UNIVERSITI SAINS MALAYSIA

First Semester Examination
2014/2015 Academic Session

December 2014/January 2015

ESA 321/3 – Aerospace Structure
[Struktur Aeroangkasa]

Duration : 3 hours
Masa : 3 jam

Please ensure that this paper contains **TEN (10)** printed pages, **TWO (2)** pages appendix and **FIVE (5)** questions before you begin examination.

*Sila pastikan bahawa kertas soalan ini mengandungi **SEPULOH (10)** mukasurat bercetak, **DUA (2)** mukasurat lampiran dan **LIMA (5)** soalan sebelum anda memulakan peperiksaan.*

Instructions : Answer **ALL** questions.
Arahan *: Jawab **SEMUA** soalan.*

1. **Appendix**/*Lampiran* **[2 pages/*mukasurat*]**

Student may answer the questions either in **English or Bahasa Malaysia**.

*Pelajar boleh menjawab soalan dalam **Bahasa Inggeris atau Bahasa Malaysia.***

Each questions must begin from a new page.

Setiap soalan mestilah dimulakan pada mukasurat yang baru.

In the event of any discrepancies, the English version shall be used.

Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah diguna pakai.

Answer **ALL** questions.
*Jawab **SEMUA** soalan.*

1. Using **Figure 1** shown below, draw the FBD, shear and bending moment diagram of the fuselage.

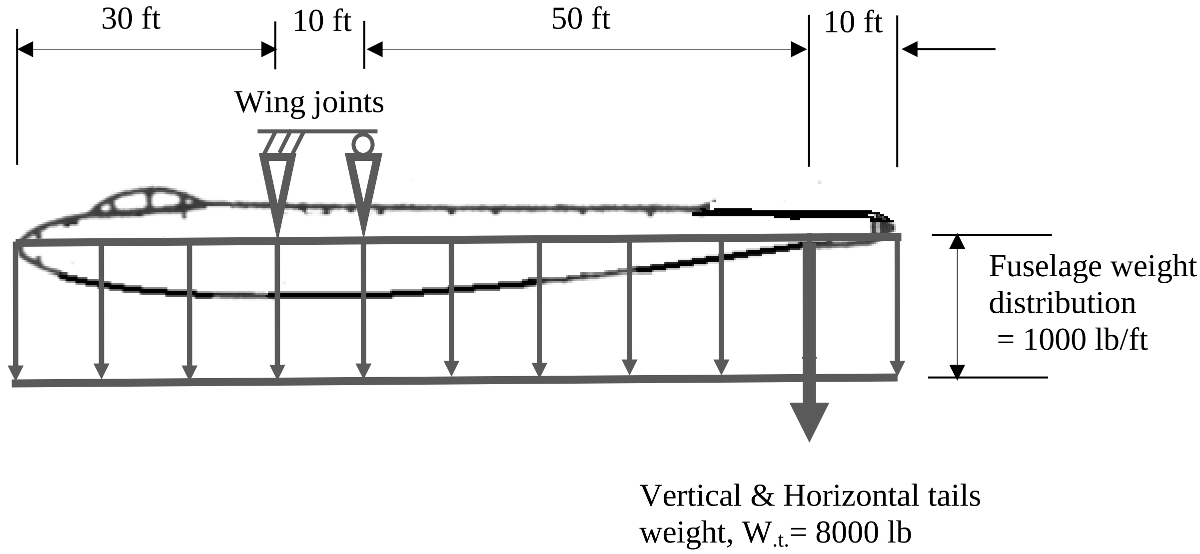
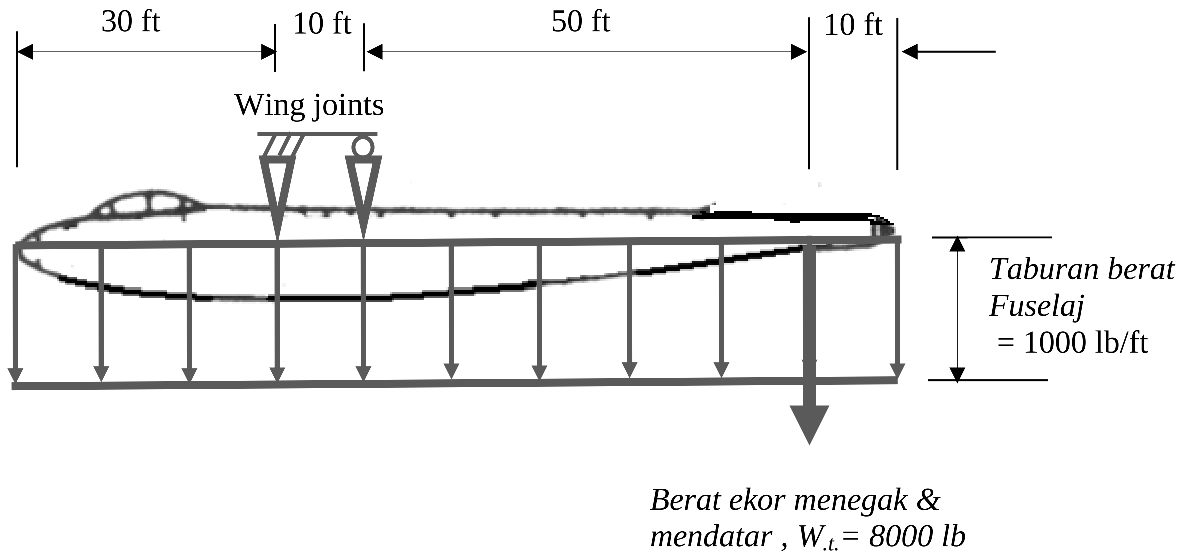


