UNIVERSITI SAINS MALAYSIA

First Semester Examination
2015/2016 Academic Session

December 2015/January 2016

ESA 321/3 – Aerospace Structure
[Struktur Aeroangkasa]

Duration : 3 hours
Masa : 3 jam

Please ensure that this paper contains **ELEVEN (11)** printed pages, **THREE (3)** pages appendix and **FIVE (5)** questions before you begin examination.

*Sila pastikan bahawa kertas soalan ini mengandungi **SEBELAS (11)** mukasurat bercetak, **TIGA (3)** mukasurat lampiran dan **LIMA (5)** soalan sebelum anda memulakan peperiksaan.*

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

1. **Appendix**/*Lampiran* **[3 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.

1. Using **Figure 1** shown below, draw the Free Body Diagram (FBD), shear load and bending moment diagrams of the half- wing while the attack aircraft is on the tarmac.

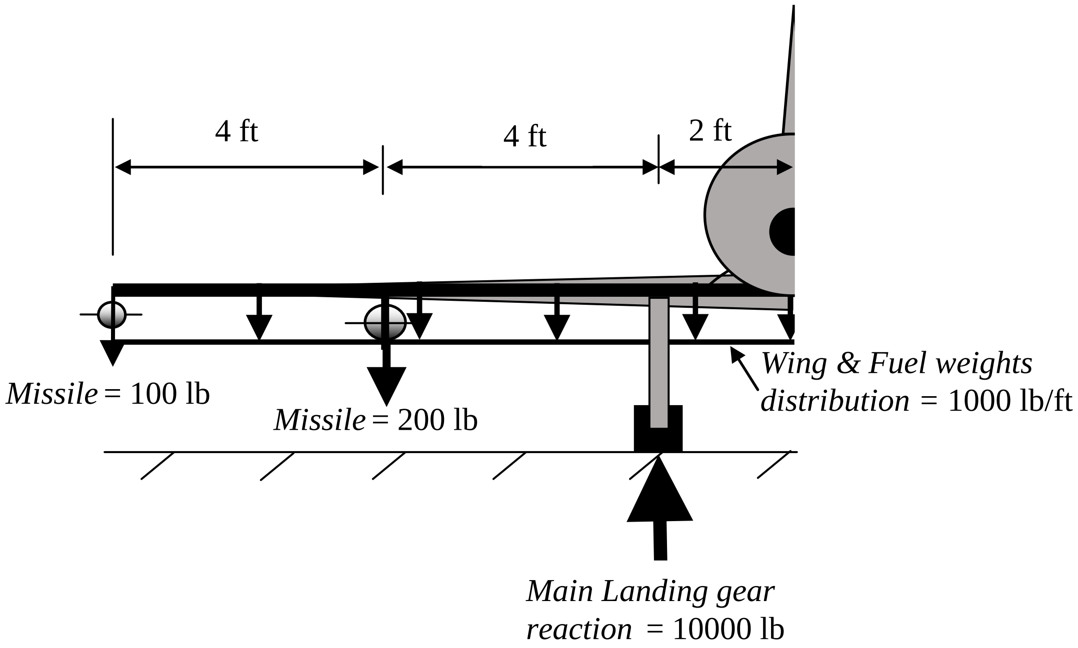
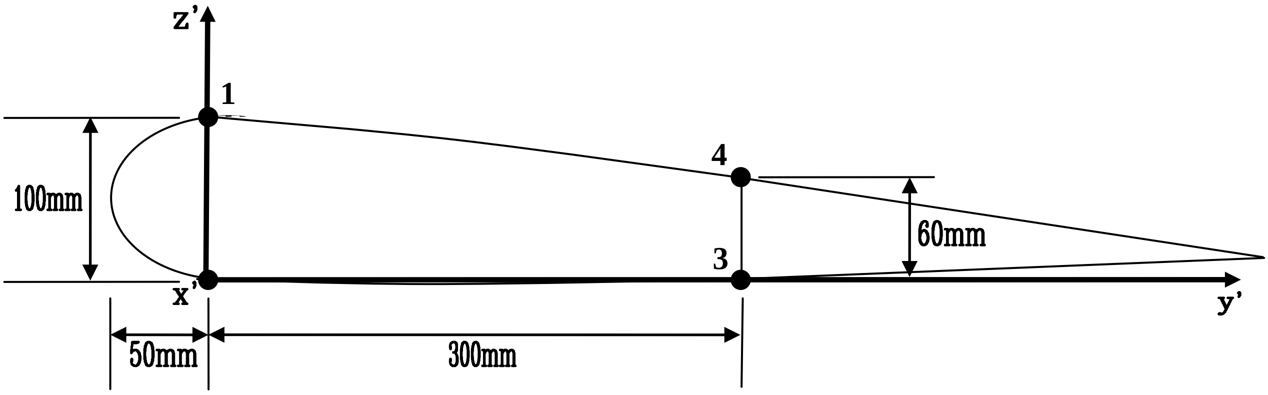


