CEL232 – Concrete Material and Design
Reinforced Concrete Design
Dr. Shashank Bishnoi

- Working stress method and Limit state method
- Working stress design of rectangular flexural sections
    - Balanced sections
    - Under-reinforced sections
    - Over-reinforced sections
- Limit state design of flexural sections
    - Singly-reinforced: Under-reinforced, Balanced and over-reinforced rectangular sections
    - Doubly-reinforced rectangular sections
    - Flanged sections
    - Shear design
    - Torsion design
    - Bond – detailing
- Serviceability design of RC Beams
    - Deflection limits
    - Crack-width
- Limit-state design of RC columns
    - Pure compression
    - Uni-axial and biaxial eccentricity
- Limit-state design of slabs
    - One-way and two-way slabs
    - Detailing of edges
- Limit-state design of isolated footings

Breakup of marks: 15% Testing lab, 5% Design lab, 21% Minor I (6 materials + 15 design), 21% Minor II (6 materials + 15 design), 38% Major (8 materials + 30 design)

It is compulsory for all students to bring a copy of IS456:2000 and SP16 to all lectures, tutorials and design-labs

Recommended books:

1. S.N. Sinha, Reinforced Concrete Design, Tata McGraw Hill
2. P. Dayaratnam, Design of Reinforced Concrete Structures, Oxford and IBH Publishing

Department of Civil Engineering
Indian Institute of Technology Delhi

CEL232 – Minor Exam – II Sem. 2011-12

Question 1 (4 marks): C=300 gms of OPC cement is uniformly added to 0.45C gms of water(W=0.45C), Calculate the volume of gel pores, volume of un-hydrated cement, total volume of capillary pores and hence total porosity when the specimen was fully submerged in water to attain 55% degree of hydration. assume realistically any data necessary.

Question 2 (11 marks): A framed structure contains several spans of continuous beams and slabs in both directions. Design a the section at mid-span of one of the internal beams for flexure for an ultimate moment capacity of 420 kN-m with a given width of 250 mm. The effective span of all beams is 3000 mm and the thickness of the slab is 100 mm. The grade of the concrete is M20 and the steel is Fe415.

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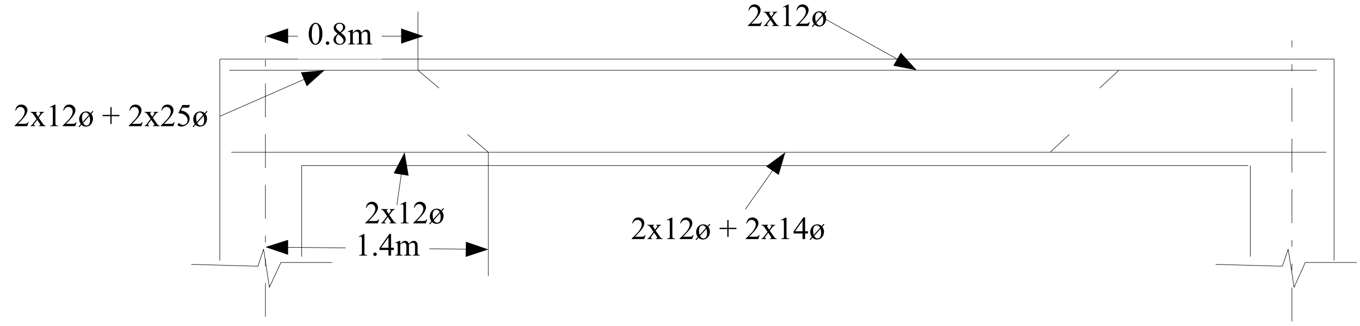
CEL232 – Minor II Exam – IInd Sem. 2011-12

Question 1 (5 marks): Explain through figures and sketches how, m.s.a, grading and shape of aggregates influence the paste requirement in normal strength concrete?

Question 2 (12 marks): A beam with 230 mm width and 500 mm effective depth is supported on 300 mm thick columns at both ends. The centre-centre distance between the columns is 5 metres. Both ends of the beam are fixed and the moment along the length of the beam is given by the equation:

$$M = \frac{wlx}{2} - \frac{wl^2}{12} - \frac{wx^2}{2}$$

where w is the uniform load on the beam, x is the distance from the centre of the support and l is the effective length of the beam. The service load on the beam can be assumed to be 50 kN/m, including all dead loads, live loads and the self-weight of the beam. 2 legged 8 mm ø bars are provided at 300 mm c/c throughout the length of the beam. Check if the design of the beam below is sufficient to resist these forces. The concrete is of M20 grade and steel is Fe415. A clear cover of 30 mm may be assumed.



