minimum eccentricity, $e_{min} = \frac{L}{500} + \frac{D}{30}$

$\nless$ 20 mm (subjected to a minimum of 20 mm)



column with major and Minor Principal axes.

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Eccentricity with respect to major principal axis, $e_{xx} = \frac{3000}{500} + \frac{600}{30}$

$$= 6 + 20 = 26 \text{ mm}$$

Eccentricity with respect to minor principal axis, $e_{xx} = \frac{3000}{500} + \frac{450}{30}$

$$= 6 + 15 = 21 \text{ mm}$$

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04. A 16 mm thick plate 650 mm × 420 mm is used as a base plate for an ISHB 300 column subjected to a factored axial compressive load of 2000 kN. As per IS 456-2000, the minimum grade of concrete that should be used below the base plate for safely carrying the load is 2011

a. M15 b. M20 c. M30 d. M40

Ans. a

$$\text{Permissible stress,}\ \sigma_{cbc} = \frac{\text{Load on column}}{\text{plan area of base plate}}$$

$$\text{Factored load,}\ P_u = 2000\,\text{kN}$$

Size of base plate : 650x420mm

$$\text{Working load} = \frac{\text{Factored load}}{\text{Factor of safety}} = \frac{2000}{1.5} = 1333.33\text{kN}$$

$$\sigma_{cbc} = \frac{1333.33\times10^3}{650\times420} = 4.88\ \text{N/mm}^2\ ;\ 5\ \text{N/mm}^2$$

Therefore, minimum grade of concrete: M15

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05. A rectangular column section of 250 mmx400 mm is reinforced with five steel bars of grade Fe 500, each of 20 mm diameter. Concrete mix is M 30. Axial load on the column section with minimum eccentricity as per IS:456-2000 using limit state method can be applied upto 2005

a. 1707.37 kN b. 1805.30 kN c. 1806.40 kN d. 1903.7 kN

Ans. a

Axial load carrying capacity of the column is given by

$$P_u = 0.4\, f_{ck} . A_c + 0.67\, f_y . A_{sc}$$

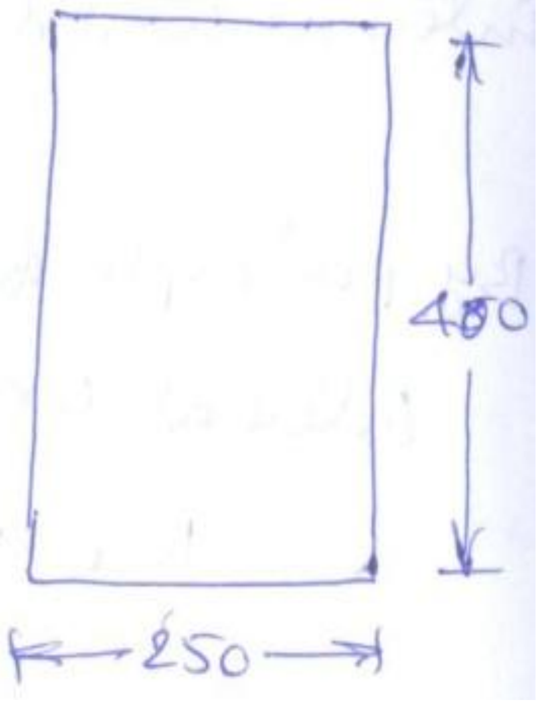
Characteristic strength of concrete, f_{ck} = 30 N/mm^2

Characteristic strength of steel, f_y = 500 N/mm^2

Area of compression steel reinforcement, A_{sc}= 5×314 = 1570 mm^2

Area of concrete, A_c=A_g – A_{sc} = 250×400 – 1570 = 98430 mm^2

P_u = 0.4×30×98430 + 0.67×500×1570 = 1707.37 kN



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06. An R.C. short column with 300 mm x 300 mm square cross-section is made of M20 grade concrete and has 4 numbers, 20 mm diameter longitudinal bars of Fe 415 steel. It is under the action of a concentric axial compressive load. Ignoring the reduction in the area of concrete due to steel bars, the ultimate axial load carrying capacity of the column is 2004

a. 1659 kN b. 1548 kN c. 1198 kN **d.** 1069 kN

Ans. d

Size of column = 300 mm×300 mm

$f_{ck} = 20$ N/mm^2, $f_y = 415$ N/mm^2

A_{sc} : Area of steel reinforcement

=4x314=1256mm^2

P_u : Ultimate load carrying capacity of the column under the action of concentric axial compressive load.

When the minimum eccentricity does not exceed 0.05 D,

$$P_u = 0.4\ f_{ck}.A_c + 0.67\ f_y.A_{sc} = 0.4\times20\times300\times300 + 0.67\times415\times1256 = 1069 \text{ kN}$$

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07. The effective length of a column in a reinforced concrete building frame, as per IS:456-2000, is independent of the 2003

a. frame type i.e., braced (no sway) or un-braced (with sway)

b. span of the beam

c. height of the column

d. loads acting on the frame

Ans. d

The effective length of columns in framed structure may be obtained from the ratio of effective length to unsupported length (l_{eff}/l). Effective length of column depends upon

i. The end conditions

ii. Flexural stiffness ($K_c=EI/L$) of columns joining at a point

iii. Flexural stiffness ($K_b=EI/L$) of beams joining at a point.

iv. Type of frame (sway or non-sway)

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08. Consider the following two statements related to reinforced concrete design, and identify whether they are TRUE or FALSE: 2001

I. Curtailment of bars in the flexural tension zone in beams reduces the shear strength at the cut-off locations.

II. When a rectangular column section is subject to biaxially eccentric compression, the neutral axis will be parallel to the resultant axis of bending.

a. Both statements I and II are TRUE.

b. Statement I is TRUE, and Statement II is FALSE.

c. Statement I is FALSE, and statement II is TRUE.

d. Both Statements I and II are FALSE.

Ans. b

Shear strength of concrete (τ_c) depends on the percentage of tensile steel reinforcement. Therefore, curtailment of bars in the flexural tension zone reduces shear strength at the cutoff locations.

Statement I is true.

When a rectangular column section is subjected to biaxially eccentric compression, the neutral axis is not parallel to the resultant axis of bending. i.e., biaxial bending about diagonal axis.

Statement II is false.

09. In reinforced concrete, pedestal is defined as a compression member, whose effective length does not exceed its dimension by 1999

a. 12 times **b.** 3 times c. 16 times d. 8 times

Ans. b

Pedestal is defined as a compression member whose effective length does not exceed its least lateral dimension by 3 times.

10. A reinforced concrete wall carrying vertical loads is generally designed as per recommendations given for columns. The ratio of minimum reinforcements in the vertical and horizontal directions is 1998

a. 2:1 b. 5:3 c. 1:1 **d.** 3:5

Ans. d

For deformed bars upto 16 mm diameter, minimum reinforcement in vertical and horizontal directions is 0.12 and 0.2% of cross sectional area respectively.