Figure 1

(20 marks)

*Dengan menggunakan **Rajah 1** di bawah, lukiskan rajah FBD, ricih dan momen lentur fuslaj.*

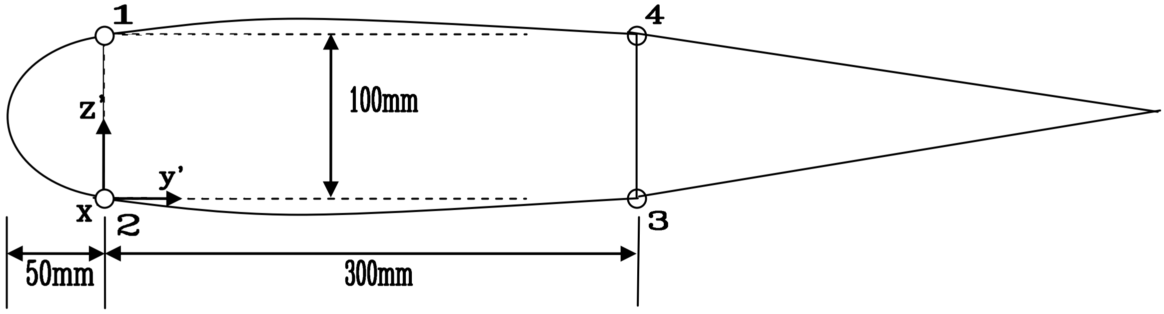


Rajah 1

(20 markah)

2. Bending moments of M_y = -50 kNm and M_z = 10 kNm are applied on the idealized thin-walled 4 booms wing beam section shown in **Figure 2**.

Determine the axial stresses in all booms.



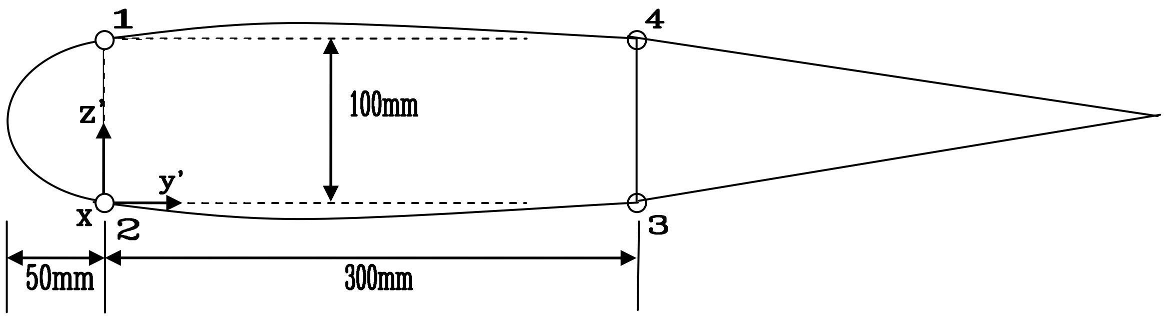
Area of all booms,
$A_1 = A_2 = A_3 = 3000\ mm^2$
$A_4 = 2000\ mm^2$

