UNIVERSITI SAINS MALAYSIA

1st. Semester Examination
2004/2005 Academic Session

October 2004

EAS 665/4 – Bridge Engineering

Duration: 3 hours

Instructions to candidates:

1. Ensure that this paper contains **NINE (9)** printed pages, including appendices, before you start your examination.
2. This paper contains **FIVE (5)** questions. Answer **ALL (5)** questions.
3. All questions carry equal marks.
4. All questions **MUST BE** answered in English.
5. Each question **MUST BE** answered on a new sheet.
6. Write the answered question numbers on the cover sheet of the answer script.

1. (a) List out **FIVE (5)** factors influencing the wind pressure on a bridge.

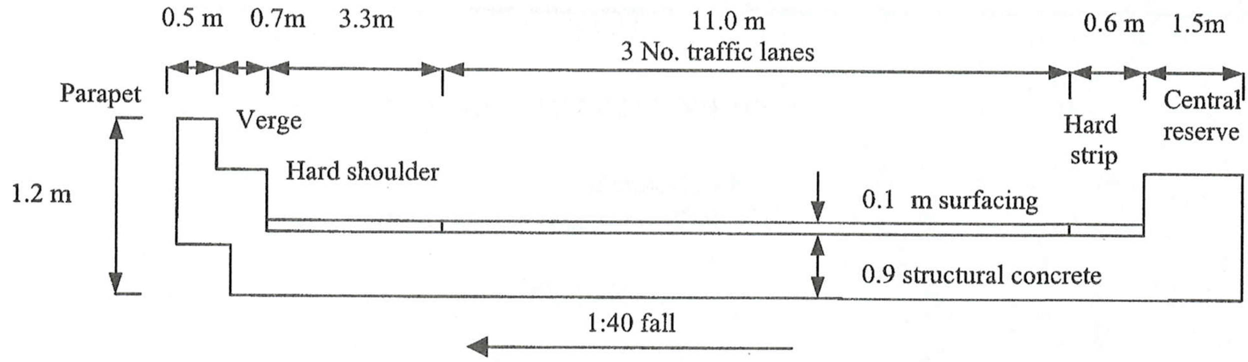


Figure 1.0

(5 marks)

(b) Fig 1.0 shows the cross-section of a highway underbridge of composite slab, zero skew and a span of 15 m. The bridge is situated in Kuala Kurau area at a site which is 120 m above sea level and there are no special funneling, gust or frost conditions. The anticipated effective bridge temperature at the time of setting the bearing is 16°C. Assume open parapet.

i. Calculate the diameter at neutral axis for HA and HB loading.
ii. Summarize the load on central reserve and verge, longitudinal, skidding and collision to parapet.
iii. Calculate the average of intensity on footway loading.

(15 marks)

2. (a) Define HA and HB loading with respect to highway bridge live loads.

(4 marks)

2. (b) Figure 2 shows the design moment triad, at the ultimate limit state, in the obtuse corner of a reinforced concrete skew slab bridge.

M_x = -2.484 MNm/m
M_y = 1.139 MNm/m
M_{xy} = -0.900MNm/m

Calculate the required moments of resistance in the reinforcement directions, if the latter are:

i. parallel and perpendicular to the abutments
ii. parallel to the slab edges.

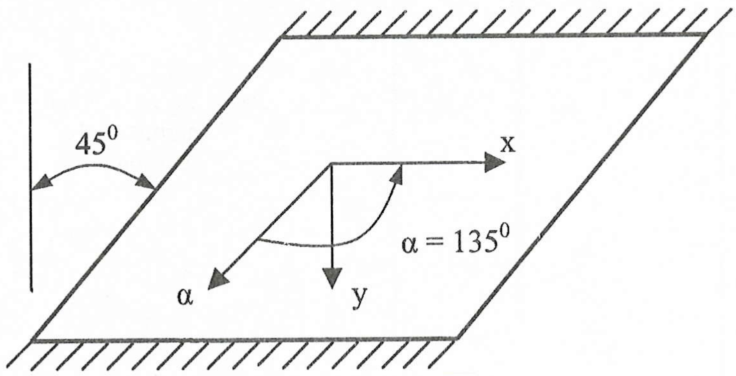


Fig. 2.0 Skew slab axes

(10 marks)

(c) i. Describe the general principles of diaphragms
ii. Discuss and sketch the transferring of the symmetrical and asymmetrical bearing loads of the superstructure from the webs into the bearings.