Figure 1

(20 marks)

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.

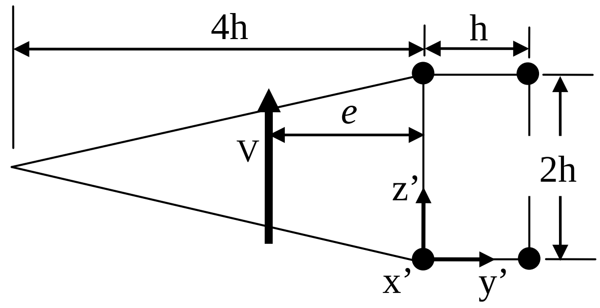


Area of booms
$A_1 = A_2 = A_3 = 3000\ mm^2$
$A_4 = 2000\ mm^2$

Figure 2

(20 marks)

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



Original thickness of all walls = t

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

Figure 3

(20 marks)

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 by finding appropriate rib and stringer spacings, a and b such that if buckling failure occurs, skins and stringers should fail simultaneously.

- Ratio a/b > 3

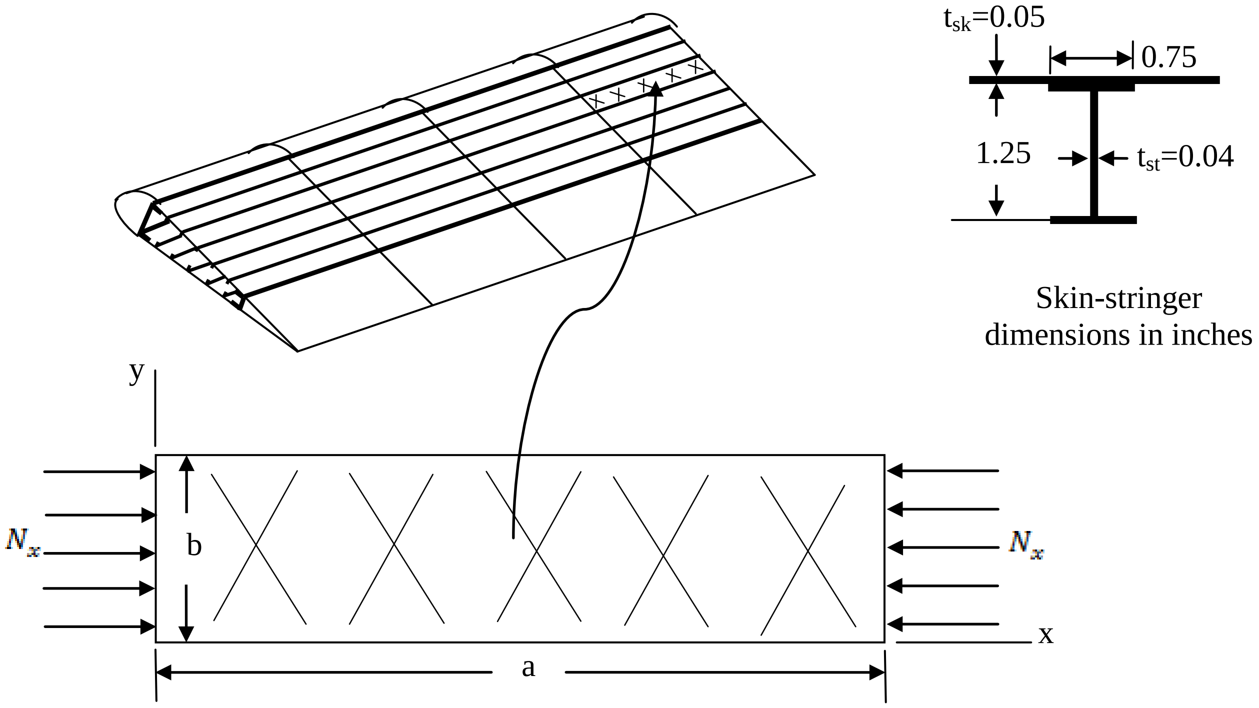


Figure 4

(15 marks)

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

(6 marks)

