4 CHAPTER
Analysis and Design by Limit State Method

Q.1 Consider the following statements:
1. Flexural strength of concrete is $0.7\sqrt{f_{ck}}$ N/mm²
2. The creep coefficient at 7 days of loading is 1.6.
3. Modulus of elasticity of concrete can be expressed as $5000\sqrt{f_{ck}}$ N/mm².

Which of these statement/s is/are correct?
(a) Both 1 and 3 (b) Both 2 and 3
(c) Both 1 and 2 (d) 1, 2 and 3

Q.2 In case of simply supported beam, the clear distance between lateral restraints shall not exceed
(a) $60b$ or $250\frac{b^2}{d}$ (b) $60b$ or $\frac{100^2}{d}$
(c) $25b$ or $250\frac{b^2}{d}$ (d) $25b$ or $100\frac{b^2}{d}$

Q.3 The lap length in compression shall not be less than
(a) 24ϕ (b) 30ϕ
(c) 22ϕ (d) 12ϕ

Q.4 The straight length of lap shall not be less than
(a) 15ϕ or 200 mm (b) 24ϕ or 240 mm
(c) 15ϕ or 240 mm (d) 30ϕ or 200 mm

Q.5 The distance between expansion joints shall not be exceed
(a) 45 m (b) 60 m
(c) 35 m (d) 15 m

Q.6 The area of the stress block in stress-strain curve for concrete is equal to
(a) $0.36 f_{ck} x_u$ (b) $0.446 f_{ck} x_u$
(c) $0.42 f_{ck} x_u$ (d) none of the above

Q.7 The depth of the centre of compressive force from the extreme compression fibre is
(a) $0.42 x_u$ (b) $0.446 x_u$
(c) $0.87 x_u$ (d) $0.15 x_u$

Q.8 The minimum area of tension reinforcement in a beam shall not be less than
(a) $\frac{0.85 f_y}{bd}$ (b) $\frac{0.85\, bd}{f_y}$
(c) $\frac{0.4 f_y}{bd}$ (d) $\frac{0.4\, bd}{f_y}$

Q.9 In limit state design, the limiting value of the depth of the neutral axis when Fe 415 steel is used, is
(a) $0.48d$ (b) $0.53d$
(c) $0.46d$ (d) $0.446d$

Q.10 In the limit state design, the maximum limit on the redistribution of moments in statically indeterminate beams is
(a) 15% (b) 25%
(c) 30% (d) 10%

Q.11 Match List-I with List-II and select the correct answer:

List-I
A. Minimum percentage of tension reinforcement of RC beam
B. Minimum percentage of shear reinforcement of RC beam
C. Maximum allowable percentage of tension reinforcement of RC beam
D. Maximum allowable percentage of compression reinforcement of RC beam

List-II
1. 4
2. $85/f_y$
3. $40 S_v / f_y d$

Codes:

	A	B	C	D
(a)	2	1	3	1
(b)	2	3	1	1
(c)	1	3	1	2
(d)	3	2	1	1

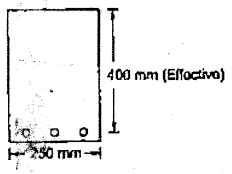
Q.12 A 240 mm × 500 mm rectangular section of M25 grade concrete is subjected to flexure. The cracking moment (M_{cr}) will be
(a) 3.5 kN-m (b) 70 kN-m
(c) 7.0 kN-m (d) 35 kN-m

Q.13 A rectangular beam 200 mm wide and 300 mm deep is reinforced with A_{st} = 800 mm². The materials are M20 grade concrete and mild steel reinforcement of Fe250. Find out the correct statement about the beam.
(a) x_u = 121 mm and beam is over reinforced
(b) x_u = 200 mm and beam is over reinforced
(c) x_u = 121 mm and beam is under reinforced
(d) none of the above

Q.14 The effective depth of a singly reinforced rectangular beam is 30 cm. The section is over reinforced and the neutral axis is 12 cm below the top. If the maximum stress attained by concrete is 50 kg/cm² and the modular ratio is 18, then the stress developed in steel would be
(a) 1800 kg/cm²
(b) 1600 kg/cm²
(c) 1350 kg/cm²
(d) 1300 kg/cm²

Q.15 A reinforced concrete beam is subjected to the following bending moments:
Dead load 20 kNm
Live load 30 kNm
Seismic load 10 kNm
The design bonding moment for limit state of collapse is
(a) 60 kNm (b) 75 kNm
(c) 72 kNm (d) 80 kNm

Q.16 A simply supported RC beam having clear span 5 m and support width 300 mm has the cross-section as shown in figure below.



What is the effective span of the beam as per IS:456?
(a) 5300 mm (b) 5400 mm
(c) 5200 mm (d) 5150 mm

Q.17 Which one of the following statements about the percentage of tensile steel required to produce a balanced reinforced concrete section is correct? The required percentage of steel
(a) reduces as the yield strength of steel increases
(b) remains unchanged irrespective of the yield strength of steel
(c) is the same for a given quality of steel irrespective of whether working stress method is followed or ultimate load method is used
(d) is only a function of the modulus of elasticity of steel.

