Second Semester Examination
2021/2022 Academic Session

July/August 2022

EAS356 – Reinforced Concrete Structural Design II

Duration : 2 hours

Please ensure that this examination paper contains **NINE (9)** printed pages including appendix before you begin the examination.

Instructions: This paper contains **FIVE (5)** questions. Answer **FOUR (4)** questions.

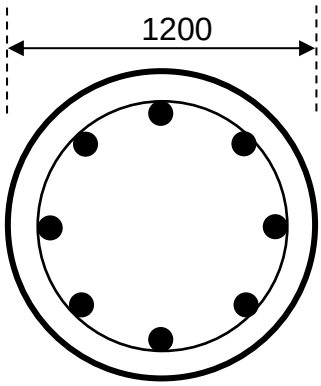
All questions **MUST BE** answered on a new page.

1. (a) Determine the minimum number of H12 vertical reinforcement that are required for a 250 mm diameter micro pile in order to support allowable working load = 650 kN. The soil condition is expected to be unstable and the use of permanent casing is deemed compulsory. Consider grout strength = 30 N/mm^2, characteristic strength of steel reinforcement f_{yk} = 500 N/mm^2, Modulus of Elasticity of grout E_g = 18 kN/mm^2, Modulus of Elasticity of steel E_s = 200 kN/mm^2 and Factor of Safety = 2.0. The minimum and maximum percentage of reinforcement shall be 0.5% and 4.0%, respectively.

[9 marks]

(b) The proposed cross-sectional detail of a 1200 mm diameter bored pile is shown in **Figure 1**. The pile will be used for a marine construction project and exposed to cyclic wet and dry conditions. The terms of reference for the project stated that the structural design of all piles must be in accordance to BS EN 1992-1-1, 100 years design life and only subjected to axial load. If the allowable pile working capacity of the pile is 8000 kN, evaluate the design and the detailing of the proposed bored pile.

[16 marks]



Concrete Grade: C25/30
Main Reinforcement: 8 H20
Nominal Concrete Cover: 40 mm
Link: H12
(all dimensions in mm)

Figure 1

2. The propose plan view of a pile cap with six pile group is shown in **Figure 2**. The pile cap is required to support unfactored column load with G_k = 4200 kN and Q_k = 1000 kN. If the overall depth of the pile cap is taken as 1200 mm, provide the design and full detailing of the pile cap. Consider f_{ck} = 35 N/mm^2, f_{yk} = 500 N/mm^2, pile embedded length = 75 mm and z = 0.95*d*. Use reinforcement H32 and H16 mm for resisting maximum and minimum moment, respectively. Ignore the check for maximum shear resistance at the column face, maximum percentage of the bending reinforcement, the reinforcement spacing and the anchorage length (only sketch the anchorage length for detailing purposes).

[25 marks]