[b] Within the context of plane element, explain the meaning of plane stress and plane strain.

(4 marks)

[c] A beam shown in **Figure 5** is loaded with force **P** and moment **M** at the beam's mid-span. The beam ends are fixed to the wall. The properties of the beam are given in **Table 5[c]**. By discretizing the beam into 2 elements, find answers of the following questions as a function of E, I, L, P and M.

(i) Stiffness matrix of element 1

(2 marks)

(ii) Stiffness matrix of element 2

(2 marks)

(iii) Global assembly matrix of the structure

(2 marks)

(iv) Displacement and rotation at the beam's mid-span

(4 marks)

Table 5[c]

Elastic modulus	**E**
Moment of inertia	**I**
Length	**L**

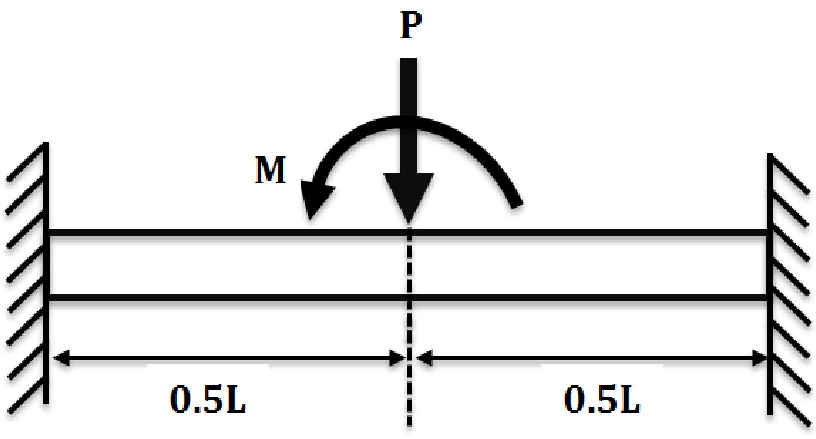
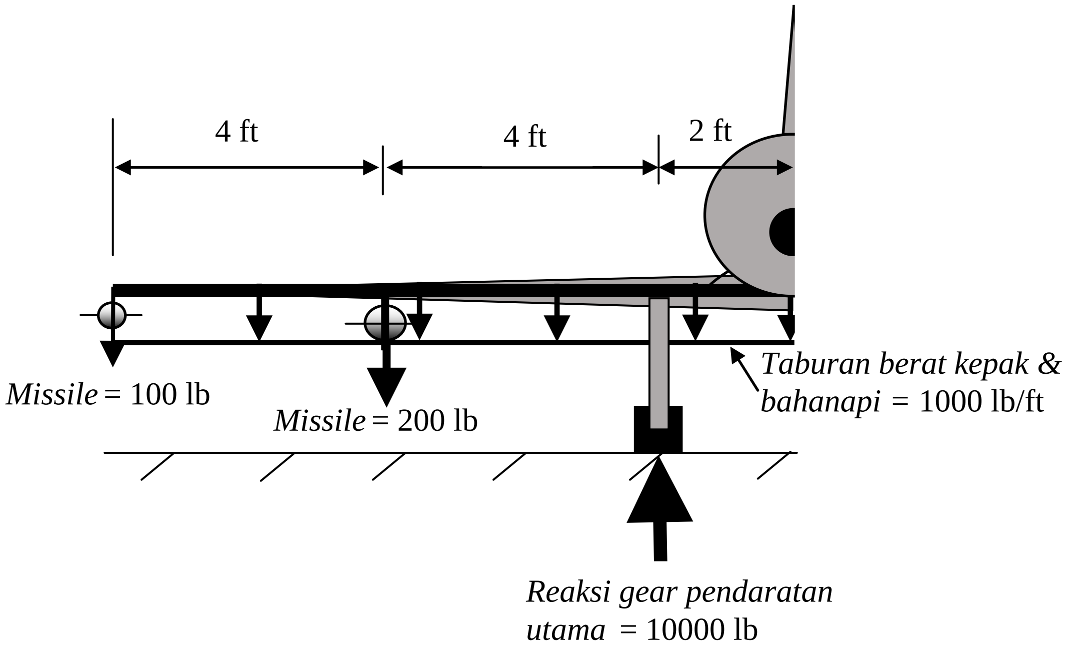


