UNIVERSITI SAINS MALAYSIA

First Semester Examination
2017/2018 Academic Session

January 2018

ESA321 – Aerospace Structure
[Struktur Aeroangkasa]

Duration : 3 hours
Masa : 3 jam

Please ensure that this paper contains **FOURTEEN (14)** printed pages, included **THREE (3)** pages appendix and **FIVE (5)** questions before you begin examination.

*Sila pastikan bahawa kertas soalan ini mengandungi **EMPAT BELAS (14)** mukasurat bercetak termasuk **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].

Each student is allowed to bring an A4-sized sheet of self-prepared two-page summary note.

[Setiap pelajar dibenarkan untuk membawa sehelai nota ringkasan bersaiz A4 yang mempunyai dua mukasurat yang ditulis sendiri].

1. [a] Describe the general procedure for performing structural analysis using finite element method software.

(3 marks)

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

(1 marks)

[c] A structure is made of three trusses is shown in figure 1. It is loaded horizontally with force, P with a magnitude of 1,000 Newton at node 2. Node 1 is fixed at the anchor point. Node 2 is fixed vertically while node 3 is free to displace. The properties of the truss are given in **Table 1.** Find the answers of the following questions :

(i) Global stiffness matrix of element 1
(ii) Global stiffness matrix of element 3
(iii) Global assembly matrix of the truss structure
(iv) Displacement of node 3 in horizontal direction

(16 marks)

Table 1 Truss properties

Parameter		Value	Unit
Elastic modulus	**E**	**210,000**	**Pa**
Cross sectional area	**A**	**1**	**m^2**
Length	**L**	**10**	**m**

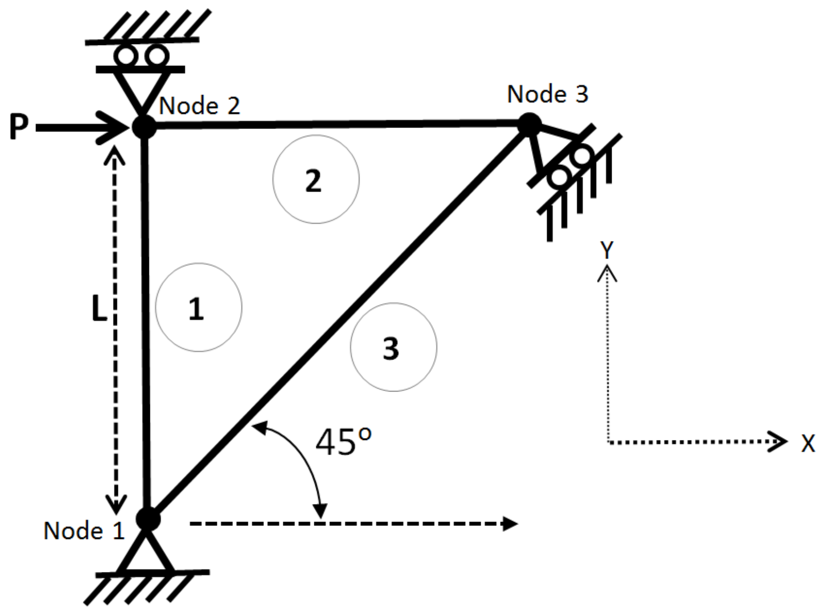


Figure 1 Truss Structure

2. Using **Figure 2** shown below, draw the shear load and bending moment diagrams of the half- wing while the aircraft is in flight.

