UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 4 Examination in Engineering: September 2023

Module Number: CE4302 **Module Name: Design of Concrete Structures I**

[Three Hours]

[Answer **all questions.** All questions carry equal marks]

SLS EN 1992 and BS8110 Part I: 1997 is provided.

Q1 a) Among the different design philosophies like working stress method and load factor method, explain how the limit state approach coupled with different partial safety factors for materials and loads adopted by SLS EN 1992 ensure safer and more economical reinforced concrete design compared to earlier methods.

[3 Marks]

b) Explain the design provisions under SLS EN 1992 for ensuring yielding of tensile reinforcement before concrete crushing (under reinforced section) and prevented the occurrence of premature shear failure in reinforced concrete flexural elements.

[3 Marks]

b) Figure Q1 shows a cross-section detail of a reinforced concrete beam. Taking into account the reinforcement in both top and bottom, calculate sagging moment capacity of the section under the current orientation. Take the strength of concrete f_{ck} 30 N/mm², the yield strength high yield strength bars 500 N/mm², cover to all reinforcement is 50mm and shear links used is of 8mm diameter.
(Consider both tension reinforcement and compression reinforcement in the computation of the capacity of the section)

[6 Marks]

Q2 a) Figure Q2 shows slab with panel dimensions of 6 m X 6 m. Slab is subjected to a uniformly distributed imposed load of 4 kN/m². Take density of the 150 mm thick reinforced concrete slab as 25 kN/m³ and load from slab finishes as 1 kN/m². Calculate the final design bending moments for internal slab panel "E" considering 1 m wide strips across two perpendicular directions of the panel and carrying out moment distribution based on moment coefficients in Table 14 of the BS8110:1997.

[4 Marks]

b) Calculate the reinforcement requirement for bending at all phases of the slab panel E. Cover to all reinforcement shall be taken as 25 mm. All reinforcement requirements shall be provided using 10 mm diameter high yield steel bars conforming to SLS 375 and BS 4449. Take the strength of concrete as f_{ck} 30 N/mm² and design strength of high yield steel bars f_{yk}500 N/mm².

[3 Marks]

c) Check for reinforcement requirement for crack control and deflection and minimum reinforcement requirement of the slab panel E above.

[3 Marks]

d) Provide final reinforcement detail of the slab panel E with due consideration to bending, deflection, reinforcement requirement for crack control and minimum reinforcement requirement as specified by SLS EN 1992 .

[2 Marks]

Q3 Bending moment diagram and shear force diagram of a continuous beam ABCD is shown in the Figure Q3. Assume the cross section dimension for the beam as 300 mm x 500 mm and cover to all reinforcement as 25 mm. Take the strength of concrete f_{ck} 30 N/mm^2 and design strength of high yield steel barsf_{yk} 500 N/mm^2. All the requirement of shear reinforcement is provided through diameter 8 mm high steel having a yield strength of f_{ywk} -500 N/mm^2.

a) Calculate the reinforcement requirement of the beam at supports and at the middle between beam supports. Consider 150 mm thick slab spanning 5m is available at either side of the beam in designing the beam sections for sagging moment. Bending moment envelop is provided in Figure Q3 (a)

[4 Marks]

b) With due consideration, the shear force distribution along the beam and shear capacity enhancement close to the support, calculate the shear reinforcement requirement at critical sections to suggest a scheme for providing shear reinforcement for the beam ABCD . Shear force envelop is provided in Figure Q3 (b)

[4 Marks]

c) Based on the answer to Q3. a), Q3. b) and due consideration for detailing rules (i.e. anchorage, lap length and curtailment of reinforcement) draw the reinforcement detail of the beam ABCD.

[4 Marks]

Q4 Figure Q4 (a) shows the details of a ground floor and a first floor columns of a four-story brazed frame with individual footing connected at the ground level and beams. Beams having 500 mm X 300 mm cross sections are connected at the first floor levels. The height of the column in the ground floor, from the top of foundation to top of the first floor is 6 m, whilst, rest of the floor to floor height is 3.5m. The foundation is an individual pad footing of the type that will not provide moment resistance.

a) Compute the slenderness of the ground floor and first floor column and determine whether the columns are classified into short or slender based on the geometries given in Figure Q4 (a).

