TECHNICAL UNIVERSITY OF MOMBASA

FACULTY OF ENGINEERING AND TECHNOLOGY
DEPARTMENT OF BUILDING & CIVIL ENGINEERING
UNIVERSITY EXAMINATION FOR:
BACHELOR OF SCIENCE IN CIVIL ENGINEERING

ECE 2415: STRUCTURAL DESIGN II
SPECIAL/SUPPLEMENTARY EXAMINATION
SERIES: SEPTEMBER 2018
TIME: 2 HOURS

Instructions to the candidate:

You should have the following for this examination:
Answer booklet.
Mathematical Table/Pocket Calculator.
This paper consists of **FOUR** questions.
Answer question **ONE (Compulsory)** and any other **TWO** questions.
Do not write on the question paper.

Question One (Compulsory) 30 Marks

(a) The design moment for a beam, width 250 mm and effective depth 700 mm is 300 kNm. If f_{cu} = 40 N/mm^2 and f_y = 460 N/mm^2, design the reinforcement using chart Figure 1.1.

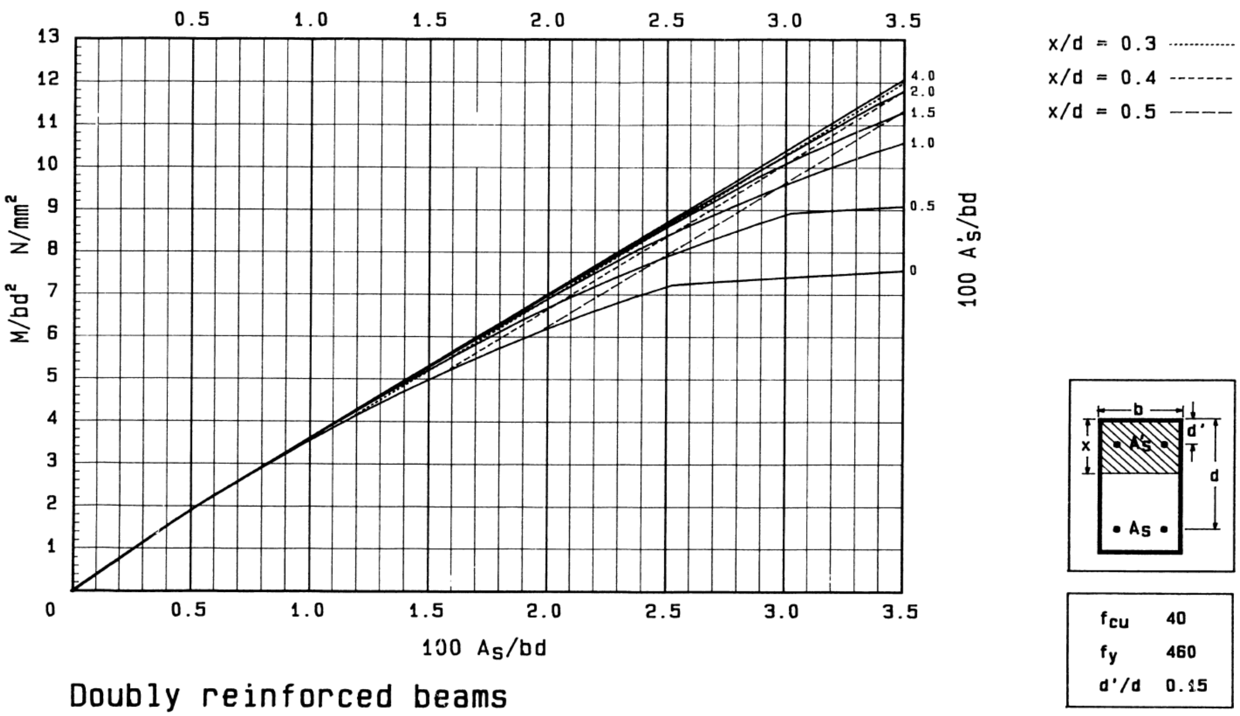

Figure 1.1: Beam design chart - ultimate limit state (BS8110)

(5 marks)

(b)(i) The ultimate moment of resistance, about tension steel, of a singly reinforced rectangular concrete beam subjected to flexure is given by equation 1.1:

$$M_u = 0.156 f_{cu} b d^2 \qquad 1.1$$

Where:

$f_{cu} = concrete\ characteristic\ strength,$

$b = beam\ width,$

$d = beam\ effective\ depth.$

Using a neat sketch of BS 8110 simplified rectangular stress block, derive equation 1.1.

