UNIVERSITI SAINS MALAYSIA

First Semester Examination
2007/2008 Academic Session

October / November 2007

EAS 665/4 – Bridge Engineering

Duration: 3 hours

Please check that this examination paper consists of <u>**NINE**</u> pages of printed material including appendices before you begin the examination.

<u>**Instructions**</u>: Answer **ALL (5)** questions. All questions carry the same marks.

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

All questions <u>**MUST BE**</u> answered on a new sheet.

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

1. (a) Briefly describe the effects of shrinkage of concrete structures to overall bridge components.

(5 marks)

(b) A bridge deck comprises of prestressed beam (pretensioned) at 1 m centres acting compositely with a 160 mm thick concrete slab. The characteristic strengths of prestressed beam and slab concretes are 50 MPa and 30 MPa, respectively. The deflected patterns of tendons at quarter span and at support are shown in Figure 1. The total tendon force after all losses have occurred is 3440 kN. The span is 25 m, the overall beam length is 25.5 m and the nominal values per beam of the critical forces and moments at the support and at quarter span for load combination I are given in Table 1.

Design the reinforcement for both vertical and interface shear at quarter span.

(10 marks)

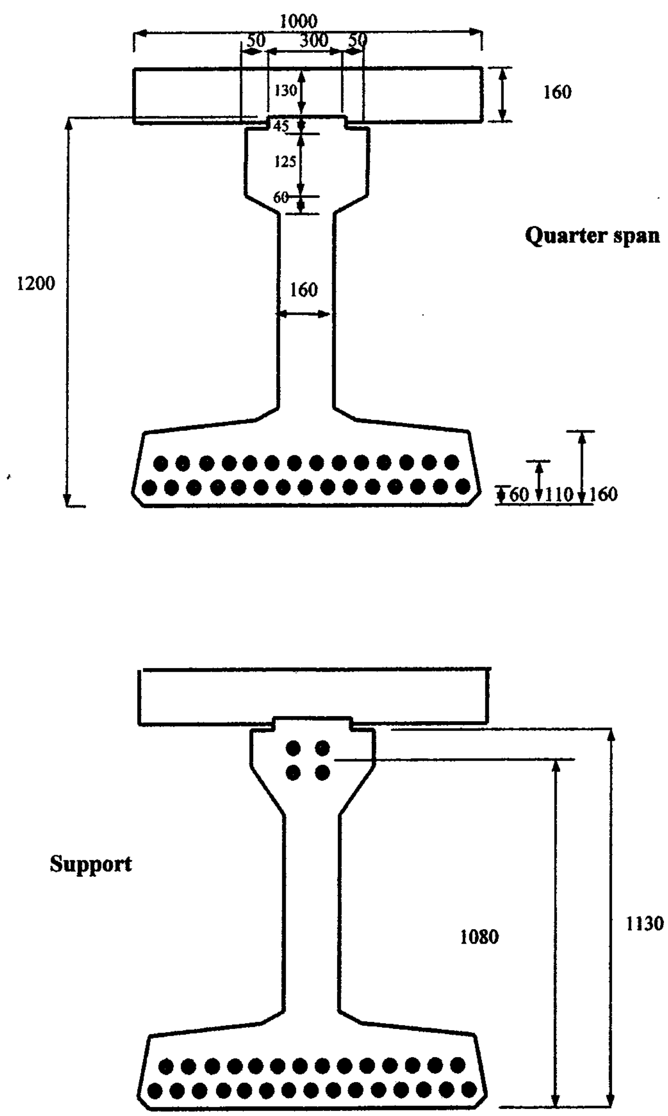


Fig. 1 Composite beam cross-sections

Table 1

Load	Support		Quarter Span	
	Shear force (kN)	Moment (kNm)	Shear force (kN)	Moment (kNm)
Selfweight	164	0	81	763
Parapet	27	0	14	132
Surfacing	29	0	15	135
HB + associated HA	332	0	196	1333

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

(5 marks)

2. (a) Movements of bridge structures always generate problems for bearings and expansions joints. Discuss the sources of movements in the structure due to the influences of elastic and plastic properties of the material.

(10 marks)

(b) A solid slab of post-tensioned prestressed concrete bridge deck is simply supported over a span of 20 m. The relevant data of the solid slab is given below. See Figure 2.

f_{pu} = 1770 N/mm^2 $\quad$ f_{cu} = 40 N/mm^2
f_{pi} = 1239 N/mm^2 $\quad$ E_s = 195 kN/mm^2
A_{sp} = 4449 mm^2/m

Determine the ultimate moment of resistance of the section at mid-span.