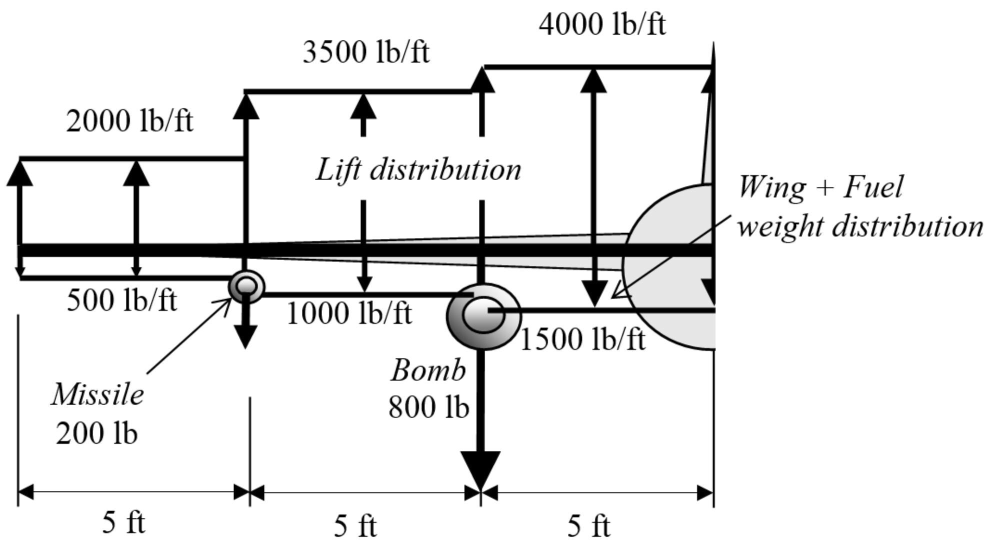
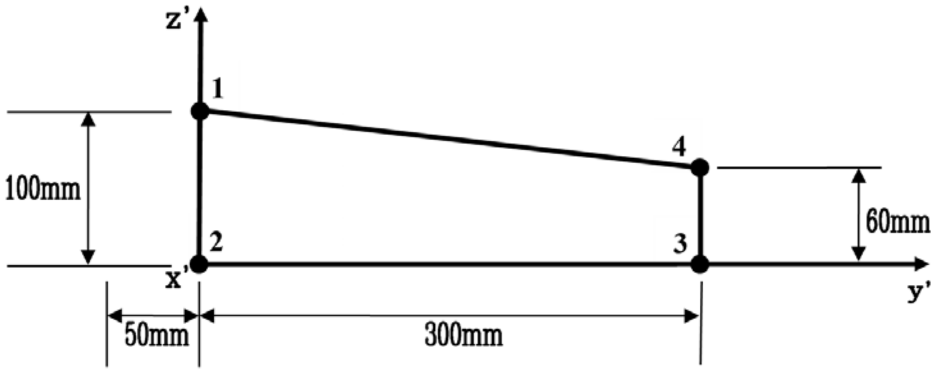


Figure 2

(20 marks)

3. Bending moments of M_y = -50 Nm and M_z = -10 Nm are applied on the idealized thin-walled 4 booms wing beam section shown in **Figure 3**.

   Determine the axial stresses in all booms.

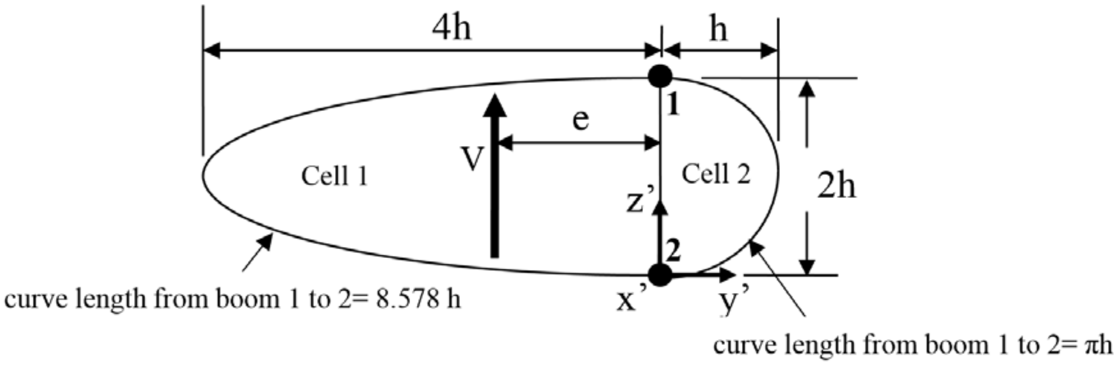


Area of booms 1, 2 & 3 = 3000 mm^2
Area of booms 4 = 2000 mm^2

Figure 3

(20 marks)