(8 marks)

(b)(ii) The design moment M for a rectangular reinforced concrete beam of width 300 mm and effective depth 700 mm is 415 kNm. If f_{cu} = 40 N/mm^2 and f_y = 460 N/mm^2, design the reinforcement (Institute of structural Engineer's Manual procedure may be followed).

Table 1.1: Lever arm and neutral axis depth factors

$K = \frac{M}{f_{cu}bd^2}$	0.05	0.06	0.07	0.08	0.09	0.10	0.104	0.11	0.119	0.13	0.132	0.14	0.144	0.15	0.156
z/d	0.94	0.93	0.91	0.90	0.89	0.87	0.87	0.86	0.84	0.82	0.82	0.81	0.80	0.79	0.775
x/d	0.13	0.16	0.19	0.22	0.25	0.29	0.30	0.32	0.35	0.39	0.40	0.43	0.45	0.47	0.50

(8 marks)

(c)

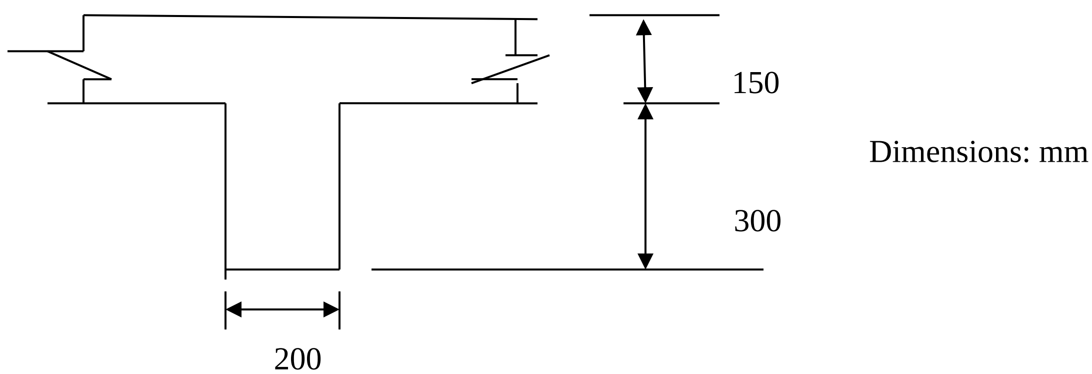

Figure 1.2: T- beam

Figure 1.2 shows a flanged beam subjected to flexure. The effective span l = 5.0 m, design moment = 300 kNm, f_{cu} = 40 N/mm^2, f_y = 460 N/mm^2 and concrete cover is 20 mm. Design the beam for ultimate limit state (approximate method).

(9 marks)

Question Two (20 Marks)

(a)(i) The BS 8110 design formula for an axially loaded reinforced concrete column is the equation 2.1:

$$Ultimate\ load\ N = 0.4f_{cu}A_c + 0.75f_yA_{sc} \qquad 2.1$$

Where:

$f_{cu} = the\ characteristic\ strength\ of\ the\ concrete,$

$f_y = the\ characteristic\ strength\ of\ the\ reinforcing\ steel,$

$A_c = area\ of\ concrete,$

$A_{sc} = area\ of\ reinforcing\ bars\ in\ compression$

From basic concepts derive this expression.

(6 marks)

(ii) Design a short braced reinforced concrete column for an axial load of 2500 kN.

Given: f_{cu} = 40 N/mm^2 and f_y = 460 N/mm^2.

(7 marks)

(b) Design the longitudinal reinforcement for a braced short column of dimensions 400 x 200 mm if ultimate axial load N = 1600 kN, moments M_x = 70 kNm. Characteristic strengths: f_{cu} = 40 N/mm^2 and f_y = 460 N/mm^2.

