UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session 2008/2009

November 2008

EAS 664/4 – Principle of Structural Design

Duration: 3 hours

Please check that this examination paper consists of **TEN (10)** pages of printed material including appendix before you begin the examination.

Instructions: Answer **FIVE (5)** questions. All questions carry the same marks.

You may answer the question either in Bahasa Malaysia or English.

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

Write the answered question numbers on the cover sheet of the answer script.

1. (a) Briefly explain the Hillerborg's Strip Method.

[8 Marks]

(b) State the rules for yield line theory. Figure 1 portrays the yield lines for a two-way rectangular slab simply supported at every edge under uniformly distributed load of w/unit area. Determine the moment.

[12 Marks]

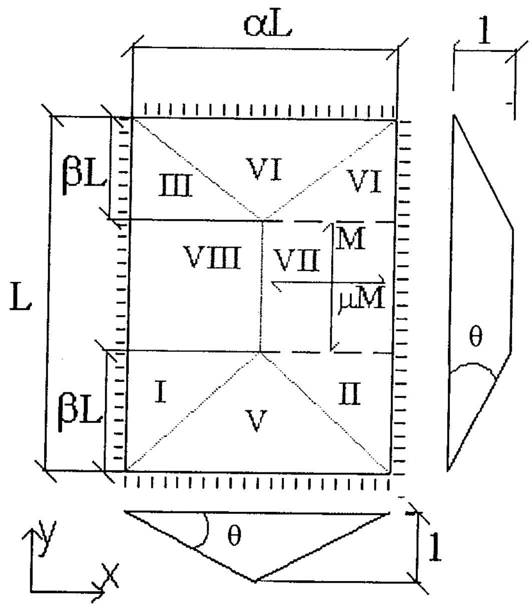

Figure 1

2. (a) Briefly describe **FIVE (5)** factors that influenced the wind load calculation in the code of practice.

[5 marks]

2. (b) A ten storey rigid frame building as shown in Figure 2 refers to the terrain category **THREE (3)** in Penang with a basic wind speed of $33.5 m/s^2$. Calculate the value of design wind force from first floor up to the roof level of the frame based on MS1553:2002. The height of each storey is 3m, which makes the total accumulated height of the building of 24m. The frame spacing is 6m with the width and height of the building of 28m and 30m respectively. The height of each is 3m, which makes the total accumulated height of the building of 24m. The frame spacing is 6m with the width and height of the building of 28m and 30m respectively. The storey height is typically 3.0m, to give a total height of 24m. The frames are spaced at 6m, the width of building is 28m and the length is 30m. Please indicate all the assumed values used in the calculations.

[15 marks]

