UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session 2008/2009

November 2008

# EAS 665/4 – Bridge Engineering

Duration: 3 hours

Please check that this examination paper consists of **NINE (9)** 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) Figure 1 shows a cross – section of reinforced concrete solid slab highway bridge. The bridge is simply supported having 12m total width, 600mm thickness of deck slab and 30° of skew. The specified highway loading is HA and 45 units of HB. The nominal superimposed dead load is equivalent to a uniformly distributed load of 2.5kN/m$^2$ and the nominal parapet loading is 3.5kN/m along each free edge. Compute the moment resistance for bottom reinforcement placed parallel to the slab edges by yield line theory for load combination 1. Neglect the contribution of top reinforcement toward strength. Use the data below.

| **Load** | $\gamma$ f$_3$ | $\gamma$ f$_2$ |
|---|---|---|
| Dead | 1.1.5 | 1.2 |
| Surfacing | 1.15 | 1.75 |
| Parapet | 1.15 | 1.75 |
| HA (alove) | 1.1 | 1.5 |
| HA (with HB) | 1.1 | 1.3 |
| HB | 1.1 | 1.3 |
| Footway | 1.1 | 1.5 |

$\gamma$ f$_2$ is partial safety factors applied to load, $\gamma$ f$_3$ is partial safety factor applied to load effect.

[20 marks]

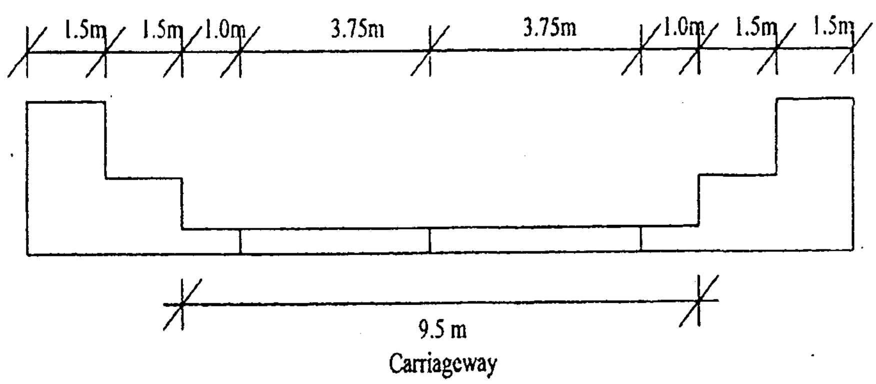



**Figure 1**

2. (a) Sketch **FIVE (5)** types of abutment and briefly describe their functions and purposes.

[5 marks]

(b) The method used for selecting and specifying bearings for bridges are very important to ensure the transformation of loads and movements to the substructure and foundations is safe. Highlight the particular points which are relevant in drafting the specification.

[7.5 marks]

(c) The purpose of expansion joint is to accommodate movements of the structure in the longtitudinal, transverse, vertical and rotational direction. However, the expansion joints are in the most vulnareble position on any bridge, situated at surface level where it is subjected to the unabsorbed impact and vibration of the traffic and exposed not only to dust, silt, grit and water but also to the effects of ultra-violet rays, ozone attach and chemical derivatives. In assessing the abovementioned phonmeonera, derive the requirements for the expansion joint.

[7.5 marks]

3. (a) Figure 2 shows a cross-section of a simply supported beam to support the concrete bridge girders. Design the stirrups of 250N/mm$^2$ characteristic strength to resists an ultimate shear force of 550kN applied. The concrete is of grade 50.