Figure 2

(20 marks)

*Momen lentur M_y = -50 kNm dan M_z = 10 kNm dikenakan ke atas keratan–rentas rasuk dinding-nipis 4 gelegar yang ditunjukkan di **Rajah 2**.*

Tentukan tegasan paksi pada setiap gelegar.

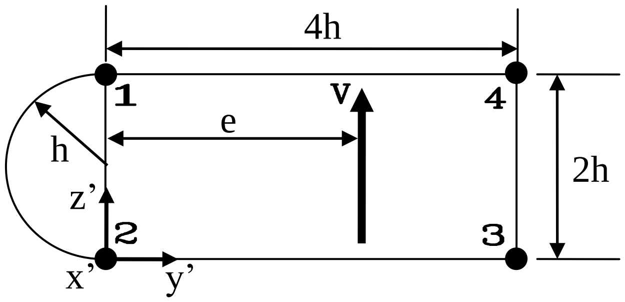


Luas semua gelegar,
$A_1 = A_2 = A_3 = 3000\ mm^2$
$A_4 = 2000\ mm^2$

Rajah 2

(20 markah)

3. Determine e, the shear center of the idealized thin-walled 4-boom wing beam section shown in **Figure 3**.



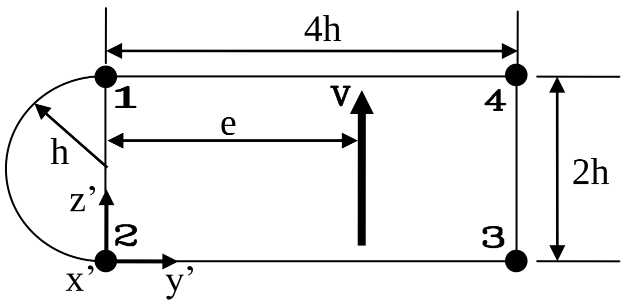
Thickness of all walls = t

Area of booms
$A_1 = A_2 = 2A$
$A_3 = A_4 = A$

Figure 3

(20 marks)

Tentukan e, pusat ricih rasuk kotak 4-gelegar ideal yang ditunjukkan di ***Rajah 3.***



Tebal semua dinding = t

Luas gelegar,
$A_1 = A_2 = 2A$
$A_3 = A_4 = A$

Rajah 3

(20 markah)

4. **Figure 4** shows 2-spar wing structure.

- Wing box skins are considered flat
- Structure made of aluminum *:*
  $E = 10x10^6$ psi; $\upsilon = 0.32$; σ_{yield} =37 ksi; σ_{ult} +=42 ksi
- Max compressive load N_x 1200 lb/in
- Skin thickness, t_{sk} 0.05 in
- Stringer thickness, t_{st} 0.04 in
- Rib spacing, a 24 in
- Stringer spacing, b 3 in

[a] Determine if the skin and stringer can fail in buckling.

(5 marks)

[b] Optimize the skin-stringer structure design to delay structural failure by finding appropriate rib and stringer spacings, a & b. (Hint: failure in buckling in all skins and stringers should occur simultaneously)

