UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 4 Examination in Engineering: November 2022

Module Number: CE4301 (NC) **Module Name: Design of Concrete Structures I**

[Three Hours]

[Answer **all questions**, all questions carry twelve marks each.]

BS 8110 Part I: [1997] is allowed

(All symbols used in the paper have their usual meaning unless otherwise stated)

Q1. a) Show that the maximum moment flange sections can carry, singly reinforced under reinforced condition is given by the following expression. See Fig. Q1 (a) for the description of the symbols used in the derivation. In addition, note: f_{ck} -is the characteristic strength of concrete, f_{yk} -is the characteristic design strength of reinforcement, b_f -is the width of the flange, b_w -is the thickness of the web, h_f-height of the slab, d-effective depth for tension reinforcement.

$$M = (b_f - b_w)0.45f_{cu}h_f\left(d - \frac{h_f}{2}\right) + b_w(0.9x)0.45f_{cu}(d - 0.45x)$$

$$M = \beta_f f_{cu} b_f d^2,\ \beta_f = 045\left(1 - \frac{b_w}{b_f}\right)\frac{h_f}{d}\left(1 - \frac{h_f}{2d}\right) + 0.15\frac{b_w}{b_f}$$

[2 Marks]

b) Derived and expression for reinforcement requirement in a flange section with web compression and show that this expression can be reduced to the equation given below for x/d=0.45.

$$\mathrm{M} = 0.95f_yA_s\left[d - \frac{h_f}{2}\right] - 0.45f_{cu}b_w(0.9x - h_f)\left[\frac{h_f}{2} + \left[\frac{0.9x - h_f}{2}\right]\right]$$

$$x/d=0.5, \quad A_s = \frac{M + (0.45d - h_f)0.1b_wf_{cu}d}{0.95\left(d - \frac{h_f}{2}\right)f_y}$$

[3 Marks]

c) Fig. Q1 (c) is a flange section expected to support a bending moment of 275 kNm. From the first principals, calculate the reinforcement requirement of the above section to resist applied bending moment. Take $f_{ck} = 25\ N/mm^2$, $f_{yk} = 500\ N/mm^2$ and d=357mm.

[5 Marks]

d) Discuss the advantages and limitation for the use of the expression derived in Q1 b) for the calculation of required reinforcement of flange section subjected web compression. (Specially, the sections subjected web compression but x/d<0.45.

[2 Marks]

Q2. a) Two adjacent edges continuous 4 m x 6 m corner slab panel extracted from a sufficiently large slab is shown in the Fig. Q2. Slab is expected to support 4 kN/m^2 imposed load, self-weight of the deck and load from finishes applied amounted to 1 kN/m^2 (Consider as permanent load). Take density of concrete as 25 kN/m^3 and calculate the critical moments at the continuous and discontinuous edges and in the mid-way of the slab panel. Take the thickness of the slab as 125 mm.

[5 Marks]

b) Calculate the critical reinforcement requirement at the beam supports and at the middle of the slab panel based on requirement to resist applied bending moment, crack width control, deflection control, and satisfy the minimum reinforcement requirement. Take cover to all reinforcement in the major direction of bending as 20mm, $f_{ck} = 25\ N/mm^2$, $f_{yk} = 500\ N/mm^2$, and the slab is reinforced with 10 mm diameter high yield steel bars.

[5 Marks]

c) Calculate and show whether adequate shear resistance is provided by the selected slab thickness.

[2 Marks]

Q3 a) Elastic bending moment diagrams for the continuous beam for the critical load combinations described in BSEN1992 UK national annex are shown in Fig. Q3 a) and include; i), All span fully loaded ii) Alternative span fully loaded Case 1 and iii) Alternative span fully loaded Case 2. Calculate main reinforcement requirement of the beam based on elastic bending moment diagram. Take $f_{ck} = 25\ N/mm^2$, $f_{yk} = 500\ N/mm^2$, cross sectional dimension of the beam as 250x450 mm, and the effective depth to tension reinforcement *(d)* and compression reinforcement *(d')* as 404.5 mm and 45.5 mm respectively. Main reinforcement requirement is sufficient to be calculated at the support and the middle of the span. Plan view of the beam ABCD is given in Fig. Q2. Take the thickness of the slab available for flange action as 125 mm.

