UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESI 2018/2019

COURSE NAME	:	STRUCTURAL DESIGN
COURSE CODE	:	DAC 31903
PROGRAMME CODE	:	DAA
EXAMINATION DATE	:	DECEMBER 2018/JANUARY 2019
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS IN PART A AND **ONE(1)** QUESTION IN PART B

THIS QUESTION PAPER CONSISTS OF **SEVENTEEN (17)** PAGES

PART A

Q1 (a) List the differences between ultimate limit state and serviceability limit state.

(2 marks)

(b) Explain the importance of partial safety factor in structural design.

(2 marks)

(c) Sketch the suitable location of reinforcement bar on **Figure Q1(c)**. Use any relevant assumption if needed.

(7 marks)

(d) A series of reinforced concrete beams of span 8 m and spaced 6 m centre to centre are designed to carry a one-way slab of 170 mm thick. The size of the beam is 550 mm height and 230 mm width. The columns that supports both ends of the beam are 240 mm by 240 in cross section. The slab carry the following load:

Tile finishes	=	1.8 kN/m^2
Imposed load	=	3.5 kN/m^2

Assuming the beam is simply supported, calculate:

(i) the ultimate design load,
(ii) the reaction on the column,
(iii) the maximum bending moment on the beam.

(14 marks)

Q2 (a) Determine the ultimate moment of resistance of a cross-section of a beam as shown in **Figure Q2(a)** using the simplified stress block in accordance to EC2. Given the following data:

Characteristic strength of steel, f_{yk}	=	500 N/mm^2
Characteristic strength of concrete, f_{ck}	=	25 N/mm^2

(10 marks)

(b) **Figure Q2(b)** shows a concrete slab size of 4.0 m x 7.0m and a thickness of 175 mm built to span two 400 mm thick walls. This slab is support by two main beams and two secondary beams. The main beam AB is constructed as a simply supported rectangular beam of 250 × 450 mm. Given the following data:

Characteristic strength of steel, f_{yk}	=	500 N/mm^2
Characteristic strength of concrete, f_{ck}	=	30 N/mm^2
Weight of concrete	=	25 kN/m^3
Weight of floor finishes	=	1.4 kN/m^2
Imposed load on floor	=	3.0 kN/m^2
Concrete cover	=	30 mm

(i) Calculate the design load on beam AB in kN/m.

(5 marks)

(ii) Calculate the design moment and reaction on the supports.

(2 marks)

(iii) Determine the main reinforcement needed for the beam.

(4 marks)

(iv) Check the minimum tension reinforcement and the maximum distance between bars.

(4 marks)

Q3 (a) Explain the difference between one way slab and two ways slab

(4 marks)

(b) Design the reinforcement for a simply supported slab of size 4.5 m x 6.3 m. The slab supports a variable load of 10 kN/m^2. Given the slab is 220 mm thick, f_{ck} = 25 N/mm^2 , f_{yk} = 500 N/mm^2 and exposure conditions XC-1.

(i) Determine ultimate load of the slab.

(5 marks)

(ii) Design the solid slab for main reinforcement.

(6 marks)

(iii) Design the solid slab for distribution reinforcement.

(6 marks)

(iv) Check the minimum of steel area.

(4 marks)

PART B

Q4 (a) **Figure Q4(a)** shows a braced column of size 400 mm x 300 mm and has a floor to floor height of 3000 mm. The column is monolithically connected to the beams as shown . Given the following data:

f_{ck} = 25 N/mm^2
Ultimate axial load, N_{ed} = 1280 kN

Determine whether the column is short or slender.

(8 marks)

(b) **Figure Q4(b)** shows a short-braced column of size 300 x 275 mm is subjected to an ultimate axial load of 1280 kN and bending moments of 35 kNm about z-z axis and 25 kNm about y-y axis. Given the following data:

f_{yk}	= 500 N/mm^2
f_{ck}	= 30 N/mm^2
diameter of link(assume)	= 8 mm
main reinforcement (assume)	= 20 mm
Cover	= 35 mm

(i) Determine whether the column should be design as unaxial bending or biaxial bending.

(3 marks)

(ii) Design the main reinforcement and link for the column.

(7 marks)

(iii) Determine the minimum reinforcement required and the spacing between ties.

(5 marks)

(iv) Sketch the column details.

(2 marks)

Q5 (a) Name the **four (4)** classes of steel section according to BS 5950.

