SRI VIDYA COLLEGE OF ENGINEERING & TECHNOLOGY

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CE6505 DESIGN OF REINFORCED CONCRETE ELEMENTS

UNIT – II

LIMIT STATE DESIGN FOR FLEXURE

QUESTIONS & ANSWERS

PART – A

1. Write a short notes on (i) Characteristics strength of materials (ii) Characteristics of loads

Characteristics strength: The term characteristic strength means that value of the strength of the material below which not more than 5 percent of the test results are expected to fall

Characteristics of loads: The term characteristic load means that the value of load which has a 95% probability of not being exceeds during the life of the stricture

2. What are the assumptions made in limit state of collapse in flexure?

- Plane sections normal to the axis remain plane after bending i.e the distribution of strain across any section is linear to its distance from the neutral axis

- The maximum strain in concrete at the outermost compression fibre is taken as 0.0035 in bending.

- The relationship between the compressive stress distribution in concrete and strain concrete may be assumed to be rectangle, trapezoid, parabola or any other shape which results in the prediction of strength in sustained agreement with results of tests .The partial safety $\gamma_m = 1.5$

- The tensile strength of concrete is ignored.

- The maximum strain in the tension reinforcement in the section at failure shall not be less than $f_y/1.15E_s +0.002$

  Where f_y = characteristic strength of steel E_s= modulus of elasticity of steel

3. Write a short on doubly reinforced sections.

Doubly reinforced sections are generally adopted when the dimensions of the beam have been predetermined from other considerations and the design moments exceed the moments of resistance of a singly reinforced section.

4. What do you understand by limit state of collapse?

The limit state of collapse of the structure or part of the structure could be assessed from rupture of one or more critical section and from buckling due to elastic or plastic instability or overturning or fatigue etc. The resistance to bending, shear torsion and axial loads at every sections shall not be less than the appropriate value at that section produced by the probable most unfavorable combination of loads on the structure using the structure using the appropriate partial safety factors.

5. Write short note on balanced sections.

Reinforced concrete sections in flexure reach the failure stage when the compressive strain in concrete reaches a value of 0.0035.when the sections are reinforced in such a way that the section steel reaches the yield of $\epsilon y = (0.87fy) + Es + 0.002$ and simultaneously the concrete strain is $\epsilon c = 0.0035$, the section is termed as balanced sections

6. Write short note on under reinforced sections.

In under reinforced sections, the tension steel reaches yield strain at loads lower than the load at which concrete reaches the failure strain. When the steel yields earlier than concrete, there will be excessive deflections and cracking with a clear indication of impending failure. Hence preferable to design beams as under reinforced since failure will take place after yielding of steel with clear warning signals like excessive deflections and cracking before the ultimate failure.

7. Write short note on over reinforced sections.

Over reinforced sections are those in which concrete reaches the yield strain earlier than that of steel. Over reinforced beams fail by compression failure of concrete without much warning and with very few cracks and negligible deflections. Over reinforced concrete beams are not preferred since they require large quantities of steel and they fail suddenly with explosive failures without any warning.

8. What are the conditions to be followed in design of slab?

Main bars: The reinforcement constituting the main bars shall be based on the maximum bending moment. The reinforcement shall not be less than 0.15% of cross sectional area. (0.12 when high strength deformed bars are used). The pitch of the main bars shall not exceed the following.

    (i)   three times of effective depth of slab

    (ii)   450mm

9. What is the necessity of doubly reinforced sections?

Doubly reinforced concrete sections are required in beams of restricted depth due to head room requirements. When the singly reinforced section is insufficient to resist the bending moment on the section, additional tension and compression reinforcements are designed based on steel beam theory.

The doubly reinforced section comprises of two parts outlined as

1. singly reinforced section with the restricted depth providing the limiting moment of resistance ($M_{u\ lim}$) which is less than the design moment M_u
2. Based on steel beam theory, a steel beam with tension and compression reinforcement providing balance moment given by (M_u- $M_{u\ lim}$)

10. How to select cross sectional dimensions for beams?

1. The effective and overall depth of the beam is estimated from span/depth rations to satisfy the limit state of serviceability. Overall depth to width should be in the range of 1.5 to 2
2. The width of the section should accommodate the required number of bars with sufficient spacing between them with minimum side covers of 20mm to the links.
3. The depth of the beam should be such that the percentage of steel required is around 75% of any one layer
4. The minimum number of bars on tension face should be not less than two and not more than six in any one layer.
5. In flanged beams, the depth of the slab is generally taken as 20% of the overall depth.
6. Common widths of beams are 150,200,230,300mm.Also the width of the beam should be equal to or less the dimensions of the column supporting the beam.