[5 Marks]

b) Shear force diagrams for the same beam ABCD is shown in Fig.Q3 b). Propose a shear reinforcement arrangement for the beam ABCD. Assuming only 8 mm diameter high yield steel is used for the shear reinforcement. Take$f_{ck} = 30\ N/mm^2$,$f_{ywk} = 500\ N/mm^2$.

[3 Marks]

c) Check serviceability limit state cracking and deflection performance of the beam ABCD based on deemed to satisfy conditions and propose the final reinforcement arrangement for the beam. Wherever required, take 2/3 of the of the ultimate limit state loading as the serviceability limit state loading of the beam. Take minimum cover to all reinforcement as 25mm.

[2 Marks]

d) Provide the reinforcement detail for the beam based on answers above showing clearly lap length and anchorage length requirements. (Use separate graph sheet for the reinforcement detail)

[2 Marks]

Q4 Plan view, and two cross sections of a ground floor column located in a brazed structure is shown in Fig Q4. Column is connected to a non moment carrying based at the bottom and monolithically cast beams and slab at the first floor level. The cross section dimensions of the beams connected at the first floor level were 300 mm x500 mm. From the frame analysis it is found that the column is subjected to axial load and bending moment about its major axis as shown in the Table Q4 below. Column is a square section with 400 mm x400 mm cross sectional dimensions. The height of the column from top of foundation to the top of the first floor level is 6.0m.

Table Q4. Loading details of the column

Axial Load	Moment about major axis (kNm)		Moment about minor axis (kNm)	
	Y-Y Axis		Z-Z Axis	
	Top	Bottom	Top	Bottom
1800 kN	120	0	80	0

a) Calculate the effective length, slenderness ratio of the column about the two axis and determine whether the given column is short or slender about the two axes.

[4 Marks]

b) Based on above classification, applied load and applied initial bending moment, calculate the reinforcement detail for the above column located in the ground floor level. Take characteristic strength of concrete and steel $f_{ck} = 25\ N/mm^2$, $f_{yk} = 500\ N/mm^2$ respectively and assume d_2/h (d/h=0.9) of the column as 0.1. The relevant column interaction diagram is given in the Fig. Q4 (b).

[8 Marks]

Q5. An internal column 400 mm × 400 mm carries un-factored permanent (Dead load) of 900 kN and an un-factored variable (Imposed load) of 500 kN. The ground where the structure is expected to be constructed is estimated to have a bearing capacity of 225 kN/m².

a) Considering, that the column will be supported by an individual footing, and the connection between column and footing idealized as pinned, select suitable square dimension for the column foundation and a thickness for the footing.
(Hint: Initial trail depth (d) for the footing shall be based on $d = 10.5\ N^{0.5}$ where d is in mm (axial load is in kN.)

[2 Marks]

b) Based on the selected foundation detail above, calculate the reinforcement detail for the above foundation based on the bending moment requirement at the critical section. Assume compressive strength of concrete $f_{ck} = 30\ N/mm^2$, $f_{yk} = 500\ N/mm^2$. Take cover to all reinforcement as 50 mm.

[4 Marks]

c) Calculate the line shear and punching shear resistance of the pad and check whether the required shear resistances are provided by the selected dimensions of the foundation in the Q5 a) above.

[5 Marks]

d) Draw the reinforcement detail for the footing

[1 Mark]