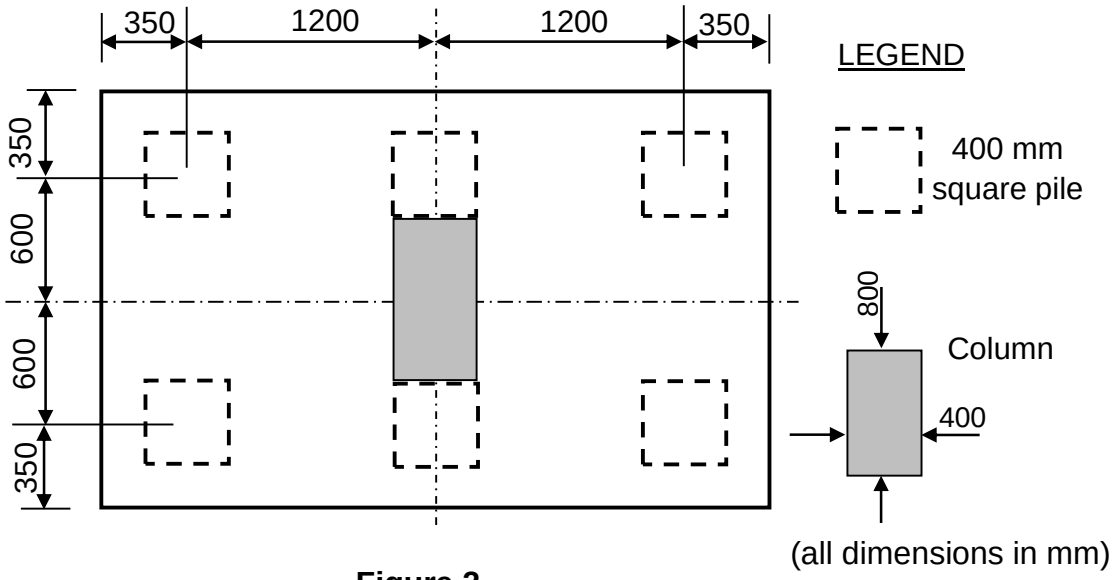


Figure 2

3. The As-Built piling drawing of a pile cap is shown in **Figure 3**. It can be seen that piles are not symmetrically positioned and deviated from the actual pile spacing. If the column load and selfweight of the pile cap are calculated to be 4500 kN, evaluate the pile capacity individually and as a group. The allowable pile working capacity is 800 kN.

[25 marks]

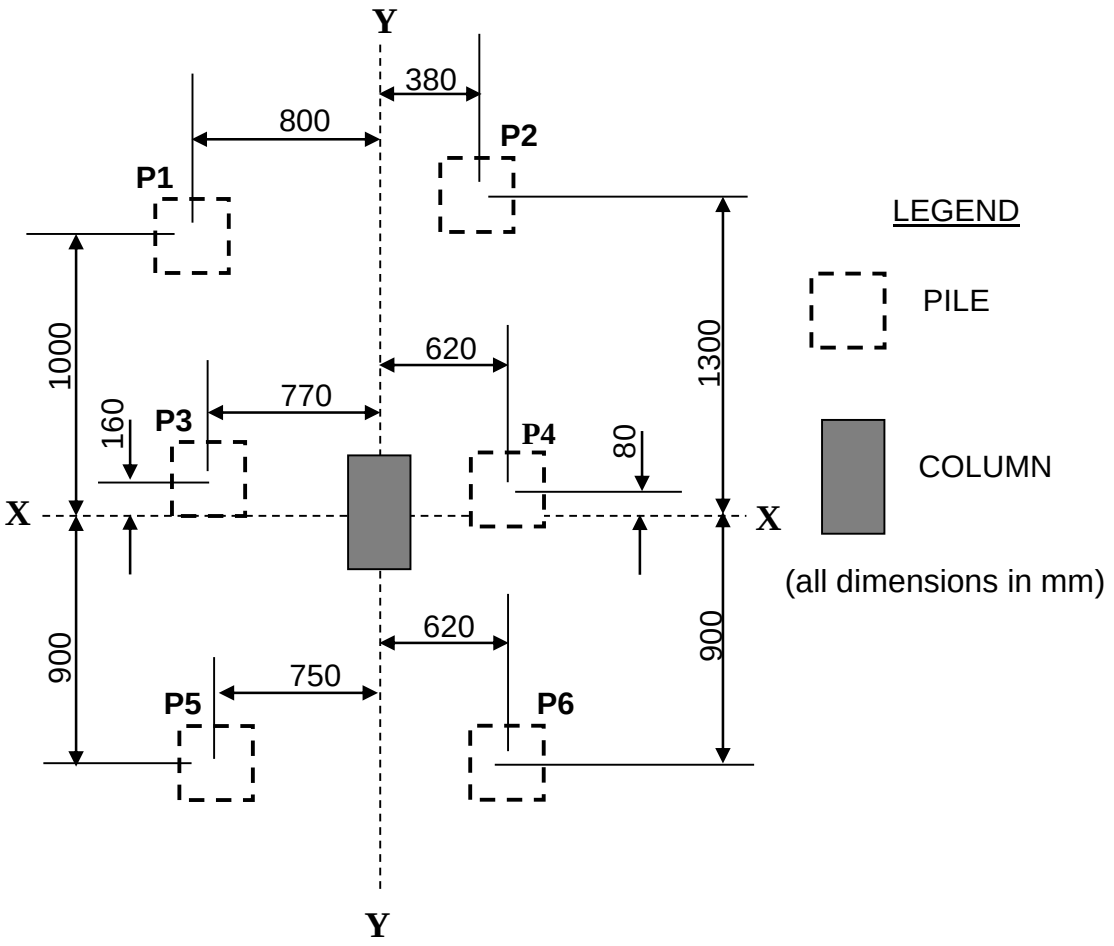


Figure 3

4. **Figure 4** shows a cantilever RC retaining wall proposed for an embankment project. Design parameters to be used are also given in the figure.