4. Determine e, the shear center of the idealized thin-walled 2-boom beam section shown in **Figure 4**.



Original thickness of all walls = t

Area of booms 1 & 2 = A

Area of cell 1 = 6.283 h^2

Area of cell 2 = $\dfrac{\pi h^2}{2}$

Figure 4

(20 marks)

5. **Figure 5** shows a fuselage structure.

- Fuselage skins between the stringers are considered flat
- Structure is made of aluminum:

  $E = 10x10^6$ psi; $\upsilon = 0.3$; σ_{yield} =63 ksi; σ_{ult} =74 ksi

- Skin thickness, t_{sk} 0.05 in
- Stringer thickness, t_{st} 0.04 in

[a] Determine whether the skin and stringer can fail in buckling (including local buckling), given

- Maximum compressive load N_x 1200 lb/in
- Frame/former spacing, L 24 in
- Stringer spacing, W 3 in

(5 marks)

[b] Optimize the skin-stringer (stiffened-panel/panel-strut) structure design by finding the appropriate frame and stringer spacings, L and W such that if buckling failure occurs, the skins, stringers and stiffened-panel structure should fail simultaneously (i.e. local and general/global buckling occurs at the same critical stress).

Design requirements:

- All stringer dimensions are fixed.
- Ratio *L/W >> 3*

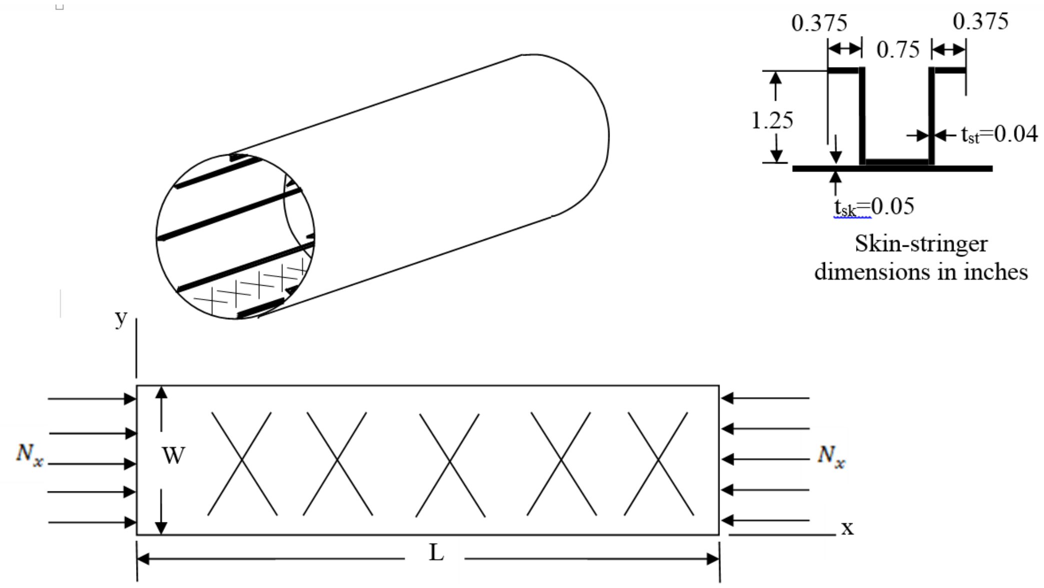


Figure 5

(15 marks)

1. [a] *Perihal tatacara am untuk melakukan analisa struktur dengan menggunakan perisian kaedah unsur terhingga.*

