Section 1 — Structural analysis: CIVL3014

This example compares RKALC FEAKalc3D results with a University of Western Sydney CIVL3014 frame tutorial.

It illustrates how the program represents the frame and reports support reactions, member end forces, and axial force, shear, and bending moment diagrams (results match exactly with the theoretical matrix solution)

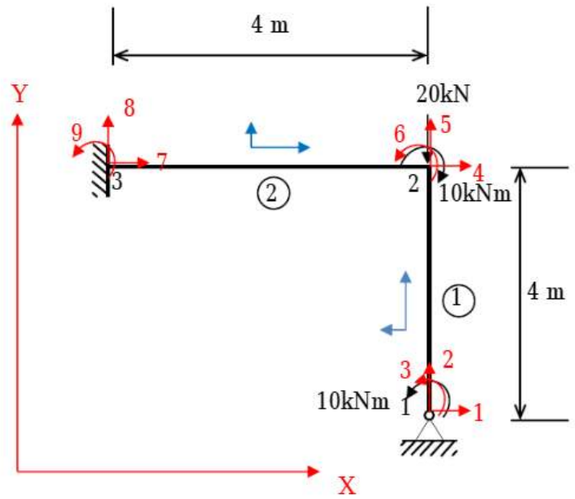
Educational Example Only – Refer to current Australian Standards and project-specific requirements before design.

Question

CIVL3014 Structural Analysis

Question 2. A frame is under load shown below. Take E = 200 GPa, I= 280(10^6) mm^4, A= 18(10^3) mm^2 for each member. Using the Matrix Method, determine

1) the structure stiffness matrix **K** for the frame;
2) the reaction forces for the frame; and
3) member end forces for all members



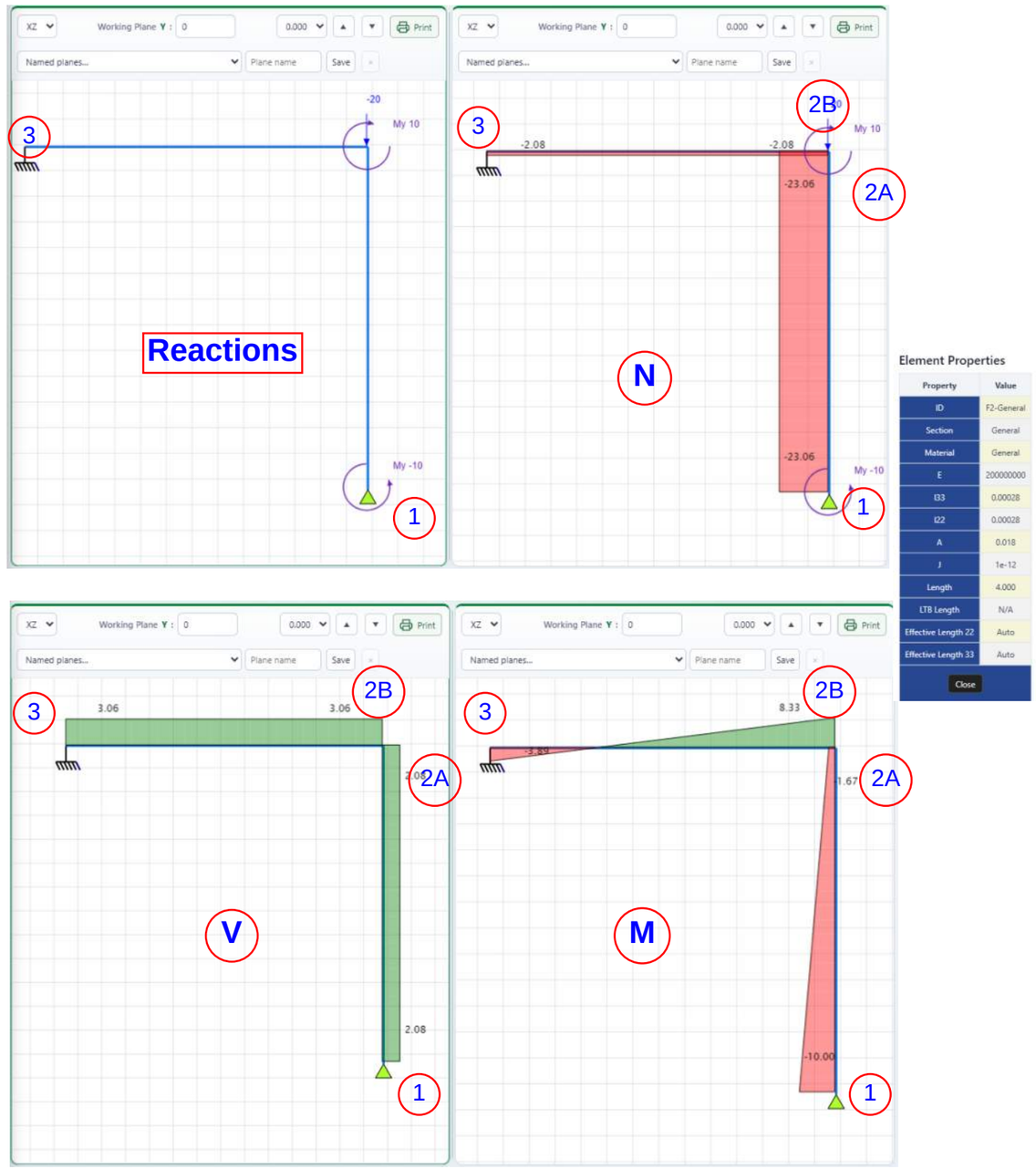
Therefore, we can obtain the member end forces for member 1