Q.18 Side face reinforcement shall be provided in the beam when depth of the web in a beam exceeds
(a) 750 mm (b) 450 mm
(c) 400 mm (d) 300 mm

Q.19 As per IS 456 : 2000, the maximum compressive stress in concrete for design purpose is
(a) 0.37 f_{ck} (b) 0.416 f_{ck}
(c) 0.446 f_{ck} (d) 0.67 f_{ck}

Q.20 A simply supported beam is required to carry a load of 23 kN/m including self weight over an effective span of 6.0 m. This beam shall be designed for a factored bonding moment in limit state method of:
(a) 103.500 kN-m (b) 119.025 kN-m
(c) 155.250 kN-m (d) 187.273 kN-m

Q.21 Bending moment coefficients and shear coefficients for continuous beams of uniform cross-section as per IS 456 (table 12 and 13) may be used only when spans do not differ with respect to the longest span by
(a) 20% (b) 10%
(c) 12% (d) 15%

Q.22 Combination of partial factor of safety for loads under limit state of collapse and serviceability will be:
(a) 1.5 (DL + LL) or 1.5 (DL + WL),or 1.2 (DL + LL + WL) and DL + 0.8 (LL + WL)
(b) 1.5 (DL + LL) and DL + 0.8 (LL + WL)
(c) 1.5 (DL + LL) or 1.5 (DL + WL) or 1.2 (DL + LL + WL) and (DL + LL) or 1(DL + WL) or DL + 0.8(LL + WL)
(d) 1.2(DL + LL + WL) and 1(DL + LL) or 1(DL + WL) or DL + 0.8(LL + WL)

Q.23 Which of the following statement is correct?
(a) $\frac{x_{u,max}}{d}$ is independent of grades of steel and concrete.
(b) $\frac{x_{u,max}}{d}$ is independent of grade of steel but changes with grade of concrete.
(c) $\frac{x_{u,max}}{d}$ changes with grade of concrete and steel.
(d) $\frac{x_{u,max}}{d}$ is independent of grade of concrete and changes with grade of steel.

Q.24 A simply supported rectangular beam (300 × 600 mm) having effective depth 550 mm is reinforced with (4 – 20ϕ + 2 – 16ϕ) bars. (f_y = 415 N/mm², f_{ck} = 20 N/mm²) A_{st} = 1658 mm². The moment of resistance of the section is:
(a) 200 kNm (b) 250 kNm
(c) 150 kNm (d) 300 kNm

Q.25 The limiting (maximum) value of neutral axis depth corresponding to grade of steel, f_y = 550 N/mm² and E_s = 2.1 × 10⁵ N/mm² is given by
(a) 0.459d (b) 0.456d
(c) 0.452d (d) 0.450d

Q.26 Consider a rectangular beam of section 250 mm width and effective depth as 350 mm having tension steel as 1500 mm². As per IS:456 the maximum strain in concrete should be limited to 0.0035. Assuming f_{ck} = 30 MPa and Fe 250 steel, the force acting on compression failure zone of section is:
(a) 324 kN (b) 434 kN
(c) 284 kN (d) 384 kN

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Answers Analysis and Design by Limit State Method

1. (a)	2. (a)	3. (a)	4. (a)	5. (a)	6. (a)	7. (a)	8. (b)	9. (a)	10. (c)
11. (b)	12. (d)	13. (c)	14. (c)	15. (b)	16. (b)	17. (a)	18. (a)	19. (c)	20. (c)
21. (d)	22. (c)	23. (d)	24. (b)	25. (d)	26. (a)				

1. (a)
Creep coefficient
at 7 days = 2.2
at 28 days = 1.6

2. (a)
According to clause 23.3 of IS 456 : 2000. A simply supported or continuous beam shall be so proportioned that the clear distance between the lateral restraints does not exceed 60 b or 250 b^2/d whichever is less.

3. (a)
According to clause 26.2.5.1 of IS 456 : 2000 the lap length in compression shall be equal to the development length in compression but not less than 24ϕ.

4. (a)
This is as per clause 26.2.5.1 (c) of IS 456 : 2000.

8. (b)
According to clause 26.5.1.1 of IS 456 : 2000 the minimum area of tension reinforcement shall not be less than that given by

$$\frac{A_{st,min}}{bd} \geq \frac{0.85}{f_y}$$

9. (a)
For Fe 250 $x_{u,lim} = 0.53\,d$
Fe 500 $x_{u,lim} = 0.46\,d$

10. (c)
For design based on elastic theory (working stress), maximum redistribution of moment = 15%. In limit state, maximum redistribution is 30%.