[4 Marks]

b) Calculate the longitudinal reinforcement requirement for the Ground floor column under the ultimate limit state loading given in the Table Q4. Consider column of 300mm square section. Take strength of concrete f_{ck} 35 N/mm^2, strength of high yield steel f_{yk}500 N/mm^2. Assume d'/h for the column is 0.1. The intersection curves for the column are given in Figure Q4(b).

Table Q4

Axial Load	Moment about major and minor axis (kNm)	
	Y-Y Axis	Z-Z Axis
	Top	Top
1800 KN	76	68

[8 Marks]

Q5. An internal column having cross-section of 300 mm×300 mm carrying an un-factored permanent load of 750 kN and an un-factored variable load of 450 kN is connected to an individual footing. The allowable bearing capacity of the soil in the site is estimated to be 250 kN/m^2.

a) Punching shear at the column and pad connection is an important additional design consideration for individual footings. Explain this statement with respect to a traditional slab beam-column connection and how the punching shear capacity can be enhanced in pad column connection if it is found to be inadequate.

[2.0 Marks]

b) Design a square base individual footing to transmit the above loads to the ground. Assume strength of concrete f_{ck} 30 N/mm²and strength of high yield steel reinforcement f_{yk}-500 N/mm² are used in the design. Use single diameter to provide reinforcement requirement in both directions of the base. Cover to all reinforcement shall be maintained at 50mm.

(Hint: Line bending, line shear and punching shear have to be checked before deciding the final reinforcement requirement. Initial trail depth (d) for the footing shall be based on $d = 10\,N^{0.5}$ where d is in mm N (Ultimate axial load) is in kN. The footing has to be designed to resist only axial loads)

[10 Marks]

