UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2015/2016

COURSE NAME	:	REINFORCED CONCRETE DESIGN 1
COURSE CODE	:	BFC 32102
PROGRAMME	:	BACHELOR OF CIVIL ENGINEERING WITH HONOURS
EXAMINATION DATE	:	DECEMBER 2015/ JANUARY 2016
DURATION	:	2 HOURS AND 30 MINUTES
INSTRUCTION	:	1. ANSWER **ALL** QUESTIONS IN **SECTION A** AND **THREE (3)** QUESTIONS IN **SECTION B** 2. DESIGN SHOULD BE BASED ON: BS EN 1990:2002+A1:2005 BS EN 1991-1-1:2002 BS EN 1992-1-1:2004

THIS QUESTION PAPER CONSISTS OF **THIRTEEN (13)** PAGES

SECTION A: ANSWER ALL QUESTIONS

Q1 (a) The requirement for minimum area of reinforcement that must be provided within tensile zone is described in Section 7.3.2 and Section 9.2.1 EN 1992-1-1. Explain the purpose and importance of the minimum area of reinforcement in reinforced concrete design.

(4 marks)

(b) In reinforced concrete design, slab can be analysed using an elastic method. Describe **THREE (3)** techniques of elastic method that can be implemented to calculate shear force and bending moment of slab. What are the alternative methods used to determine shear force and bending moment?

(8 marks)

(c) An architecture plan of first floor resident house is shown in **FIGURE Q1**. By using an appropriate approach, produce a complete engineering layout of the floor plan.

(10 marks)

(d) Based on the engineering layout in **(c)**, propose a suitable size of beam and thickness of slab.

(3 marks)

SECTION B: ANSWER THREE (3) QUESTIONS ONLY

Q2 (a) A T-section beam as shown in **FIGURE Q2** is designed to resist an ultimate moment of 430 kNm. The characteristics strength of concrete and steel are 30 N/mm^2 and 500N/mm^2 respectively. Draw the stress block diagram and determine the required area of reinforcement with an assumption that the design of T-section beam is conservative.

(9 marks)

(b) A simply supported beam with length of 5.6 m carries a distributed permanent action of 50 kN/m (excluded selfweight of beam) and a variable action of 10 kN/m. The size of beam is 250 mm × 500 mm. The characteristics strength of concrete and steel are 25 N/mm^2 and 500 N/mm^2 respectively. The beam is located inside building (XC1) and subjected to 1-hour fire resistance. The design life of building is 50 years. Assume the diameter of reinforcements, $Ø_{bar1}$=20 mm (tension), $Ø_{bar2}$=16 mm (compression, if required) and $Ø_{link}$=8 mm.

(i) Calculate the nominal cover of beam.

(4 marks)

(ii) Design the flexural reinforcement and sketch simple detailing of the beam.

(12 marks)

Q3 <u>**FIGURE Q3**</u> shows part of a first floor office plan. All beams and slabs are cast simultaneously with specification of long-term water contact, 1-hour fire resistance and 50 years design life. Given the following data:

Cross-section of beam ($b \times h$)	= 250 mm × 500mm
Thickness of slab	= 100 mm
Nominal cover	= 35 mm
Concrete strength	= C25/30
Characteristic strength of steel	= 500 N/mm^2

Assume the diameter of reinforcements, $Ø_{bar1}$ =12mm (tension), $Ø_{bar2}$=10mm (compression), $Ø_{link}$=8mm. Meanwhile, the total characteristic variable and permanent actions on T-beam 2/A-D are 9 kN/m and 12 kN/m respectively.

(a) Determine the shear force and bending moment of T-beam 2/A-D.

(4 marks)

(b) Analyse b_{eff} and illustrate the cross-section of T-beam at each span. Use appropriate label for the dimension and necessary property of the beam.

(9 marks)

(c) Design the middle span of T-beam 2/A-D.

(12 marks)

Q4 <u>**FIGURE Q4**</u> shows a continuous beam with various spans around 8 m to 8.8m. Given the following data:

Total permanent action	= 22 kN/m
Total variable action	= 10 kN/m
Dimension of beam ($b \times h$)	= 200 mm × 500 mm
Effective depth, d	= 450 mm
Effective depth, d'	= 50 mm
Diameter of reinforcement, $Ø_{bar1}$	= 20 mm
Diameter of reinforcement, $Ø_{bar2}$	= 16 mm
Diameter of reinforcement, $Ø_{link}$	= 8 mm

(a) By using Simplified Method, draw the shear force and bending moment diagrams of the beam.