For mild steel, minimum reinforcement in vertical and horizontal directions is 0.15% and 0.25% of cross sectional area respectively.

Minimum reinforcement in vertical to horizontal directions $= \dfrac{0.12\%}{0.20\%} = \dfrac{12}{20} = \dfrac{3}{5}$

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11. Which one of the following set of values give the minimum clear cover (in mm) for the main reinforcements in the slab, beam, column and footing respectively, according to IS:456-1978? 1995

a. 20, 25, 30, 75 b. 5, 15, 25, 50 **c.** 15, 25, 40, 75 d. None of these

Ans. c

Structural element	**Minimum clear cover**
Slab	15 mm
Beam	25 mm
Column	40 mm
Footing	75 mm

12. The lateral ties in a reinforced concrete rectangular column under axial compression are used to 1995

a. avoid the buckling of the longitudinal steel under compression

b. provide adequate shear capacity

c. provide adequate confinement to concrete

d. reduce the axial deformation of the column

Ans. a

Lateral ties in a reinforced concrete rectangular column under axial compression are used

i. to avoid the buckling of the longitudinal steel under compression.

ii. to keep the longitudinal bars in proper position.

iii. to provide adequate confinement to concrete.

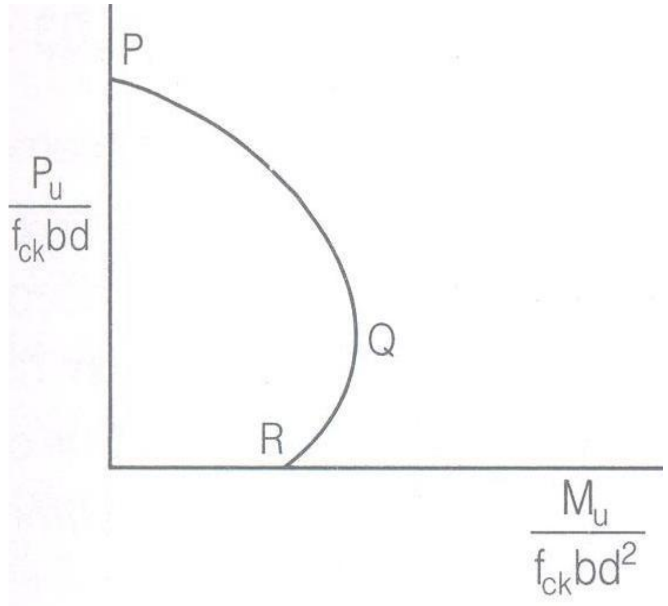
13. Interaction diagram of a rectangular reinforced concrete beam column is shown in figure. With reference to this figure, which of the following statements in (i) and in (ii) below are correct? 1993

(i) **a.** Point Q represents balanced failure

b. Point R represents balanced failure

c. Point P represents balanced failure

d. Point Q represents balanced failure under maximum eccentric compression.



(ii) a. PQ corresponds to the primary tension failure range

b. QR corresponds to the primary tension failure range

c. QR corresponds to the primary compression failure range

d. PQ corresponds to the range of increase in axial force capacity with increase in bending moment capacity

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Ans. (i). a

(ii). b

R: Column subjected to only moment

Q: Balanced failure

P: Column subjected to only axial load

PQ: Primary compression failure

QR: Primary tension failure

When the axial compressive load is zero, the column section behaves as a doubly reinforced beam. It is represented by point ‘R’ and the moment carrying capacity is M_o. As the axial compressive load increases, the moment carrying capacity increases until the balanced section is reached at the point ‘Q’.

14. A circular column is subjected to an un-factored load of 1600 kN. The effective length of the column is 3.5 m, the concrete is M 25, and the value of $\rho_g = \frac{A_{SC}}{A_g} = 2\%$ for *Fe415* steel. The design diameter of the column will be nearly IES 2019

a.446mm b.432mm c.424mm d.410mm

Ans. a

Unfactored load on column, P = 1600 kN

Effective length of the column, $l_e = 3.5m$

Grade of concrete: M25

p=2% for *Fe415* grade steel $\Rightarrow A_{SC} = 2\%\ of\ A_g$

Diameter of the column, *D*=?

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Load carrying capacity of the column,

$$P_u = 0.4\, f_{ck}.A_c + 0.67\, f_y A_{SC}$$

$$1.5\times1600\times10^3 = 0.4\times25(A_g - A_{SC}) + 0.67\times415\,A_{SC}$$

$$1.5\times1600\times10^3 = 0.4\times25(A_g - 0.02\,A_g) + 0.67\times415\times0.02\,A_g$$

$$A_g = 156.2\times10^3$$

$$A_g = \frac{\pi D^2}{4} \Rightarrow 156.2\times10^3 = \frac{\pi D^2}{4} \Rightarrow D = 446mm$$

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15. The ultimate load carrying capacity of a short circular column of 300 mm diameter with 1% helical reinforcement of *Fe415* grade steel and concrete of *M20* grade, is nearly

a. 451 kN b. 500 kN c. 756 kN **d**. 794 kN

Ans. D

Ultimate load carrying capacity of short column, $P_u = 0.4\, f_{ck} . A_c + 0.67\, f_y A_{sc}$

$$A_g = \frac{\pi}{4} 300^2 = 70685.8\, mm^2$$

$$A_{sc} = 1\% \text{ of } A_g = 0.0 \times 70685.8 = 706.9\ mm^2$$

$$f_{ck} = 20\, N / mm^2 \quad f_y = 415\, N / mm^2$$

$$P_u = 0.4 \times 20 \times 70685.8(1-0.01) + 0.67 \times 415 \times 706.9 = 559.8 + 196.6 = 756.4$$

$$(P_u)_{helical} = 1.05 \times 756.4 = 794.2\ kN$$

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16. An RCC column of 4 m length is rigidly connected to the slab and to the foundation. Its cross-section is 400 x 400 mm^2. The column will behave as a/an

a. Long column **b**. Short column

c. Intermediate column d. Linkage

Ans. b

L = 4 m

Size of column: 400 × 400 mm

$$\frac{L}{D} = \frac{4000}{400} = 10 < 12 \Rightarrow \text{short column}$$

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17. A certain R.C. short column with 300 mm square cross-section is made of M20 grade concrete and has 4 numbers, 20 mm diameter, longitudinal bars of Fe415 grade steel. It is under the action of a concentric axial compressive load. Ignoring the reduction in the area of concrete due to the steel bars, the ultimate axial load carrying capacity of the column as by the relevant code is

a. 1069 kN b. 1198 kN c. 1548 kN d. 1659 kN

Ans. A

Size of column: 300 mm × 300 mm

$f_{ck} = 20\,N/mm^2 \quad f_y = 415\,N/mm^2$

$A_{sc} : 4 - 20\,mm\phi$

$P_u = 0.4\,f_{ck}.A_c + 0.67\,f_y A_{sc} = 0.4 \times 20 \times 300 \times 300 + 0.67 \times 415 \times 4 \times 314$