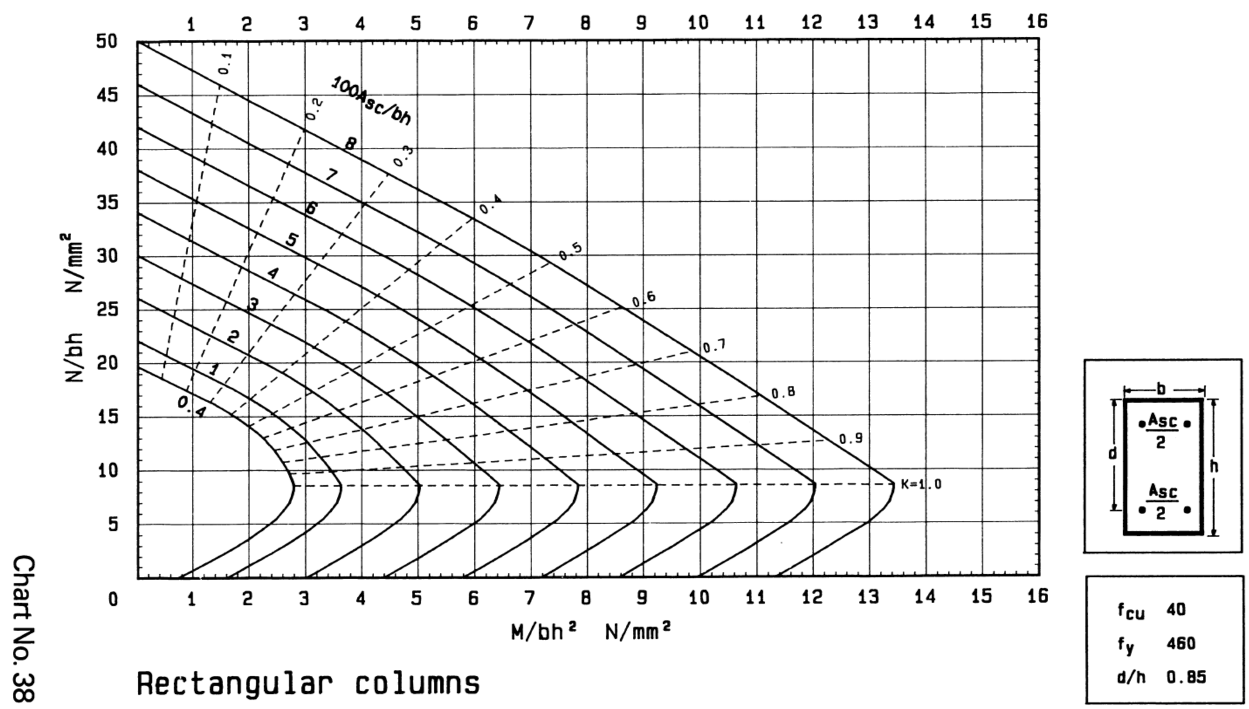

Fig.2.1: Column design chart – BS 8110

(7 marks)

Question Three (20 Marks)

Fig. 3.1 shows an interior concrete floor slab panel supported on reinforced concrete beams on all four sides. Using the relevant tables attached, design the slab for the ultimate limit state. The factored design load n = 35.0 kN/m^2, slab initial trial thickness = 150 mm, f_{cu} = 40 N/mm^2, f_y = 460N/mm^2.

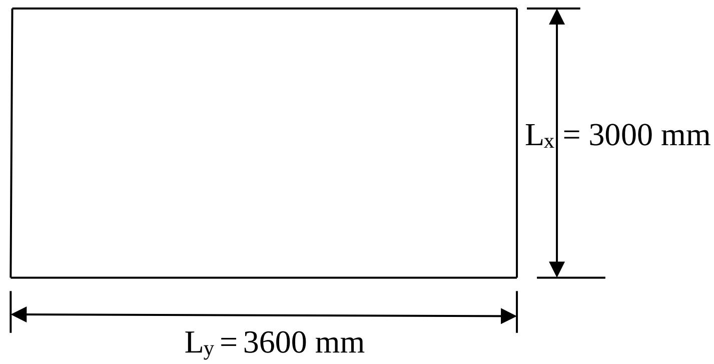

Fig. 3.1: Interior solid reinforced concrete floor slab panel

(20 marks)

Table 3.1: Bending moment coefficients (BS 8110: clause 3.5.3.4)

Bending moment coefficients for rectangular panels supported on four sides with provision for torsion at corners									
Type of panel and moments considered	Short span coefficients, β_{sx}								Long span coefficients, β_{sy}, for all values of l_y/l_x
	Values of l_y/l_x								
	1.0	1.1	1.2	1.3	1.4	1.5	1.75	2.0	
Interior panels									
Negative moment at continuous edge	0.031	0.037	0.042	0.046	0.050	0.053	0.059	0.063	0.032
Positive moment at mid-span	0.024	0.028	0.032	0.035	0.037	0.040	0.044	0.048	0.024

Table 3.2: Lever- arm and neutral axis depth factors

K = M/(bd^2f_{cu})	0.05	0.06	0.07
(z/d)	0.94	0.93	0.91
(x/d)	0.13	0.16	0.19

Table 3.3: Minimum areas of reinforcement in members (BS 8110: clause 3.12.5.1)

situation	Definition of percentage	Minimum percentage	
		f_y = 250 N/mm^2	f_y = 460 N/mm^2
		%	%
Tension reinforcement			
Rectangular section (in solid slabs, this minimum should be provided in both directions)	$100A_s/A_c$	0.24	0.13

Question Four (20 Marks)

A footing is required to transmit, from a 400 mm x 200 mm column with 16 mm diameter dowels, the following axial loads:

(i) Dead loads G_k = 750 kN,
(ii) Live loads Q_k = 250 kN.

