UNAM

UNIVERSITY OF NAMIBIA

FACULTY	AGRICULTURE, ENGINEERING AND NATURAL SCIENCES
DEPARTMENT	CIVIL AND MINING ENGINEERING
SUBJECT	REINFORCED AND PRE-STRESSED CONCRETE DESIGN
SUBJECT CODE	TCVD3792
DATE	NOVEMBER 2023
DURATION	3 HOURS / **MARKS** 100

FIRST OPPORTUNITY EXAMINATION

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This question paper consists of **7** pages including appendices but excluding this front page.

Instructions

1. **Closed** book examination.
2. Read the questions carefully.
3. The paper contains 3 questions. **Attempt ALL three questions** for full marks.
4. Some relevant formulae, equations, tables and charts are provided.
5. Answers should be brief and to-the-point and where necessary be supplemented with neat and clear sketches.
6. Marks for each question are indicated.
7. Make reasonable and logical assumptions where necessary.
8. Unless otherwise stated, the reference code of practice is SANS 10100 Part 1.

Question 1 **(35 marks)**

a) A simply supported reinforced concrete rectangular beam is loaded as shown in Figure Q1. The applied loads are at the Serviceability Limit State (SLS).

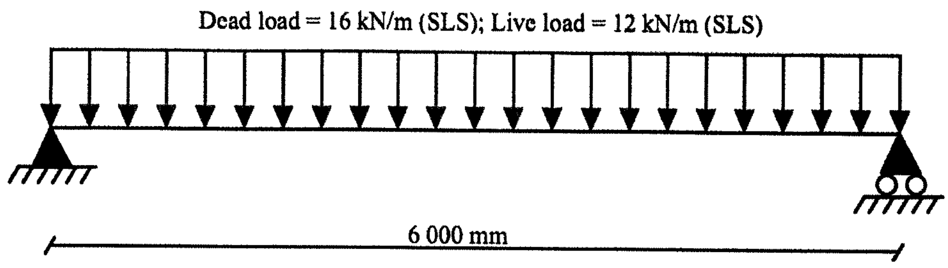

Figure Q1: A loaded rectangular simply supported reinforced concrete beam

Additional information

Dead load (including self-weight) at SLS	= 16 kN/m
Live load at SLS	= 12 kN/m
Effective span	= 6000 mm
Moment redistribution, β	= 0%
Width of beam, b	= 300 mm
Overall depth of beam, h	= 600 mm
Diameter of longitudinal tension reinforcement (high yield)	= 20 mm
Diameter of longitudinal hangar bars/compression reinforcement (high yield)	= 12 mm
Diameter of transverse/shear reinforcement (mild steel)	= 10 mm
Yield strength of longitudinal tension and hangar bars/compression reinforcement, f_y	= 460 MPa
Yield strength of transverse/shear reinforcement, f_{yv}	= 250 MPa
Characteristic strength of concrete in compression at 28 days, f_{cu}	= 25 MPa
Material factor for concrete in shear, γ_m	= 1.4
Cover to reinforcement (uniform throughout)	= 25 mm
Basic l/d ratio	= 20

Use the given information to:

i. Design the longitudinal reinforcement that will resist the applied moment at the Ultimate Limit State (ULS). ***(11 Marks)***

ii. Design the transverse/shear reinforcement that will resist the applied shear forces at the Ultimate Limit State (ULS). ***(7 Marks)***

iii. Check the deflection in the beam due to the reinforcement designed in (i). ***(5 Marks)***

iv. Sketch the layout of the reinforcement designed in (i) and (ii). ***(4 Marks)***

Useful notes:

i. You do not need to curtail the designed reinforcement.
ii. Appropriate tables, charts and formulae have been provided in the Appendix
iii. Assume that the beam is supported on a square 300x300 mm reinforced concrete column.
iv. Spacing of shear rebars should be in whole number multiples of 25 mm (e.g., 100, 125, 150, 175….)

b) Show that the yielding of tension reinforcement in a reinforced concrete rectangular beam cross-section reinforced with high yield steel (yield strength, f_y = 460 MPa, γ_m = 1.15, elastic modulus, E, = 200 GPa) can only be achieved when the following condition is met: ***(8 Marks)***

$$x \ngtr 0.636d$$

Where:

i. x is the depth of the neutral axis.
ii. d is the effective depth.

Question 2 **(25 marks)**

Figure Q2 shows the typical floor layout of a multi-storey hostel block for NIMT students in Arandis.