(10 marks)

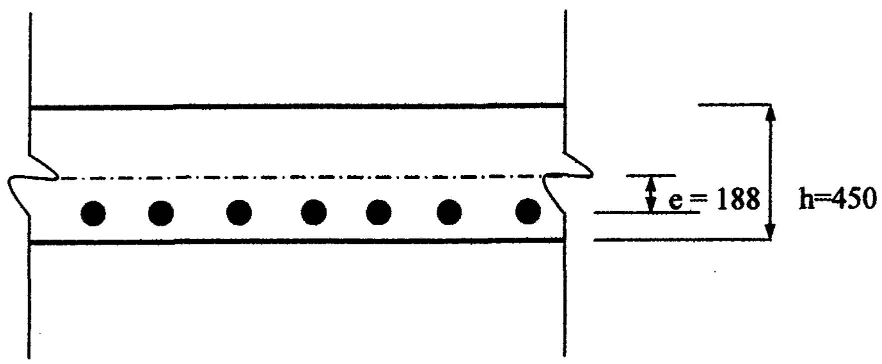


Fig. 2 Post-tensioned prestressed concrete slab

3. (a) Figure 3 shows a reinforced concrete abutment which is 8 m high and 12 m wide. There are wing walls at both ends of the abutment monolithically attached to the abutment. The lateral loads acting on the abutment are earth pressure, which varies from zero at the top to 5.5 H kN/m^2 at a depth H; the surcharge, HA with the nominal value 30 kN/m of acting at the top of the abutment. Calculate the resulting moments at critical point using Hillerborg Strip Method. Draw the loading and bending moment diagrams.

(15 marks)

(b) States **FIVE (5)** load and force criteria to be considered in the design of piers and abutments.

(5 marks)