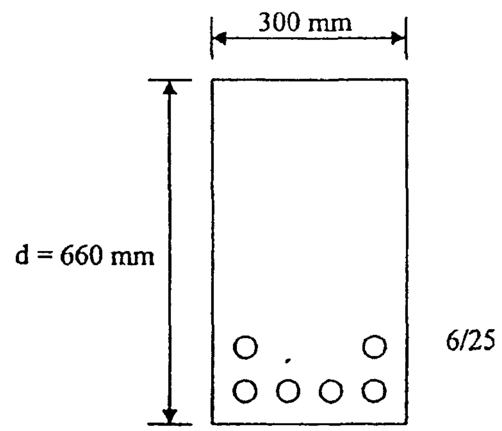
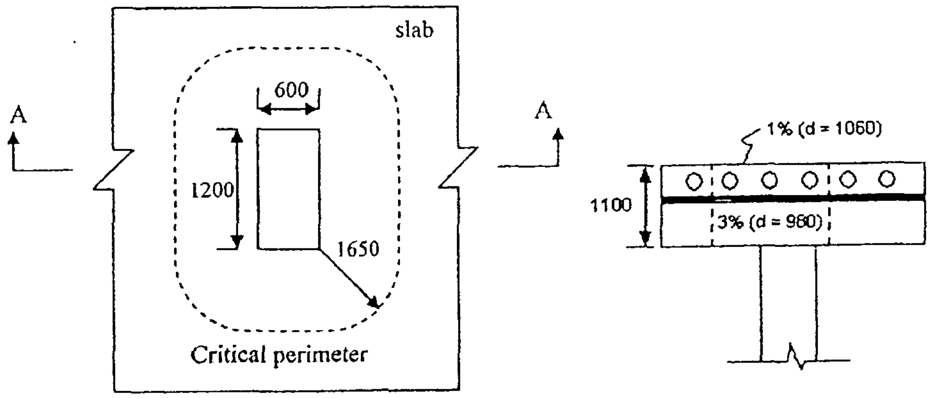



**Figure 2.0 : Cross section of reinforced concrete beam**

[7.5 marks]

(b) Design the slab shown in Figure 3(b) and (c) to resist punching shear if the characteristic strength of the steel and concrete are 460 and 50N/mm$^2$ respectively and the column reaction at the ultimate limit state is 15MN.




(a) Plan (b) Section A-A

**Figure 3(b) and (c)**

[7.5 marks]

(c) List the main advantages to be gained by using continuous against simply supported deck.

[5 marks]

4. (a) The bridge deck in Figure 4 is subjected to distributed loading as shown in Figure 5 Explain with the aid of suitable sketches/diagrams why the bridge deck will undergo both flexural and torsional deformations under the loading condition as shown in Figure 5.

[3 marks]

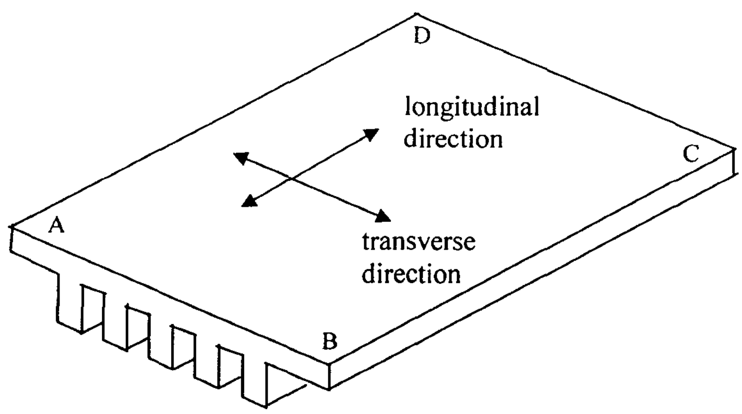



**Figure 4**

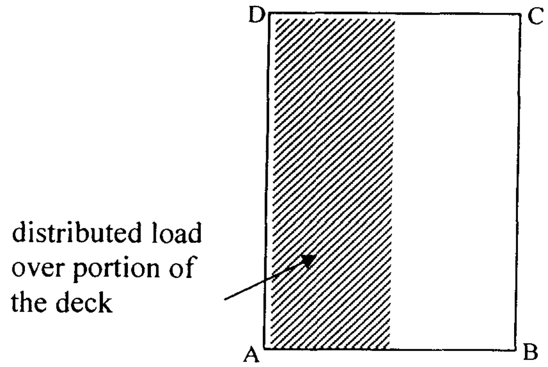



**Figure 5**

(b) Figure 6 shows a grillage structure lying in x-y plane. A point load of 125kN acts at point 2 in the direction of z-axis (directed towards the plane of paper). In addition to that, a uniformly distributed load of 7.5kN/m in the direction of z-axis acts along member 4-2. Coordinates of points 1, 2, 3, 4 and 5 are given in Table 1. Points1, 3, 4 and 5 are all fixed. Cross-section for all the members in the grillage is as shown in Figure 7. By using the element connectivity data in Table 2, obtain the structure stiffness equation for the grillage using matrix displacement method. Assume elastic modulus as E=30GPa and shear modulus as G=12.5GPa.