(4 marks)

(b) Based on analysis in **(a)**, design the critical part of beam using a rectangular section. Use f_{ck} =30 N/mm^2 and f_{yk} = 500 N/mm^2.

(12 marks)

(c) Design the shear link at the critical support.

(9 marks)

Q5 A plan view of continuous slab for a leisure building is shown in **FIGURE Q5**. The slab is supported by beams of size 200 mm × 450 mm spaced at 4.8 m centers. The variable and permanent actions of slab are 3.0 kN/mm^2 and 1.5 kN/mm^2 respectively. The strength of concrete according to cube test is 30 N/mm^2. Meanwhile, the characteristic strength of steel reinforcement is 500 N/mm^2. The slab is inside the building that subjected to 90 minutes fire resistance and 50 years design life.

(a) Determine the design actions of slab by assuming that the thickness is 150mm.

(4 marks)

(b) Design the main reinforcement of slab at first interior support and end span. Use steel reinforcement with diameter 16mm.

(12 marks)

(c) Check the deflection of slab.

(9 marks)

- END OF QUESTION -

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1' = 0.305 m

FIGURE Q1

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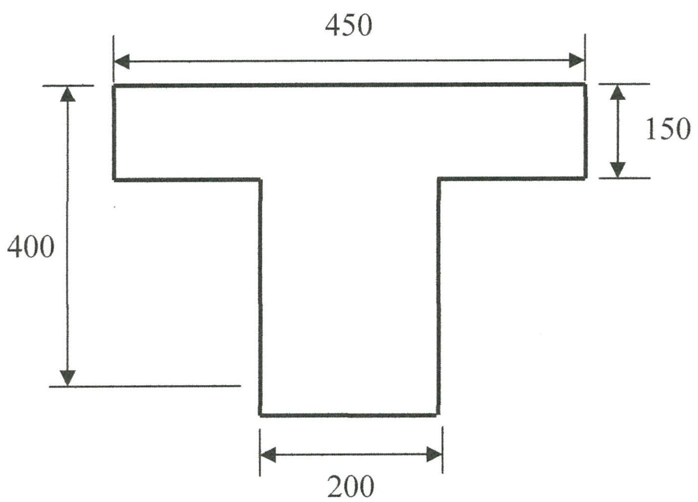

