

Problem 1.15



Define degrees of freedom (DOF):



Form structural stiffness matrix:

$$u_1 = 1, \quad u_2 = u_3 = 0$$



$$k_{11} = 2 \frac{12 EI_c}{h^3} = \frac{24 EI_c}{h^3}$$

$$k_{21} = k_{31} = \frac{6 EI_c}{h^2}$$

$$u_2 = 1, \quad u_1 = u_3 = 0$$



$$k_{22} = \frac{4 EI_c}{h} + \frac{4 EI_b}{(2h)} = \frac{4 EI_c}{h} + \frac{EI_c}{h} = \frac{5 EI_c}{h}$$

$$k_{32} = \frac{2 EI_b}{(2h)} = \frac{EI_c}{2h}$$

$$k_{12} = \frac{6 EI_c}{h^2}$$

$$u_3 = 1, \quad u_1 = u_2 = 0$$



$$k_{33} = \frac{4 EI_c}{h} + \frac{4 EI_b}{(2h)} = \frac{4 EI_c}{h} + \frac{EI_c}{h} = \frac{5 EI_c}{h}$$

$$k_{23} = \frac{2 EI_b}{(2h)} = \frac{EI_c}{2h}$$

$$k_{13} = \frac{6 EI_c}{h^2}$$

Hence

$$k = \frac{EI_c}{h^3} \begin{bmatrix} 24 & 6h & 6h \\ 6h & 5h^2 & \frac{1}{2}h^2 \\ 6h & \frac{1}{2}h^2 & 5h^2 \end{bmatrix}$$

The lateral stiffness k of the frame can be obtained by static condensation since there is no force acting on DOF 2 and 3:

$$\frac{EI_c}{h^3} \begin{bmatrix} 24 & 6h & 6h \\ 6h & 5h^2 & \frac{1}{2}h^2 \\ 6h & \frac{1}{2}h^2 & 5h^2 \end{bmatrix} \begin{Bmatrix} u_1 \\ u_2 \\ u_3 \end{Bmatrix} = \begin{Bmatrix} f_1 \\ 0 \\ 0 \end{Bmatrix}$$

First partition k as

$$k = \frac{EI_c}{h^3} \begin{bmatrix} 24 & 6h & 6h \\ 6h & 5h^2 & \frac{1}{2}h^2 \\ 6h & \frac{1}{2}h^2 & 5h^2 \end{bmatrix} = \begin{bmatrix} k_{11} & k_{12} \\ k_{12}^T & k_{00} \end{bmatrix}$$

where

$$k_{11} = \frac{EI_c}{h^3} [24]$$

$$k_{12} = \frac{EI_c}{h^3} [6h \quad 6h]$$

$$k_{00} = \frac{EI_c}{h^3} \begin{bmatrix} 5h^2 & \frac{1}{2}h^2 \\ \frac{1}{2}h^2 & 5h^2 \end{bmatrix}$$

Then compute the lateral stiffness k from

$$k = k_{11} - k_{12} k_{00}^{-1} k_{12}^T$$

Since

$$k_{00}^{-1} = \frac{4h}{99 EI_c} \begin{bmatrix} 5 & -\frac{1}{2} \\ -\frac{1}{2} & 5 \end{bmatrix}$$

we get

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M Lipman



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