(4 marks)

(b) **Figure Q5(b)** shows a main beam AC of size UB 406 x 178 x 74 kg/m which is simply supported on angles between two columns and carries a secondary beam at B. The design loading on the main beam AC is as shown.

The following are the properties of the main beam:

$p_y = p_{yw} = 275\ N/mm^2$		
D= 412.8 mm	b/T = 5.61	$Z_x = 1320\ cm^3$
B= 179.5 mm	d/T = 37.9	$Z_y = 172\ cm^3$
t= 9.5 mm	$S_x = 1500\ cm^3$	$A = 94.5\ cm^2$
T=16 mm	$S_y = 267 cm^3$	r = 10.2 mm
d=360 mm	$E = 205000\ N/mm^2$	$I_{xx} = 27300\ cm^4$

(i) Sketch the shear force and bending moment diagram of the main beam and calculate the maximum shear force and bending moment.

(6 marks)

(ii) Classify the beam cross-section.

(2 marks)

(iii) Check the shear capacity of the beam at the support.

(3 marks)

(iv) Check the moment capacity of the beam.

(5 marks)

(v) Check the deflection of beam AC under serviceability load based on the following values:

Imposed load, w_d (unfactored) = 6 kN/m
Point load, W_i (unfactored) = 18 kN

(Given the maximum deflection, $\partial = \frac{5w_d L^4}{384EI} + \frac{W_i a^2 b^2}{3EIL}$)

(5 marks)

-END OF QUESTIONS –

FINAL EXAMINATION

SEMESTER / SESSION : SEM 1 / 2018/2019 PROGRAMME CODE: DAA
COURSE NAME : STRUCTURAL DESIGN COURSE CODE : DAC 31903

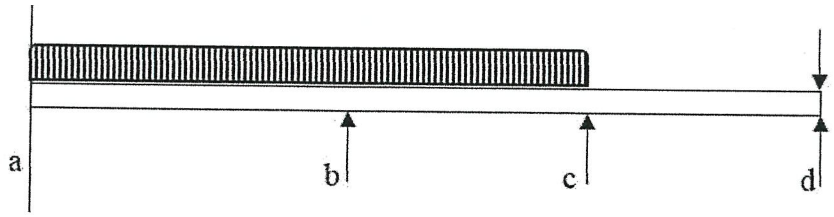


Figure Q1(c)

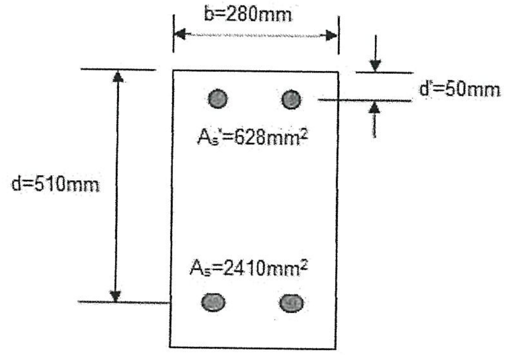


Figure Q2(a)