Figure 5

*Jawab **SEMUA** soalan.*

1. *Dengan menggunakan **Rajah 1** di bawah lukiskan Rajah Jasad Bebas, rajah daya ricih dan rajah momen lentur kepak-separuh semasa pesawat pejuang sedang di atas tarmac.*

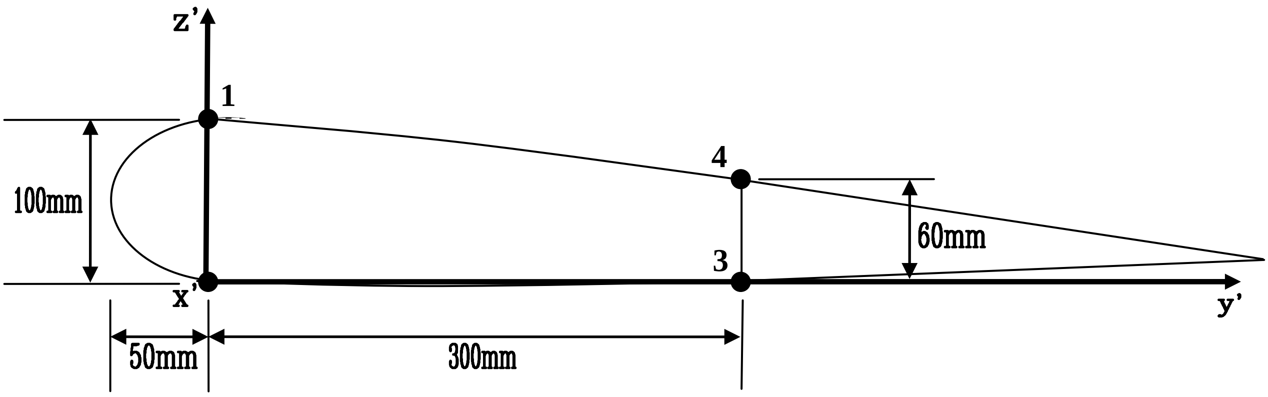


Rajah 1

(20 markah)

2. *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.