- Ratio a/b > 3

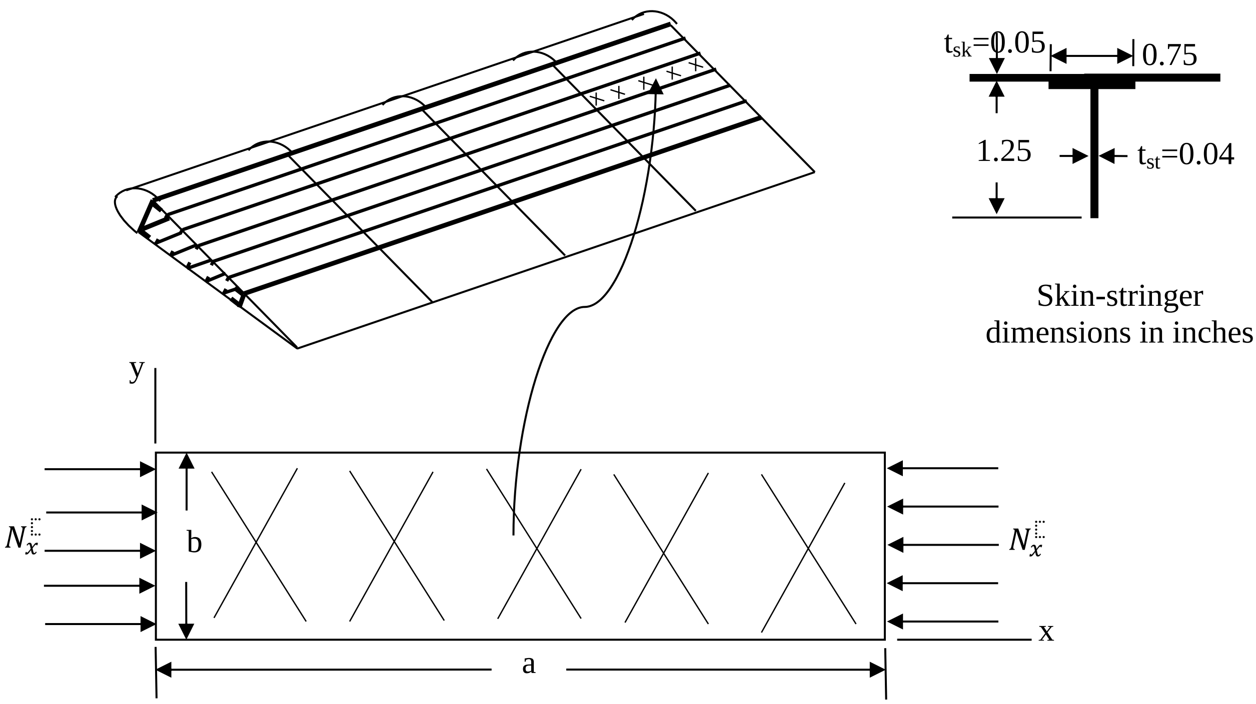


Figure 4

(15 marks)

Rajah 4 menunjukkan struktur sayap 2-spar.

- *Kulit kotak sayap dianggap rata.*
- *Struktur dibuat dari aluminum:*

  $E = 10x10^6$ *psi;* $\upsilon = 0.32$; $\sigma_{yield} = 37$ *ksi;* $\sigma_{ult} += 42$ *ksi*