[17 marks]

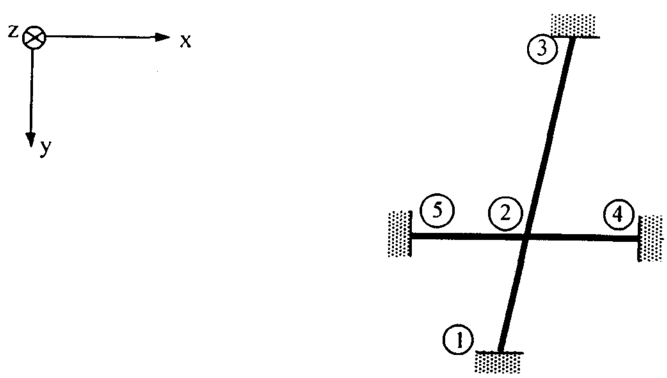



**Figure 6**

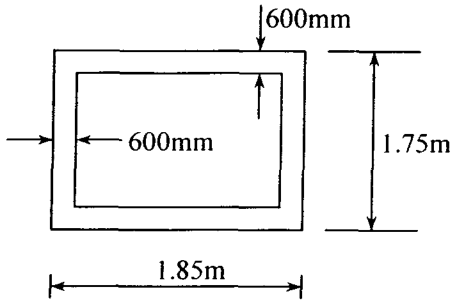



**Figure 7**

**Table 1**

| Point | x-coordinate (m) | y-coordinate (m) |
|---|---|---|
| 1 | -5 | 10 |
| 2 | 0 | 0 |
| 3 | 10 | 20 |
| 4 | 15 | 0 |
| 5 | -15 | 0 |

**Table 2**

| Point | x-coordinate (m) | y-coordinate (m) |
|---|---|---|
| 1 | 1 | 2 |
| 2 | 3 | 2 |
| 3 | 4 | 2 |
| 4 | 5 | 2 |

5. (a) A 36 meter single span bridge with $5^0$ skew angle is subjected to a Knife Edge Load (KEL).

   (i) Construct the equivalent grillage and provide marking for all major elements

   (ii) Sketch all critical sections

   (iii) Mark the notional lanes and disperse the KEL load to the appropriate nodes

   The cross section of the bridge is shown in Figure 8.

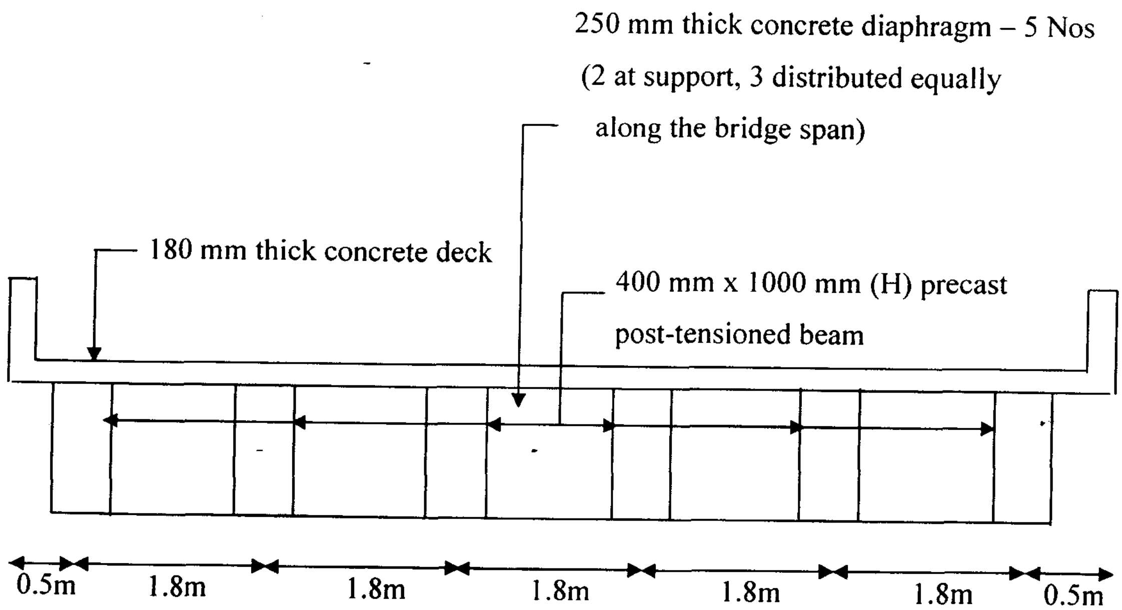



**Figure 8 : Typical Cross Section**

[15 Marks]

(b) The result of the support reactions may be extremely important in some design cases. Briefly discuss **TWO (2)** important criteria pertaining to the support when arranging the geometric layouts using grillage analysis.