$= 720.0 + 349.2 = 1069.2\,kN$

18. When a spirally reinforced short column is loaded axially, the concrete inside the core is subjected to

a. Bending and compression b. Biaxial compression

c. Triaxial compression d. Uniaxial compression

Ans. c

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19. The purpose of lateral ties in a short RC column is to

a. Avoid buckling of longitudinal bars

b. Facilitate compaction of concrete

c. Increase the load carrying capacity of the column

d. Facilitate construction

Ans. a

20. Which one of the following represents the ratio of volume of helical reinforcement to volume of core?

a. $0.36\left(\frac{A_g}{A_c}-1\right)\frac{f_{ck}}{f_y}$ b. $0.36\left(\frac{A_g}{A_s}-1\right)\frac{f_{ck}}{f_y}$ c. $0.36\left(\frac{A_s}{A_c}-1\right)\frac{f_{ck}}{f_y}$ d. $0.36\left(\frac{A_c}{A_s}-1\right)\frac{f_{ck}}{f_y}$

where A_g, A_S and A_c are gross cross-sectional area of the member, area of steel and core area; and f_{ck} and f_y are characteristic strength of concrete and steel respectively.

Ans. a

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21. Magnitudes of minimum reinforcement recommended for reinforced concrete using mild steel in slabs / columns are a. 0.15% / 0.60% b. 0.25% / 0.80% c. 0.50% / 1.00% **d.** 0.15% / 0.80%

Ans. d

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22. A reinforced concrete column of size b x D is carrying an axial load P and a bending moment M about an axis parallel to its width. The magnitude of bending moment is such that the neutral axis lies outside the section over which extent of depth from the highly compressed edge will the compressive stress have a constant value $0.45f_{ck}$?

a. $\frac{3}{7}D$ b. $\frac{4}{7}D$ c. $\frac{D}{2}$ d. D

Ans. a

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23. The effective length of a R.C. column continuing through two storeys, properly restrained at both ends in position and direction, is

a. 0.50L b. 0.75L c. L d. 2L

Ans. a

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24. Minimum clear cover (in mm) to the main steel bars in slab, beam, column and footing respectively, are

a. 10, 15, 20 and 25 **b.** 15, 25, 40 and 75

c. 20, 25, 30 and 40 d. 20, 35, 40 and 75

Ans. b

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25. According to IS:456-2000, minimum slenderness ratio for a short concrete column is

a. Less than 12 b. between 12 and 18

c. Between 18 and 24 d. More than 24

Ans. a

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26. The purpose of lateral ties in short R.C. columns is to

a. Increase the load carrying capacity of column

b. Facilitate compaction of concrete

c. facilitate construction

d. Avoid buckling of longitudinal bars

Ans. d

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27. If the load acting on a commonly conventional sized RC column increases continuously from zero to higher magnitudes, the magnitude of the uniaxial ultimate moment that can be allowed on the column.

a. Increases b. Decreases **c.** Increases and then decreases d. Remains constant

Ans. c

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28. The load carrying capacity of a column designed by working stress method is 500 kN. The ultimate collapse load of the column is

a. 500 kN b. 662.5 kN **c.** 750 kN d. 1100 kN

Ans. C

Working load, $P_w = 500\,kN$

Ultimate load, $P_u = 1.5 \times 500 = 750 kN$

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29. What shall be the maximum area of reinforcement (i) in compression and (ii) in tension to be provided in an RC beam, respectively, as per IS:456-2000?

a. 0.08% and 2%   b. 2% and 4%   c. 4% and 2%   **d.** 4% and 4%

Ans. d

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30. A RC column of square cross-section 400 x 400 mm has its column load moment interaction diagram as shown in figure below. What is the maximum uniaxial eccentricity at which a factored load P_u=640 kN can be applied safely? (Take $f_{ck} = 20$ MPa) IES 2009

a. 300 mm   b. 400 mm   **c.** 600 mm   d. 800 mm

Ans. C

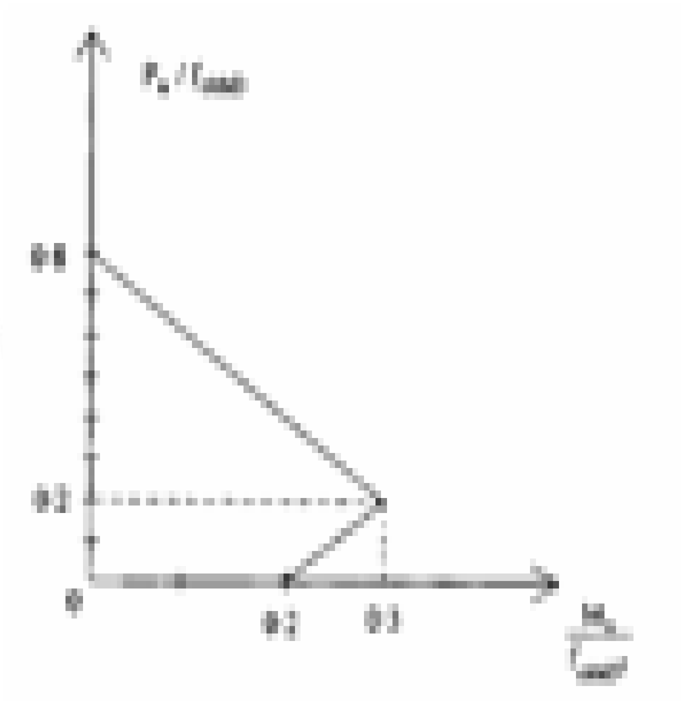
Size of column: 400 × 400 mm

Maximum uniaxial eccentricity, $e_{\max} = ?$

Factored load, $P_u = 640\,kN$

$$f_{ck} = 20\,N/mm^2$$

$$\frac{P_u}{f_{ck}bd} = \frac{640\times10^3}{20\times400\times400} = 0.2 \qquad \frac{M_u}{f_{ck}bd^2} = 0.3$$



$$\frac{640\times10^3\times e_{\max}}{20\times400\times400} = 0.3 \Rightarrow e_{\max} = 600mm$$

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31. What is the minimum nominal percentage longitudinal reinforcement to be provided in a concrete pedestal as per relevant IS code ?

a. 0.4 b. 0.2 **c.** 0.15 d. 0.1

Ans. c

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32. A beam is designed for uniformly distributed loads causing compression in the supporting columns. Where is the critical section for shear? (d is effective depth of beam, L_d is the development length)

a. A distance L_d/3 from the face of the support

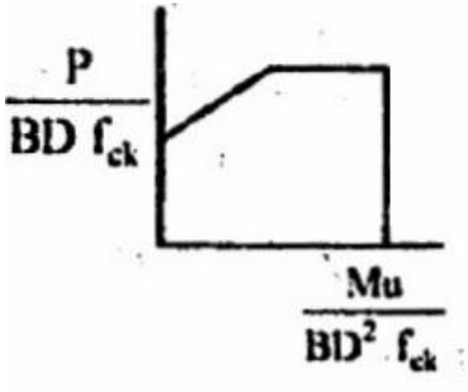
b. A distance d from the face of the support