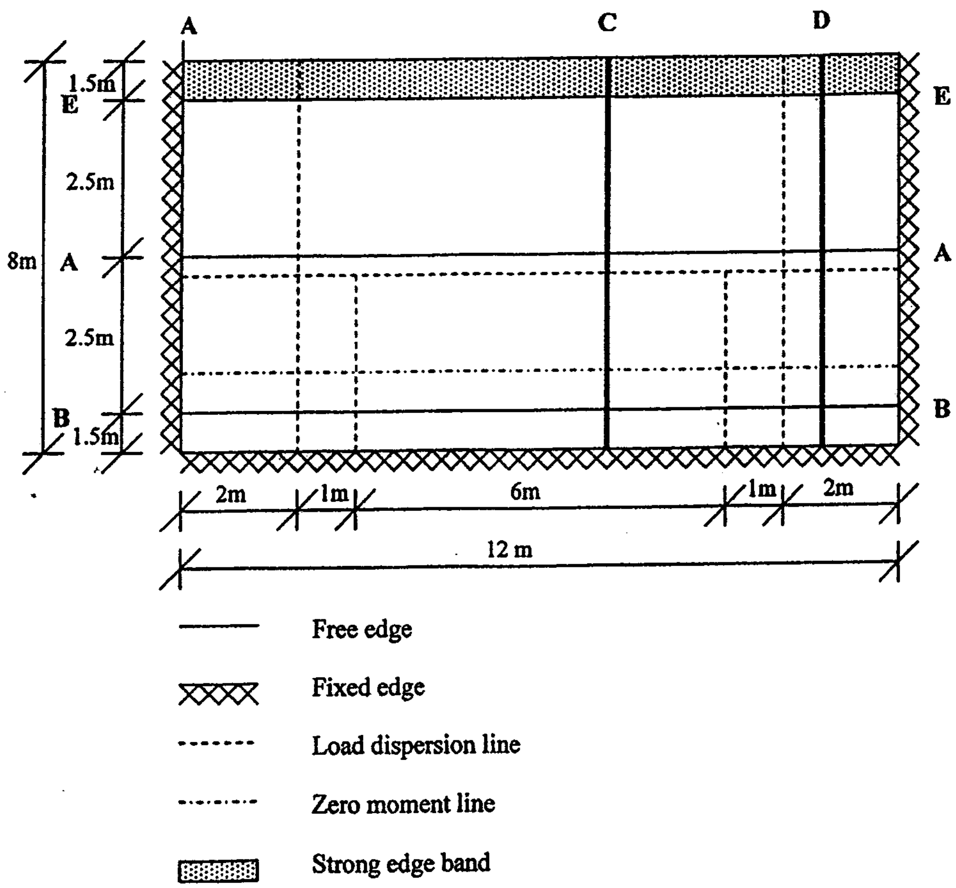
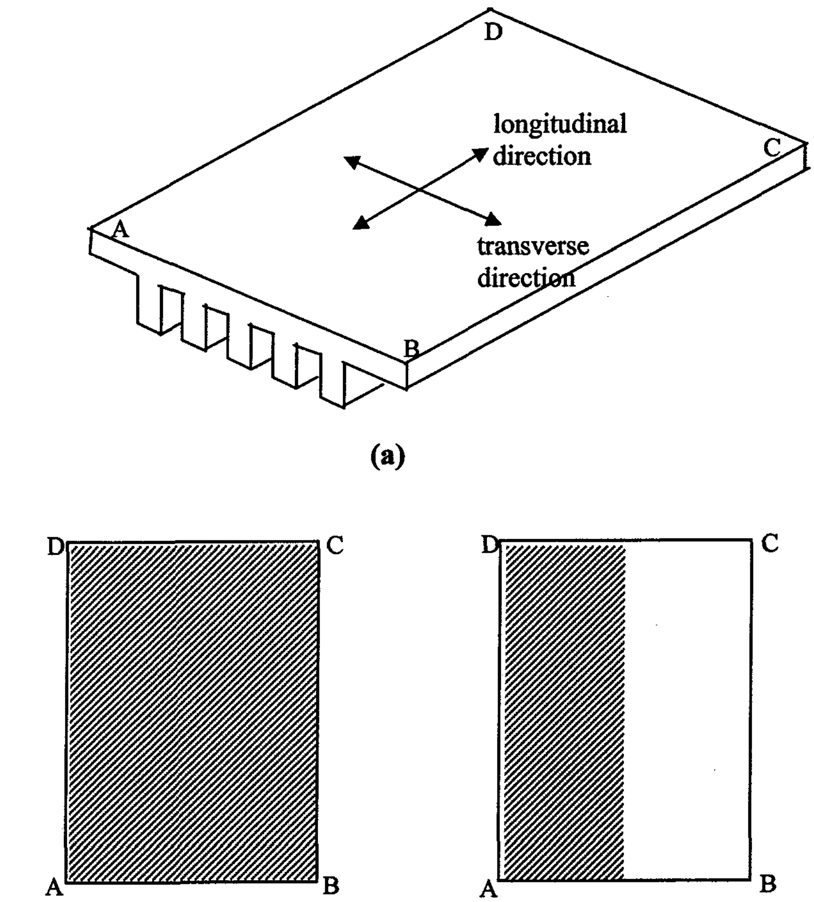


Fig. 3.0 Front elevation of abutment

4. (a) The bridge deck in Figure 4(a) is subjected to two different distributed loading cases as shown in Figure 4(b) and (c). Explain the differences in behavior of the bridge deck in terms of deformation that will occur in longitunidal and transverse directions.

(6 marks)



(b) Case I : loaded over the whole deck

(c) Case II : loaded over partial portion of the deck

Figure 4

4. (b) Figure 5(a) shows a grillage structure lying in x-y plane. A point load of 100kN 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. Points 1, 3 and 4 are all fixed. Cross-section for all the members in the grillage is as shown in Figure 5(b). By using the element connectivity data in Table 1, obtain the structure stiffness equations for the grillage based on matrix method. Assume elastic modulus as E = 30GPa.

(14 marks)

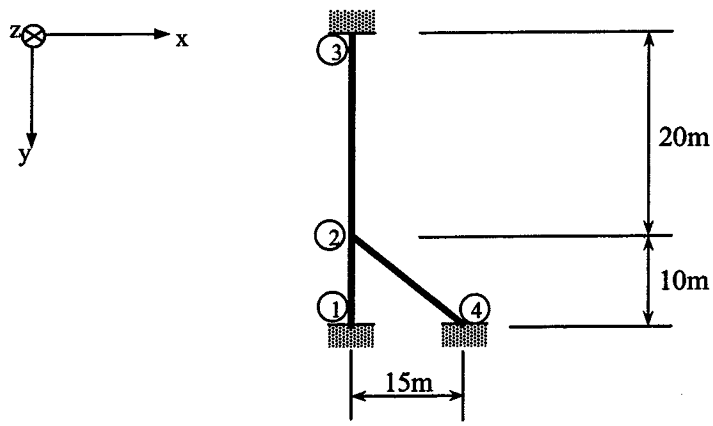


Figure 5(a)