(6 marks)

3. (a) Explain the purpose of abutments and bearings for the substructure of the bridge.

(3 marks)

3. (b) Figure 3.0 shows a reinforced concrete bridge column. The loads indicated are design loads at the ultimate limit state. Design reinforcement for the column, at the ultimate limit state, if the characteristic strengths of the reinforcement and concrete are 425 N/mm^2 and 40 N/mm^2 respectively. Assume that the articulation of the deck is such that a) sidesway is prevented and b) sidesway can occur.

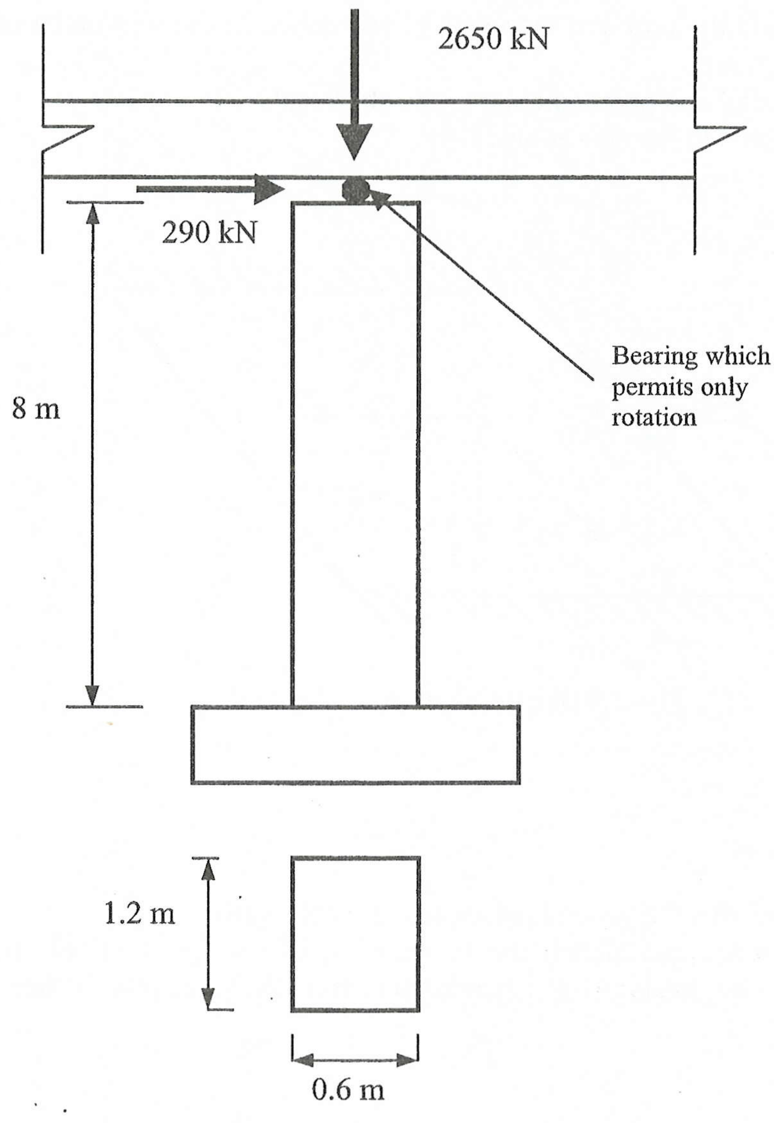


Figure 3.0 : Bridge Column

(8 marks)

3. (c) Design the four-pile cap shown in Fig. 4.0 if the characteristic strengths of the reinforcement and concrete are 460 N/mm^2 and 35 N/mm^2 respectively. The design load at the ultimate limit state is 540 ton.