(3 markah)

[b] *Senaraikan* ***5 kelebihan*** *kaedah elemen terhingga.*

(1 markah)

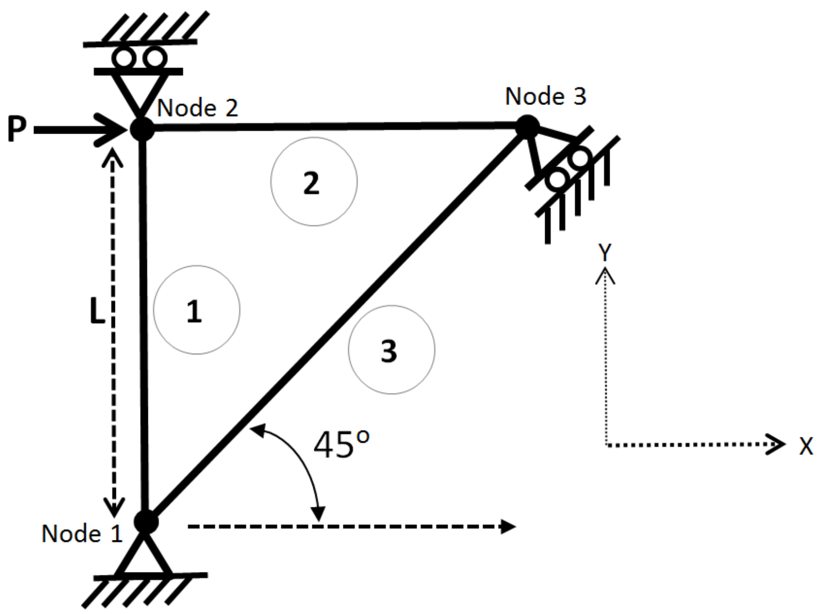
[c] *Satu struktur yang terdiri daripada 3 palang yang serupa seperti yang ditunjukkan dalam* ***Rajah 1****. Beban P dikenakan pada nod 1 dengan magnitud daya berjumlah 1,000 Newton. Nod 1 ditambatkan pada penambat. Nod 2 ditambatkan secara menegak manakala nod 3 tidak ditambatkan. Sifat palang tersebut diberikan dalam* ***Jadual 1****. Cari jawapan kepada soalan berikut :*

(i) *Matrik kekakuan global elemen 1*
(ii) *Matrik kekakuan global elemen 3*
(iii) *Matrik himpunan global struktur tersebut*
(iv) *Sesaran pada nod 3 dalam arah mendatar*

(16 markah)

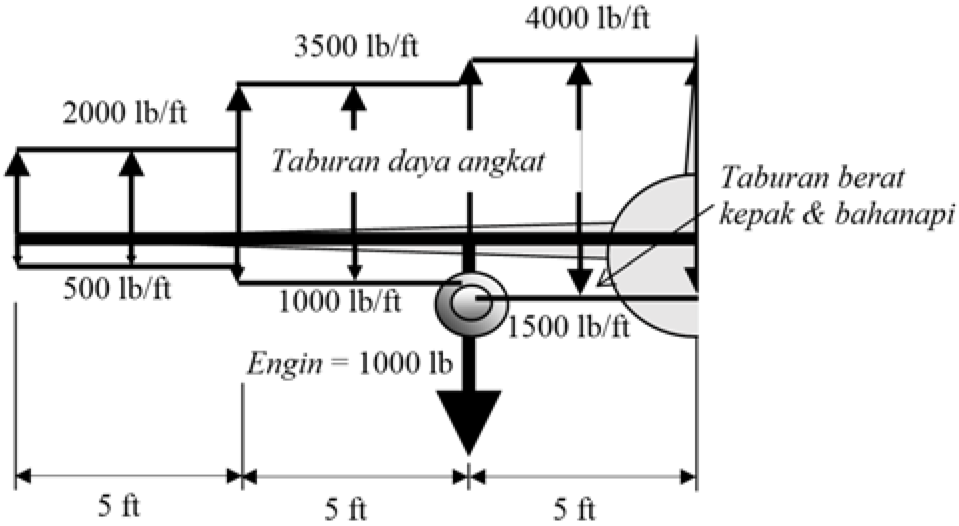
Jadual 1 Sifat Palang

Parameter		Nilai	Unit
Modulus kenyal	**E**	**210,000**	**Pa**
Luas keratan rentas	**A**	**1**	**m^2**
Panjang	**L**	**10**	**m**