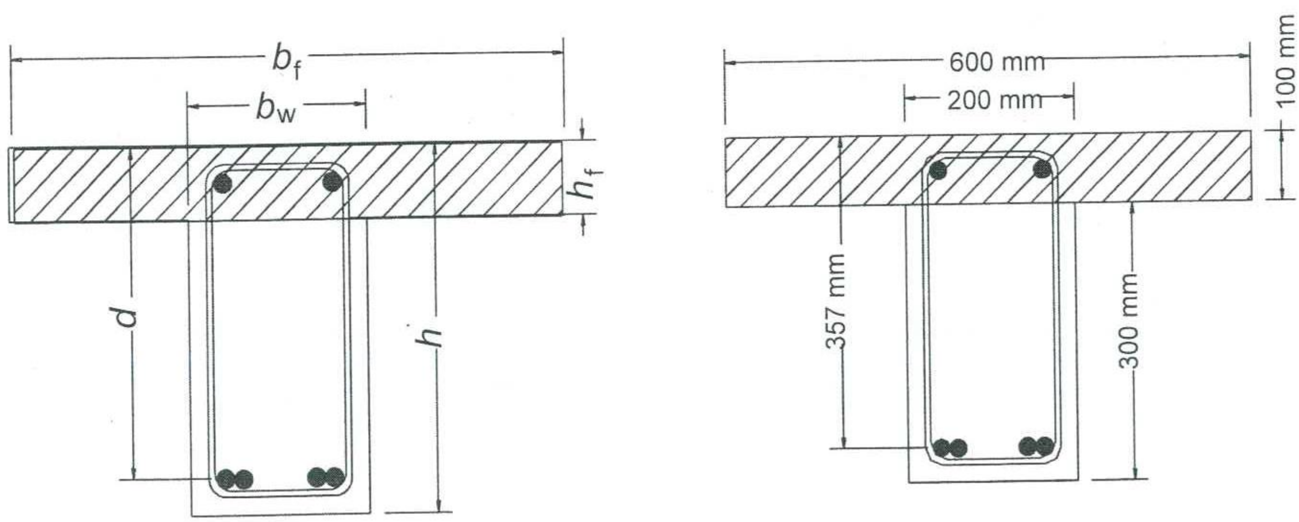


Fig. Q1 a) Flange section

Fig. Q1 b) Flange section