Question 3 (3 marks): Design the torsion reinforcement in a two-way square slab of effective span 5 metres restrained and discontinuous on all four corners, with an ultimate moment of 20 kN-m/m at mid-span in both directions. The effective thickness of the slab is 175 mm, the grade of concrete is M20 and the grade of steel is Fe415.

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CEL232 – Major Exam – IInd Sem. 2011-12

Question 1 (3 marks): Two prisms having same area of cross-section but differs in aspect ratio, one with length/diameter ratio of 1.2 and other with 1.8. Which one would exhibit higher load carrying capacity when tested under uni-axial compression in a compression testing machine. Justify your answer with diagrams.

Question 2 (2 marks): Explain the role of shape of aggregate in workability of concrete

Question 3 (3 marks): A consultant proposed to cast a concrete element with a water cement ratio of 0.0.6 with moist curing period of only for 3 days. However another consultant proposed to use a water cement ratio of 0.5 and a moist curing period of 14 days for the same element, which concrete would be more durable? Justify your answer.

Question 4 (13 marks): Design a biaxially eccentric loaded braced rectangular column deforming in single curvature for the following data:

Ultimate axial load P_u = 2200 kN
Ultimate biaxial moments at bottom: M_{ux1} = 205 kNm; M_{uy1} = 105 kNm
Ultimate biaxial moments at top: M_{ux2} = 160 kN-m; M_{uy2} = 50 kN-m
Unsupported length = 7 m
Effective length l_{ex} = 8.4 m; l_{ey} = 4.6 m
Column section B = 400 mm (along x-axis); D = 600 mm (along y-axis)
M25 concrete and Fe415 steel
Subscript x denotes bending about x axis.

Question 5 (9 marks): Design a reinforced concrete footing for the column designed above using the biaxial moments acting at the bottom of the column. Assume that the column is in the middle of the property with no space constraints. Weight of soil = 18 kN/m^3; angle of repose 33°; allowable bearing capacity = 175 kN/m^2; concrete of M25 grade and Fe415 steel.

Question 6 (5 marks): Explain the detailing of reinforcement in a 2-way solid slab supported on all 4 sides and restrained from rotation at all corners using drawings only.

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Tutorial sheet 1 – Working-stress method

Question 1) Determine the percentage of tension reinforcement for balanced design of a reinforced concrete rectangular beam section as a function of the properties of the concrete and steel used.

Question 2) A rectangular beam section of 250 mm width and 450 mm effective depth is reinforced with 4x12 mm ϕ tension bars. Determine the stress induced in the top compression fibre of concrete and tension steel when it is subjected to a moment of 25kN-m. Consider concrete of grade M25 and steel of Fe415 grade.

Question 3) Analyse a rectangular beam section of 200 mm width and 400 mm effective depth to determine moment of resistance and stresses induced in top compression fibre of concrete and steel for two cases of tension reinforcement: (i) 3x12 mm ϕ, (ii) 3x18 mm ϕ. Consider a concrete grade of M25 and steel of Fe415.

Question 4) Design a rectangular beam subject to a moment of 50 kN-m using a concrete grade of M20 and Fe415 steel.

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Tutorial sheet 2 – Flexural design using Limit-state method

Question 1) Determine the percentage of tension reinforcement for balanced design of a reinforced concrete rectangular beam section.

Question 2) Determine the ultimate moment of resistance of a balanced reinforced section of 300 mm breadth and 600 mm effective depth using M30 concrete and Fe415 steel. Also find the area of steel required to balance the section.

Question 3) Analyse a rectangular beam section of 200 mm width and 400 mm effective depth to determine the ultimate moment of resistance for two cases of tension reinforcement: (i) 3x18 mm ϕ, (ii) 4x20 mm ϕ. Consider a concrete grade of M25 and steel of Fe415.

Question 4) Design a singly-reinforced rectangular beam section subjected to an ultimate moment of 150kN-m using concrete of M25 grade and Fe415 steel.