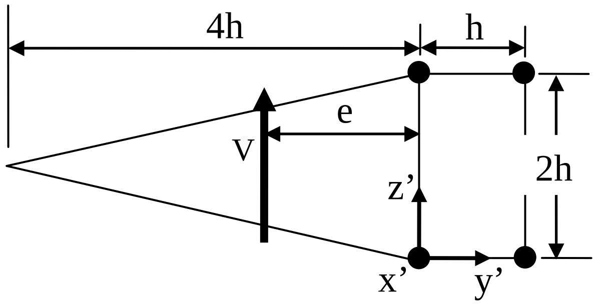


Keluasan gelegar
$A_1 = A_2 = A_3 = 3000\ mm^2$
$A_4 = 2000\ mm^2$

Rajah 2

(20 markah)

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



Tebal asal semua dinding = t

Keluasan gelegar
$A_1 = A_2 = 2A$
$A_3 = A_4 = A$

Rajah 3

(20 markah)

4. ***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*

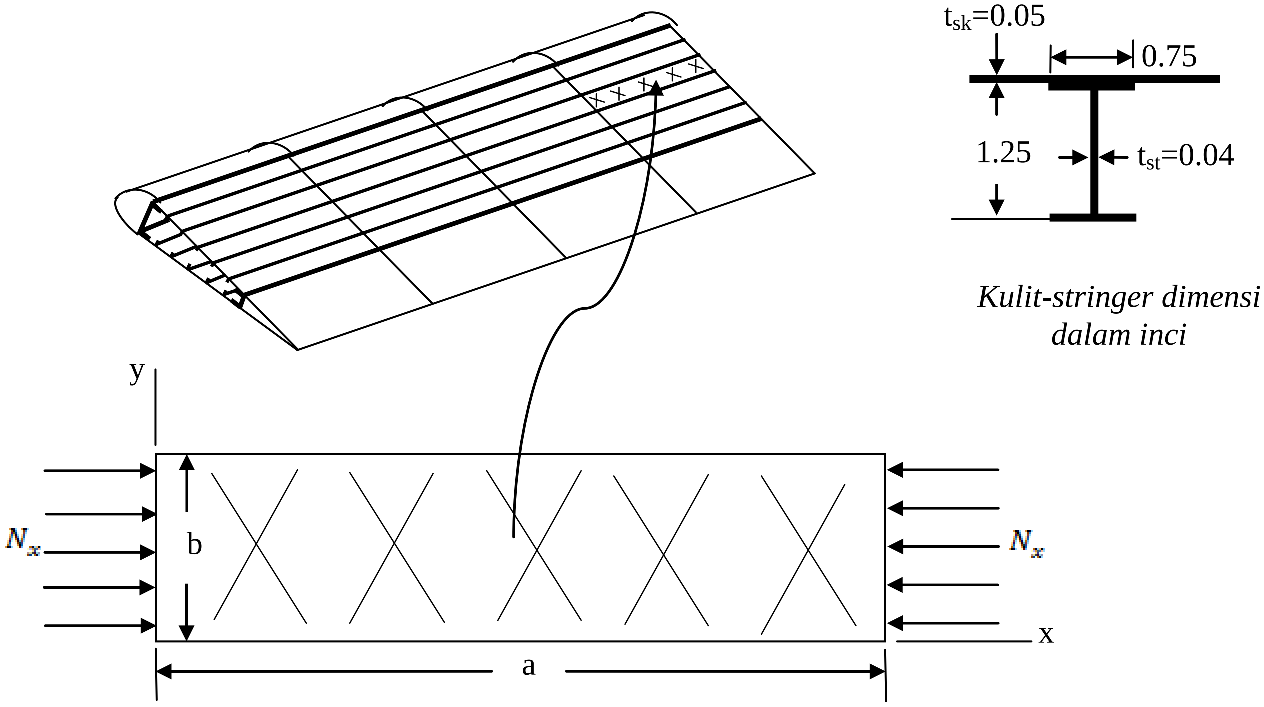
- *Beban mampat mak,* N_x — *1200 lb/in*
- *Tebal kulit,* t_{sk} — *0.05 in*
- *Tebal gelegar,* t_{st} — *0.04 in*
- *Jarak rusuk, a* — *24 in*
- *Jarak gelegar, b* — *3 in*