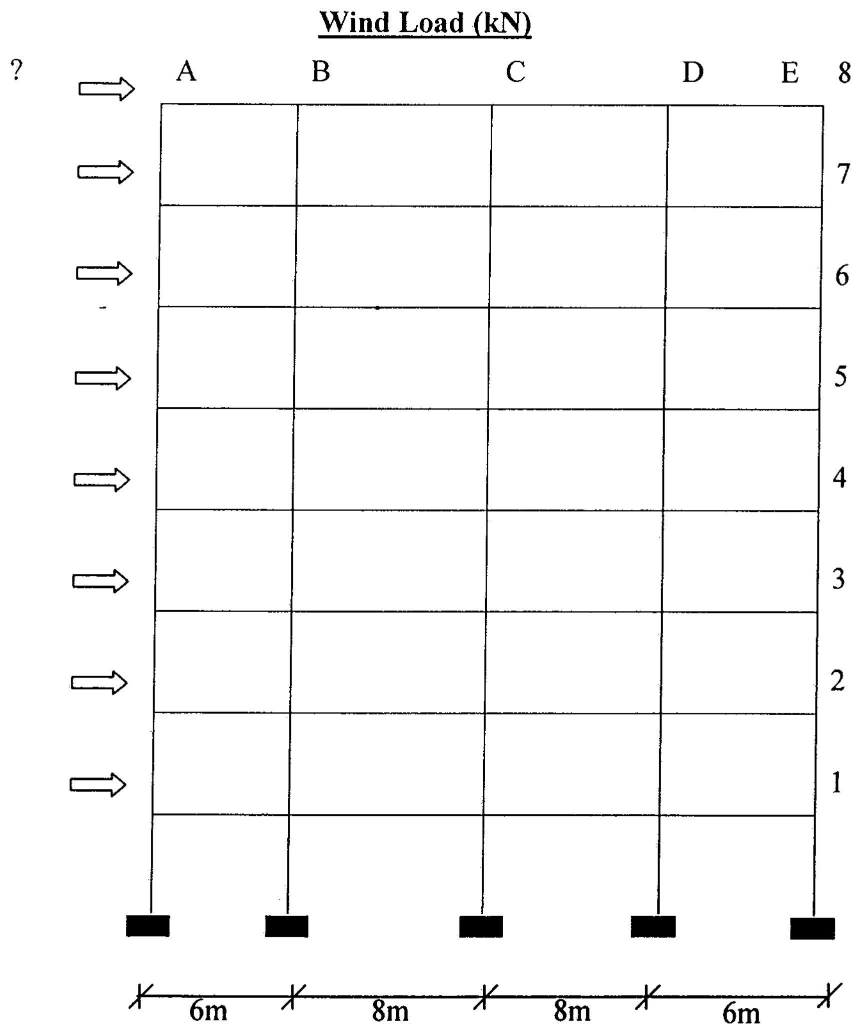

Figure 2

3. (a) Briefly describe **TWO (2)** structural form and **TWO (2)** reinforced concrete floor systems in a high-rise building, in the form of sketches.

[8 marks]

(b) Ten-storey rigid frames as shown in Figure 3 reflects the terrain category 3 in Kuantan with the basic wind speed of $33.5m/s^2$. The basic wind speed has been converted into equivalent horizontal force as indicated in the figure. The story height is typically at 3.0m, each giving give a total height of 30m for the whole building. The frames are spaced at 9m. Using the Portal Method, calculate :

(i) The horizontal external shear at mid-story level for each story.

(ii) The shear to half-columns above and below of fifth story

(iii) The maximum moment above and below joint at fifth story.

(iv) The shear in the girder at fifth story.

Indicates all values (i – iv) on the diagram.

[8 marks]

(c) Determine the limit of total deflection for building in Figure 3 and state the inter story drift limit for any tall building.

[4 marks]

4. (a) **TWO (2)** main characteristics of shell structures compared to non-shell structures are: curvature and continuity. Explain by means of suitable sketches/drawings how these two characteristics help in the load transfer of shell structures.

[5 marks]

(b) A circular cylindrical water tank with an internal diameter of d = 21m and height of H = 6.0m as shown in Figure 4 is to be constructed. Thickness of the wall is 250mm. A cover in the form of spherical roof with half open angle $\alpha = 30°$ is to be provided. Thickness of the spherical roof has been chosen as 75mm. Calculate the membrane stress resultant N_ϕ at the base of the spherical roof. The designed load for the spherical roof is $3.75 kN/m^2$ which is to be considered as distributed over the surface.

Next, using a concrete of strength $f_{cu} = 30 N/mm^2$ and reinforcement of $f_y = 460 N/mm^2$, design the wall of the cylindrical tank. Design data, formula and reinforcement requirement are given in Appendix A. Tables of reinforcement bars and their sectional areas are given in Appendix B.