11. Briefly explain about one way slab.

Reinforced concrete slabs supported on two opposite sides or on all four sides with the ratio of long to short exceeding 2 are referred to as one way slabs. The slabs are designed as beams of unit width for a given type of loading and support conditions. The span/depth rations specified in IS450-2000 code for beams is also applicable for slabs

The percentage of reinforcement in slabs is generally low range of 0.3 to 0.5%.Hence the use of modification factor (K_t) for tension reinforcement results in the span/ depth ratio in the range of 25 to 30 for one way slab.

12. Briefly explain about limit state of serviceability.

The following limit state of serviceability are considered in design

      1. Deflection

      2. Cracking

13. Briefly explain about partial safety factor

When assessing the strength of a structure or structural member for limit state of collapse, the value of partial safety factor γ_m should be taken as1.5 for concrete and 1.15 for steel.

A higher value of partial safety factor for concrete has been adopted because there are greater chances of variation in strength of concrete due to improper compaction, inadequate curing and mixing and variations in the properties of ingredients.

14. Define singly reinforced section

In a reinforced concrete, if steel is provided to take up only tension, the section is called as singly reinforced section.

15. Write about limiting neutral axis.

Limiting neutral axis, Xu(max) which gets formed when the strain in concrete and strain in steel reaches their maximum permissible values ie 0.0035 and (0.87fy/Es) +0.002

UNIT 2

LIMIT STATE DESIGN FOR FLEXURE

1. Design a one way slab with a clear span of 5m, simply supported on 230mm thick masonry walls and subjected to a live load of 4kN/m² and a surface finish of 1kN/mm².Assume Fe 415 steel. Assume that the slab is subjected to moderate exposure conditions.

Step 1: Type of Slab.

Ly/lx = 5/1 = 5>2.
It has to be designed as one way slab.

Step 2: Effective depth calculation.

D   = span/(basic value x modification factor)
    = 5000/(20x0.95)
    = 270mm
D   = 270 + 20 + 10/2
    = 295mm

Step 3: Effective Span.

Le = clear span + effective depth
    = 5000 + 270 = 5.27m (or)
Le = c/c distance b/w supports
    = 5000 + 2(230/2)
     = 5.23m.
Adopt effective span = 5.23m least value.

Step 4: Load calculation.

Live load   = 4kN/m²
Dead load   = 1x1x0.27x25
              = 6.75kN/m²
Floor Finish   = 1kN/m²
Total load   = 11.75kN/m²
Factored load = 11.75 x 1.5
              = 17.625kN/m²

Step 5: Moment calculation.

M = wl²/8
   = (17.625x5.232)/8
   = 60.26kNm

Step 6: Check for effective depth

M = Qbd²
d^2 = M/Qb
    = 60.26/2.76x1
    = 149.39mm say 150mm.

For design consideration adopt d = 150mm.

Step 7: Area of Steel

$Mu = 0.87$ fy Ast d (1- (fy ast)/(fck b d))
60.26x106
    =087x415xAstx150(1-(415 Ast)/(20x1000x150)) Ast = 300mm²
Use 10mm dia bars Spacing ,
S = ast/Astx1000
= (78.53/300)1000
= 261mm say 260mmc/c.
 Provide 10mm dia @260mm c/c.

STEP 8: DETAILING

Diagram

2. Design a simply supported RC beam having an effective span of 5m.the beam has to carry a load of 25 kN/m. sketch the reinforcement details. (NOV-DEC 2010) (NOV-DEC 2012).

Step 1: Effective length

Effective span,le = 5m

Step 2: Size of the beam

Effective depth = le/10
                = 5000/10
                = 500mm
Assume, b = 2/3d = 2/3x500 = 333.2mm.
Say 340mm.

Step 3: Load Calculation

Live load = 25kN/m
Dead load = 1x.340x.500x25
            = 4.25kN/m
Total load= 29.25kN/m
Factored load = 29.25x1.5 = 43.85kN/m

Step 4: Moment Calculation.

M   = wl^2/8
    = (43.85x52)/8
    = 137.08kNm

Step 5: Check for effective depth.

M = Qbd²
 d^2 = M/Qb
    = 137.08/2.76x.340
    = 382.2mm say 380mm.
d = 380mm > 500mm
Hence it is safe.

Step 6: Check for effective depth.

Mbal = Qbd^2
 = 2.97x340x500^2
= 252.06kNm > M
Hence it can be designed as singly reinforced

beam section.

Step 7: Area of Steel

$Mu = 0.87$ fy Ast d (1- (fy ast)/(fck b d))
$137.08 \times 10^6 = 087 \times 415 \times Ast \times 500(1-(415$ Ast)/(20x340x500))
Ast = 846.15mm².
Use 20mm dia bars
No of bars = Ast/ast
            = 846.15/314.15
            = 2.45 say 3nos
Provide 3#20mm dia as tension reinforcement.