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

(5 markah)

[b] *Optimumkan rekabentuk struktur kulit-stringer dengan mencari jarak sesuai, a & b rusuk dan gelegar, yang mana jika berlaku kegagalan secara lengkokan kulit dan stringer hendaklah gagal serentak.*

- *Nisbah a/b > 3*



Rajah 4

(15 markah)

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

(6 markah)

[b] *Dalam konteks elemen satah, jelaskan maksud tegasan satah dan terikan satah.*

(4 markah)

[c] *Satu rasuk yang ditunjukkan dalam* **Rajah 5** *dikenakan daya* **P** *dan momen* **M** *pada rentang tengah. Hujung rasuk tersebut diikat pada dinding. Sifat rasuk diberikan dalam* **Jadual 5[c].** *Dengan mendiskritkan rasuk kepada 2 elemen, Cari jawapan kepada soalan berikut sebagai fungsi E, I, L, P dan M.*

(i) *Matrik kekakuan global elemen 1*

(2 markah)

(ii) *Matrik kekakuan global elemen 2*

(2 markah)

(iii) *Matrik himpunan global struktur rasuk*

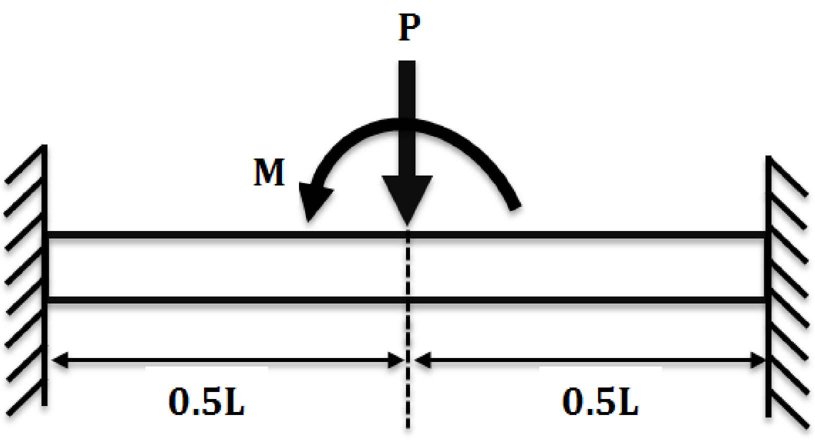
(2 markah)

(iv) *Sesaran dan putaran pada rentang tengah rasuk*

(4 markah)

Jadual 5[c]