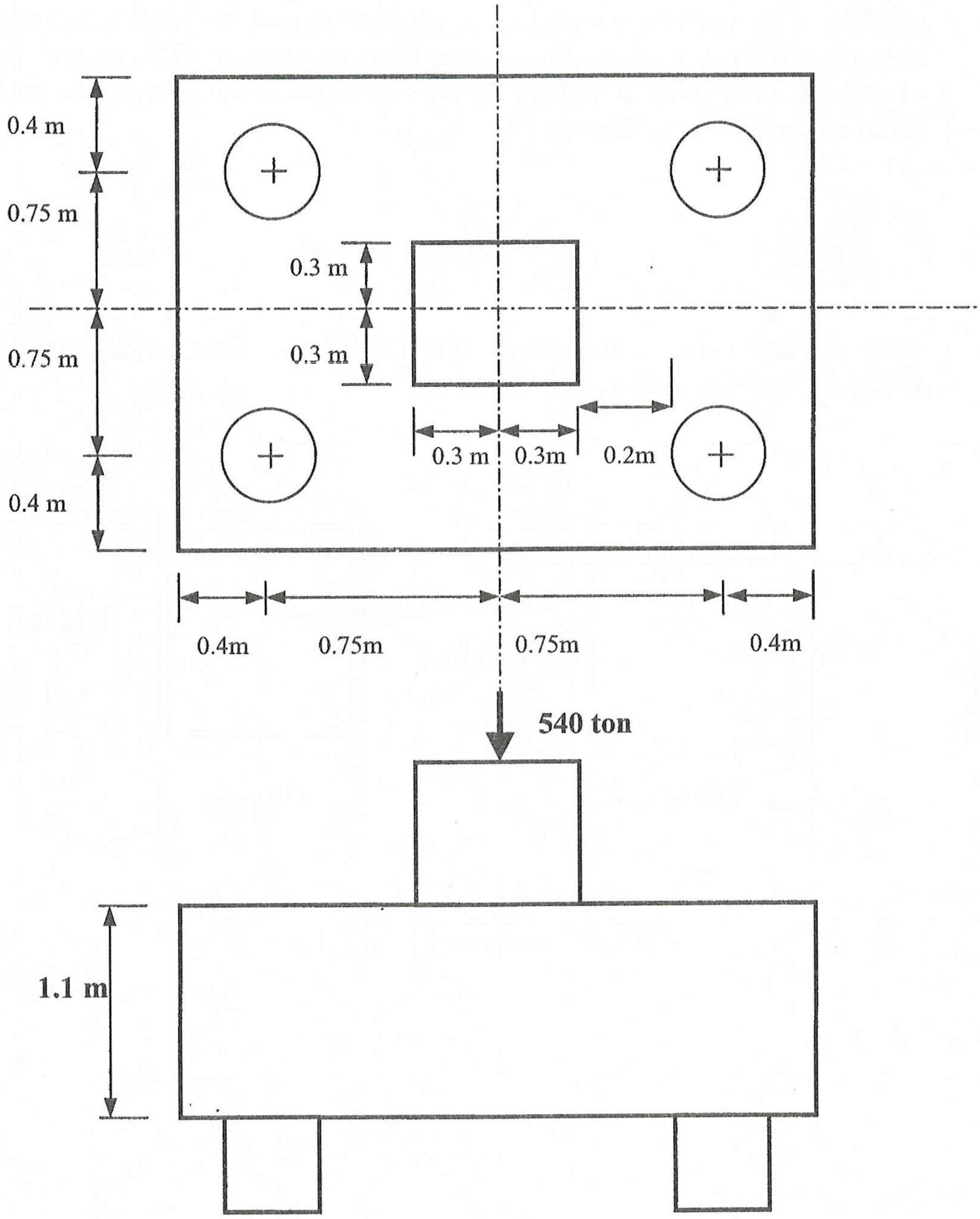


Figure 4.0 : Pile cap

(9 marks)

4. (a) Explain by using suitable sketches why a bridge deck will in general be subjected to both bending and torsion.