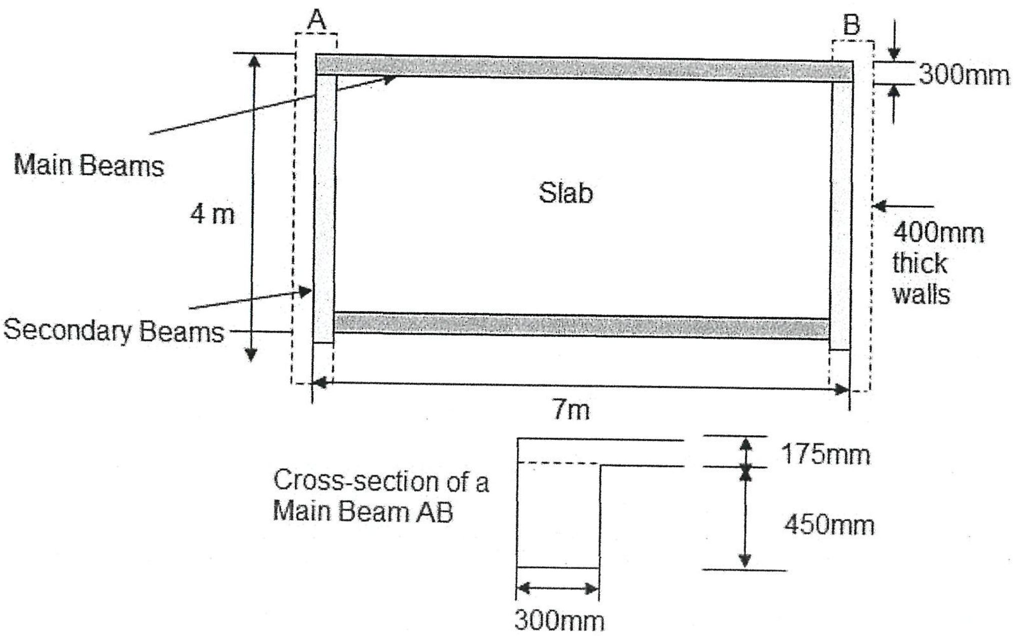


Figure: Q2 (b)

FINAL EXAMINATION

SEMESTER / SESSION : SEM 1 / 2018/2019
COURSE NAME : STRUCTURAL DESIGN

PROGRAMME CODE : DAA
COURSE CODE : DAC 31903

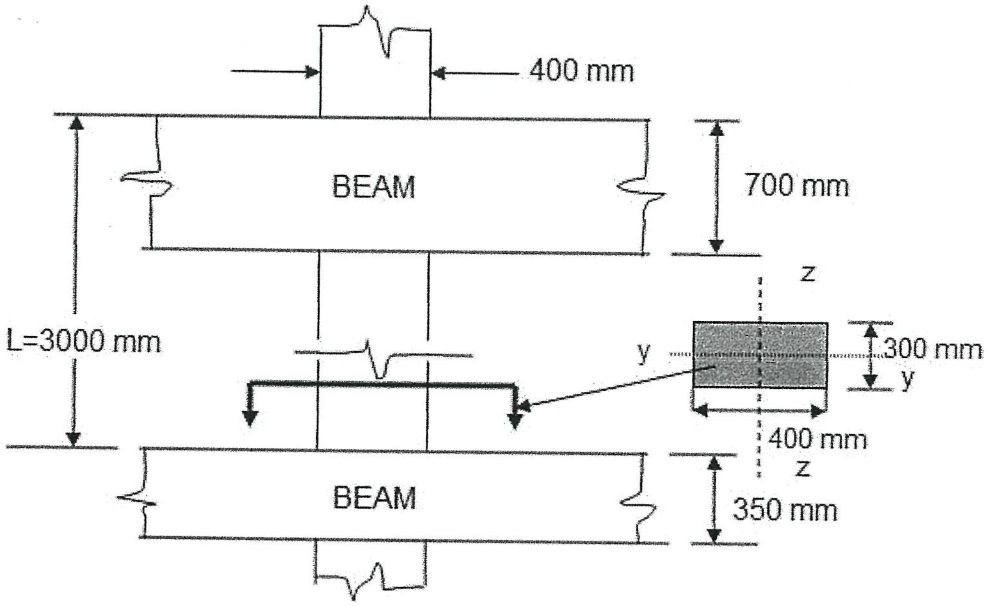


Figure Q4(a)

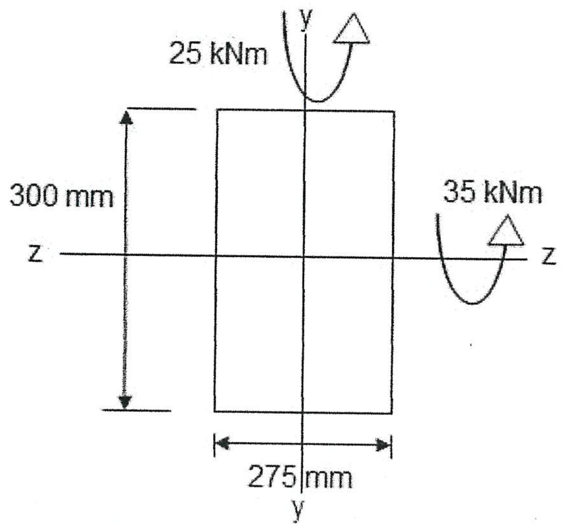


Figure Q4 (b)