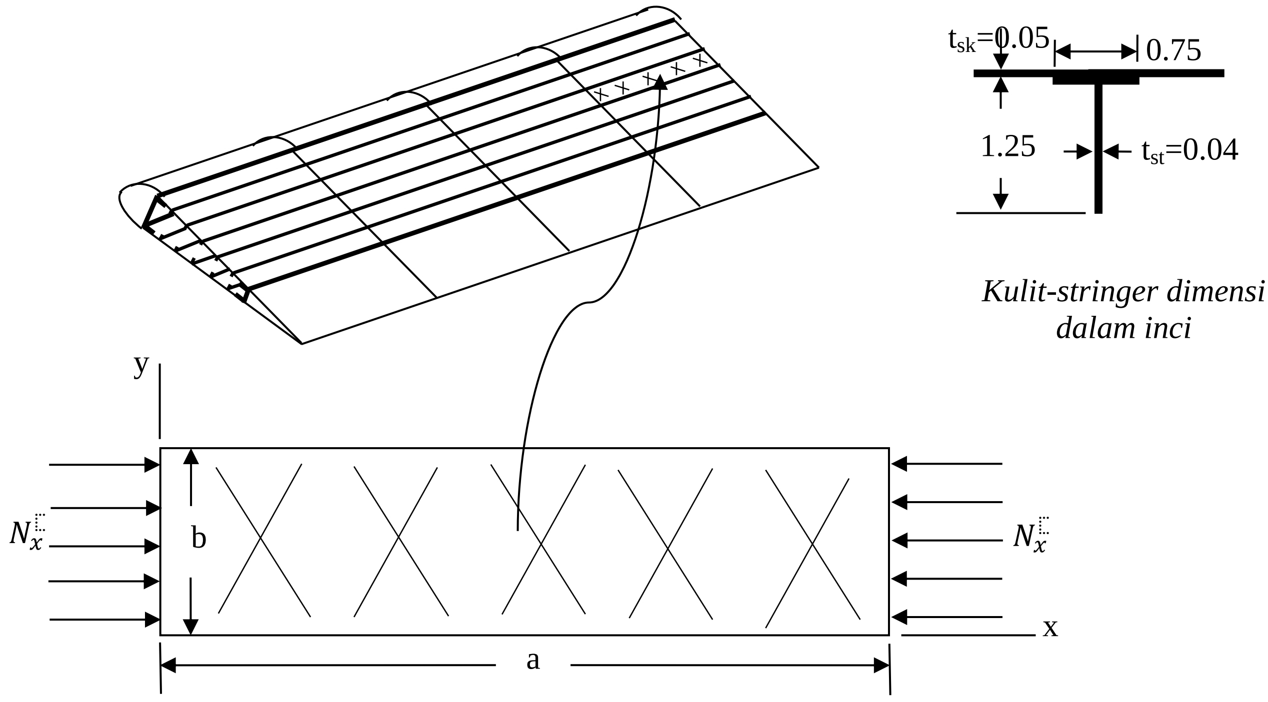
- *Beben mampat mak,* N_x *1200 lb/in*
- *Tebal kulit,* t_{sk} *0.05 in*
- *Tebal gelegar,* t_{st} *0.04 in*
- *Jarak rusuk, a*   *24 in*
- *Jarak gelegar, b*   *3 in*

[a] *Tentukan jika kulit dan gelegar boleh gagal secara lengkokan.*

(5 markah)

[b] *Optimumkan rekabentuk struktur kulit-stringer untuk menunda kegagalan dengan mencari jarak sesuai, a & b rusuk dan gelegar,(Petunjuk : kegagalan secara lengkokan semua kulit dan stringer hendaklah berlaku serentak).*

- *Nisbah a/b > 3*



Rajah 4

(5 markah)

5. [a] Describe the general procedure for performing finite element analysis.

(3 marks)

[b] List 5 advantages of using finite element method.

(3 marks)

[c] A plane truss is made of two identical bars as shown in **Figure 5**. It is loaded with Px and Py at node 2. Node 1 and 3 are fixed to the wall. The properties of the bars are given in **Table 5**. Find the answers of the following questions as a function of E, A and L.

[i] Global stiffness matrix of element 1

[ii] Global stiffness matrix of element 2

[iii] Global assembly matrix of the structure

[iv] Displacement of node 2 in vertical and horizontal direction

(14 marks)