Fig. Q1 Flange section geometry

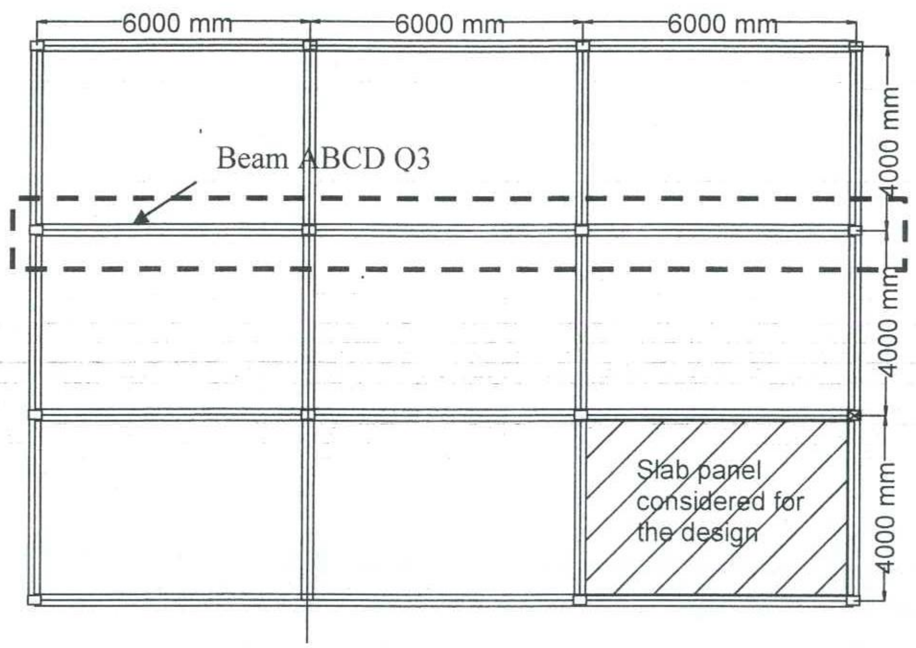
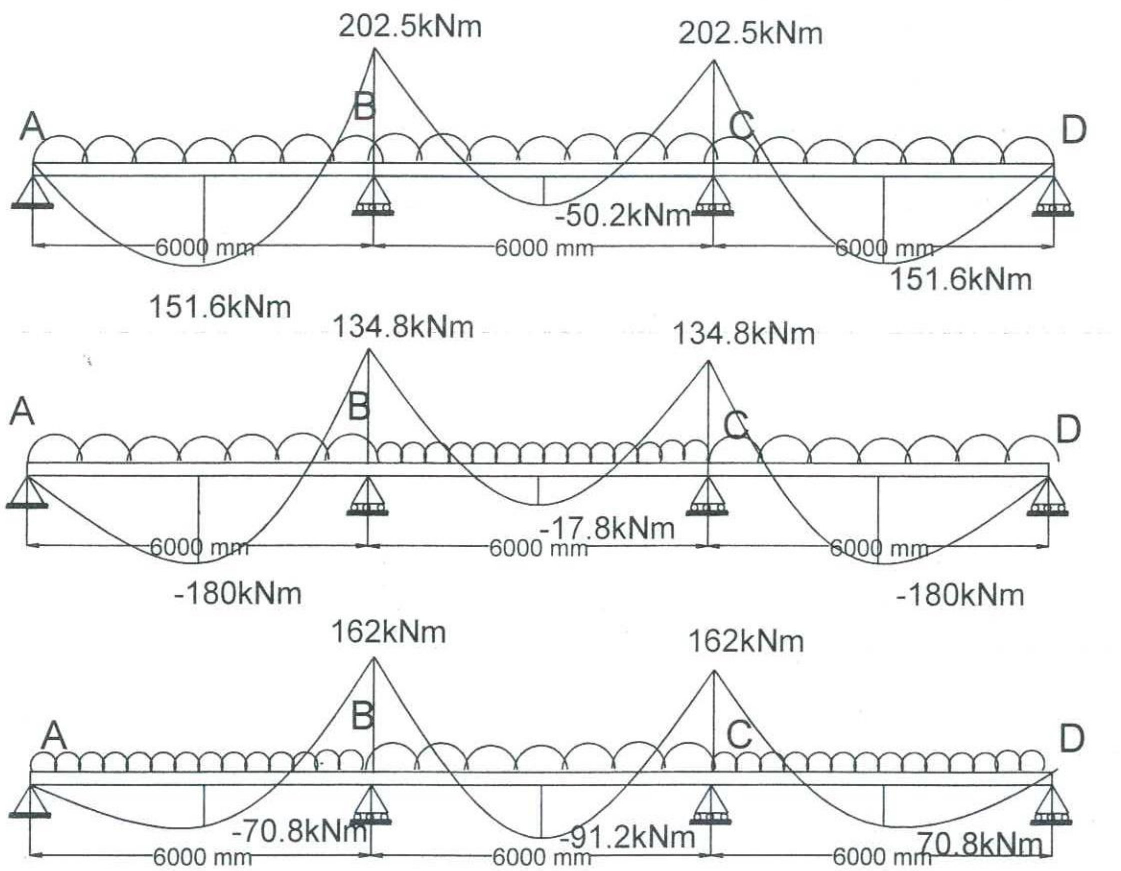