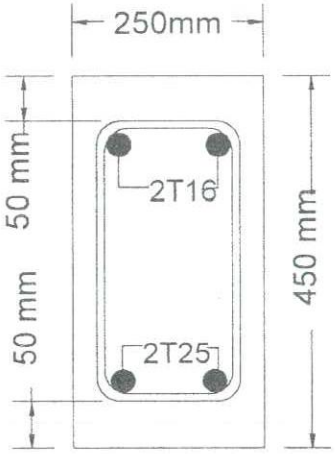


Figure. Q1 Beam Cross section

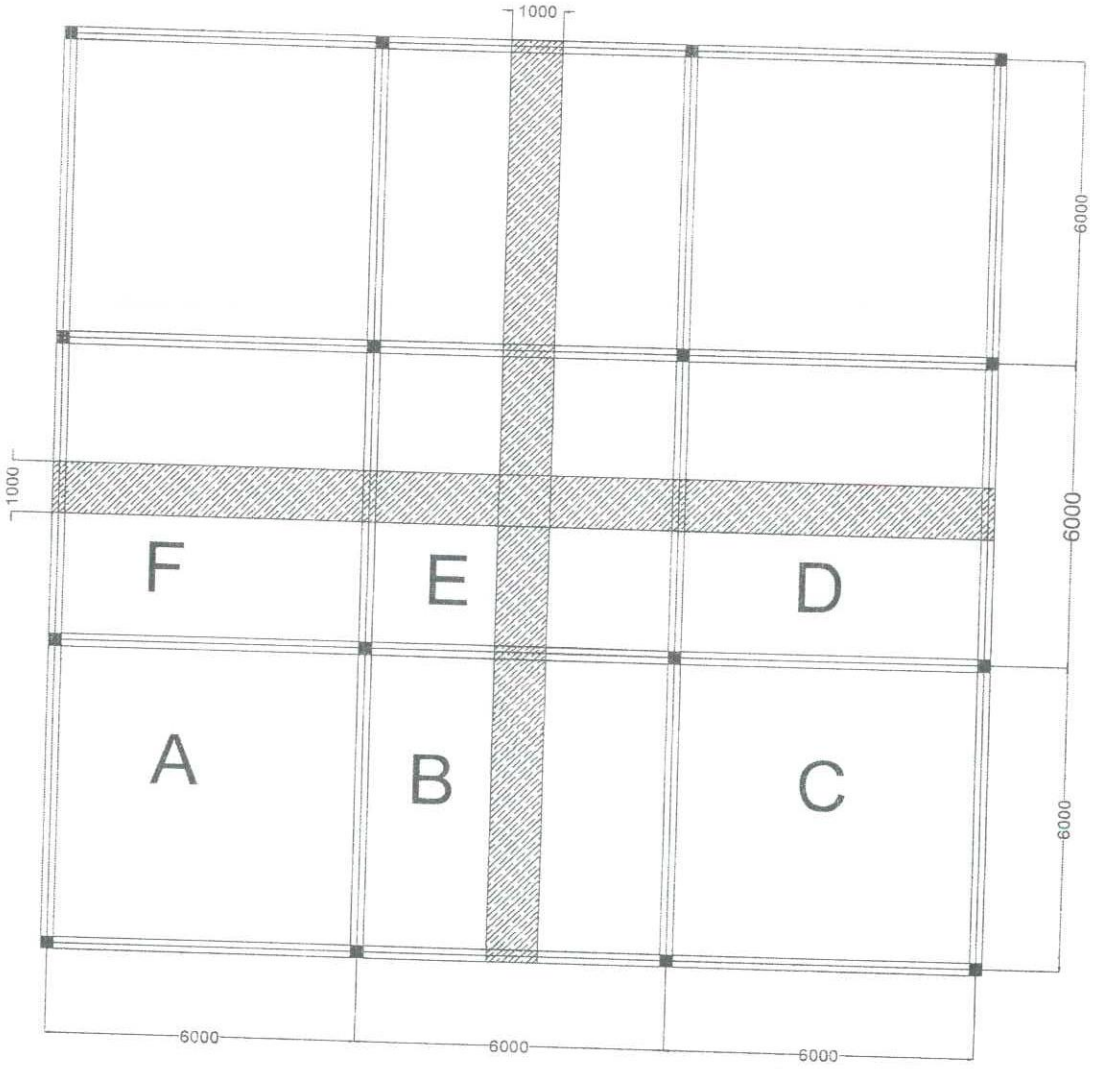


Figure Q2 Plane view of the slab panel and 1m width strips to be considered for moment distribution