FINAL EXAMINATION

SEMESTER / SESSION : SEM 1 / 2018/2019
COURSE NAME : STRUCTURAL DESIGN

PROGRAMME CODE : DAA
COURSE CODE : DAC 31903

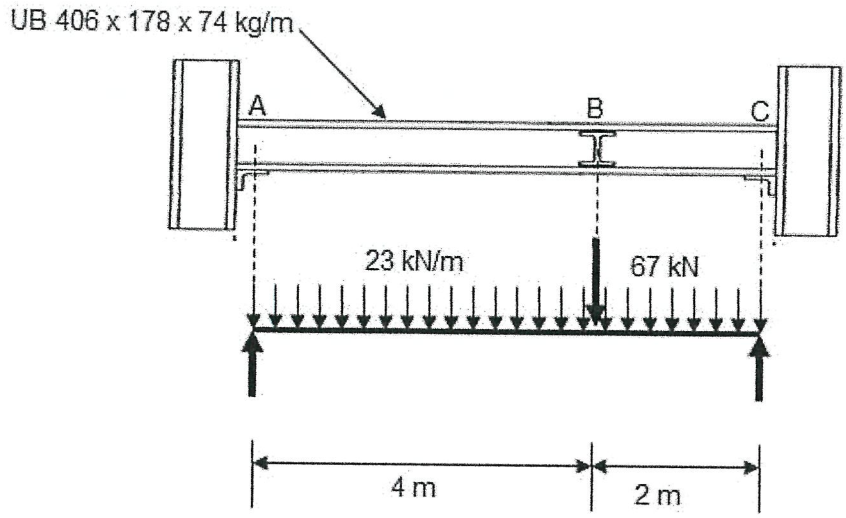


Figure Q5(b)

FINAL EXAMINATION

SEMESTER / SESSION : SEM 1 / 2018/2019
COURSE NAME : STRUCTURAL DESIGN

PROGRAMME CODE : DAA
COURSE CODE : DAC 31903

APPENDIX 1

Table 1: Cross Sectional Area (mm^2) according to Size and Numbers of Bar

Bar Size (mm)	Number of bar								Perimeter (mm)
	1	2	3	4	5	6	7	8	
H6	28.3	56.6	84.9	113	141	170	198	226	18.9
H8	50.3	101	151	201	251	302	352	402	25.1
H10	78.6	157	236	314	393	471	550	629	31.4
H12	113	226	339	453	566	679	792	905	37.7
H16	201	402	603	805	1006	1207	1408	1609	50.3
H20	314	629	943	1257	1571	1886	2200	2514	62.9
H25	491	982	1473	1964	2455	2946	3438	3929	78.6
H32	805	1609	2414	3218	4023	4827	5632	6437	100.6
H40	1257	2514	3771	5029	6286	7543	8800	10057	125.7

Table 2: Cross Sectional Area (mm^2) for every meter width at distance between bar

Bar Size (mm)	Distance between Bar (mm)									
	50	75	100	125	150	175	200	250	300	350
H6	566	377	283	226	189	162	141	113	94	81
H8	1006	670	503	402	335	287	251	201	168	144
H10	1571	1048	786	629	524	449	393	314	262	224
H12	2263	1509	1131	905	754	647	566	453	377	323
H16	4023	2682	2011	1609	1341	1149	1006	805	670	574
H20	6286	4190	3143	2514	2095	1796	1571	1257	1048	898
H25	9821	6548	4911	3929	3274	2806	2455	1964	1637	1402
H32	16091	10728	8046	6437	5364	4598	4023	3218	2682	2298
H40	25143	16762	12571	10057	8381	7184	6286	5029	4190	3590

Design Formula For Beam

$K = M/bd^2f_{ck}$

$$z = \frac{d}{2}\left[1+\sqrt{1-3.53K}\right] \leq 0.95d$$

$$A_s = \frac{M_d}{0.87 f_{yk} z}$$

If K > 0.167

$$z = \frac{d}{2}\left[1+\sqrt{1-3.53K'}\right]$$

$$A_s' = \frac{(K-K')f_{ck}bd^2}{0.87 f_{yk}(d-d')}$$

$$A_s = \frac{K' f_{ck}bd^2}{0.87 f_{yk} z_{bal}} + A_s'$$

TERBUKA

FINAL EXAMINATION

SEMESTER / SESSION : SEM 1 / 2018/2019
COURSE NAME : STRUCTURAL DESIGN

PROGRAMME CODE : DAA
COURSE CODE : DAC 31903

APPENDIX 2

Table 3: Nominal concrete cover to reinforcement for concrete made with OPC for a 50-year design life