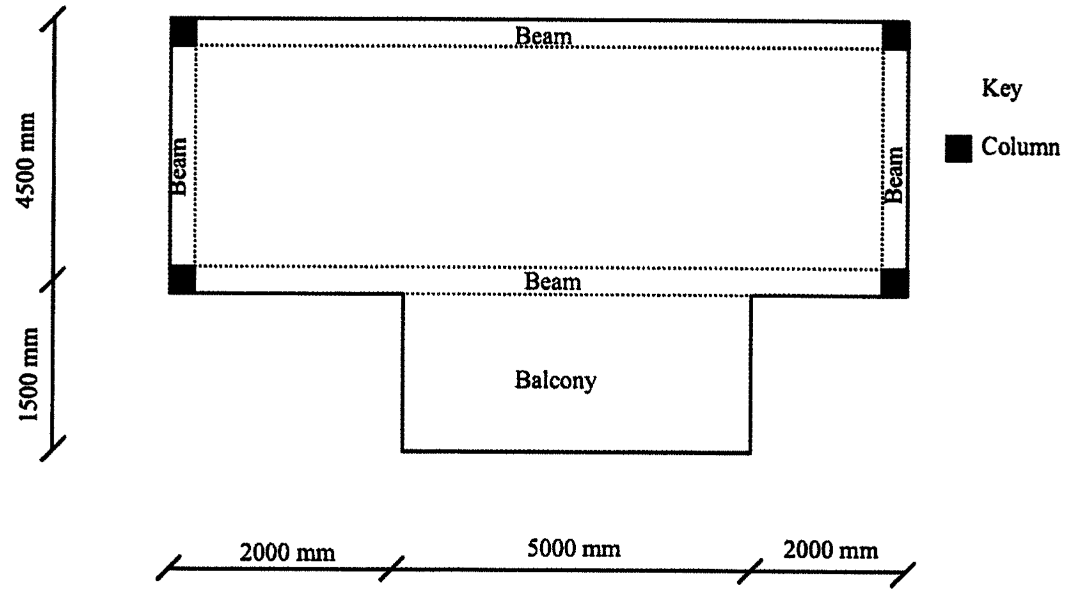

Figure Q2: Typical floor layout of a student hostel block

Additional information

Overall thickness of the slab, h	= 150 mm
Imposed load on the slab (SLS), Q_k	= 2.0 kN/m^2
Thickness of plaster finishing	= 20 mm
Unit weight of concrete, γ_{conc}	= 24 kN/m^3
Unit weight of plaster, $\gamma_{plaster}$	= 23 kN/m^3
Characteristic strength of concrete in compression at 28 days, f_{cu}	= 25 MPa
Moment redistribution, β	= 0%
Diameter of all reinforcement (high yield)	= 10 mm
Yield strength of reinforcement, f_y	= 460 MPa
Cover to reinforcement (uniform throughout)	= 20 mm
Effective span	= 1500 mm
Basic l/d ratio	= 7

Use the given information to:

i. Design the reinforcement for the cantilevered floor slab (i.e., the balcony) at the Ultimate Limit State (ULS). ***(16 Marks)***
ii. Check the deflection in the slab due to the reinforcement designed in (i). ***(4 Marks)***
iii. Sketch the layout of the reinforcement designed in (i). ***(5 Marks)***

Useful notes:

i. You do not need to curtail the designed reinforcement.
ii. Appropriate tables, charts and formulae have been provided in the Appendix
iii. Spacing of reinforcement should be in whole number multiples of 50 mm (e.g., 100, 150, 200, etc.)

Question 3 **(40 marks)**

The reinforced concrete combined footing shown in Figure Q3 is expected to resist axial loads from a 400x400 mm and a 450x450 mm square column. The distance between the centres of the columns is 4500 mm. Use the given information to design an appropriate combined footing for the two columns.