Fig. Q2 Corner slab panel with all to adjacent edges discontinuous.



Q3 a) Ultimate limit state bending moment diagrams for the selected load cases

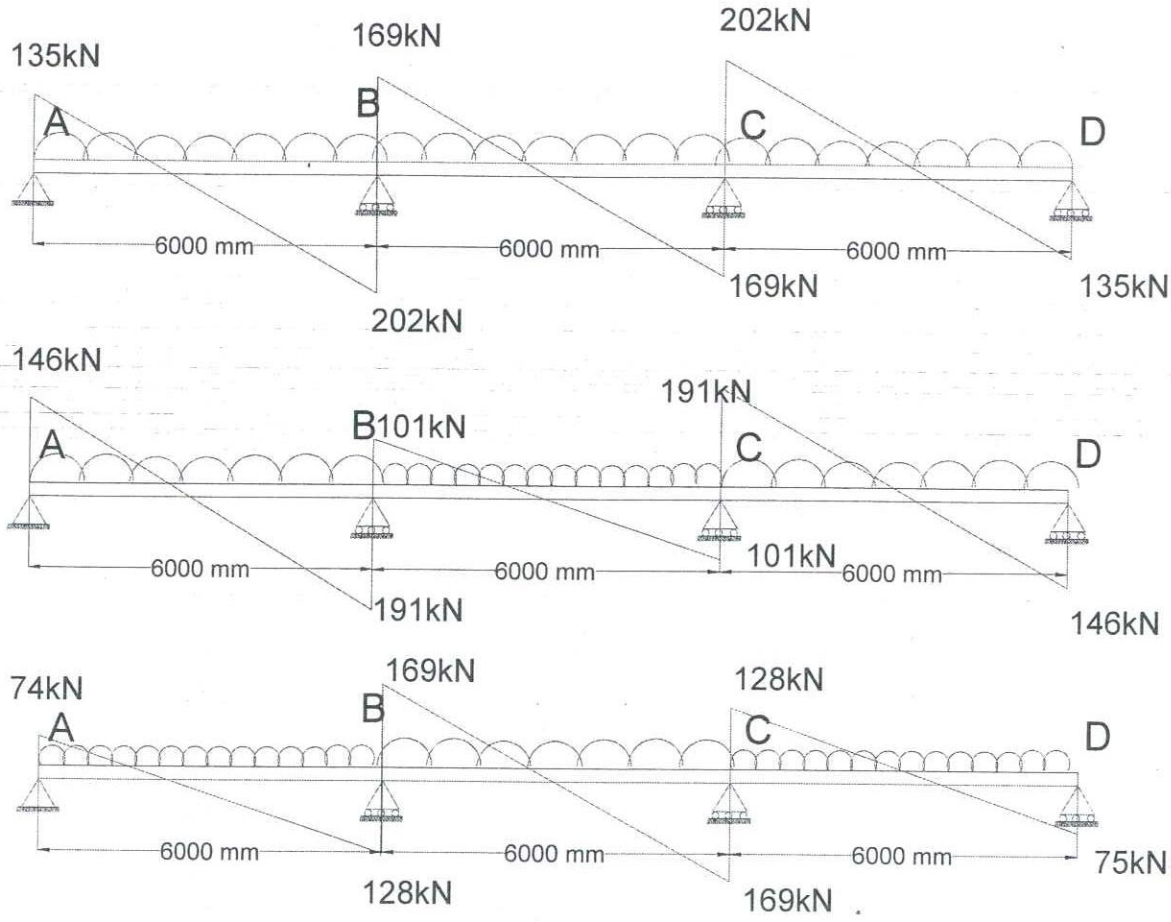
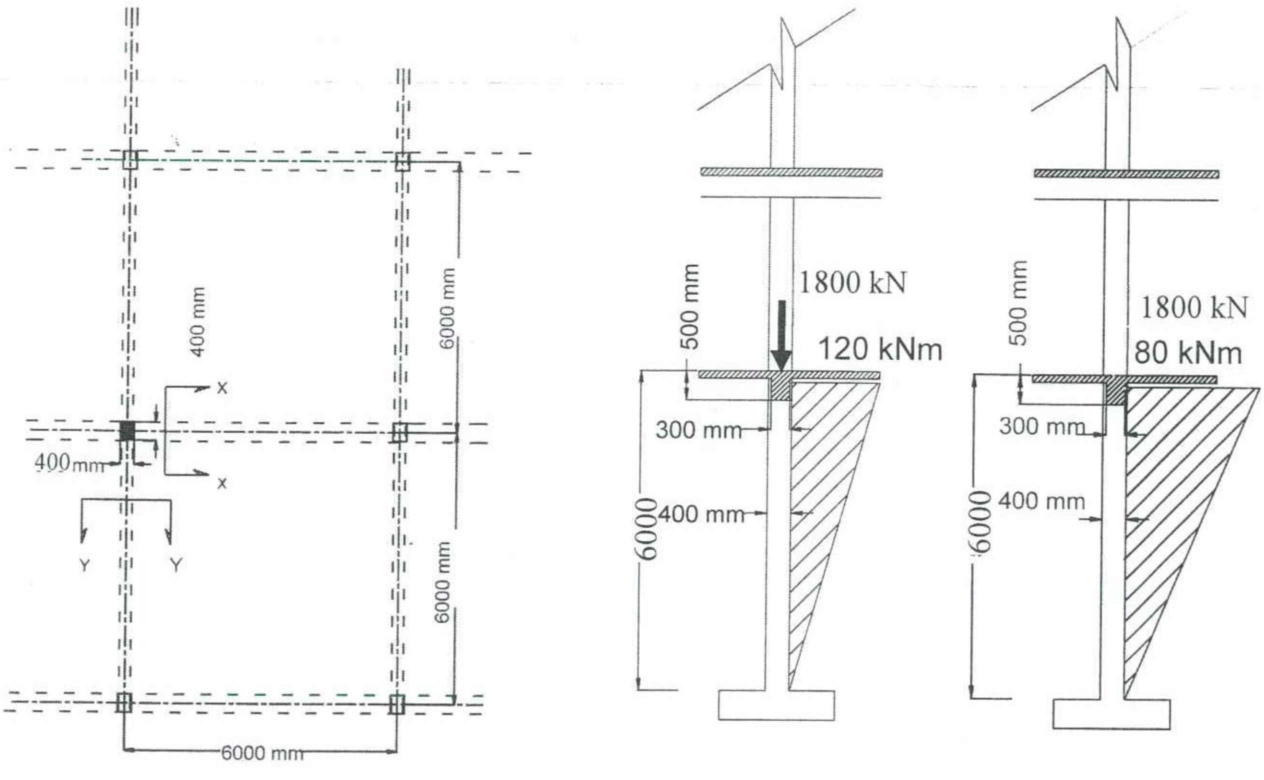