Exposure class	Nominal cover to all reinforcement (mm)							
	25	30	35	40	45	50	55	60
XC1	C20/25 0.7 240							
XC2			C25/30 0.65 260					
XC3/4		C40/50 0.45 340	C32/40 0.55 300	C28/35 0.6 280	C25/30 0.65 260			
XD1			C40/50 0.45 360	C32/40 0.55 320	C28/35 0.60 300			
XD2				C40/50 0.40 380	C32/40 0.50 340	C28/35 0.55 320		
XD3						C45/55 0.35 380	C40/50 0.40 380	C35/45 0.45 360
XS1				C50/60 0.35 380	C40/50 0.45 360	C35/45 0.50 340		
XS2				C40/50 0.40 380	C32/40 0.50 340	C28/35 0.55 320		
XS3							C45/55 0.35 380	C40/50 0.40 380
Key to entries:		C40/50 0.40 380	← Minimum concrete grade ← Maximum water/cement ratio ← Minimum cement content in kg/m^3					

Table 4: Bending coefficients for slab spanning in two directions at right angle, simply supported on all four sides

l_y/l_x	1.0	1.1	1.2	1.3	1.4	1.5	1.75	2.0
α_{sx}	0.062	0.074	0.084	0.093	0.099	0.104	0.113	0.118
α_{sy}	0.062	0.061	0.059	0.055	0.051	0.046	0.037	0.029

Table 5: Minimum percentage of tensile reinforcement in beams and slabs

Conc. strength f_{ck} (N/mm^2)	25	28	30	32	35	40	45	50
Minimum % of reinforcement	0.14	0.15	0.15	0.16	0.17	0.19	0.20	0.22

This table uses $0.016f_{ck}^{2/3}$ as recommended by the *IStructE manual for the design of concrete building structures to Eurocode 2* in place of $0.0156f_{ck}^{2/3}$ in EC2.

FINAL EXAMINATION

SEMESTER / SESSION : SEM 1 / 2018/2019
COURSE NAME : STRUCTURAL DESIGN
PROGRAMME CODE : DAA
COURSE CODE : DAC 31903

APPENDIX 3

Table 6 : Maximum bar size or maximum bar spacing for 0.3-mm crack width limit for load-induced cracking in beams and in slabs more than 200 mm thick

Steel stress (N/mm^2): see note 1	160	200	240	280	320	360	400
Max. bar size Max. bar spacing (mm)	H32 300	H25 250	H16 200	H12 150	H10 100	H8 50	H6 –

Notes:
(1) These rules do not apply to secondary or distribution reinforcement.
(2) The steel stress can be taken as $435(G_k + 0.8Q_k)/(1.35G_k + 1.50Q_k)$ N/mm^2, or conservatively as 320 N/mm^2.
(3) Cracks may be controlled by meeting either the max. bar spacing requirement *or* the max. bar size requirement. It is not necessary to meet both requirements. For example, if the steel stress is 280 N/mm^2 then either bars of size H12 or smaller can be used at any spacing or bars of any size can be used at a spacing of 150 mm or less.
(4) Data are from Tables 7.2N and 7.3N of EC2 Part 1-1.

Design Formula For Slab

$m_{sx} = \alpha_{sx} n l_x^2$ $m_{sy} = \alpha_{sY} n l_x^2$ where: n – total design ultimate load per unit area $(1.35G_k + 1.5\ Q_k)$ l_x- length of shorter side	$A_{sx} = M_{sx}/0.87f_{yk}z$ $A_{sy} = M_{sy}/0.87f_{yk}z$

FINAL EXAMINATION

SEMESTER / SESSION : SEM 1 / 2018/2019
COURSE NAME : STRUCTURAL DESIGN

PROGRAMME CODE : DAA
COURSE CODE : DAC 31903

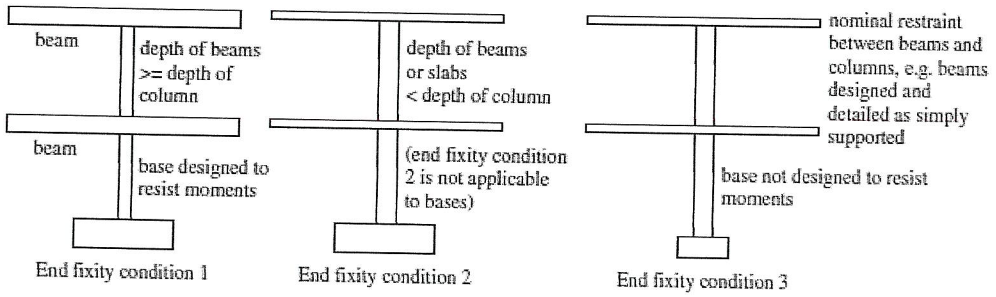
APPENDIX 4

Column Design

Table 7: Ends Fixity of reinforced concrete column

End condition at bottom	End condition at top		
	1	2	3
1	0.75	0.80	0.90
2	0.80	0.85	0.95
3	0.90	0.95	1.00