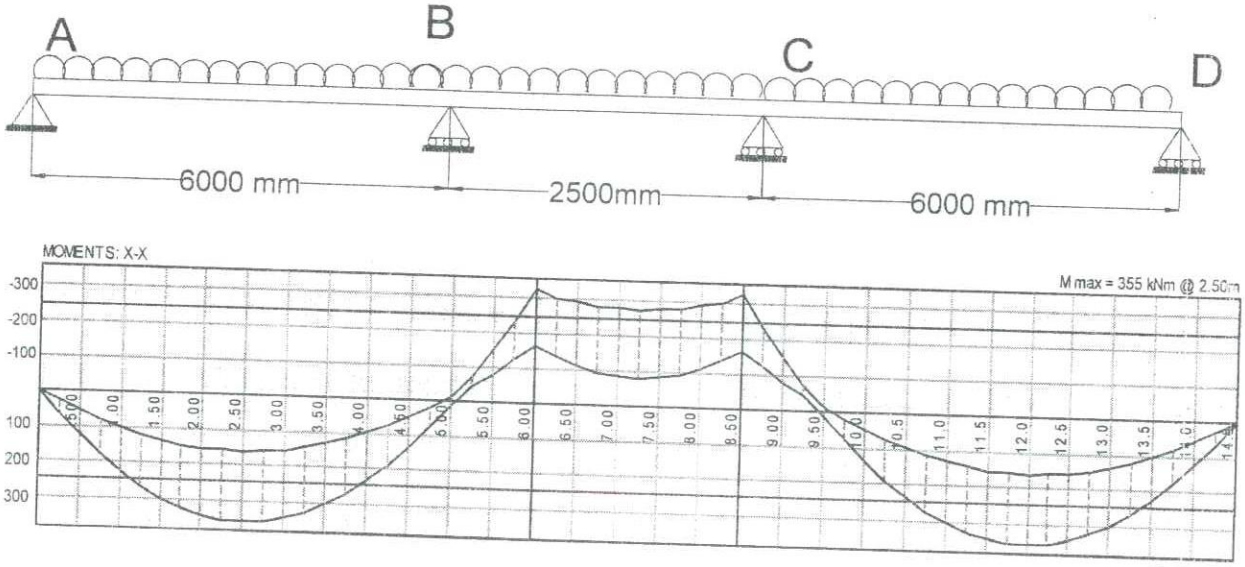


Figure Q3 (a) Bending moment envelop

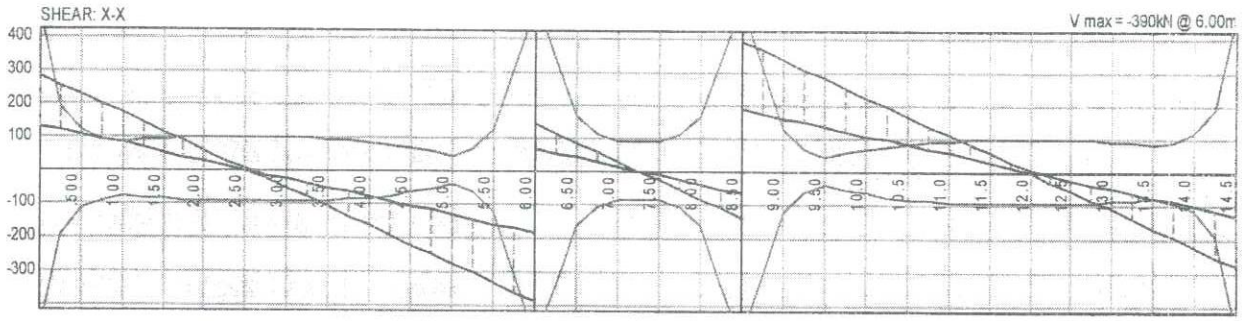
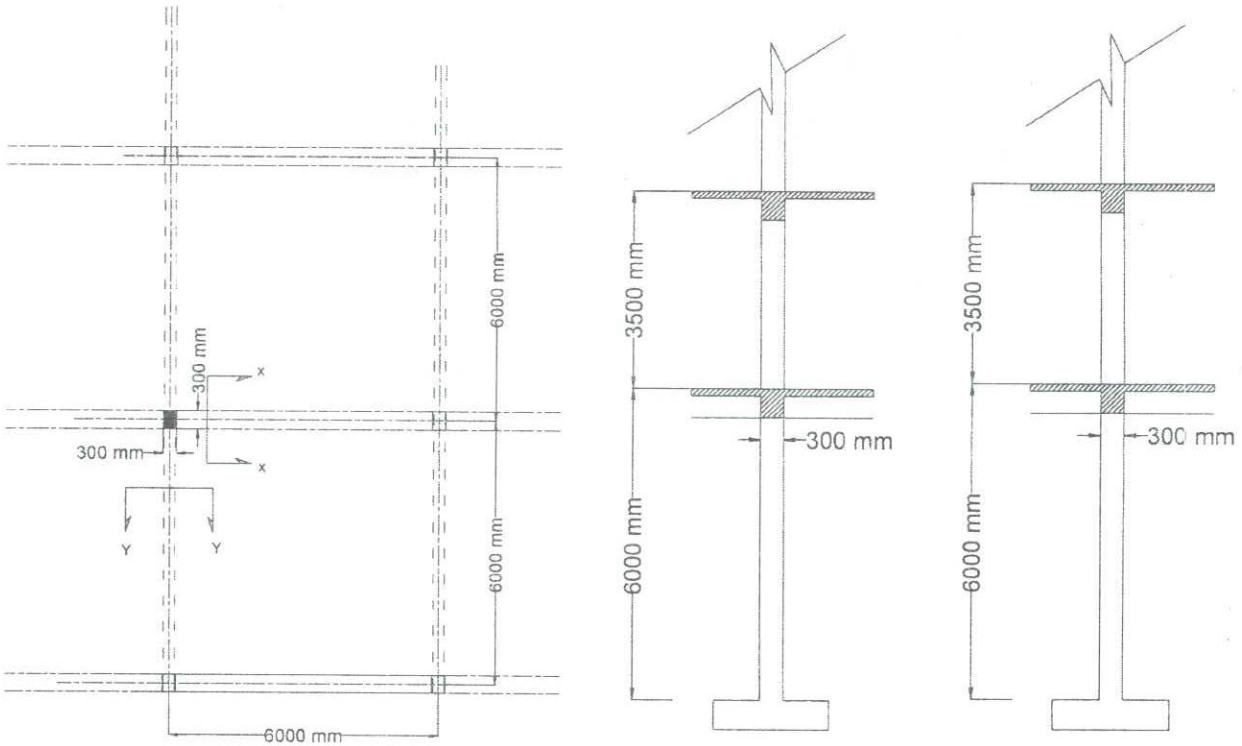