$$\mathbf{f}_1 = \mathbf{k}_1\mathbf{T}_1\mathbf{D}_{12} = \begin{bmatrix} 23.06\ \text{kN} \\ 2.08\ \text{kN} \\ 10.00\ \text{kNm} \\ -23.06\ \text{kN} \\ -2.08\ \text{kN} \\ -1.67\ \text{kNm} \end{bmatrix} \begin{matrix} \text{N} \\ \text{V} \\ \text{M} \\ \text{N} \\ \text{V} \\ \text{M} \end{matrix} \begin{matrix} \} 1 \\ \\ \\ \} 2\text{A} \\ \\ \end{matrix}$$

Therefore, we can obtain the member end forces for member 2

$$\mathbf{f}_2 = \mathbf{k}_2\mathbf{T}_2\mathbf{D}_{23} = \begin{bmatrix} 2.08\ \text{kN} \\ -3.06\ \text{kN} \\ -3.89\ \text{kNm} \\ -2.08\ \text{kN} \\ 3.06\ \text{kN} \\ -8.33\ \text{kNm} \end{bmatrix} \begin{matrix} \text{N} \\ \text{V} \\ \text{M} \\ \text{N} \\ \text{V} \\ \text{M} \end{matrix} \begin{matrix} \} 2\text{B} \\ \\ \\ \} 3 \\ \\ \end{matrix}$$

FEAKalc 3D



Stiffness Method Solution (Lecture Notes)

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Question 2. A frame is under load shown below. Take E = 200 GPa, I= $280(10^6)$ mm^4, A= $18(10^3)$ mm^2 for each member. Using the Matrix Method, determine
1) the structure stiffness matrix **K** for the frame;
2) the reaction forces for the frame; and
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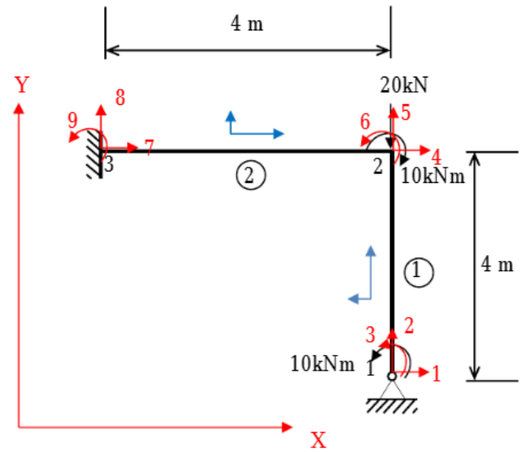