(6 marks)

(b) Girder with the sectional shape as shown in Figure 5(a) and (b) are being considered for use in a bridge deck structure. Discuss the relative stiffness and strength of the two sections shown under the action of torsional moment. Length of girder is L, modulus of rigidity for the material is G and torsional constant J is given by the following formula:

$$J = \frac{4A^2}{\oint \frac{ds}{t}}$$

where A : area enclosed by median line of section, s : length along median line and t : thickness of section.

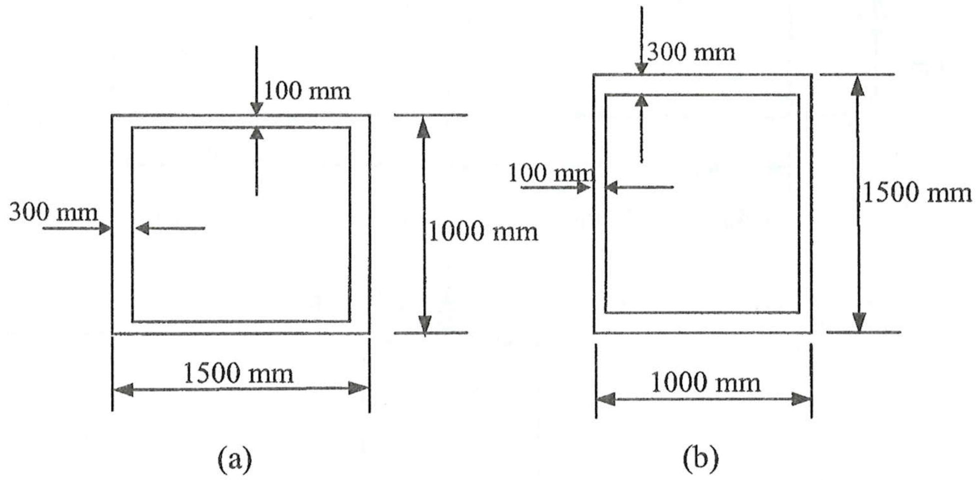


Figure 5

(6 marks)

4. (c) Explain the similarity and dissimilarity between a plane frame and a grillage. Explain also the derivation process of the following stiffness equation in local coordinate system for a grillage member as shown in Figure 6.

$$\begin{Bmatrix} M_{xi} \\ M_{yi} \\ W_i \\ M_{xj} \\ M_{yj} \\ W_j \end{Bmatrix} = \begin{bmatrix} GJ/L & 0 & 0 & -GJ/L & 0 & 0 \\ 0 & 4EI/L & -6EI/L^2 & 0 & 2EI/L & 6EI/L^2 \\ 0 & -6EI/L^2 & 12EI/L^3 & 0 & -6EI/L^2 & -12EI/L^3 \\ -GJ/L & 0 & 0 & GJ/L & 0 & 0 \\ 0 & 2EI/L & -6EI/L^2 & 0 & 4EI/L & 6EI/L^2 \\ 0 & 6EI/L^2 & -12EI/L^3 & 0 & 6EI/L^2 & 12EI/L^3 \end{bmatrix} \begin{Bmatrix} \theta_{xi} \\ \theta_{yi} \\ w_i \\ \theta_{xj} \\ \theta_{yj} \\ w_j \end{Bmatrix}$$

Use suitable sketches in your explanation.