Table 5

Elastic modulus	**E**
Cross sectional area	**A**
Length	**L**

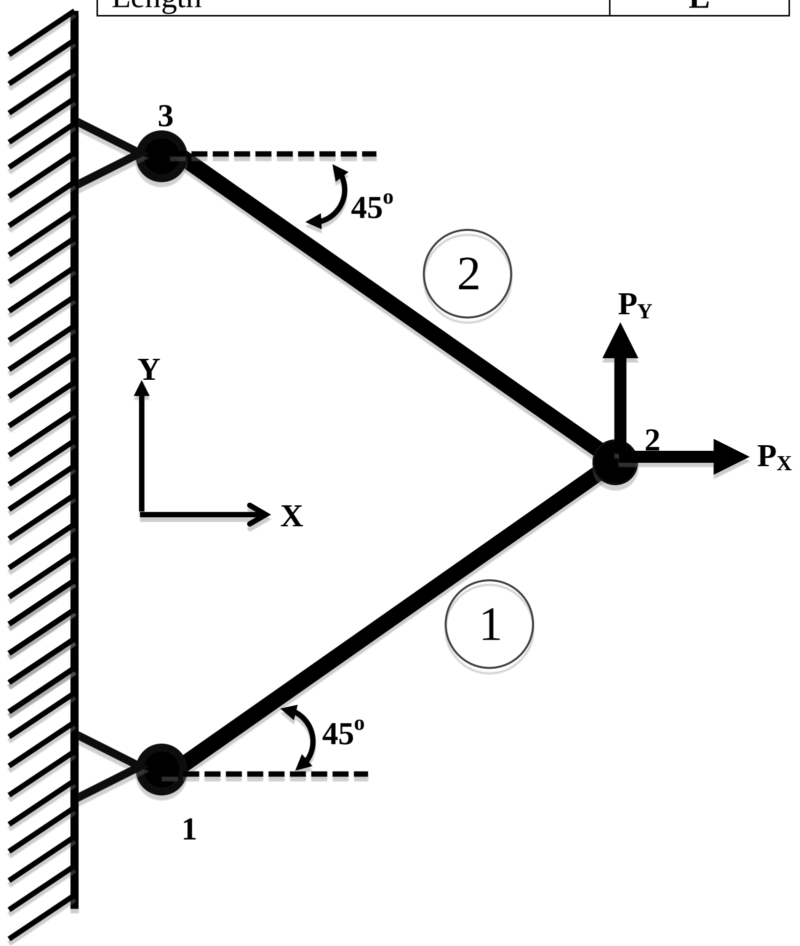


Figure 5

[a] *Perihal tatacara am untuk melakukan analisa kaedah unsur terhingga.*

(3markah)

[b] *Senaraikan 5 kebaikan mengunakan kaedah unsur terhingga.*

(3markah)

[c] *Satu elemen kekuda terdiri daripada 2 palang yang serupa seperti yang ditunjukan dalam* ***Rajah 5.*** *Beban Px and Py dikenakan pada nod 2. Nod 1 dan 3 ditetapkan pada dinding. Sifat palang tersebut diberikan dalam* ***Jadual 5.*** *Cari jawapan kepada soalan berikut dalam fungsi E, A and L.*

[i] *Matrik kekakuan global elemen 1*

[ii] *Matrik kekakuan global elemen 2*

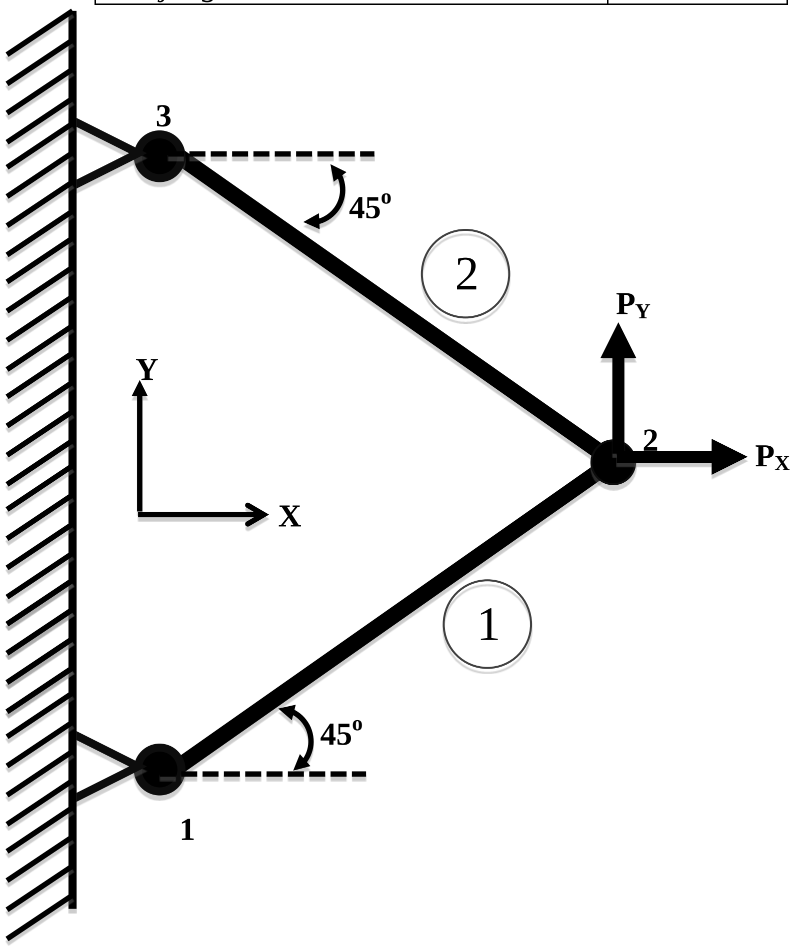
[iii] *Matrik himpunan global struktur tersebut*