End fixity conditions, see Figure 3.26.
Condition 1: Column is connected monolithically to beams on each side that are at least as deep as the overall depth of the column in the plane considered. Where column is connected to a foundation this should be designed to carry moment.
Condition 2: Column connected monolithically to beams or slabs on each side that are shallower than the overall depth of the column in the plane considered but generally not less than half the column depth.
Condition 3: Column connected to members that do not provide more than nominal restraint to rotation.
Values taken from *IStructE Manual for the Design of Reinforced Concrete Building Structures to Eurocode 2.*



Limiting l_0 / b ratio = $\mathbf{6.19\sqrt{(bhf_{ck} / N_{Ed})}}$

FINAL EXAMINATION

SEMESTER / SESSION : SEM 1 / 2018/2019
COURSE NAME : STRUCTURAL DESIGN

PROGRAMME CODE : DAA
COURSE CODE : DAC 31903

APPENDIX 5

Table 8 : Limits on longitudinal reinforcement in columns

Area of longitudinal reinforcement.	Not less than or Not more than or	$0.12N/f_{yk}$ $0.002bh$ $0.04bh$ generally $0.08bh$ at laps
Size of longitudinal reinforcement	Not less than	12 mm
Number of longitudinal bars	Not fewer than	4 in a square column 6 in a circular column

Table 9 : Limits on ties in reinforced concrete columns

Size of ties	Not less than or	main bar size/4 6 mm
Spacing of ties generally	Not less than or or	20 × main bar diameter the least column dimension 400 mm
Spacing of ties over a height equal to the larger dimension of the column above or below a beam or slab	Not more than or or	12 × main bar diameter 0.6 × the least column dimension 240 mm
Spacing of ties where longitudinal bars exceeding 12 mm in size are lapped	Not more than or or	12 × main bar diameter 0.6 × the least column dimension 240 mm

FINAL EXAMINATION

SEMESTER / SESSION : SEM 1 / 2018/2019
COURSE NAME : STRUCTURAL DESIGN

PROGRAMME CODE : DAA
COURSE CODE : DAC 31903

APPENDIX 6

$\frac{e_z}{h} / \frac{e_y}{b} \geq 0.2$ and $\frac{e_y}{b} / \frac{e_z}{h} \geq 0.2$

(a) if $\frac{M_z}{h'} \geq \frac{M_y}{b'}$

then the increased single axis design moment is

$M'_z = M_z + \beta \frac{h'}{b'} \text{ x } M_y$

(b) if $\frac{M_z}{h'} < \frac{M_y}{b'}$

then the increased single axis design moment is

$M'_y = M_y + \beta \frac{b'}{h'} \text{ x } M_z$

Table 10: Coefficient of β

$\frac{N_{ED}}{bhf_{ck}}$	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	≥0.75
β	1.00	0.91	0.81	0.72	0.63	0.53	0.44	0.35	0.3