Solution

$$\mathbf{D}_u = \begin{bmatrix} \Theta_1 \\ D_{x2} \\ D_{y2} \\ \Theta_2 \end{bmatrix}\begin{matrix}3\\4\\5\\6\end{matrix},\ \mathbf{D}_k = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}\begin{matrix}1\\2\\7\\8\\9\end{matrix},\ \mathbf{F}_k = \begin{bmatrix} M_1 \\ F_{x2} \\ F_{y2} \\ M_2 \end{bmatrix} = \begin{bmatrix} 10 \\ 0 \\ -20 \\ -10 \end{bmatrix}\begin{matrix}3\\4\\5\\6\end{matrix}$$

1) Assign nodal and member numbers
2) Establish local and global coordinate systems
3) Calculate member stiffness matrices

The parameters are the same as Q1, we can set the same coordinate systems as Q1, member's $\mathbf{k_g}$ the same.

K will also be the same.

Link to this document (accessed online 9/11/2026)
https://www.studocu.com/en-au/document/western-sydney-university/structural-analysis/civl3014-structural-analysis-tutorial-10-solutions-summary/137397460?sid=933dda99-0865-41d6-9b9c-bef4469de6201794232705

4) Assemble to form and partition the total stiffness matrix

$$\mathbf{K} = (10^3)\left[\begin{array}{cccc|ccccc|c} 3 & 4 & 5 & 6 & 1 & 2 & 7 & 8 & 9 & \\ 56 & 21 & 0 & 28 & -21 & 0 & 0 & 0 & 0 & 3 \\ 21 & 910.5 & 0 & 21 & -10.5 & 0 & -900 & 0 & 0 & 4 \\ 0 & 0 & 910.5 & -21 & 0 & -900 & 0 & -10.5 & -21 & 5 \\ 28 & 21 & -21 & 112 & -21 & 0 & 0 & 21 & 28 & 6 \\ \hline -21 & -10.5 & 0 & -21 & 10.5 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & -900 & 0 & 0 & 900 & 0 & 0 & 0 & 2 \\ 0 & -900 & 0 & 0 & 0 & 0 & 900 & 0 & 0 & 7 \\ 0 & 0 & -10.5 & 21 & 0 & 0 & 0 & 10.5 & 21 & 8 \\ 0 & 0 & -21 & 28 & 0 & 0 & 0 & -21 & 56 & 9 \end{array}\right]$$

5) Determine unknown displacements

$$\mathbf{F}_k = \mathbf{K}_{11}\mathbf{D}_u$$

$$\begin{bmatrix} 10 \\ 0 \\ -20 \\ -10 \end{bmatrix} = (10^3)\begin{bmatrix} 56 & 21 & 0 & 28 \\ 21 & 910.5 & 0 & 21 \\ 0 & 0 & 910.5 & -21 \\ 28 & 21 & -21 & 112 \end{bmatrix}\begin{bmatrix} \Theta_1 \\ D_{x2} \\ D_{y2} \\ \Theta_2 \end{bmatrix}$$

In excel, using MINVERSE function, we can obtain

$$\mathbf{K}_{11}^{-1} = (10^{-3})\begin{bmatrix} 0.020534 & -0.0003563 & -0.00011737 & -0.00509 \\ -0.00036 & 0.001109 & -2.755(10^{-6}) & -0.00012 \\ -0.00012 & -2.755(10^{-6}) & 0.00110376 & 0.000237 \\ -0.00509 & -0.0001194 & 0.0002368 & 0.010268 \end{bmatrix}$$

And using MMULT function, we can calculate

$$\mathbf{D}_u = \mathbf{K}_{11}^{-1}\mathbf{F}_k = (10^{-3})\begin{bmatrix} 0.020534 & -0.0003563 & -0.00011737 & -0.00509 \\ -0.00036 & 0.001109 & -2.755(10^{-6}) & -0.00012 \\ -0.00012 & -2.755(10^{-6}) & 0.00110376 & 0.000237 \\ -0.00509 & -0.0001194 & 0.0002368 & 0.010268 \end{bmatrix}\begin{bmatrix} 10 \\ 0 \\ -20 \\ -10 \end{bmatrix}$$