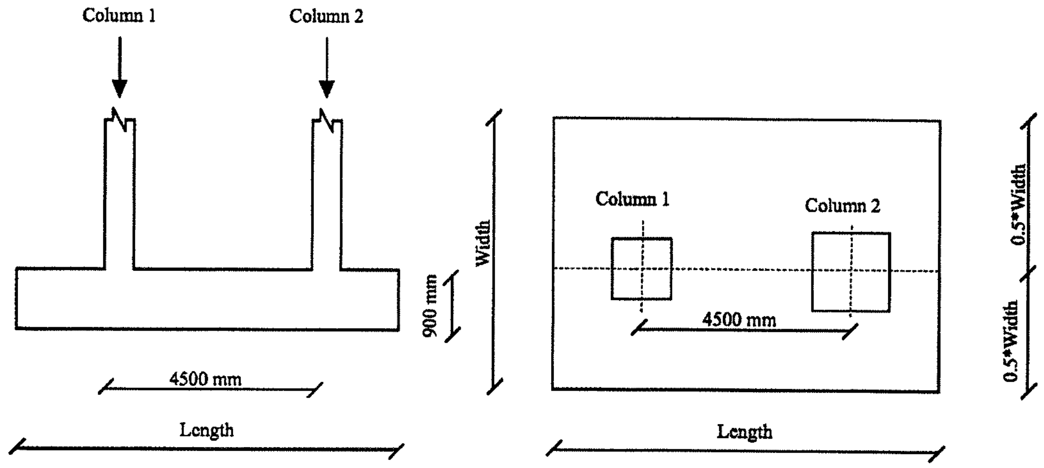

Figure Q3: Reinforced concrete footing

Additional information

Column 1 dimensions	= 400x400 mm
Column 2 dimensions	= 450x450 mm
Safe bearing pressure	= 275 kN/m^2
Loads on Column 1 (at SLS)	
Dead load (including self-weight of column)	= 1500 kN
Live load	= 400 kN
Load on Column 2	
Dead load (including self-weight of column)	= 1800 kN
Live load	= 600 kN
Distance between centres of columns	= 4500 mm
Overall thickness of footing	= 900 mm
Ratio of length:width of footing	= 2:1
Characteristic strength of concrete in compression at 28 days, f_{cu}	= 40 MPa
Yield strength of reinforcement, f_y	= 460 MPa
Diameter of reinforcement	= 25 mm (longitudinal) and 20 mm (transverse)
Cover to reinforcement (uniform throughout)	= 50 mm
Unit weight of concrete, $\gamma_{concrete}$	= 25 kN/m^3
Moment redistribution, β	= 0%

Useful notes:

i. Appropriate tables, charts and formulae have been provided in the Appendix.
ii. Assume an approximate weight of footing of 400 kN (at SLS) for your initial calculations/sizing.

APPENDICES: TCVD3792 Reinforced and Pre-stressed Concrete Design formulae, equations, charts and tables – First Opportunity Examination 2023

Service stress in steel, f_s

$$f_s = \frac{5}{8} \times f_y \times \frac{A_{s,required}}{A_{s,provided}} \times \frac{1}{\beta_b}$$

Sectional areas for groups of rebars

Bar size (mm)	Number of bars									
	1	2	3	4	5	6	7	8	9	10
6	28.3	56.6	84.9	113	142	170	198	226	255	283
8	50.3	101	151	201	252	302	352	402	453	503
10	78.5	157	236	314	393	471	550	628	707	785
12	113	226	339	452	566	679	792	905	1020	1130
16	201	402	603	804	1010	1210	1410	1610	1810	2010
20	314	628	943	1260	1570	1890	2200	2510	2830	3140
25	491	[illegible]	1470	1960	2450	2950	3440	3930	4420	4910
32	804	1610	2410	3220	4020	4830	5630	6430	7240	8040
40	1260	2510	3770	5030	6280	7540	8800	10100	11300	12600

A_{sv}/S_v for varying stirrup diameter and spacing (*NB: values only apply to stirrups with 2 legs*)

Stirrup diameter (mm)	Stirrup spacing (mm)										
	85	90	100	125	150	175	200	225	250	275	300
8	1.183	1.118	1.006	0.805	0.671	0.575	0.503	0.447	0.402	0.366	0.335
10	1.847	1.744	1.57	1.256	1.047	0.897	0.785	0.698	0.628	0.571	0.523
12	2.659	2.511	2.26	1.808	1.507	1.291	1.13	1.004	0.904	0.822	0.753
16	4.729	4.467	4.02	3.216	2.68	2.297	2.01	1.787	1.608	1.462	1.34

Areas for different bar diameters and spacing (mm^2/m)

Spacing	BAR DIAMETER						
	8	10	12	16	20	25	32
50	1005	1571	2262	4021	6283	9817	16085
75	670	1048	1508	2681	4189	6545	10723
100	503	785	1131	2011	3142	4909	8042
125	402	628	905	1608	2513	3927	6434
150	335	524	754	1340	2094	3272	5362
175	287	449	646	1149	1795	2805	4596
200	251	393	564	1005	1571	2454	4021
225	226	353	508	904	1414	2208	3619
250	201	314	452	804	1257	1963	3217
275	184	288	414	737	1152	1799	2949
300	168	262	377	670	1047	1636	2681
325	156	243	350	622	972	1519	2489
350	144	224	323	574	898	1402	2298
375	134	209	302	536	838	1309	2145
400	126	196	283	503	785	1227	2011