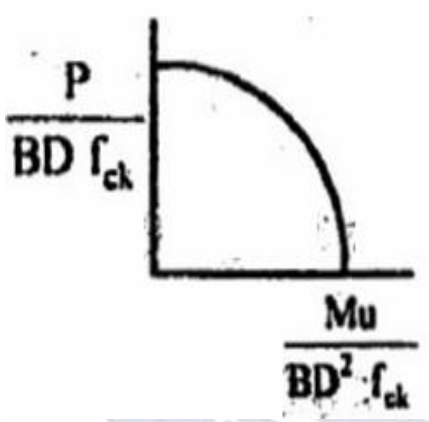
c. At the centre of the support

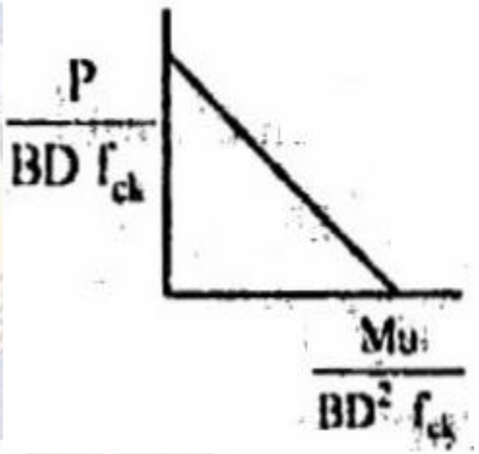
d. At the mid span of the beam

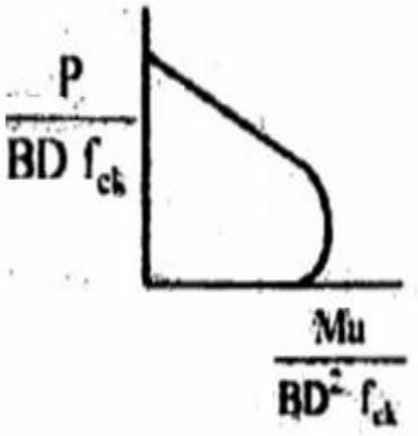
Ans. b

33. A rectangular reinforced column B x D has been subjected to uniaxial bending moment *M* and axial load *P*. Characteristic strength of concrete = f_{ck}. Which one among the following column design curves shows the relation between *M* and *P* qualitatively?

a. 

b. 

c. 

d. 

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34. An axially loaded column is of 300 x 300 mm size. Effective length of column is 3m. What is the minimum eccentricity of the axial load for the column?

a. 0 b. 10 mm c. 16 mm **d**. 20 mm

Ans. d

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35. Which of the following are the additional moments considered for design of slender compression member in lieu of deflection in x and y directions?

a. $\frac{P_u l^2_{ex}}{2000\,D}$ and $\frac{P_u l^2_{ey}}{2000\,D}$

b. $\frac{P l_{ex}}{2000\,D}$ and $\frac{P_u l_{ey}}{2000\,D}$

c. $\frac{P_u l^2_{ex}}{2000\,D}$ and $\frac{P_u l^2_{ey}}{2000\,b}$

d. $\frac{P_u l^2_{ex}}{200\,D}$ and $\frac{P_u l^2_{ey}}{200\,D}$

(where P_u is axial load; l_{ex} and l_{ey} are effective lengths in respective directions; D depth of section perpendicular to major axis; b width of the member)

Ans. c

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36. A square column section of size 350 mm x 350 mm is reinforced with four bars of 25 mm diameter and four bars of 16 mm diameter. Then the transverse steel should be:

a. 5 mm dia @ 240mm c/c
b. 6 mm dia @ 250 mm c/c
c. 8 mm dia @ 250 mm c/c
d. 8 mm dia @ 350 mm c/c

Ans. c

37. On which one of the following concepts is the basic principle of structural design based?

a. Weak column strong beam

b. Strong column and weak beam

c. Equally strong column-beam

d. Partial weak column-beam

Ans. b

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38. What is the minimum number of longitudinal bars provided in a reinforced concrete column of circular cross section?

a. 4 b. 5 **c**. 6 d. 8

Ans. c

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38. In a Pedestal, the factor by which the effective length should not exceed the least lateral dimension is

a. 2 **b**. 3 c. 4 d. 5

Ans. b

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39. In an axially loaded spirally reinforced short column, the concrete inside the core is subjected to

a. bending and compression

b. biaxial compression

c. triaxial compression

d. uniaxial compression

Ans. c

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40. Lateral ties in RC columns are provided to resist

a. bending moment

b. shear

c. buckling of longitudinal steel bars

d. both bending moment and shear

Ans. c

41. In the limit state method of design, the failure criterion for reinforced concrete beams and columns is

a. maximum principal stress theory

b. maximum principal strain theory

c. maximum shear stress theory

d. maximum strain energy theory

Ans. b

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42. A reinforced concrete slab is 75 mm thick. The maximum size of reinforcement bar that can be used is

a. 12 mm diameter

b. 10 mm diameter

c. 8 mm diameter

d. 6 mm diameter

Ans. c

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43. The reduction coefficient of a reinforced concrete column with an effective length of 4.8 m and size 250 mm × 300 mm is

a. 0.80 **b.** 0.85 c. 0.90 d. 0.95

Ans. b

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44. The limits of percentage ‘*p*’ of the longitudinal reinforcement in a column is

a. 0.15% to 2% b. 0.8% to 4% **c.** 0.8% to 6% d. 0.8% to 8%

Ans. c

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45. Which one of the following statements is correct?

a. Maximum longitudinal reinforcement in an axially loaded short column is 6% of gross cross-sectional area

b. Columns with circular section are provided with transverse reinforcement of helical type only

c. Spacing of lateral ties cannot be more than 16 times the diameter of the tie bar

d. Longitudinal reinforcement bar need not be in contact with lateral ties

Ans. a

Design of Deflection

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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.