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Tutorial sheet 3 – Flexural design using limit-state method

Question 1) Analyse rectangular beam sections of 300 mm width and 500 mm effective depth to determine the ultimate moment of resistance for two cases of reinforcement:
(i) 4x22mmϕ tension reinforcement and 4x16mmϕ compression reinforcement
(ii) 4x25mmϕ tension reinforcement and 2x16mmϕ compression reinforcement

Consider clear cover of 30 mm, concrete grade of M20 and steel grade of Fe415

Question 2) Design a concrete beam of 200 mm wide and 400 mm effective depth for an ultimate moment of 150 kN-m using M20 concrete and Fe415 steel.

Question 3) Design a rectangular beam section subjected to an ultimate moment of 175 kN-m using M30 concrete and Fe415 steel.

Question 4) Analyse the T-beam section of 250 mm width of web, 1200 mm width of flange, 100 mm thickness of flange and 450 mm effective depth of determine the ultimate moment of resistance for three cases of tension reinforcements:
(i) 4x20 mm ϕ (ii) 4x28 mm ϕ (iii) 6x28 mm ϕ for a concrete grade of M20 and Fe415 steel.

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Tutorial sheet 4 – Flexural design using limit-state method

Question 1) Analyse a T-beam section of 250 mm width of web, 1200 mm width of flange, 100 mm thickness of flange and 450 mm effective depth of determine the ultimate moment of resistance for two cases of reinforcements:

(i) 4x20 mm ϕ tension steel and 2x14 mm ϕ compression steel
(ii) 6x25 mm ϕ tension steel and 2x16 mm ϕ compression steel

Consider concrete of grade M20 and steel of grade Fe415.

Question 2) Design a T-beam section of 250 mm width of web, 1000 mm width of flange, 100 mm thickness of flange when subjected to an ultimate moment of 300 kN-m using a concrete of grade M20 and Fe415 steel.

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Tutorial sheet 5 – Shear and torsion design using limit-state method

Question 1) A rectangular bam section of 250 mm width and 450 mm effective depth is reinforced with 4 bars of 18 mmϕ. Determine the shear reinforcement required to resist shear forces of (I) 30 kN, (ii) 60 kN, (iii) 150 kN and (iv) 250 kN at service state. Consider a concrete of grade M20 and Fe415 steel.

Question 2) Design a rectangular beam section 250 mm wide, 450 mm effecive depth subjected to ultimate moment of 150 kN-m, ultimate shear force of 20 kN and ultimate torsional moment of 7.5 kN-m. Consider clear cover of 30 mm for all steel, concrete of grade M20 and Fe415 steel.

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Tutorial sheet 6 – Torsion, bond and curtailment using limit-state method

Question 1) Design a rectangular beam section 250 mm wide, 450 mm effecive depth subjected to (a) ultimate moment of 150 kN-m ultimate shear force of 50 kN and ultimate torsional moment of 40 kN-m, (b) ultimate moment of 50 kN-m ultimate shear force of 50 kN and ultimate torsional moment of 40 kN-m.
Consider clear cover of 30 mm for all steel, concrete of grade M20 and Fe415 steel.

Question 2) Determine the anchorage length of bars at the simply supported end of a reinforced concrete beam with a width of 250 mm, an effective depth of 450 mm, 3x20 mmϕ tension reinforcement and an ultimate shear force of 250 kN at the centre-point of the support.

Question 3) Check for bond bond stress at the point of inflection of a continuous beam 250 mm wide with effective depth of 450 mm. The tension reinforcement is 3x20 mm ϕ and the shear force distribution is linear with a value of 200 kN at the point of inflection.

Question 4) Check for the requirements of curtailment of tension reinforcement in a simply supported beam with a width of 250 mm and effective depth 450 mm. The length of the beam between support centres is 6000 mm with a uniform load of 70 kN/m on the entire span. The beam is supported on 450 mm wide columns at both ends. At mid-span, it is reinforced with 6x22 mm ϕ bars at the bottom, half of which are curtailed at 750 mm from the centres of the supports. 3x22mm ϕ bars are provided as top reinforcement throughout the span. 2 legged 8 mmø bars at 250 mm c/c are provided as shear reinforcement throughout the span. Consider M20 concrete and Fe415 steel.