[15 marks]

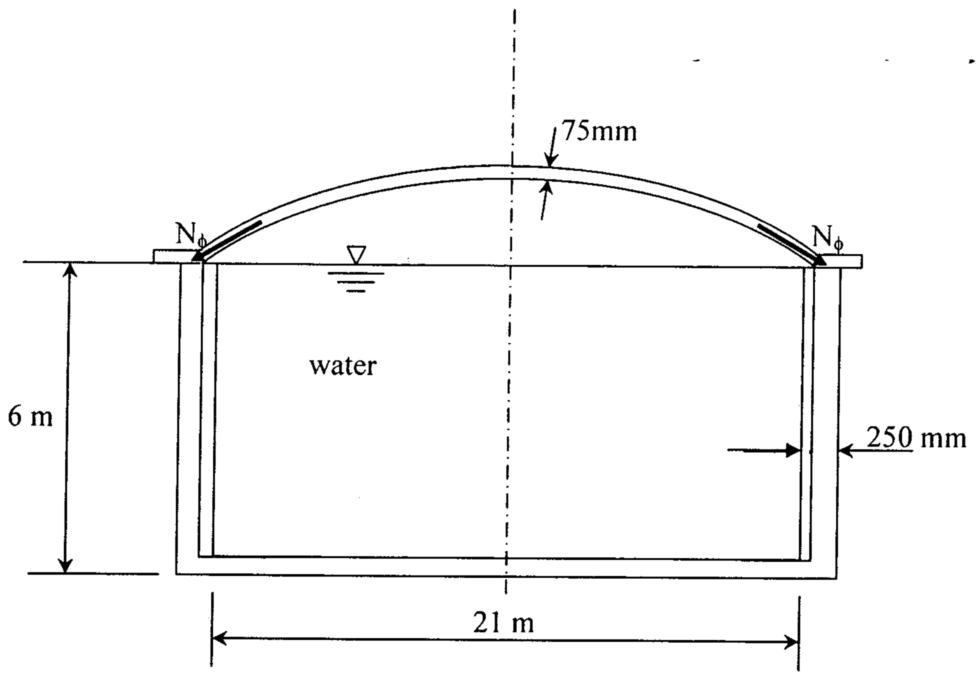

Figure 4

5. (a) Discuss briefly why a reinforced concrete deep beam cannot be treated similar to shallow flexural beam in structural analysis and design. Provide relevant sketches.

[5 Marks]

(b) A single reinforced concrete corbel projecting from 400 x 400 column is designed to support precast beam reaction forces at 150mm from the face of the column as shown in Figure 5. The factored vertical load out is 280kN. Design and provide sectional detailing of the corbel using strut and tie method. Assume the center of the uppermost tie is 50mm from top of the corbel. The characteristic strength of concrete and reinforcement is 35N/mm^2 and 460N/mm^2 respectively. Part of the code provisions (ACI 318-02) is provided in Appendix C.

[15 Marks]