Figure Q3 (b) Shear force envelop

Figure Q3 Bending moment and shear force envelops



(i) Plan view (ii) Section X-X (iii) Section Y-Y

Figure Q4 (a) Plan view and cross sections of the ground floor and first-floor column

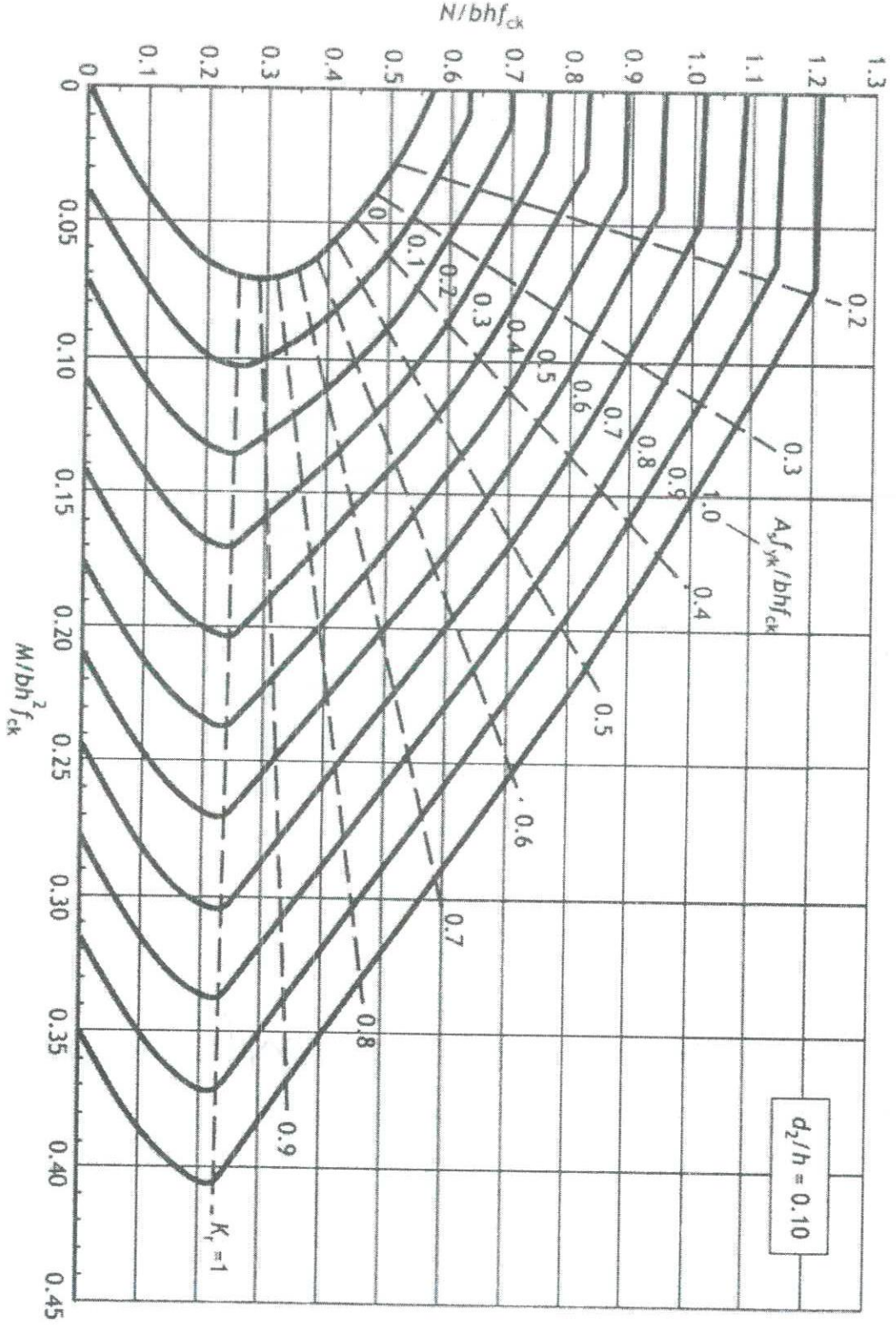


Figure Q 4(b) Column Intersection diagram