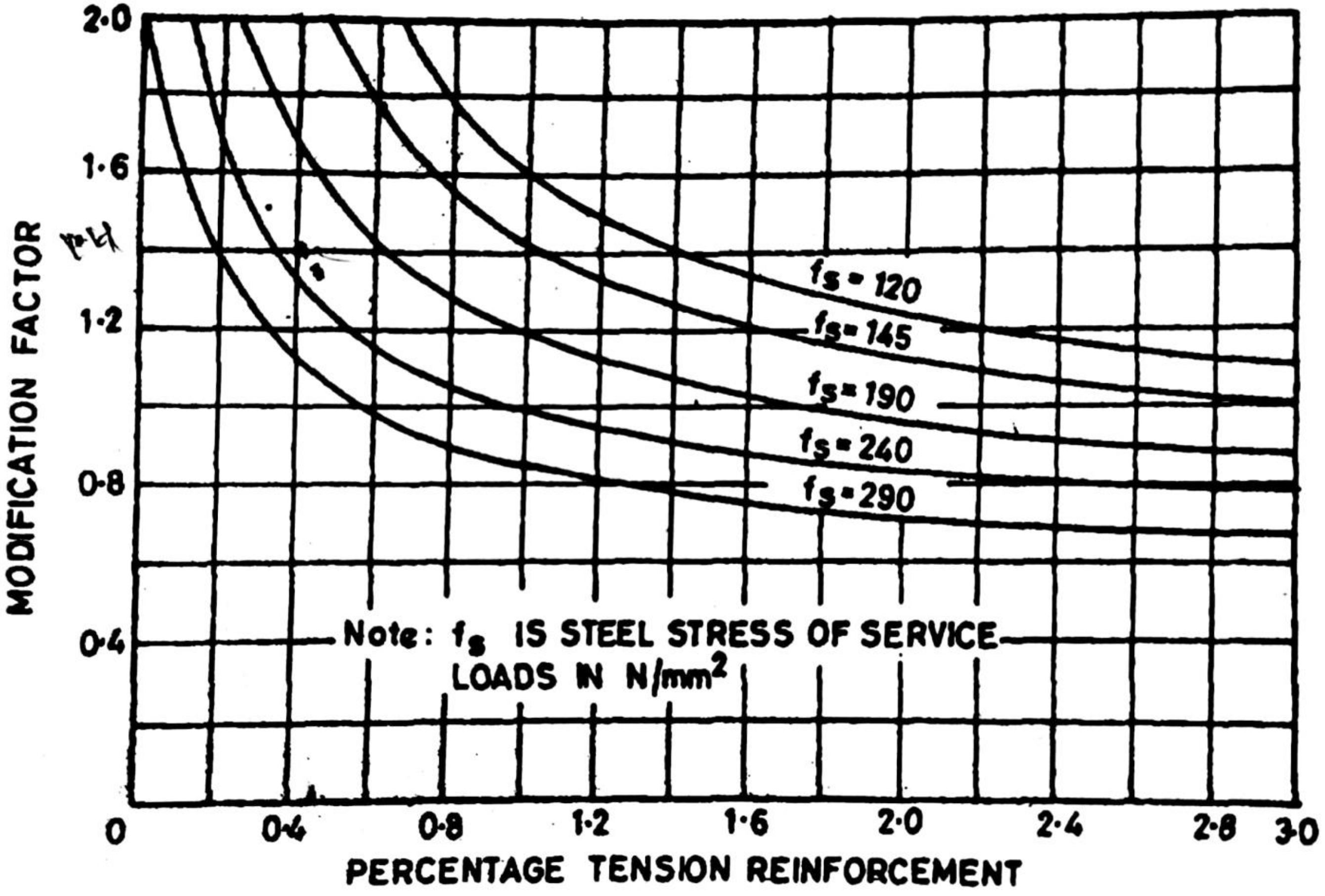
The vertical deflection limits may generally be assumed to be satisfied provided that the span to depth ratios are not greater than the values obtained as below:

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.



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

FIG. 4 MODIFICATION FACTOR FOR TENSION REINFORCEMENT

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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.

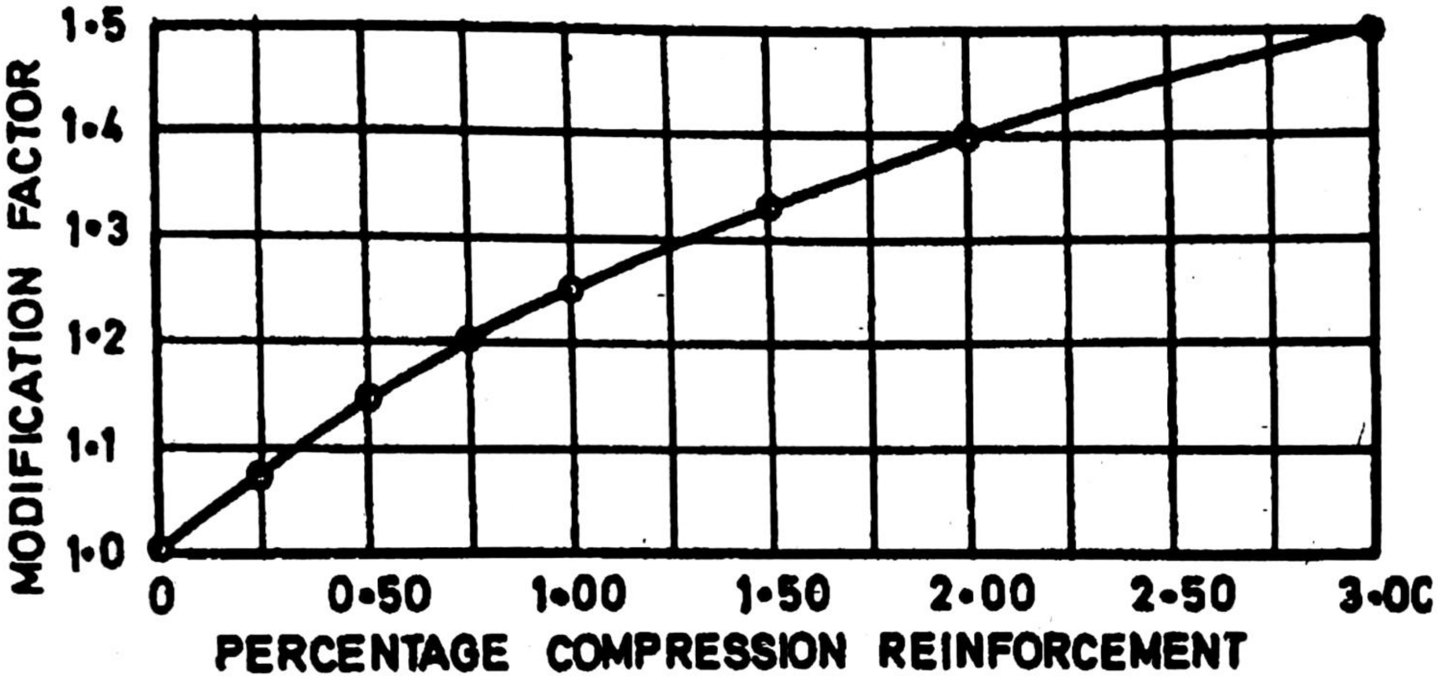

FIG. 5 MODIFICATION FACTOR FOR COMPRESSION REINFORCEMENT

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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 are of section equal to $b_f .d$