[iv] *Sesaran pada nod 2 dalam arah menegak dan mendatar*

(14 markah)

Jadual 5

Modulus kenyal	*E*
Luas keratan rentas	*A*
Panjang	*L*



Rajah 5

Appendix/*Lampiran*

Equation for truss element stiffness in global coordinate system

$$k = \frac{EA}{L}\begin{bmatrix} l^2 & lm & -l^2 & -lm \\ lm & m^2 & -lm & -m^2 \\ -l^2 & -lm & l^2 & lm \\ -lm & -m^2 & lm & m^2 \end{bmatrix} \begin{matrix} u_i & v_i & u_j & v_j \end{matrix}$$

Where

$$l = cos\theta = \frac{X_j - X_i}{L}$$

and

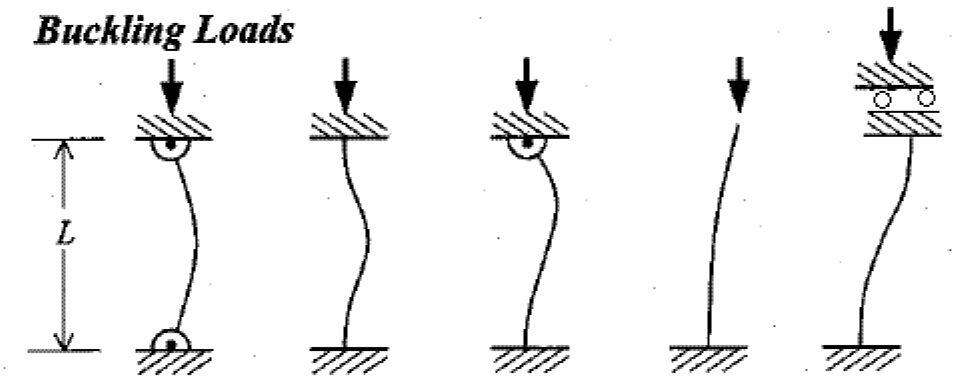
$$m = sin\theta = \frac{Y_j - Y_i}{L}$$

$$\sigma_x = \frac{P}{A} + \frac{-\left(M_z I_y + M_y I_{yz}\right)y + \left(M_y I_z + M_z I_{yz}\right)z}{I_y I_z - I_{yz}^2}$$

$$\Delta q = -\left[\frac{\left(V_y I_y - V_z I_{yz}\right)Q_z + \left(V_z I_z - V_y I_{yz}\right)Q_y}{I_y I_z - I_{yz}^2}\right] \qquad \theta = \frac{q}{2AG}\oint \frac{ds}{t}$$

$$P_{cr} = \frac{\pi^2 EI}{L_e^2} \qquad \sigma_{cr} = \frac{\pi^2 E}{\left(L_e / r\right)^2} \qquad \sigma_{cr} = k\,\frac{\pi^2 E}{12\left(1-\nu^2\right)}\left(\frac{t}{b}\right)^2$$

Buckling Loads



Buckling Load	$\frac{\pi^2 EI}{L^2}$	$\frac{4\pi^2 EI}{L^2}$	$\frac{2.045\pi^2 EI}{L^2}$	$\frac{\pi^2 EI}{4L^2}$	$\frac{\pi^2 EI}{L^2}$
Effective Length L_e	L	$0.5L$	$0.699L$	$2L$	L