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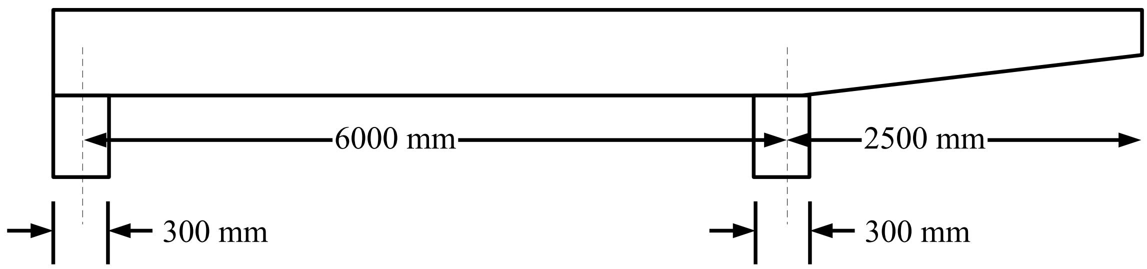
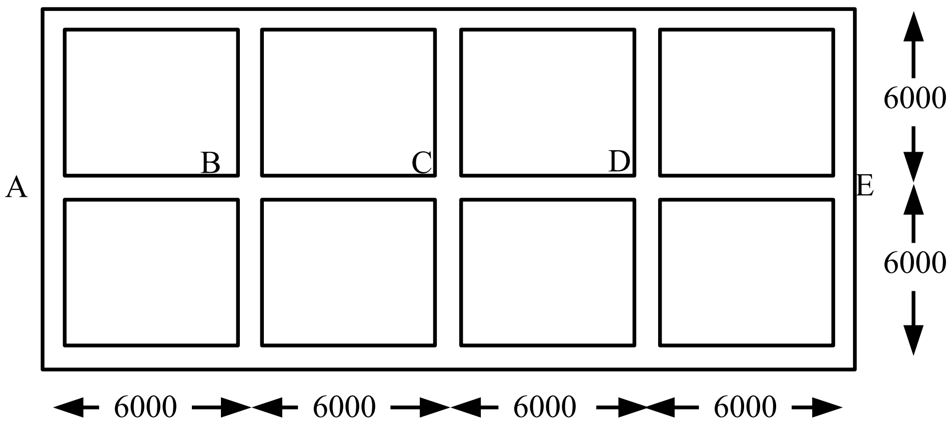
Tutorial sheet 7 – Beam design

Question 1) Design a simply supported rectangular beam of clear span of 6m and subjected to a superimposed load of 60 kN/m at servise state. Consider support width of 30 cm, concrete grade of M25 and Fe415 steel.

Question 2) Design a simply supported rectangular beam with an overhang subjected to a superimposed load of 60kN/m at service state as shown in the figure below.



Question 3) Design a continuous flanged beam ABCDE as shown in Fig below. Consider that the thickness of slab is 150 mm, floor finish of 50 mm and superimposed load of $5 kN/m^2$ at service state. Consider concrete grade of M20 and steel grade of Fe415. All beams are supported on 300 mm thick walls.



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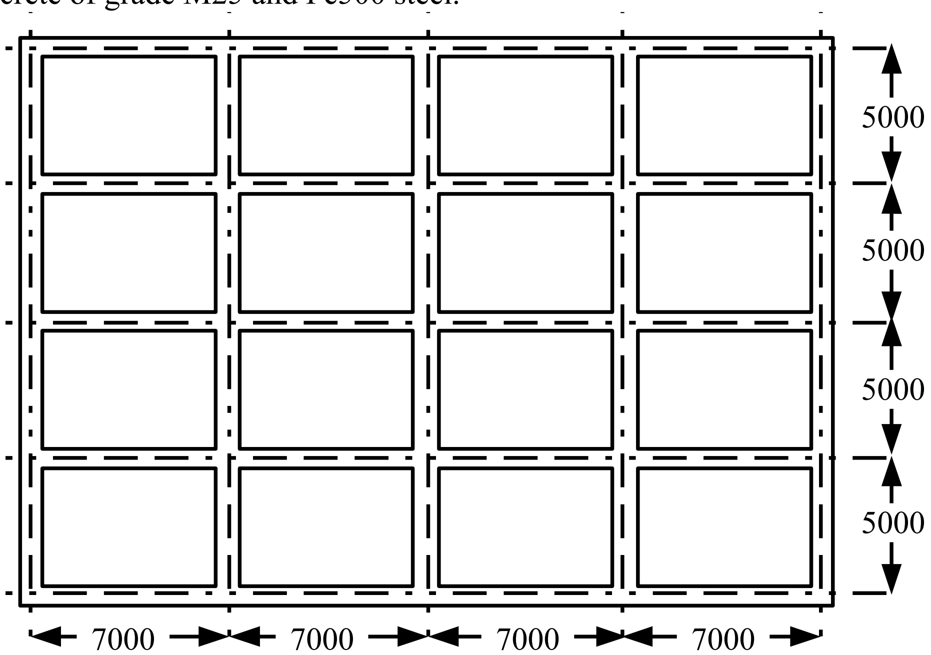
Tutorial sheet 8 – Slab design