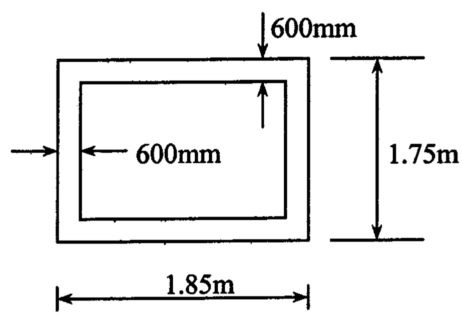


Figure 5(b)

Table 1

Element	Node i	Node j
1	1	2
2	3	2
3	4	2

5. (a) An 18 m single span non-skew bridge is subjected to a Knife Edge Load (KEL) exactly at the mid-span. Construct the equivalent grillage. Provide marking for all major elements, sketch all critical sections, mark the notional lanes and disperse the KEL to the appropriate nodes on the grillage. The cross section of the bridge is shown in Figure 6.

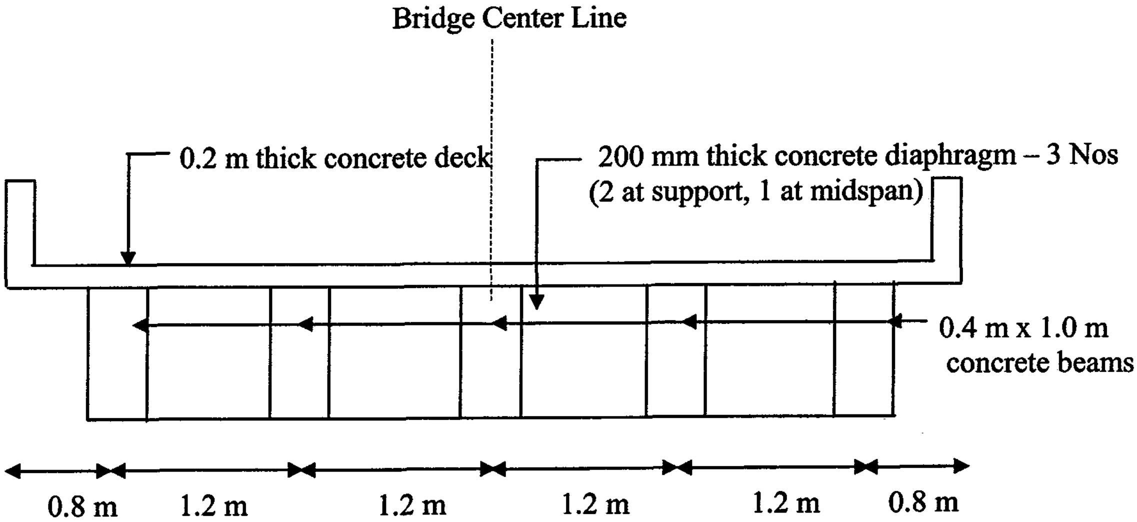


Figure 6 : Typical Cross Section

(15 marks)

(b) Discuss the general recommendations to construct an equivalent grillage for a skew beam-deck bridge.

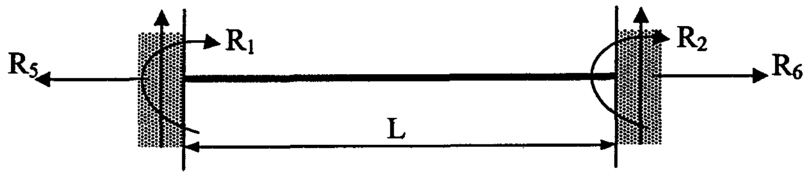
(5 marks)

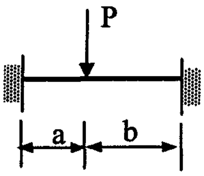
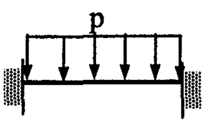
Appendix 1 : Element stiffness matrix for a grillage element

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

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) .

Appendix 2: Fixed end forces



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

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