(a) Check for satisfaction of sliding, overturning and settlement.

(b) Design for flexural reinforcement required. Use bar size of 12 mm.

(c) Provide drawing showing the detailing of the reinforcement.

[25 marks]

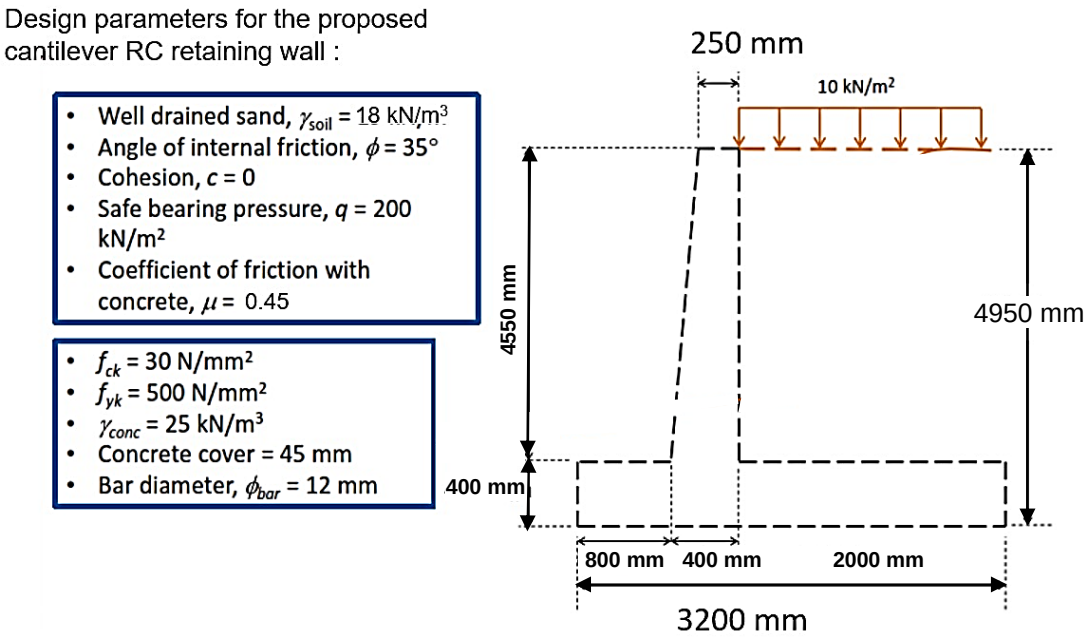


Figure 4

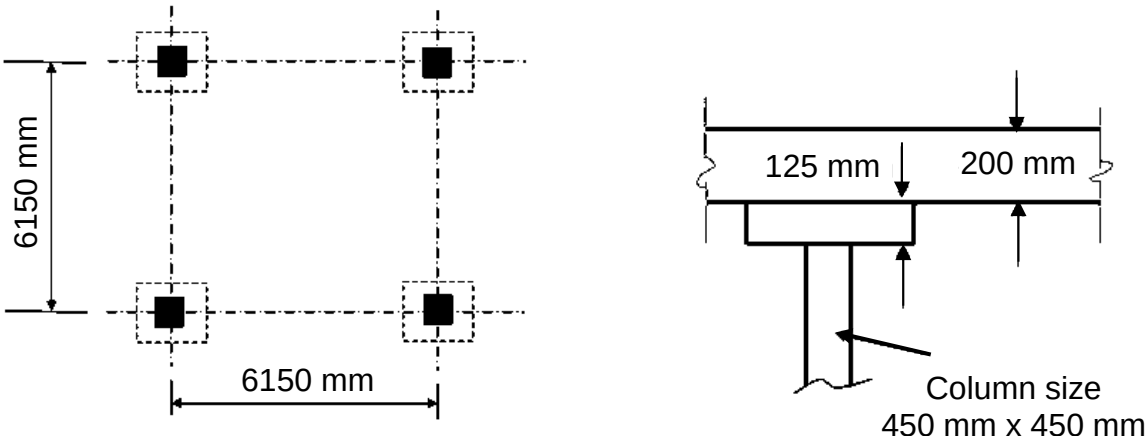
5. **Figure 5** shows an internal square panel of a flat slab with panel size of 6150 mm. Thickness of slab is 200 mm and size of drop panel is 2100 x 2100 x 125 mm. Concrete cover of 25 mm is provided. The slab is designed to carry a variable load with characteristic value of 4 kN/m^2. The characteristic material strength for concrete, f_{ck} and steel, f_{yk} are 25 N/mm^2 and 500 N/mm^2, respectively.