And obtain the unknown displacements:

$$\Theta_1 = 2.586(10^{-4})\text{rad}$$
$$D_{x2} = -2.313(10^{-6})\text{m}$$
$$D_{y2} = -2.562(10^{-5})\text{m}$$
$$\Theta_2 = -1.583(10^{-4})\text{rad}$$

Educational Example Only

Continued : (Lecture Notes)

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6) Determine reaction forces

$$\mathbf{F}_u = \mathbf{K}_{21}\mathbf{D}_u$$

$$\begin{bmatrix} F_{x1} \\ F_{y1} \\ F_{x3} \\ F_{y3} \\ M_3 \end{bmatrix} = (10^3)\begin{bmatrix} -21 & -10.5 & 0 & -21 \\ 0 & 0 & -900 & 0 \\ 0 & -900 & 0 & 0 \\ 0 & 0 & -10.5 & 21 \\ 0 & 0 & -21 & 28 \end{bmatrix}\begin{bmatrix} \Theta_1 \\ D_{x2} \\ D_{y2} \\ \Theta_2 \end{bmatrix} = \begin{bmatrix} -2.082\,\text{kN} \\ 23.055\,\text{kN} \\ 2.082\,\text{kN} \\ -3.055\,\text{kN} \\ -3.895\,\text{kNm} \end{bmatrix}$$

7) Calculate the member end forces using **f = kTD**
For member 1

$$\mathbf{k}_1 = (10^3)\begin{bmatrix} 900 & 0 & 0 & -900 & 0 & 0 \\ 0 & 10.5 & 21 & 0 & -10.5 & 21 \\ 0 & 21 & 56 & 0 & -21 & 28 \\ -900 & 0 & 0 & 900 & 0 & 0 \\ 0 & -10.5 & -21 & 0 & 10.5 & -21 \\ 0 & 21 & 28 & 0 & -21 & 56 \end{bmatrix}$$

$$\mathbf{T}_1 = \begin{bmatrix} 0 & 1 & 0 & 0 & 0 & 0 \\ -1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\mathbf{D}_{12} = \begin{bmatrix} 0 \\ 0 \\ 2.586(10^{-4}) \\ -2.313(10^{-6}) \\ -2.562(10^{-5}) \\ -1.583(10^{-4}) \end{bmatrix}$$

Therefore, we can obtain the member end forces for member 1

$$\mathbf{f}_1 = \mathbf{k}_1\mathbf{T}_1\mathbf{D}_{12} = \begin{bmatrix} 23.06\ \text{kN} \\ 2.08\ \text{kN} \\ 10.00\ \text{kNm} \\ -23.06\ \text{kN} \\ -2.08\ \text{kN} \\ -1.67\ \text{kNm} \end{bmatrix}$$

For member 2

$$\mathbf{k}_2 = (10^3)\begin{bmatrix} 900 & 0 & 0 & -900 & 0 & 0 \\ 0 & 10.5 & 21 & 0 & -10.5 & 21 \\ 0 & 21 & 56 & 0 & -21 & 28 \\ -900 & 0 & 0 & 900 & 0 & 0 \\ 0 & -10.5 & -21 & 0 & 10.5 & -21 \\ 0 & 21 & 28 & 0 & -21 & 56 \end{bmatrix}$$

$$\mathbf{T}_2 = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\mathbf{D}_{32} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ -2.313(10^{-6}) \\ -2.562(10^{-5}) \\ -1.583(10^{-4}) \end{bmatrix}$$

Therefore, we can obtain the member end forces for member 2

$$\mathbf{f}_2 = \mathbf{k}_2\mathbf{T}_2\mathbf{D}_{23} = \begin{bmatrix} 2.08\ \text{kN} \\ -3.06\ \text{kN} \\ -3.89\ \text{kNm} \\ -2.08\ \text{kN} \\ 3.06\ \text{kN} \\ -8.33\ \text{kNm} \end{bmatrix}$$

Educational Example Only