Question 1) Design is simply supported slab 10 m wide and 3.5 m long (overall) supported by a 250 mm thick wall on all 4 sides. It is subjected to a live load of 4 kN/m^2 and surface finish of 1 kN/m^2. Consider concrete of grade M25 and Fe500 steel.

Question 2) Design a simply supported square two-way square slab supported on 250 mm wide supports at a distance of 4.5 m centre-centre. The slab is subjected to a live load of 4 kN/m^2 and a surface finish of 1 kN/m^2. Consider that (i) the corners are held down and torsional reinforcement is provided, (ii) that the corners are not held down. Use concrete of M25 grade and Fe500 steel.

Question 3) Design the slab of a typical floor as shown in the figure below. The slab is supported on 250 mm thick walls and subjected to a live load of 4 kN/m^2 and a surface finish of 1 kN/m^2. Consider concrete of grade M25 and Fe500 steel.



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Tutorial sheet 9 – Column Design

Question 1) Determine the ultimate concentric load-carrying capacity of a rectangular column section of 400 mm x 600 mm reinforced with 10 bars of 25 mm ø. Consider a concrete of grade M25 and Fe415 steel.

Question 2) Determine the ultimate load carrying capacity of a circular column section of 500 mm diameter reinforced with 8 bars of 28 mm ø adequately tied either with (a) lateral ties or (b) spirals. Consider a concrete of grade M25 and Fe415 steel.

Question 3) Determine the ultimate load carrying capacity of a rectangular column section 400 mm x 600 mm in size, reinforced with 10 nos. 28 mm ø bars equally distributed on the two 400 mm wide faces. The applied load on the column has an eccentricity of 150 mm from the centre along the longer dimension of the column. The grade of the concrete is M25, the steel is Fe415 and the clear cover is 40 mm.

Question 4) Design a uniaxial eccentrically loaded column section with dimensions 600 mm x 400 mm for a load of 2500kN. The eccentricity if 180 mm along the longer dimension, the grade of concrete is M25 and steel is Fe415.

Question 5) Determine the ultimate load carrying capacity of a column section which is 600 mm x 400 mm, reinforced with 8 nos. 28 mm ø bars equally distributed on all 4 faces. The eccentricity is 80 mm along the shorter dimension and 120 mm along the longer dimension.

Question 6) Design a biaxially eccentrically loaded column section, 600 mm x 400 mm in size, with an eccentricity of 60 mm along the shorter direction and 90 mm along the longer direction for a load of 2000kN. Consider M25 and Fe415.

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Tutorial sheet 10 – Column Design

Question 1) Design axially loaded braced rectangular, square and circular columns for an ultimate axial load (P_u)=3500 kN, unsupported length (l)= 3.25 m, effective lengths l_{ex}=3.0 m, l_{ey} = 2.5 m, M20 grade concrete and Fe415 steel.

Question 2) Design a uniaxially eccentrically loaded braced rectangular column for P_u = 1500kN, Ultimate uniaxial moment M_{ux}=250 kNm, l=3.5 m, l_{ex}=3.0 m, l_{ey}=2.75 m, column dimensions B=300 mm, D=500 mm, M25 concrete and Fe415 steel.

Question 3) Design a biaxially eccentrically loaded braced circular column for P_u=1500 kN, M_{ux}=200 kNm, M_{uy}=100 kNm, l=3.5 m, l_{ex}=3.0 m, l_{ey}=2.75 m, diameter(D)=450 mm, M25 concrete and Fe415 steel.

Question 4) Design a biaxially eccentrically loaded braced rectangular column deforming in deforming in single curvature for P_u=1500 kN, Ultimate biaxial moments at bottom: M_{ux1}=200 kNm, M_{uy1}=75 kNm and at top: M_{ux2}=100 kNm, M_{uy2}=50 kNm, l=7.5 m, l_{ex}=6.5 m, l_{ey}=4.5 m, B=300 mm, D=500 mm, M25 concrete and Fe415 steel.