Table 6 – Maximum design shear stress, v_c for grade 25 concrete

1	2	3	4	5	6	7	8	9	10	11
$\frac{100 A_s}{b_v d}$	**Maximum design shear stress of concrete, v_c** MPa									
	Effective depth, d mm									
	125	150	175	200	225	250	300	400	500	800
0,15	0,38	0,36	0,35	0,34	0,33	0,32	0,31	0,28	0,27	0,24
0,25	0,45	0,43	0,41	0,40	0,39	0,38	0,36	0,34	0,32	0,28
0,50	0,57	0,54	0,52	0,51	0,49	0,48	0,46	0,43	0,40	0,36
0,75	0,66	0,62	0,60	0,58	0,56	0,55	0,52	0,49	0,46	0,41
1,00	0,72	0,68	0,66	0,64	0,62	0,60	0,58	0,54	0,51	0,45
1,50	0,82	0,78	0,75	0,73	0,71	0,69	0,66	0,61	0,58	0,52
2,00	0,90	0,86	0,83	0,80	0,78	0,76	0,73	0,67	0,64	0,57
3,00	1,03	0,99	0,95	0,92	0,89	0,87	0,83	0,77	0,73	0,65

NOTE – Allowance has been made in these figures for a γ_m of 1,40.

Table 11 - Modification factors for tension reinforcement

1	2	3	4	5	6	7	8	9	10	11	12	13
Steel service stress	**Modification factors**											
	*M/bd*²											
	0,5	1,0	1,5	2,0	2,5	3,0	3,5	4,0	4,5	5,0	5,5	6,0
300	1,60	1,33	1,16	1,06	0,98	0,93	0,89	0,85	0,82	0,80	0,78	0,76
290	1,66	1,37	1,20	1,09	1,01	0,95	0,90	0,87	0,84	0,81	0,79	0,78
280	1,72	1,41	1,23	1,12	1,03	0,97	0,92	0,89	0,85	0,83	0,81	0,79
270	1,78	1,46	1,27	1,14	1,06	0,99	0,94	0,90	0,87	0,84	0,82	0,80
260	1,84	1,50	1,30	1,17	1,08	1,01	0,96	0,92	0,88	0,86	0,83	0,81
250	1,90	1,55	1,34	1,20	1,11	1,04	0,98	0,94	0,90	0,87	0,85	0,82
240	1,96	1,59	1,37	1,23	1,13	1,06	1,00	0,95	0,92	0,88	0,86	0,84
230	2,00	1,63	1,41	1,26	1,16	1,08	1,02	0,97	0,93	0,90	0,87	0,85
220	2,00	1,68	1,44	1,29	1,18	1,10	1,04	0,99	0,95	0,91	0,88	0,86
210	2,00	1,72	1,48	1,32	1,20	1,12	1,06	1,00	0,96	0,93	0,90	0,87
200	2,00	1,76	1,51	1,35	1,23	1,14	1,07	1,02	0,98	0,94	0,91	0,88
190	2,00	1,81	1,55	1,37	1,25	1,16	1,09	1,04	0,99	0,96	0,92	0,90
180	2,00	1,85	1,58	1,40	1,28	1,18	1,11	1,06	1,01	0,97	0,94	0,91
170	2,00	1,90	1,62	1,43	1,30	1,21	1,13	1,07	1,02	0,98	0,95	0,92
160	2,00	1,94	1,65	1,46	1,33	1,23	1,15	1,09	1,04	1,00	0,96	0,93
150	2,00	1,98	1,69	1,49	1,35	1,25	1,17	1,11	1,05	1,01	0,98	0,94
140	2,00	2,00	1,72	1,52	1,38	1,27	1,19	1,12	1,07	1,03	0,99	0,96
130	2,00	2,00	1,75	1,55	1,40	1,29	1,21	1,14	1,09	1,04	1,00	0,97
120	2,00	2,00	1,79	1,58	1,43	1,31	1,23	1,16	1,10	1,05	1,01	0,98

Table 12 - Modification factors for compression reinforcement

1	2
$\frac{100A_s'}{bd}$	**Factor*)**
0,15	1,05
0,25	1,08
0,35	1,10
0,50	1,14
0,75	1,20
1,00	1,25
1,25	1,29
1,50	1,33
1,75	1,37
2,00	1,40
2,50	1,45
≥ 3,00	1,50
*)Obtain intermediate values by interpolation.	