[5 Marks]

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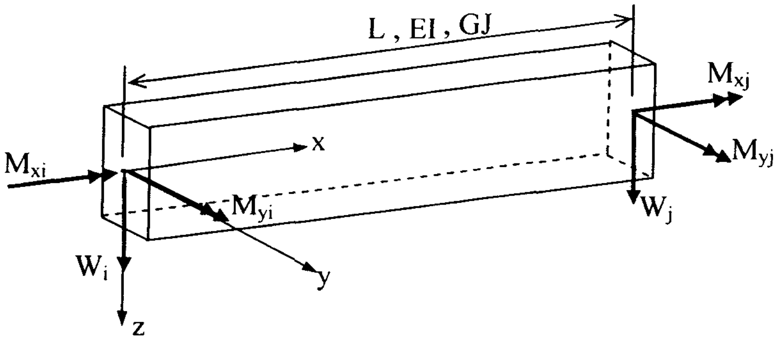
**APPENDIX A**

(a) Element stiffness matrix of a grillage element in global coordinate system

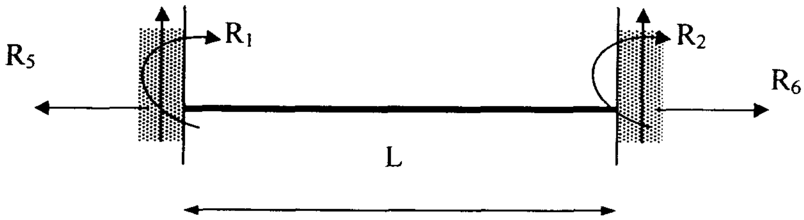


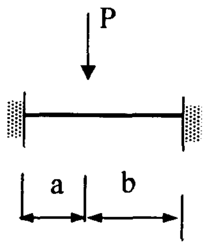
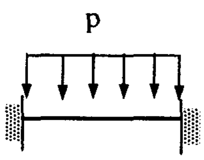

$$\theta_{\bar{x}i} \qquad \theta_{\bar{y}i} \qquad \bar{w}_i \qquad \theta_{\bar{x}j} \qquad \theta_{\bar{y}j} \qquad \bar{w}_j$$

$$\bar{\boldsymbol{k}} = \begin{bmatrix} \frac{GJe^2}{L}+\frac{4EI_yf^2}{L} & & & & & \\ \left(\frac{GJ}{L}-\frac{4EI_y}{L}\right)ef & \frac{GJf^2}{L}+\frac{4EI_ye^2}{L} & & & \textit{Symmetric} & \\ \frac{6EI_yf}{L^2} & -\frac{6EI_ye}{L^2} & \frac{12EI_y}{L^3} & & & \\ \frac{-GJe^2}{L}+\frac{2EI_yf^2}{L} & -\left(\frac{GJ}{L}+\frac{2EI_y}{L}\right)ef & \frac{6EI_yf}{L^2} & \frac{GJe^2}{L}+\frac{4EI_yf^2}{L} & & \\ -\left(\frac{GJ}{L}+\frac{2EI_y}{L}\right)ef & \frac{-GJf^2}{L}+\frac{2EI_ye^2}{L} & -\frac{6EI_ye}{L^2} & \left(\frac{GJ}{L}-\frac{4EI_y}{L}\right)ef & \frac{GJf^2}{L}+\frac{4EI_ye^2}{L} & \\ -\frac{6EI_yf}{L^2} & \frac{6EI_ye}{L^2} & -\frac{12EI_y}{L^3} & -\frac{6EI_yf}{L^2} & \frac{6EI_ye}{L^2} & \frac{12EI_y}{L^3} \end{bmatrix}$$

where $e$=cosα , $f$=sinα and α : angle made by local axis of grillage member with global x-axis in the plane of grillage(measured in clockwise direction ), $L$: length of grillage element, $J$: torsional constant of section, $I_y$: section moment inertia with respect to bending about y-axis, $E$: elastic modulus and $G$: shear modulus.

(b) Fixed end forces




| Type of loading | Moments | Vertical forces | Horizontal forces |
|---|---|---|---|
|   | $R_1 = -Pab^2/L^2$<br>$R_2 = -Pa^2b/L^2$ | $R_3 = Pb(L^2+ab-a^2)/L^3$<br>$R_4 = Pa(L^2+ab-b^2)/L^3$ | $R_5 = 0$<br>$R_6 = 0$ |
|   | $R_1 = -pL^2/12$<br>$R_2 = pL^2/12$ | $R_3 = pL/2$<br>$R_4 = pL/2$ | $R_5 = 0$<br>$R_6 = 0$ |