Step 8: Detailing

Diagram

3. Design a RC beam 350X700mm effective section, subjected to a bending moment of 300kNm.Adopt M20concrete and Fe415 steel.

Step 1: Size of the beam.

b = 350mm
D = 700mm
d = 700-25-20/2 =665mm

Step 2: Moment Calculation

M = 300kNm

Step 3: Check for effective depth.

Mbal = Qbd²
        = 2.97x350x6652
        = 459kNm > M
Hence it can be designed as singly reinforced beam section

Step 4: Area of Steel

$Mu = 0.87$ fy Ast d (1- (fy ast)/(fck b d))
$459 \times 10^6 = 087 \times 415 \times Ast \times 665(1-(415$ Ast)/(20x350x665)) Ast = 369.38 mm²
Use 20mm dia bars
No of bars = Ast/ast
            = 369.39/314.15 = 1.45
 Say 2nos Provide 2#20mm dia as tension reinforcement.

Step 5: Detailing

Diagram

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4. Design a one way slab for a clear span 4m simply supported on 230mm thick wall. Subjected to a live load of 4kN/m² and floor finish of 1kN/m².use M20 concrete and F415 steel.

Step 1: Type of Slab

$ly/lx = 4/1 = 4>2$.it has to be designed as one way slab.

Step 2: Effective depth calculation.

d = span/(basic value x modification factor)
 = 4000/(20x0.95)
 = 270mm.
D = 270 + 20 + 10/2 = 295mm

Step 3: Effective Span.

Le = clear span + effective depth
 = 4000 + 270
 = 4.27m (or)
Le =c/c distance b/w supports
 = 4000 + 2(230/2) = 4.23m.
 Adopt effective span = 4.23m least value.

Step 4: load calculation

Live load = 4kN/m²
Dead load = 1x1x0.27x25 = 6.75kN/m²
Floor Finish = 1kN/m2
Total load = 11.75kN/m²
Factored load = 11.75 x 1.5 = 17.625kN/m²

Step 5: Moment calculation.

$M = wl^2/8$
 = (17.625x4.232)/8
 = 60.26kNm

Step 6: Check for effective depth

M = Qbd²
d^2 = M/Qb
 = 60.26/2.76x1
 = 149.39mm say 150mm.
For design consideration adopt d = 150mm.

Step 7: Area of Steel.

Mu = 0.87 fy Ast d (1- (fy ast)/(fck b d))
60.26x106
  =087x415xAstx150(1-(415 Ast)/(20x1000x150)) Ast
 = 300mm²
Use 10mm dia bars Spacing ,
S = ast/Astx1000 = (78.53/300)1000 = 261mm
Say 260mmc/c Provide 10mm dia @260mm c/c.

Step 8: Detailing

Diagram

5. Deign a rectangular beam of cross section 230 x 600 mm and of effective span 6m.imposed load on the beam is 40 kN/m. Use M20 concrete and Fe415 steel. (APRIL MAY 2012)

Step 1: Size of the beam

b = 230mm & D = 600mm
d = 600-25-20/2 =565mm

Step 2: Moment Calculation.

$M = wl^2/8 = (64.86 \times 6^2)/8$
= 291.9kNm

Step 3: Check for effective depth

$Mbal = Qbd^2 = 2.97 \times 230 \times 565^2$
= 218kNm < M
Hence it can be designed as Doubly reinforced beam section.

Step 4: Load calculation

Live load = 40kN/m²
Dead load = 1x.23x.565x25 = 3.245kN/m²
Total load = 43.24kN/m²
Factored load = 43.24 x 1.5 = 64.86kN/m²

Step 5: Area of Compression steel:

Asc = (M-Mbal) / (fsc.(d-d1))
$= (291 \times 10^6 - 218 \times 10^6) / (351.8 \times (470-30))$
= 1580.65mm²
Use 20mm dia bars,
        ast = π/4 (202) = 314.15mm²
No. of bars = Ast/ast = 1580.65/314.15 = 5.5 say 6nos.

Provide 6#20mm dia bars as compression reinforcement.

Step 6: Area of Steel

Ast = Ast1 + Ast2
Mu = 0.87 fy Ast d (1- (fy ast)/(fck b d))
218×10^6 = 087x415xAstx565 (1-(415 Ast)/ (20x230x565))
Ast = 1365mm²
Use 20mm dia bars,
ast = π/4 (202) = 314.15mm²
No. of bars = Ast/ast = 1365/314.15 = 4.47 say 5nos.
Ast2 = (M-Mbal)/(0.87fy(d-d1))
    $= (291 \times 10^6 - 218 \times 10^6)/(361 \times (565-20))$
=371.03mm²
Use 20mm dia bars,
ast = π/4 (20^2) = 314.15mm²
No. of bars = Ast/ast = 371.03/314.15 = 1.8
Say 2nos