Material characteristics:

Soil bearing pressure = 200 kN/m^2, f_{cu} = 40 N/mm^2 and f_y = 460 N/mm^2.

Design the footing to include the following checks

(i) Dowel anchorage
(ii) Punching shear,
(iii) Bending
(iv) Local bond stress,
(v) Shear

(20 marks)

Table 4.1: Anchorage lengths

[Anchorage length L = (K_A) (bar size)]

	K_A			
f_{cu} =	20	25	30	40 or more
Deformed Type 2 (460)				
Tension	46	41	35	30
Compression	31	27	24	20

Table 4.2: Design concrete shear stress v_c – for $f_{cu} \geq 40\ N/mm^2$

$\frac{100A_s}{b_v d}$	Effective depth d (mm)						
	150	175	200	225	250	300	≥ 400
≤ 0.15	0.50	0.48	0.47	0.45	0.44	0.42	0.40
0.25	0.60	0.57	0.55	0.54	0.53	0.50	0.47
0.50	0.75	0.73	0.70	0.68	0.65	0.63	0.59

Table 4.3: lever- arm and neutral axis depth factors

$K = M/(bd^2 f_{cu})$	0.05	0.06	0.07
(z/d)	0.94	0.93	0.91

Table 4.4: Ultimate local bond stress in beams (N/mm^2)

Bar type	Concrete grade			
	20	25	30	40 or more
Deformed, type 2	2.5	3.0	3.4	4.1

Table 4.5: minimum areas of reinforcement in members (BS 8110: clause 3.12.5.1)

Situation	Definition of percentage	Minimum percentage	
		f_y = 250 N/mm^2	f_y = 460 N/mm^2
		%	%
Tension reinforcement			
Rectangular section (in solid slabs, this minimum should be provided in both directions)	$100A_{sc}/A_c$	0.24	0.13

DESIGN TABLES

Table A1: Areas of groups of reinforcement bars (mm^2)

Bar Size (mm)	*Number of bars*									
	1	2	3	4	5	6	7	8	9	10
8	50	101	151	201	251	302	352	402	452	503
10	79	157	236	314	393	471	550	628	707	785
12	113	226	339	452	565	679	792	905	1017	1131
16	201	402	603	804	1005	1206	1407	1608	1809	2011
20	314	628	942	1257	1571	1885	2199	2513	2827	3142
25	491	982	1473	1963	2454	2945	3436	3927	4418	4909
32	804	1608	2412	3216	4021	4825	5629	6433	7237	8042
40	1256	2513	3769	5026	6283	7539	8796	1050	11310	12570

Table A2: Reinforcement - bar areas (mm^2) per metre width for various bar spacings

Bar Size (mm)	*Bar spacing* (mm)									
	75	100	125	150	175	200	225	250	275	300
8	671	503	402	335	287	252	223	201	183	168
10	1047	785	628	523	449	393	349	314	286	262
12	1508	1131	905	754	646	566	503	452	411	377
16	2681	2011	1608	1340	1149	1005	894	804	731	670
20	4189	3142	2513	2094	1795	1571	1396	1257	1142	1047
25	6545	4909	3927	3272	2805	2454	2182	1963	1785	1636
32	-	8042	6434	5362	4596	4021	3574	3217	2925	2681
40	-	-	10050	8378	7181	6283	5585	5027	4570	4189

Table A3: Design concrete shear stress v_c – for $f_{cu} \geq 40\ N/mm^2$ (BS 8110: clause 3.4.5.4)

$\frac{100A_s}{b_v d}$	Effective depth d (mm)						
	150	175	200	225	250	300	≥ 400
≤ 0.15	0.50	0.48	0.47	0.45	0.44	0.42	0.40
0.25	0.60	0.57	0.55	0.54	0.53	0.50	0.47
0.50	0.75	0.73	0.70	0.68	0.65	0.63	0.59
0.75	0.85	0.83	0.80	0.77	0.76	0.72	0.67
1.00	0.95	0.91	0.88	0.85	0.83	0.80	0.74
1.50	1.08	1.04	1.01	0.97	0.95	0.91	0.84
2.00	1.19	1.15	1.11	1.08	1.04	1.01	0.94
≥ 3.00	1.36	1.31	1.27	1.23	1.19	1.15	1.07