FIGURE Q2

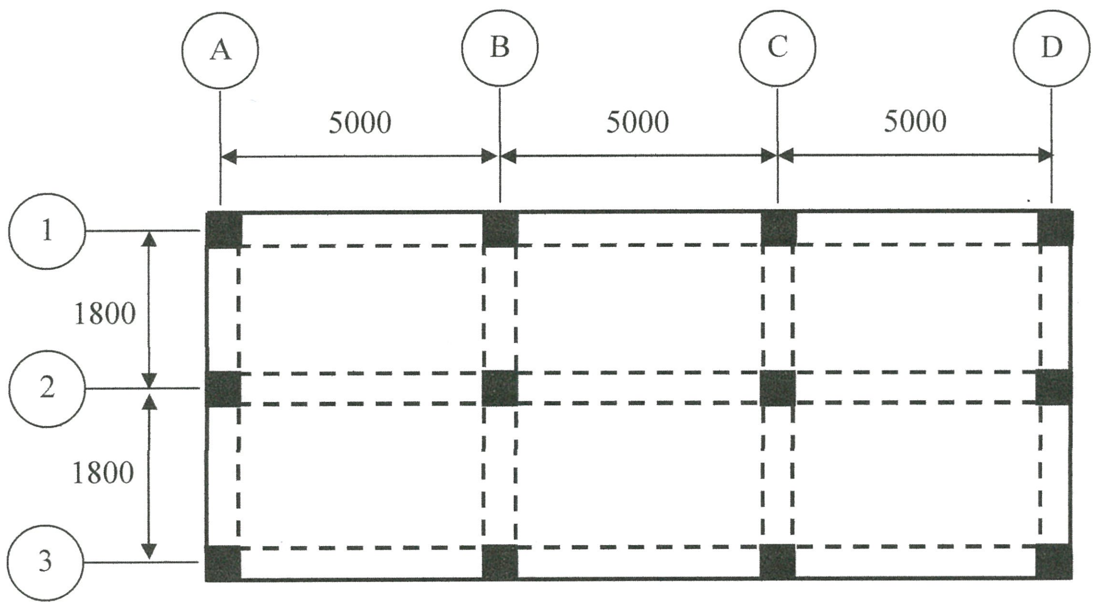

FIGURE Q3

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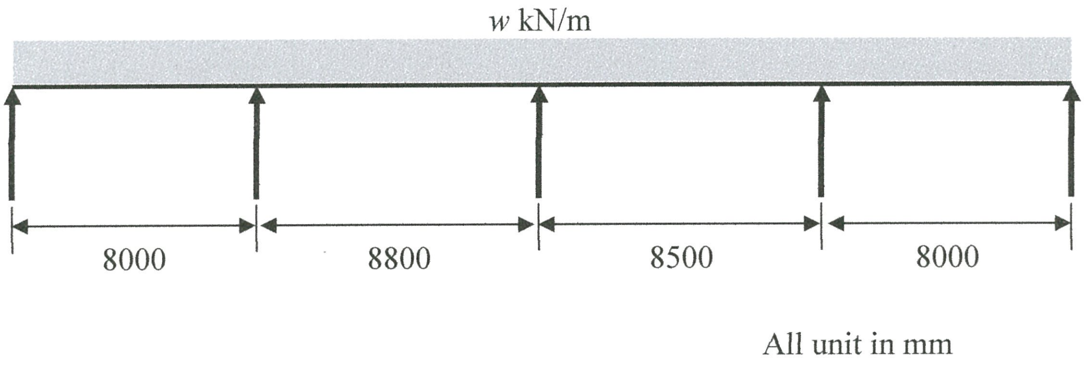

FIGURE Q4

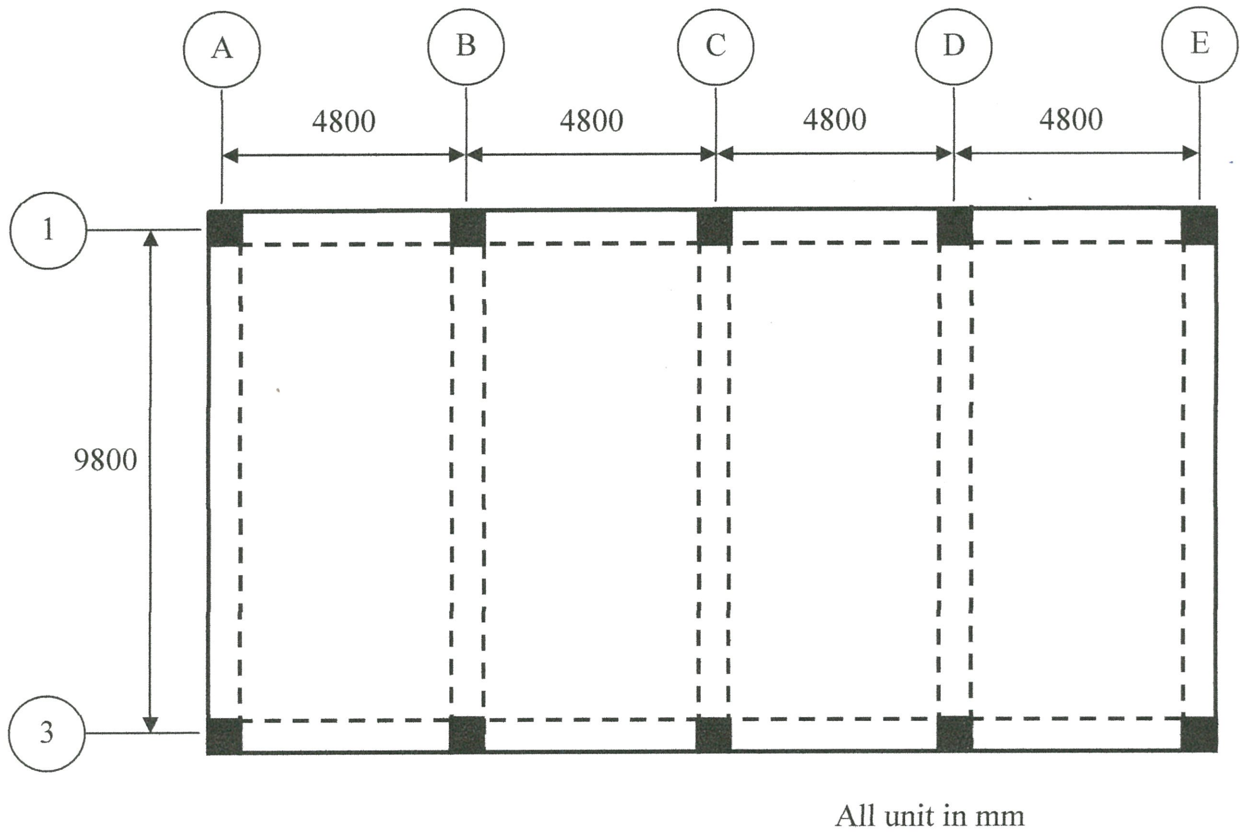

FIGURE Q5

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FORMULA

$$A_S' = \frac{(K - K_{bal}) f_{ck} b d^2}{0.87 f_{yk} (d - d')} \qquad \text{if } \frac{d'}{x} \le 0.38$$