FINAL EXAMINATION

SEMESTER / SESSION : SEM 1 / 2018/2019 PROGRAMME CODE : DAA
COURSE NAME : STRUCTURAL DESIGN COURSE CODE : DAC 31903

APPENDIX 7

CHART NO 1

Column design chart for rectangular columns $d_2/h = 0.05$

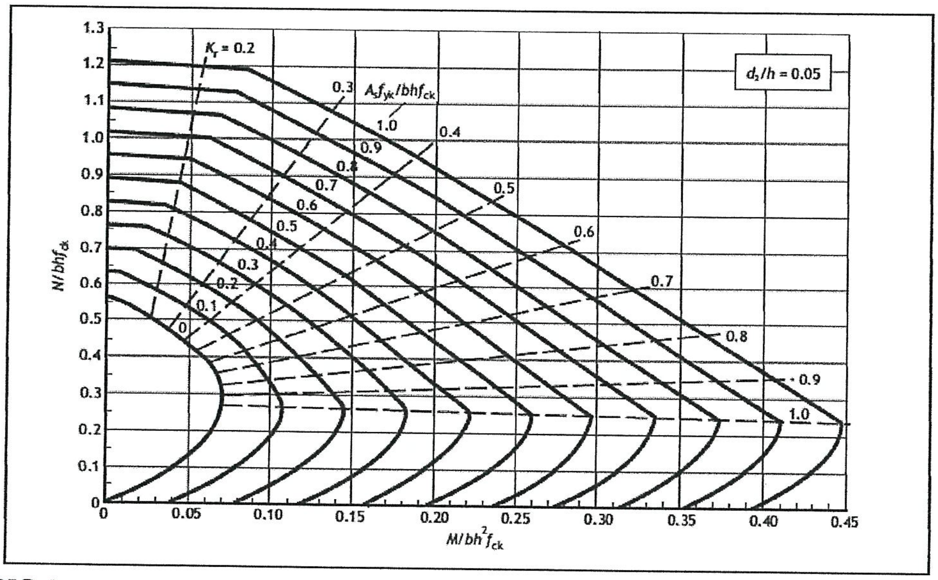
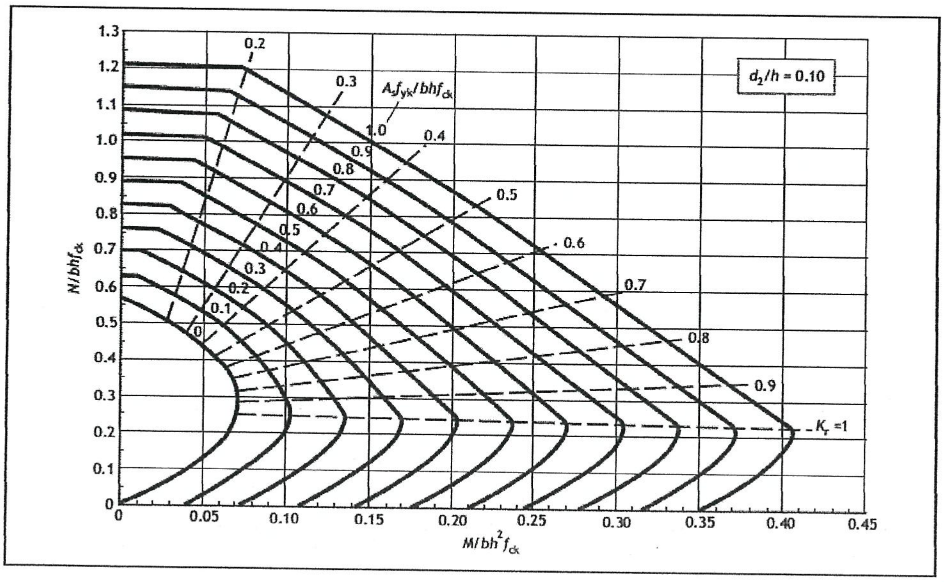