Modulus kenyal	*E*
Momen inersia	*I*
Panjang	*L*



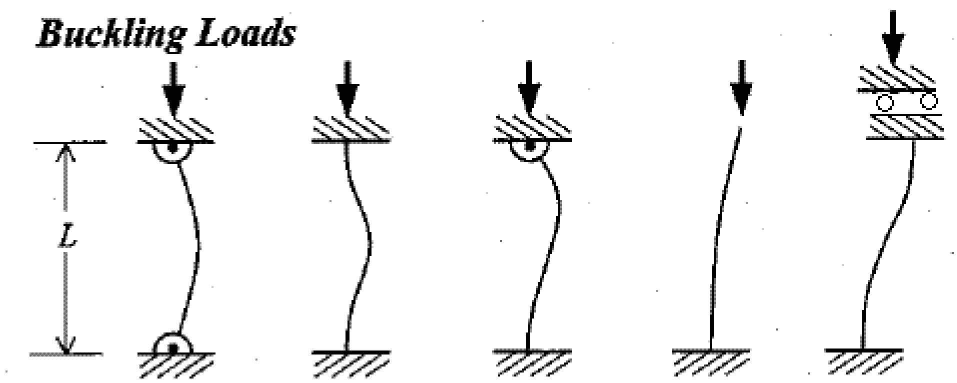
Rajah 5

Appendix/*Lampiran*

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

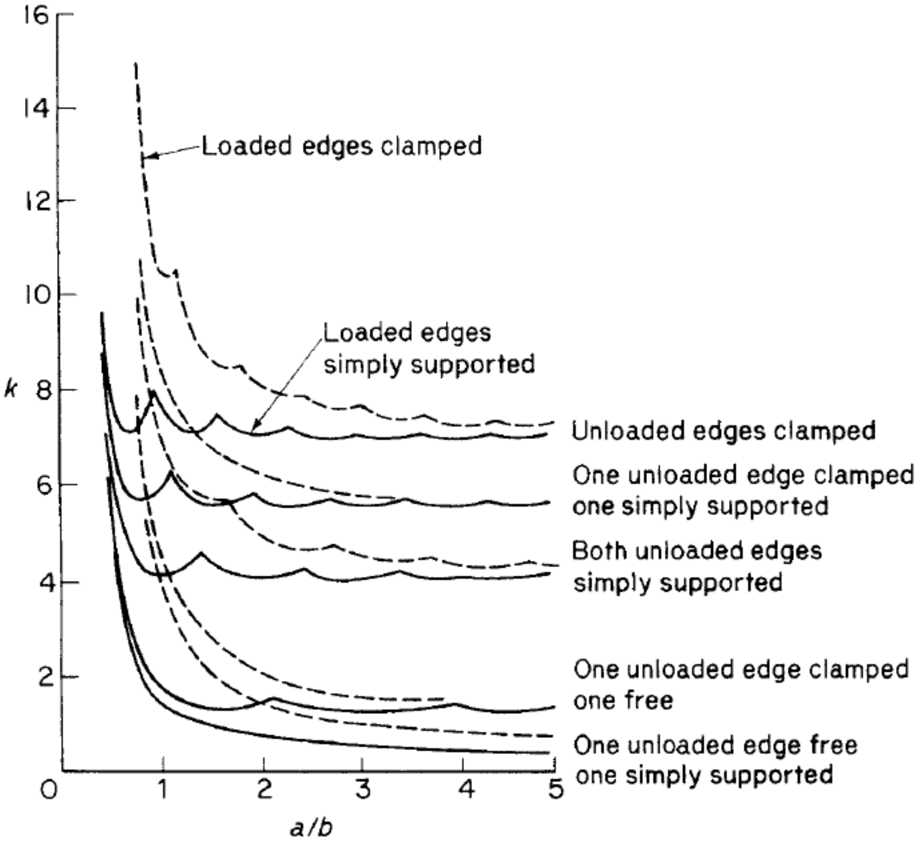
$$\Delta q = -\left[\frac{\left(V_y I_y - V_z I_{yz}\right)Q_z + \left(V_z I_z - V_y I_{yz}\right)Q_y}{I_y I_z - I_{yz}^2}\right] \qquad \theta = \frac{q}{2AG}\oint \frac{ds}{t}$$

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



Buckling 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

Appendix/*Lampiran*



Equation for beam element stiffness in global coordinate system

$$k = \frac{EI}{L^3}\begin{array}{c} \begin{array}{cccc} u_i & v_i & u_j & v_j \end{array} \\ \begin{bmatrix} 12 & 6L & -12 & 6L \\ 6L & 4L^2 & -6L & 2L^2 \\ -12 & -6L & 12 & -6L \\ 6L & 2L^2 & -6L & 4L^2 \end{bmatrix} \end{array}$$

E – Modulus of elasticity
I – Moment of inertia
L – Element length

Appendix/*Lampiran*

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

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

$$\theta = \frac{q}{2AG}\oint \frac{ds}{t}$$

$$P_{cr} = \frac{\pi^2 EI}{L_e^2}$$

$$\sigma_{cr} = \frac{\pi^2 E}{\left(L_e / r\right)^2}$$

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

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