Rajah 1 Struktur palang

2. *Dengan menggunakan **Rajah 2** di bawah, lukiskan rajah beban ricih dan momen lentur kepak-separuh semasa pesawat yang sedang dalam penerbangan*

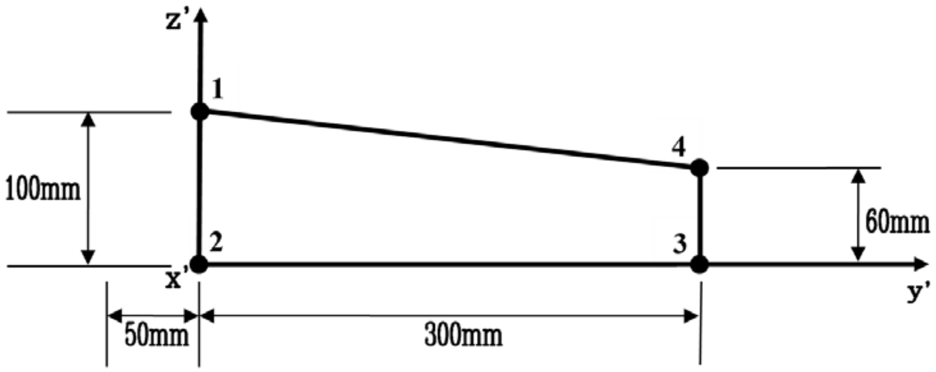


Rajah 2

(20 markah)

3. *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 3****.*

Tentukan tegasan paksi pada setiap gelegar.

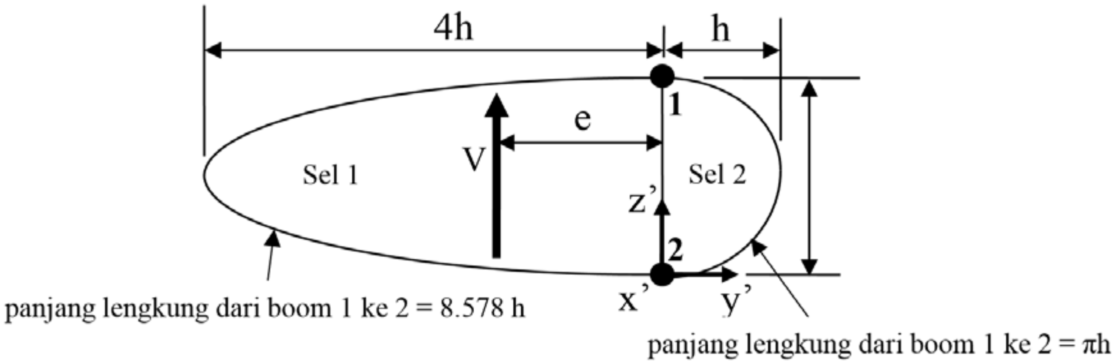


Keluasan gelegar 1, 2 & 3 = 3000 mm^2
Keluasan gelegar 4 = 2000 mm^2

Rajah 3

(20 markah)

4. *Tentukan e, pusat ricih rasuk 2-gelegar ideal yang ditunjukkan di* ***Rajah 4.***



Tebal asal semua dinding = t
Keluasan gelegar 1 & 2 = A
Keluasan sel 1 = 6.283 h^2
Keluasan sel 2 = $\dfrac{\pi h^2}{2}$