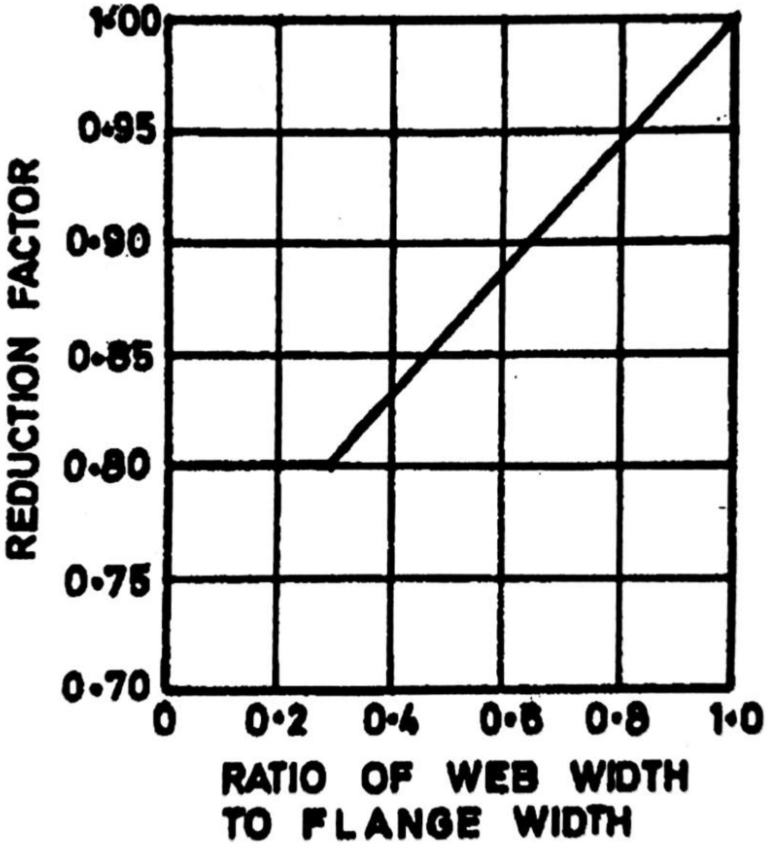

Fig. 6 Reduction factors for ratios of span to effective depth for flanged beams

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TOTAL DEFLECTION

The total deflection shall be taken as the sum of the short-term deflection and the long-term deflection.

SHORT-TERM DEFLECTION

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:

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

where

I_r = moment of inertia of the cracked section,

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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, 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.

DEFLECTION DUE TO SHRINKAGE

The deflection due to shrinkage 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,

0.063 for fully continuous members.

ψ_{cs} is shrinkage curvature equal to $k_4 \frac{\varepsilon_{cs}}{D}$

where ε_{cs} is the ultimate shrinkage strain of concrete,

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

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

Where $P_t = \frac{100 A_{st}}{bd}$ and $P_c = \frac{100 A_{sc}}{bd}$

and D is the total depth of the section, and l is the length of span.

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DEFLECTION DUETO CREEP

The creep deflection due to permanent loads $a_{cc(perm)}$ may be obtained from the following equation:

$$a_{cc(perm)} = a_{i,cc(perm)} - a_{i(perm)}$$

where

$a_{i,cc(perm)}$ = initial plus creep deflection due to permanent loads obtained using an elastic analysis with an effective modulus of elasticity,

$E_{ce} = \dfrac{E_c}{1+\theta}; \theta$ being the creep coefficient,

$a_{i(perm)}$ = short-term deflection due to permanent load using E .

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Design of Deflection

PREVIOUS GATE QUESTIONS

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01. When a specimen of M 25 concrete is loaded to a stress level of 12.5 MPa, a strain of 500×10^{-6} is recorded. If this load is allowed to stand for a long time, the strain increases to 1000×10^{-6}. In accordance with the provisions of IS:456-2000, considering the long-term effects, the effective modulus of elasticity of the concrete (in MPa) is ……. CE2 2019

01. **12500**

Grade of concrete: M 25

Elastic stress, σ = 12.5 MPa

Elastic stress, ε_e =500×10

Long term strain, ε_c =1000×10^{-6}

Effective modulus of elasticity of concrete, $E_{ce} = ?$

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$$E_{ce} = \frac{E_c}{1+\theta}$$

$$E_c = 5000\sqrt{f_{ck}} \quad = 5000\sqrt{25} \quad = 25000\text{MPa}$$

Creep coefficient, $\theta = \dfrac{\text{creep strain}}{\text{elastic strain}} = \dfrac{\varepsilon_c - \varepsilon_e}{\varepsilon_e} = \dfrac{1000\times10^{-6} - 500\times10^{-6}}{500\times10^{-6}} = 1$

$$E_{ce} = \frac{25000}{1+1} = 15{,}500 \text{ MPa}$$

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02. A simply supported reinforced concrete beam of length 10 m sags while undergoing shrinkage. Assuming a uniform curvature of 0.004 m^{-1} along the span, the maximum deflection (in m) of the beam at mid-span is ….. CE2 2015

Ans. 0.05

Length of the beam, L = 10 m

Curvature of the beam, ψ = 0.004 m^{-1}

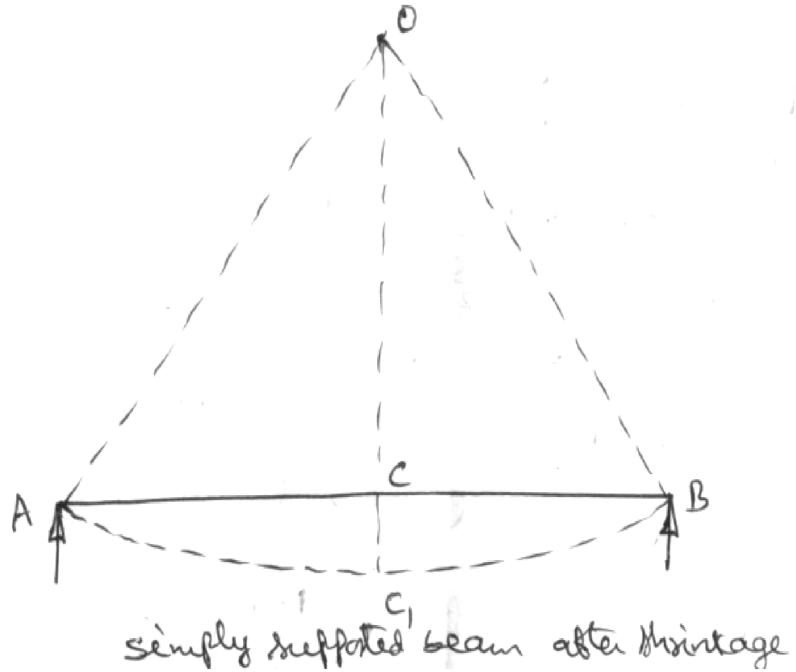
Radius of the curvature, $R = \frac{1}{\psi} = \frac{1}{0.004}$ = 250 m

Deflection at mid span=?

$$OC = \sqrt{OA^2 - AC^2} = \sqrt{250^2 - 5^2} = 249.95\text{m}$$

Deflection at mid span, $CC_1 = OC_1 - OC$

$= 250 - 249.95 = 0.05$ m



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01. The span to depth ratio limit is specified in IS: 456-2000, for the reinforced concrete beams, in order to ensure that the 1996

a. tensile crack width is below a limit

b. shear failure is avoided

c. stress in the tension reinforcement is less than the allowable value

d. deflection of the beam is below a limiting value

Ans. d

As per IS:456-2000, the span to depth ratio is specified for reinforced concrete beams to ensure that the deflection of the beam is below a limiting value.