CHART NO 2

Column design chart for rectangular columns $d_2/h = 0.10$



FINAL EXAMINATION

SEMESTER / SESSION : SEM 1 / 2018/2019
COURSE NAME : STRUCTURAL DESIGN

PROGRAMME CODE : DAA
COURSE CODE : DAC 31903

APPENDIX 8

CHART NO 3

Column design chart for rectangular columns $d_2/h = 0.15$

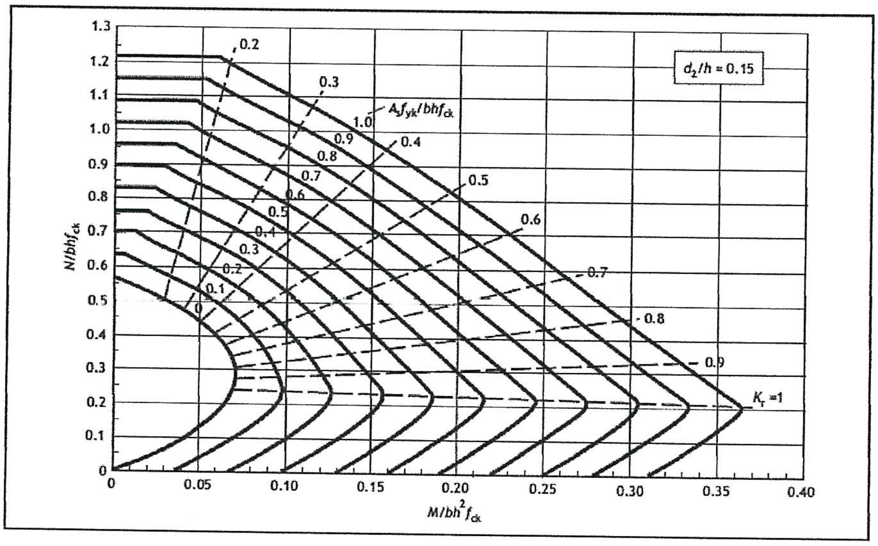
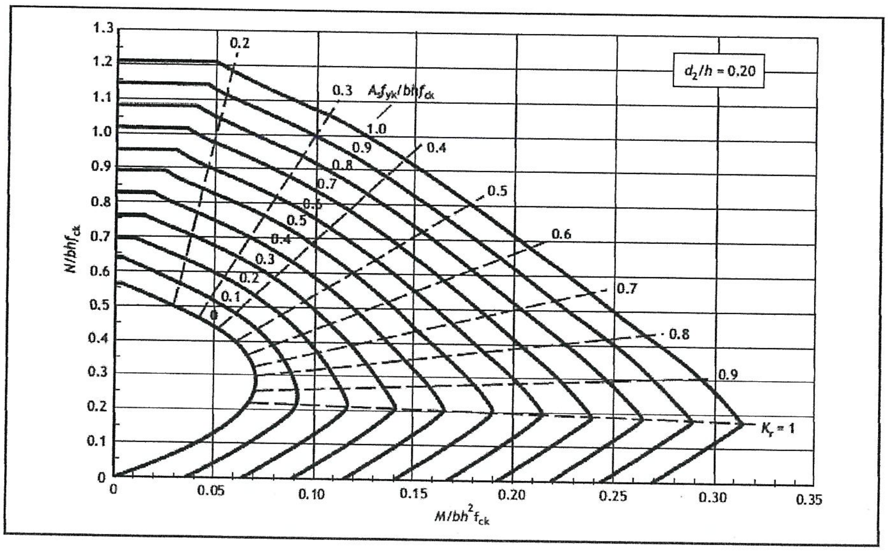


CHART NO 4

Column design chart for rectangular columns $d_2/h = 0.20$



FINAL EXAMINATION

SEMESTER / SESSION : SEM 1/2018/2019
COURSE NAME : STRUCTURAL DESIGN

PROGRAMME CODE : DAA
COURSE CODE : DAC31903

APPENDIX 9

Steel Design

Table 11 — Limiting width-to-thickness ratios for sections other than CHS and RHS

Compression element			Ratio[a]	Limiting value[b]		
				Class 1 plastic	Class 2 compact	Class 3 semi-compact
Outstand element of compression flange	Rolled section		b/T	9ε	10ε	15ε
	Welded section		b/T	8ε	9ε	13ε
Internal element of compression flange	Compression due to bending		b/T	28ε	32ε	40ε
	Axial compression		b/T	Not applicable		
Web of an I-, H- or box section[c]	Neutral axis at mid-depth		d/t	80ε	100ε	120ε
	Generally[d]	If r_1 is negative:	d/t	$\frac{80\varepsilon}{1+r_1}$ but $\geq 40\varepsilon$	$\frac{100\varepsilon}{1+r_1}$	$\frac{120\varepsilon}{1+2r_2}$ but $\geq 40\varepsilon$
		If r_1 is positive:	d/t		$\frac{100\varepsilon}{1+1.5r_1}$ but $\geq 40\varepsilon$	
	Axial compression[d]		d/t	Not applicable		

Where $\varepsilon = (275/p_y)^{1/2}$

a) for I- or H-sections with equal flanges:

$$r_1 = \frac{F_c}{dtp_{yw}} \text{ but } -1 < r_1 \leq 1$$

$$r_2 = \frac{F_c}{A_g p_{yw}}$$

Clause 4.2.3 : The shear force, F_v, should not exceed the shear capacity, P_v

$$F_v \leq P_v \quad \text{.................(1)}$$

Where $P_v = 0.6\, p_y A_v$ ....(2) $A_v = tD$

Clause 4.2.5.2: Low shear and Moment Capacity

If shear force $F_v < 0.6P_v$,

For Class 1 Plastic or Class 2 compact, the moment capacity is:

$$M_c = p_y S \leq 1.2\, p_y Z_x \text{ ....(3)}$$

Design strength, p_y

Steel grade 275, Thickness <16 mm, $p_y = 275$ N/mm^2
Thickness <40 mm, $p_y = 265$ N/mm^2