Fig. Q3 b) Ultimate limit state shear force diagrams for the selected load cases



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

Fig. Q4 Plan view and cross sections of the ground floor column

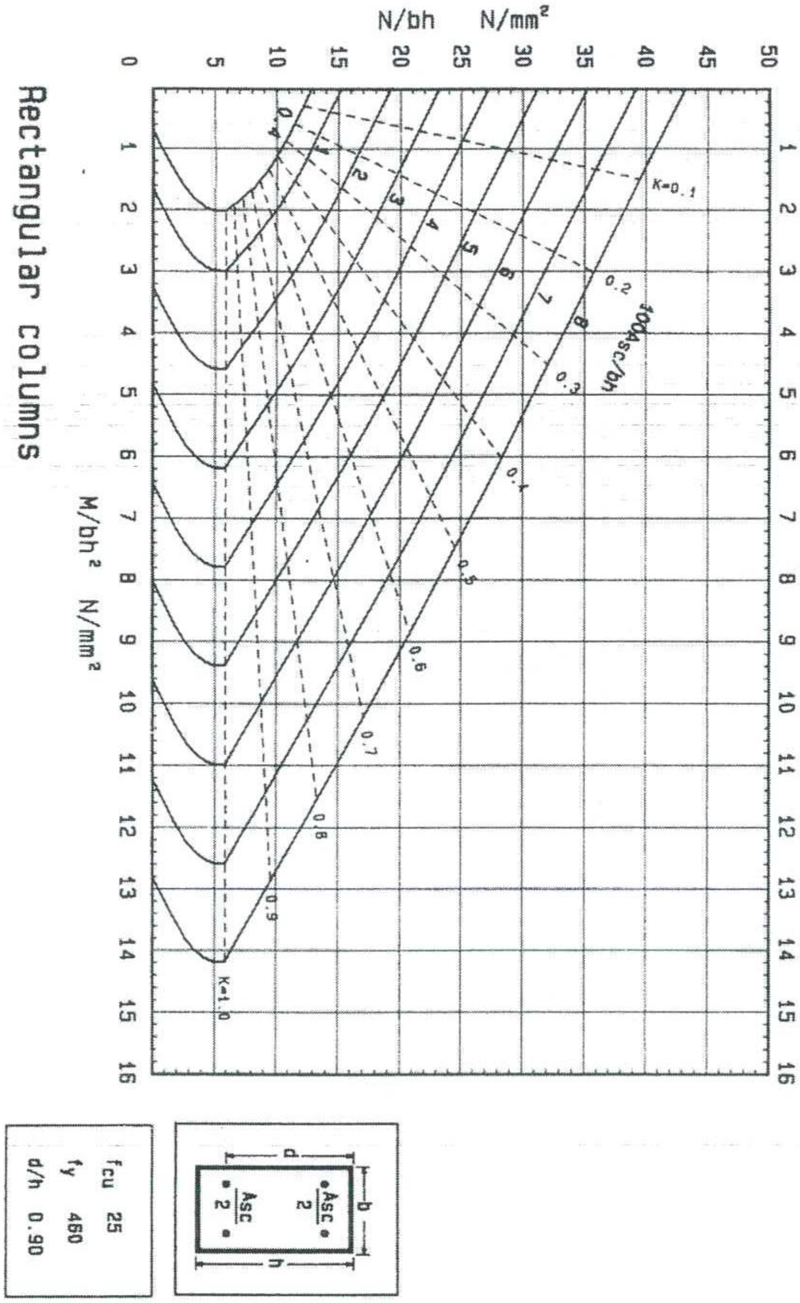


Fig. Q4 b) Relevant column interaction diagram