$$A_S' = \frac{(K - K_{bal}) f_{ck} b d^2}{f_{sc} (d - d')} \qquad \text{if } \frac{d'}{x} > 0.38$$

$$f_{sc} = 700\left(1 - \frac{d'}{x}\right)$$

$$A_S = \frac{K_{bal} f_{ck} b d^2}{0.87 f_{yk} (d - d')} + A_S'\left(\frac{f_{sc}}{0.87 f_{yk}}\right)$$

$$V_{Rd,max} = \frac{0.36 b d f_{ck} (1 - f_{ck} / 250)}{cot\theta + tan\theta}$$

$$\theta = 0.5 \sin^{-1}\left(\frac{V_{Ed}}{0.18 b d f_{ck} (1 - f_{ck} / 250)}\right)$$

$$\frac{A_{sw}}{S} = \frac{V_{Ed}}{0.78 f_{yk} d \cot\theta}$$

$$\frac{A_{sw,max}}{S} = \frac{0.08 f_{ck}^{1/2} b_w}{f_{yk}}$$

$$f_s = \frac{f_{yk}}{1.15}\left[\frac{G_k + 0.3Q_k}{1.35G_k + 1.5Q_k}\right]\frac{1}{\delta}$$

$$\frac{l}{d} = K\left[11 + 1.5\sqrt{f_{ck}}\frac{\rho_o}{\rho} + 3.2\sqrt{f_{ck}}\left(\frac{\rho_o}{\rho} - 1\right)^{3/2}\right] \qquad \text{if } \rho \le \rho_o$$

$$\frac{l}{d} = K\left[11 + 1.5\sqrt{f_{ck}}\frac{\rho_o}{\rho - \rho'} + \frac{1}{12}\sqrt{f_{ck}}\sqrt{\frac{\rho'}{\rho}}\right] \qquad \text{if } \rho > \rho_o$$

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$$b_{eff} = \Sigma b_{eff,i} + b_w \le b$$

$$b_{eff,i} = 0.2b_i + 0.1l_o \le 0.2l_o$$

$$M = \left(0.567 f_{cu} b_{eff} 0.8x\right)\left(d - 0.4x\right)$$

$$M_f = \left(0.567 f_{ck} b h_f\right)\left(d - h_f / 2\right)$$

$$M_{bal} = \beta_f f_{ck} b_{eff} d^2$$

$$A_s = \frac{M}{0.87 f_{yk}(d - 0.4x)} \qquad \text{if} \quad M < M_f$$

$$A_s = \frac{M + 0.1 f_{ck} b_w d[0.36d - h_f]}{0.87 f_{yk}(d - 0.5h_f)} \qquad \text{if} \quad M < M_{bal}$$

$$A_s = \frac{0.2 f_{ck} b_w d + 0.567 f_{ck} h_f (b_{eff} - b_w)}{0.87 f_{yk}} + A_s' \qquad \text{if} \quad M > M_{bal}$$

$$A_s' = \frac{M - M_{bal}}{0.87 f_{yk}(d - d')} \qquad \text{if} \quad M > M_{bal}$$

$$\frac{M_{bal}}{f_{ck} b_{eff} d^2} = 0.167 \frac{b_w}{b_{eff}} + 0.567 \frac{h_f}{d}\left(1 - \frac{b_w}{b_{eff}}\right)\left(1 - \frac{h_f}{2d}\right)$$

$$V_{Rd,c} = [0.12k(100\rho_1 f_{ck})^{1/3}]b_w d$$

$$V_{\min} = [0.035k^{3/2} f_{ck}^{\ 1/2}]b_w d$$

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Table 1: Minimum dimensions and axis distances for simply supported beams made with reinforced and prestressed concrete (Source: *BS EN 1992 -1-2)*