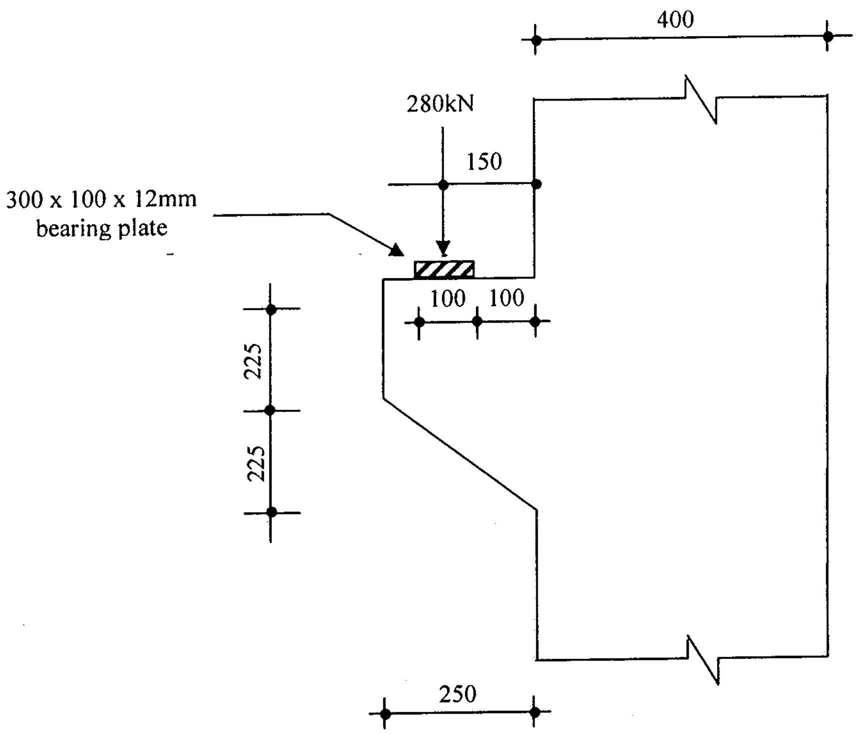

Figure 5 : Reinforced Concrete Corbel

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APPENDIX A

Formulae for membrane stress resultants in a cylindrical shell:

$N_x = -\int p_x \, dx + C$; C : integration constant , ; a : radius of the cylindrical shell

$N_\theta = p_r \, a$

Formulae for membrane stress resultants in a spherical shell:

i. case of load distributed over the shell surface:

$N_\phi = -\dfrac{pa}{1+\cos\phi}$; a : radius of spherical shell, p:distributed load

$N_\theta = -pa\left(\cos\phi - \dfrac{1}{1+\cos\phi}\right)$

ii. case of load distributed over the projected plan area:

$N_\phi = -\dfrac{qa}{2}$;·a : radius of spherical shell, q: distributed load

$N_\theta = \dfrac{-qa}{2}\cos 2\phi$

Self-weight of concrete and water:

γ_C=24 kN/m^3

γ_W=9.81 kN/m^3

Requirement for reinforcement to control restrained shrinkage and thermal movement cracking:

minimum 0.6% in two direction with not less that 0.2 % in each direction

APPENDIX B

Bar Areas and Perimeters

Sectional Areas of Groups of Bars (mm²)

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	982	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

Sectional Areas per Metre Width for Various Bar Spacings (mm²)

Bar Size (mm)	Spacing of bars								
	50	75	100	125	150	175	200	250	300
6	566	377	283	226	189	162	142	113	94.3
8	1010	671	503	402	335	287	252	201	168
10	11570	1050	785	628	523	449	393	314	262
12	2260	1510	1130	905	754	646	566	452	377
16	4020	2680	2010	1610	1340	1150	1010	804	670
20	6280	4190	3140	2510	2090	1800	1570	1260	1050
25	9820	6550	4910	3930	3270	2810	2450	1960	1640
32	16100	1700	8040	6430	5360	4600	4020	3220	2680
40	25100	16800	12600	10100	8380	7180	6280	5030	4190

Appendix C

Code Provisions (ACI 318-02)

STRUTS

fcu = 0.85 x ßs x fc'

Where

ßs = 1.0 for prismatic struts in uncracked compression zones

ßs = 0.4 for struts in tension members

ßs = 0.75, struts may be bottle shaped and crack control reinforcement is included

ßs = 0.60, struts may be bottle shaped and crack control reinforcement is not included

ßs = 0.60 for all other cases

fc' = specified compressive strength of concrete

Note :

1. Crack control reinforcement requirement is Σ ρvi sin γi $\geq$ 0.003, where ρvi = steel Ratio of the i-th layer of the reinforcement crossing the strut under review, and γi = angle between the axis of the struts and bars.

NODES

fcu = 0.85 x ßn x fc'

Where

ßn = 1.0 when nodes are bounded by struts and/or bearing areas

ßn = 0.8 when nodes anchor only one tie

ßn = 0.60 when nodes anchor more than one tie

STRENGTH REDUCTION FACTOR, Φ

Φ = 0.75 for struts, ties and nodes