(a) Design for the flexural reinforcement of the flat slab. Use reinforcement size of 20 mm.

(b) Check the sufficiency of the flat slab with respect to punching shear at basic perimeter u_1.

Draw the reinforcement details in plan view.

[25 marks]



Plan view **Sectional view**

Figure 5

APPENDIX

1. Pile capacity check:

$$P_n = \frac{P}{N} \pm \frac{M_{xx}\, y_n}{I_{xx}} \pm \frac{M_{yy}\, x_n}{I_{yy}}$$

2. Design shear resistance:

$$V_{Rd,c} = 0.12k(100\rho_1 f_{ck})^{\frac{1}{3}}\, bd$$

3. Minimum area of reinforcement:

$$A_{s,min} 0.26 \left(\frac{f_{ctm}}{f_{yk}}\right) bd$$

4. Ultimate bending moment in one-way spanning slabs

Ultimate bending moment in one way spanning slabs		
	Middle interior spans	Interior supports
Moment	0.063 *Fl*	0.063 *Fl*
F = is the total design load (1.35 *Gk* + 1.5 *Qk*) in kN; *l* = effective span		

5. Distribution of design moments in panel of flat slabs

Design moment	**Apportionment between column and middle strip expressed as percentage of the total negative or positive design moment**	
	Column strip %	**Middle strip %**
Negative	75	25
Positive	55	45
NOTE: For the case where the width of the column strip is taken as equal to that of the drop, and the middle strip is thereby increased in width, the design moments to be resisted by the middle strip should be increased in proportion to its increased width. The design moments to be resisted by the column strip may be decreased by an amount such that the total positive and the total negative design moments resisted by the column strip and middle strip together are unchanged.		

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6. Table 3: Steel stress (under quasi-permanent loading)

f_s	$= \frac{f_{yk}\,(G_k + 0.3Q_k)}{1.15(1.35G_k + 1.5Q_k)}\ x\ \frac{A_{s,req}}{A_{s,pro}}$

7. Formulae for determining ultimate load of micropile

Ultimate Load of micropile (reinforcement only = $0.87 \times f_{yk} \times A_s$

Ultimate Load of micropile (short column) = $0.4f_{ck}A_c + 0.8f_{yk}A_{sc}$

Ultimate Load of micropile (strain compatibility) = $0.5f_{yk} \times (A_s + \alpha A_c)$

Where α = modular ratio

8. Bar Areas and Perimeters

Sectional areas of groups of bars (mm^2)

Bar Size (mm)	Number of bars							
	1	2	3	4	5	6	7	8
6	28.3	56.6	84.9	113	142	170	198	226
8	50.3	101	151	201	252	302	352	402
10	78.5	157	236	314	393	471	550	628
12	113	226	339	452	566	679	792	905
16	201	402	603	804	1010	1210	1410	1610
20	314	628	943	1260	1570	1890	2200	2510
25	491	982	1470	1960	2450	2950	3440	3930
32	804	1610	2410	3220	4020	4830	5630	6430

Sectional areas per metre width for various bar spacings (mm^2)

Bar Size (mm)	Spacing of bars							
	75	100	125	150	175	200	250	300
6	377	283	226	189	162	142	113	94.3
8	671	503	402	335	287	252	201	168
10	1050	785	628	523	449	393	314	262
12	1510	1130	905	754	646	566	452	377
16	2680	2010	1610	1340	1150	1010	804	670
20	4190	3140	2510	2090	1800	1570	1260	1050
25	6550	4910	3930	3270	2810	2450	1960	1640
32	10700	8040	6430	5360	4600	4020	3220	2680

A_{sv}/s_v for varying stirrup diameter and spacing

Stirrup diameter (mm)	Number of bars										
	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

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