Standard fire resistance	Minimum dimensions (mm)						
	Possible combinations of a and b_{min} where a is the average axis distance and b_{min} is the width of beam				Web thickness b_w		
					Class WA	Class WB	Class WC
1	2	3	4	5	6	7	8
R 30	$b_{min} = 80$ $a = 25$	120 20	160 15*	200 15*	80	80	80
R 60	$b_{min} = 120$ $a = 40$	160 35	200 30	300 25	100	80	100
R 90	$b_{min} = 150$ $a = 55$	200 45	300 40	400 35	110	100	100
R 120	$b_{min} = 200$ $a = 65$	240 60	300 55	500 50	130	120	120
R 180	$b_{min} = 240$ $a = 80$	300 70	400 65	600 60	150	150	140
R 240	$b_{min} = 280$ $a = 90$	350 80	500 75	700 70	170	170	160
$a_{sd} = a + 10$mm (see note below)							

For prestressed beams the increase of axis distance according to 5.2(5) should be noted.

a_{sd} is the axis distance to the side of beam for the corner bars (or tendon or wire) of beams with only one layer of reinforcement. For values of b_{min} greater than that given in Column 4 no increase of a_{sd} is required.

* Normally the cover required by EN 1992-1-1 will control.

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Table 2: Minimum dimensions and axis distances for reinforced and prestressed concrete simply supported one-way and two-way solid slabs (Source: *BS EN 1992 -1-2)*

(1) Table 5.8 provides minimum values of axis distance to the soffit of simply supported slabs for standard fire resistance of R 30 and to R 40,
(2) In two-way spanning slabs, *a* denotes the axis distance of the reinforcement in the lower layer.

Standard fire resistance	Minimum dimensions (mm)			
	slab thickness h_s (mm)	axis-distance a		
		one way	two way:	
			$l_y/l_x \leq 1,5$	$1,5 < l_y/l_x < 2$
1	2	3	4	5
REI 30	60	10*	10*	10*
REI 60	80	20	10*	15*
REI 90	100	30	15*	20
REI 120	120	40	20	25
REI 180	150	55	30	40
REI 240	175	65	40	50

l_x and l_y are the spans of a two-way slab (two directions at right angles) where l_y is the longer span.

For prestressed slabs the increase of axis distance according to 5.2(5) should be noted.

The axis distance *a* in Column 4 and 5 for two-way slabs relate to slabs supported at all four edges. Otherwise, they should be treated as one-way spanning slab.

* Normally the cover required by EN 1992-1-1 will control.

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Table 3: Design ultimate bending moments and shear forces (Source: *BS 8110 -1: 1997*)

	At outer support	Near middle of end span	At first interior support	At middle of interior spans	At interior supports
Moment	0	0.09Fl	-0.11Fl	0.07Fl	-0.08Fl
Shear	0.45F	-	0.6F	-	0.55F

NOTE: l is the effective span;
F is the total design ultimate load ($1.35G_k + 1.5\ Q_k$)
No redistribution of the moment calculated from this table should be made.

Table 4: Ultimate bending moment and shear force in one-way spanning slabs (Source: *BS 8110 -1: 1997*)

	End support/slab connection				At first interior support	Middle interior spans	Interior supports
	Simple		Continuous				
	At outer support	Near middle of end span	At outer support	Near middle of end span			
Moment	0	0.086Fl	-0.04Fl	0.075Fl	-0.086Fl	0.063Fl	-0.063Fl
Shear	0.45F	-	0.46F	-	0.6F	-	0.5F

NOTE: l is the effective span;
F is the total design ultimate load ($1.35G_k + 1.5\ Q_k$)

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Table 5: 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	
6	28.3	56.6	84.9	113	141	170	198	226	18.9
8	50.3	101	151	201	251	302	352	402	25.1
10	78.6	157	236	314	393	471	550	629	31.4
12	113	226	339	453	566	679	792	905	37.7
16	201	402	603	805	1006	1207	1408	1609	50.3
20	314	629	943	1257	1571	1886	2200	2514	62.9
25	491	982	1473	1964	2455	2946	3438	3929	78.6
32	805	1609	2414	3218	4023	4827	5632	6437	100.6
40	1257	2514	3771	5029	6286	7543	8800	10057	125.7

Table 6: 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
6	566	377	283	226	189	162	141	113	94
8	1006	670	503	402	335	287	251	201	168
10	1571	1048	786	629	524	449	393	314	262
12	2263	1509	1131	905	754	647	566	453	377
16	4023	2682	2011	1609	1341	1149	1006	805	670
20	6286	4190	3143	2514	2095	1796	1571	1257	1048
25	9821	6548	4911	3929	3274	2806	2455	1964	1637
32	16091	10728	8046	6437	5364	4598	4023	3218	2682
40	25143	16762	12571	10057	8381	7184	6286	5029	4190