02. In limit state approach, spacing of main reinforcement controls primarily

a. Cracking b. deflection c. durability d. collapse

Ans. a

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03. How is the deflection in RC beams controlled as per IS:456 - 2000?

a. By using large aspect ratio
b. By using small modular ratio
c. By controlling span / depth ratio
d. By moderating water-cement ratio

Ans. c

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04. Usually stiffness of a simply supported beam is satisfied if the ratio of its span to depth does not exceed which one of the following?

a. 7 b. 10 **c.** 20 d. 26

Ans. c

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05. The final deflection due to all including effects of temperature, creep and shrinkage measured from as cast level of the supports of floors, roofs and all other horizontal members of reinforced concrete should not normally exceed

a. Span / 350

b. Span / 250

c. (Span / 350) or 20 mm whichever is less

d. (5/348) of span

Ans. b

06. Temperature and shrinkage steel is provided in reinforced concrete slabs because

a. it occupies larger area   b. its thickness is less

c. it is a main structural element   d. it is a flexural member

Ans. a

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07. The specified span to depth ratios of beams satisfying the limits of vertical deflection are for spans up to 10 m.

1. for higher spans, these are to be modified by multiplying the ratio by (10/span in metre)
2. For higher spans, these are to be modified by multiplying the ratios by (span in metre/10)
3. They get further modified depending on area and type of tension reinforcement
4. However, they do not change further with the area and type of compression reinforcement

Select the correct answer using the codes given below:

a. 1 and 3 b. 2 and 3 c. 1 and 4 d. 2 and 4

Ans. a

08. Shrinkage in a concrete slab

a. causes shear cracks

b. causes tension cracks

c. causes compression cracks

d. does not cause any cracking

Ans. b

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09. A simply supported rectangular beam of spam 20.0 m is subjected to u.d.l. The minimum effective depth required to check deflection of this beam, when modification factor for tension and compression are 0.9 and 1.1 respectively, will be

a. 2.0 m　　b. 1.8 m　　c. 1.3 m　　**d.** 0.5 m

Ans. a

$$\left(\frac{l}{d}\right)_{perm} = \alpha.\beta.\gamma.\delta.\lambda$$

$$= 20\times\frac{20}{10}\times 0.9\times 1.1\times 1.0 = 39.6$$

$$\frac{20}{d} = 39.6 \Rightarrow d = 0.5 \text{ m}$$

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10. For the purpose of design as per IS: 456, deflection of RC slab or beam is limited to

a. 0.2% of span   b. 0.25% of span   **c.** 0.4% of span   d. 0.45% of span

Ans. c

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11. As per IS: 456, the vertical deflection limit for beams may generally be assumed to be satisfied provided that the ratio of span to effective depth of a continuous beam of span up to 10 m is not be greater than

a. 35 **b.** 26 c. 20 d. 18

Ans. b

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12. In limit state design of reinforced concrete, deflection is computed by using

a. initial tangent modulus b. secant modulus

c. tangent modulus **d.** short and long-term values of Young's modulus

Ans. d

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13. The final deflection due to all loads including the effects of temperature, creep and shrinkage and measured from as cast level of supports of floors, roofs and all other horizontal members should NOT exceed

a. span/350 b. span/300 **c.** span/250 d. span/200

Ans. c

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14. Unequal top and bottom reinforcement in a reinforced concrete section leads to

a. creep deflection
b. shrinkage deflection
c. long-term deflection
d. large deflection

Ans. b

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15. In limit state approach, spacing of main reinforcement controls primarily

a. Collapse **b.** Cracking c. deflection d. durability

Ans. b

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16. Deflection can be controlled by using the appropriate

a. aspect ratio
b. modular ratio
c. span/depth ratio
d. water/cement ratio

Ans. c

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17. From limiting deflection point of view, use of high strength steel in RC beam results in

a. reduction in depth
b. no change in depth
c. increase in depth
d. increase in width

Ans. c

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18. Limit state of serviceability for deflection including the effects due to creep, shrinkage and temperature occurring after erection of partitions and application of finishes as applicable to floors and roofs is restricted to

a. $\frac{\text{Span}}{150}$ b. $\frac{\text{Span}}{200}$ c. $\frac{\text{Span}}{250}$ **d.** $\frac{\text{Span}}{350}$

Ans. d

19. Shrinkage deflection in case of rectangular beams and slabs can be eliminated by putting

a. compression steel equal to tensile steel

b. compression steel more than tensile steel

c. compression steel less than tensile steel

d. compression steel 25% greater than tensile steel

Ans. a

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Design of Slabs

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SLABS

Minimum reinforcement

The mild steel reinforcement in either direction in slabs shall not be less than 0,15 percent of the total cross sectional area. However, this value can be reduced to 0.12 percent when high strength deformed bars or welded wire fabric are used.

Maximum diameter

The diameter of reinforcing bars shall not exceed one-eight of the total thickness of the slab.