12. (d)

$$M_{cr} = f_{cr} \times \frac{bd^2}{6}$$

Where $f_{cr} = 0.7\sqrt{f_{ck}}$

$= 0.7 \times \sqrt{25}$
$= 3.5\ \text{N/mm}^2$

$$\therefore \quad M_{cr} = 3.5 \times \frac{240 \times (500)^2}{6}\ \text{N-mm}$$

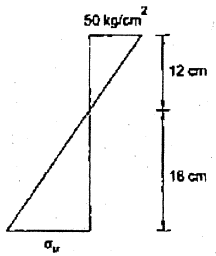
$= 35 \times 10^6$ N-mm $= 35$ kN-m

13. (c)

$$x_u = \frac{0.87 \sigma_y A_{st}}{0.36 \sigma_{ck} b}$$

$x_u = 121$ mm
$x_{u,lim} = 0.53d = 0.53\,(300 - 50)$
$= 132.5$ mm
$\therefore \quad x < x_u$
$\Rightarrow$ Under-reinforced section.

14. (c)



From similar triangles

$$\frac{50}{12} = \frac{\sigma_{st}}{18}$$

$\Rightarrow \quad \sigma_{st} = 75\ \text{N/mm}^2$
$\therefore$ Stress developed in steel
$= m\sigma_{st}$
$= 18 \times 75 = 1350\ \text{kg/cm}^2$

15. (b)
Design bending moment
$= 1.5$ D.L $+ 1.5$ L.L
$= 1.5 \times 20 + 1.5 \times 30$
$= 75$ kN

16. (a)
As per clause 22.2 of IS:456-2000, for simply supported beam or slab, the effective span of a member that is not built integrally with its supports shall be taken as clear span plus the effective depth of slab or beam or centre to centre of supports, whichever is less.
$\therefore$ Effective span =

$$\text{Min. of} \begin{cases} \text{Clear span} + d \\ \text{c/c distance between supports} \end{cases}$$

$$= \begin{cases} 5000 + 400 \\ 500 + \frac{300}{2} + \frac{300}{2} = 5300\ \text{mm} \end{cases}$$

17. (a)
For a balanced section
$0.36\, f_{ck} \cdot b \cdot x = 0.87\, f_y\, A_{st}$

$$\Rightarrow \quad A_{st} = \frac{0.36\, f_{ck} \cdot b \cdot x}{0.87\, f_y}$$

As f_y increases A_{st} decreases.

18. (a)
When subjected to torsion, side face reinforcement is provided in depth of beam > 450 mm.

19. (c)
For design purpose, compressive strength of concrete shall be assumed to 0.67 times f_{ck}.
The partial factor of safety for concrete is 1.5.

$$\therefore \quad \text{Design stress} = \frac{0.67 f_{ck}}{\text{PartialFOS}}$$

$$= \frac{0.67 f_{ck}}{1.5} = 0.446 f_{ck}$$

Hence option (c) is correct.

20. (c)

$w = 23$ kN/m
$l_{eff} = 6.0$ m
Factor load $= 1.5 \times w = 1.5 \times 23$
$= 34.5$ kN/m

$$M_{design} = M_{max} = \frac{w l_{eff}^2}{8}$$

$$M_{Design} = \frac{34.5 \times 6^2}{8}$$

$M_{Design} = 155.250$ kN-m
Hence option (c) is correct.

23. (d)

$$\frac{x_{u,max}}{d} = \frac{0.0035}{\frac{0.87 f_y}{E_s} + 0.0055}$$

or $\quad \frac{x_{u,max}}{d} = f_n(f_y)$

24. (b)
$x_{u,max} = 0.48d = 263.45$ mm

$$x_u = \frac{0.87 f_y A_{st}}{0.362 f_{ck} b} = \frac{0.87 \times 41.5 \times 1658}{0.362 \times 20 \times 300}$$

$= 277.14\ \text{mm} > x_{u,max}$
$\therefore$ the beam is over-reinforced.
For $x_u > x_{u,max}$, we have,

$$M_u = 0.36 f_{ck} B d^2 \times \frac{x_{u,max}}{d}\left(1 - 0.42 \frac{x_{u,max}}{d}\right)$$

$= 0.36 \times 20 \times 300 \times (550)^2 \times 0.48\,(1 - 0.42 \times 0.48)$
$M_u = 250$ kNm

25. (d)
We know, $\frac{x_{u,max}}{d} = \frac{0.0035}{0.0055 + 0.87 \frac{f_y}{E_s}}$

$$\Rightarrow \quad \frac{x_{u,max}}{d} = \frac{0.0035}{0.0055 + 0.87 \times \frac{550}{2.1 \times 10^5}}$$

$\Rightarrow \quad \frac{x_{u,max}}{d} = 0.45$
or, $\quad x_{u,max} = 0.45d$

26. (a)
Depth of neutral axis, $x_u \Rightarrow \frac{0.87 f_y A_{st}}{0.36 f_{ck} b}$
As per IS:456,
Force = Area of stress block
$= 0.36 f_{ck} x_u b$

$$\therefore \quad x_u = \frac{0.87 \times 250 \times \frac{\pi}{4} \times (d)^2}{0.36 \times 30 \times 250}$$

$$= \frac{0.87 \times 250 \times 1500}{0.36 \times 30 \times 250}$$

$= 120.16$ mm
$\therefore \quad F = 0.36 \times 30 \times 120.166 \times 250$
$\Rightarrow \quad F = 324.45$ kN

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