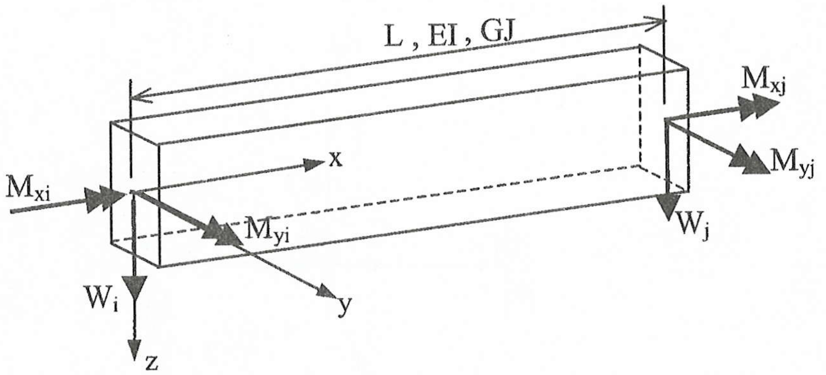


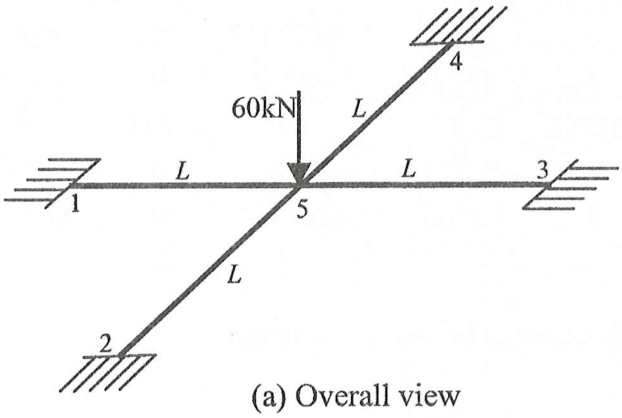
Figure 6

(8 marks)

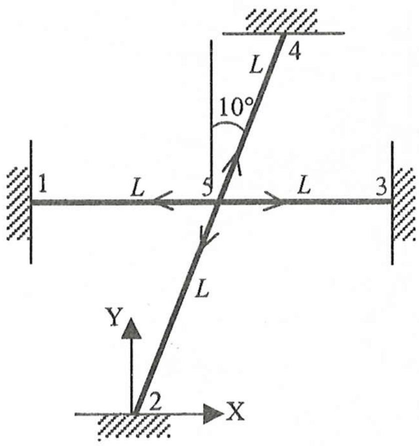
5. (a) Explain the basic steps involved in preparing the data necessary for the analysis of a bridge model using computer program capable of carrying out grillage analysis. Use suitable sketch in your answer.

(8 marks)

5. (b) Figure 7 shows a skew grillage subjected to a point load of 60kN at joint 5. Form the stiffness equation necessary for solving the grillage problem. Given L = 20m, I = 94 x 10^9 mm^4 and J = 100x10^9 mm^4 and E = 35 GPa. Element stiffness matrix for a grillage element is given in Appendix 1.



(a) Overall view



(b) Plan view

Figure 7

(12 marks)

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Appendix 1

$$\bar{k} = \left[\begin{array}{ccc:ccc} \theta_{xi} & \theta_{yi} & \bar{w}_i & \theta_{xj} & \theta_{yj} & \bar{w}_j \\ \frac{GJe^2}{l}+4\frac{EI_y}{l}f^2 & & & & & \\ \left(\frac{GJ}{l}-4\frac{EI_y}{l}\right)ef & \frac{GJf^2}{l}+4\frac{EI_y}{l}e^2 & & & \text{Symmetric} & \\ \frac{6EI_yf}{l^2} & -6\frac{EI_y}{l^2}e & 12\frac{EI_y}{l^3} & & & \\ \hdashline \frac{-GJe^2}{l}+2\frac{EI_y}{l}f^3 & -\left(\frac{GJ}{l}+2\frac{EI_y}{l}\right)ef & 6\frac{EI_y}{l^2}f & \frac{GJe^2}{l}+4\frac{EI_y}{l}f^2 & & \\ -\left(\frac{GJ}{l}+2\frac{EI_y}{l}\right)ef & \frac{-GJ}{l}f^2+2\frac{EI_y}{l}e^2 & -6\frac{EI_y}{l^2}e & \left(\frac{GJ}{l}-4\frac{EI_y}{l}\right)ef & \frac{GJ}{l}f^3+4\frac{EI_y}{l}e^2 & \\ -6\frac{EI_y}{l^2}f & 6\frac{EI_y}{l^2}e & -12\frac{EI_y}{l^3} & -6\frac{EI_y}{l^2}f & 6\frac{EI_y}{l^2}e & 12\frac{EI_y}{l^3} \end{array}\right]$$

where $e=\cos\alpha$, $f=\sin\alpha$ and α : angle made by local axis of grillage member with global x-axis in the plane of grillage (measured in clockwise direction) .