RESTRAINED SLABS

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

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

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

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where

α_x and α_y are coefficients given in Table 26,

$w =$ total design load per unit area,

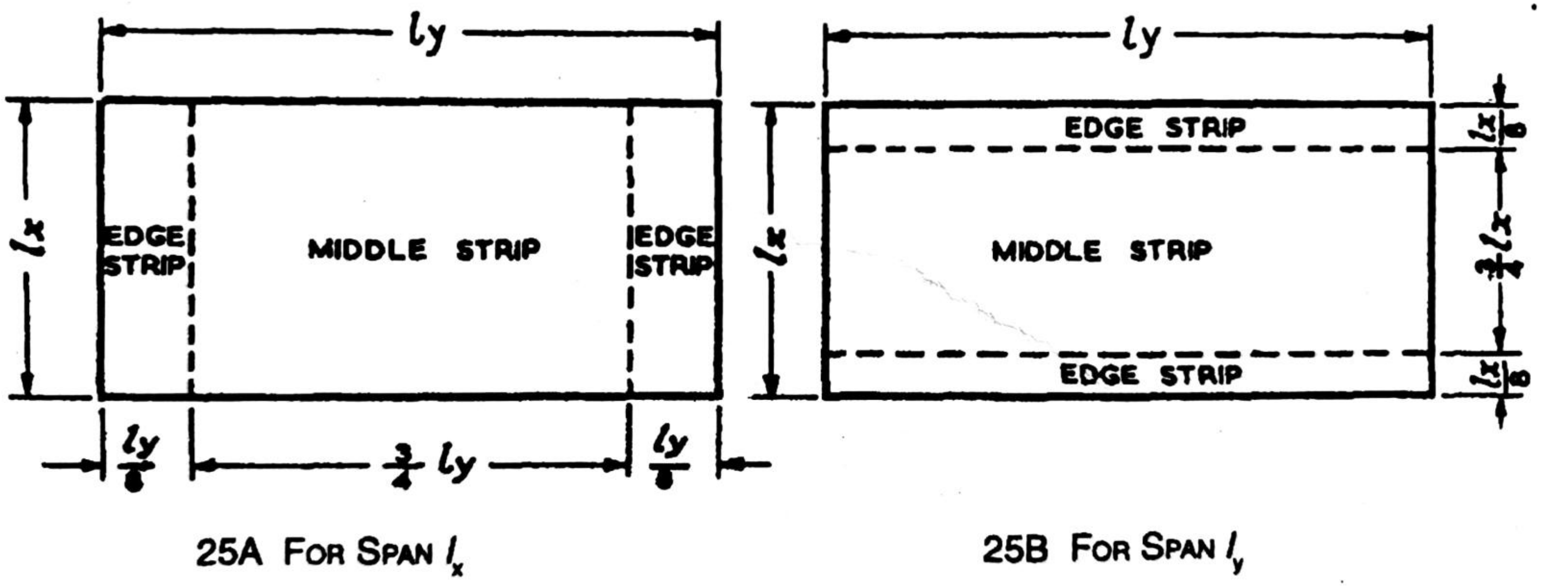
$M_x, M_y =$ moments on strips of unit width spanning l_x, and l_y respectively and

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

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

- 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*.
- 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.
- 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.

- Torsion reinforcement equal to half that described shall be provided at a corner contained by edges over only one of which the slab is continuous.
- Torsion reinforcements need not be provided at any comer contained by edges over both of which the slab is continuous.
- Torsion $\frac{l_y}{l_x}$ is greater than 2, the slabs shall be designed as spanning one way.



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SIMPLY SUPPORTED SLABS

When simply supported slabs do not have adequate provision to resist torsion at corners and to prevent the corners from lifting, the maximum moments per unit width are given by the following equation:

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

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

where

$$M_x, M_y, w, l_x, l_y$$

α_x and α_y are moment coefficients.

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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 α_x (Values of l_y/l_x)								Long Span Coefficients α_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	*Interior Panels:*									
	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	*One Short Edge Continuous:*									
	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	*One Long Edge Discontinuous:*									
	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	*Two Adjacent Edges Discontinuous:*									
	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	*Two Short Edges Discontinuous:*									
	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	*Two Long Edges Discontinuous:*									
	Negative moment at continuous edge	—	—	—	—	—	—	—	—	0.045
	Positive moment at mid-span	0.035	0.043	0.051	0.057	0.063	0.068	0.080	0.088	0.035
7	*Three Edges Discontinuous (One Long Edge Continuous):*									
	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	*Three Edges Discontinuous (One Short Edge Continuous):*									
	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	*Four Edges Discontinuous:*									
	Positive moment at mid-span	0.056	0.064	0.072	0.079	0.085	0.089	0.100	0.107	0.056

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SLABS

1. For slabs spanning in two directions, the shorter of the two spans should be used for calculating the span to effective depth ratios.

2. For two-wav 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^2.

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.

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Design of Deflection

PREVIOUS GATE QUESTIONS

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01. A reinforced-concrete slab with effective depth of 80 mm is simply supported at two opposite ends on 230 mm thick masonry walls. The centre-to-centre distance between the walls is 3.3 m. As per IS 456:2000, the effective span of the slab (in m, up to two decimal places) is…… CE2 2018

Ans. 3.15

Effective depth of slab, d= 80 mm

Width of masonry support wall = 230 mm

Center to center distance between the walls = 3.3 m

Clear span = 3.3 – 0.23 = 3.07 m

Effective span of slab = Least of

i. clear span + effective depth = 3.07 + 0.08 = 3.15 m

ii. c/c distance of walls = 3.3 m

Therefore, effective span = 3.15 m

02. Torsion reinforcement provided at the corners of a two way slab

a. distributes bending moment uniformly   b. prevents corners from lifting

c. controls cracking at corners   d. does not allow any twist at corners

Ans. c

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03. The main reinforcement of a R.C. slab consists of 10 mm bars at 100 mm spacing; if it is desired to replace the 10 mm bars by 12 mm bars, then the spacing of 12mm bars should be

a. 120 mm b. 140 mm **c.** 144 mm d. 160 mm

Ans. c

Main reinforcement: $10\,mm\phi$ bars at 100 mm c/c

$$\phi_1 = 10\,mm \qquad S_1 = 100\,mm$$

$$\phi_2 = 12\,mm \qquad S_2 = ?$$

Spacing of bars, $S = \dfrac{1000\,a}{A_S} \Rightarrow s \propto a \Rightarrow S \propto \phi^2$

$$\frac{S_2}{S_1} = \frac{\phi_2^2}{\phi_1^2} \Rightarrow S_2 = 100 \times \frac{12^2}{10^2} = 144 \text{ mm.}$$

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04. A reinforced concrete slab is 75 mm thick. The maximum size of reinforcement bar that can be used is

a. 6 mm diameter **b.** 8 mm diameter c. 10 mm diameter d. 12 mm diameter

Ans. b

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05. When is an R.C.C roof slab designed as a two way slab?

a. If the slab is continuous over two opposite edges only

b. It the slab is un-supported at one edge only

c. If the ratio of spans in two directions is > 2

d. If the ratio of spans in two directions is < 2

Ans. d

06. As per codal provisions in two way slabs, the minimum mild steel reinforcement to be provided in the edge strip is

a. On the basis of minimum bending moment

b. Half of the area of steel provided in middle strip in the shorter span

c. Half of the area of steel provided in middle strip in the longer span

d. 0.15 % of the cross-sectional area of concrete

Ans. d

07. What is the value of minimum reinforcement (in case of *Fe415*) in a slab?

a. 0.1% **b.** 0.12% c. 0.15% d. 0.2%

Ans. b

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08. In case of two-way slab, the deflection of the slab is

a. Primarily a function of the long span

b. Primarily a function of the short span

c. Independent of the span, long or short

d. Mostly long span but sometimes short span

Ans. b

09. In the design of two-way slab restrained at all edges, torsional reinforcement required is

- **a.** 0.75 times the area of steel provided at mid-span in the same direction
- b. 0.375 times the area of steel provided at mid-span in the same direction
- c. 0.375 times the area of steel provided in the shorter span
- d. Nil

Ans. a

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10. In case of 2-way slab, the limiting deflection of the slab is

a. primarily a function of the long span

b. primarily a function of the short span

c. independent of long or short spans

d. dependent on both long and short spans

Ans. b