Rajah 4

(20 markah)

5. ***Rajah 5*** *menunjukkan struktur fuselaj.*

- *Kulit fuselaj di antara gelegar dianggap rata.*
- *Struktur dibuat dari aluminum:*

  $E = 10x10^6$ *psi;* $\upsilon = 0.3$; σ_{yield} =63 *ksi;* σ_{ult} =74 *ksi*

- *Tebal kulit,* t_{sk} 0.05 *in*
- *Tebal gelegar,* t_{st} 0.04 *in*

[a] *Tentukan jika kulit dan gelegar boleh gagal secara lengkokan (termasuk lengkokan lokal), jika*

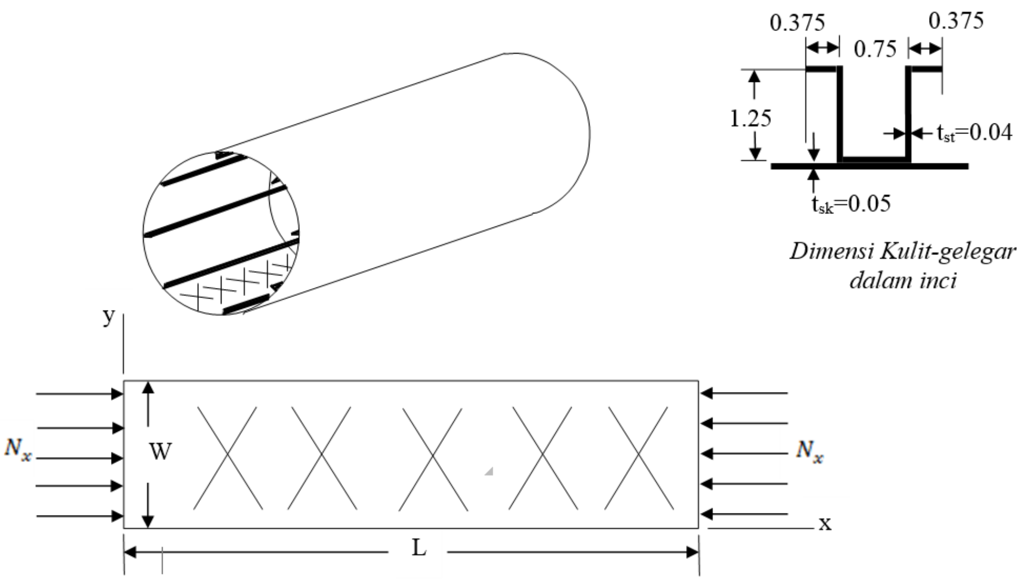
- *Beban mampat maksimum,* N_x 1200 *lb/in*
- *Jarak antara rusuk/bingkai,* L 24 *in*
- *Jarak antara gelegar,* W 3 *in*

(5 markah)

[b] *Optimumkan rekabentuk struktur kulit-gelegar dengan mencari jarak sesuai,* L *(antara rusuk ke rusuk) dan* W *(antara gelegar ke gelegar) di mana andai jika berlaku kegagalan secara lengkokan kulit, gelegar dan struktur kulit-gelegar, hendaklah gagal serentak (iaitu kegagalan lokal dan global berlaku pada tegasan kritikal yang sama)*.

Keperluan rekabentuk :

- *Semua dimensi gelegar tidak berubah*
- *Nisbah L/W >> 3*



Rajah 5

(15 markah)

Appendix/***Lampiran***

Equation for truss element stiffness in global coordinate system

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

Where

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

and

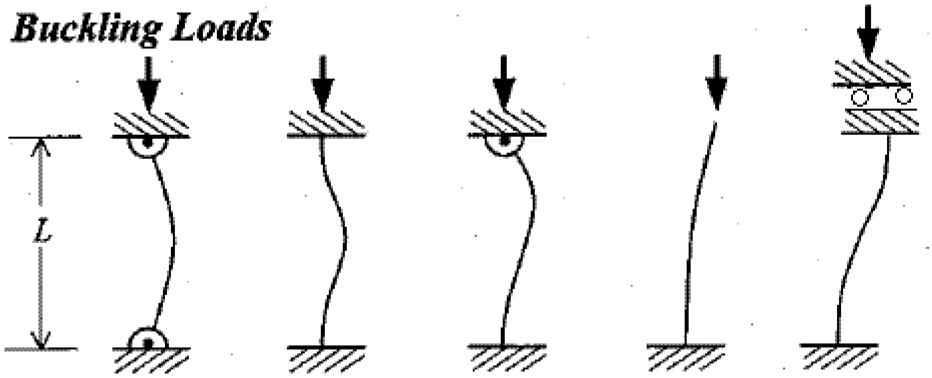
$$m = sin\theta = \frac{Y_j - Y_i}{L}$$

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

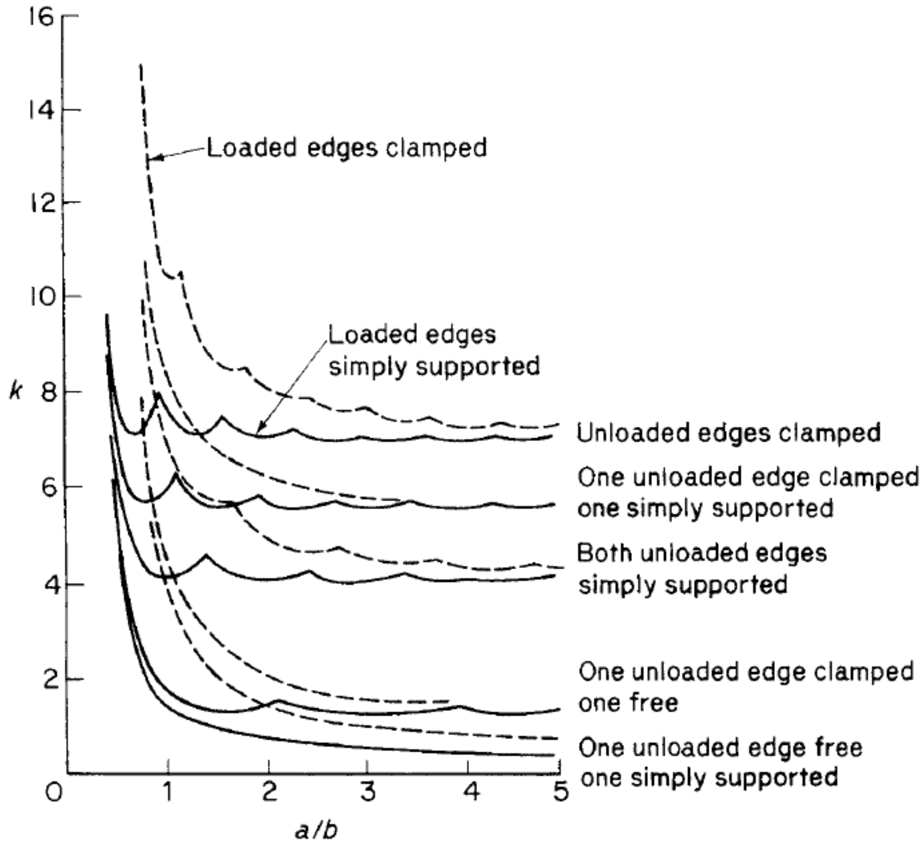
$$\Delta q = -\left[\frac{\left(V_y I_y - V_z I_{yz}\right)Q_z + \left(V_z I_z - V_y I_{yz}\right)Q_y}{I_y I_z - I_{yz}^2}\right] \qquad \theta = \frac{q}{2AG}\oint \frac{ds}{t}$$

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

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



Equation for truss element stiffness in global coordinate system

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

Where

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

and

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

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