Checking the Inventor Model with a Hands-on Approach

As an electrical engineer by profession, I am undertaking a self-study project to enhance my knowledge in structural engineering. I have designed a structure to support a large pipe weighing 32,000 kN, distributed across eight legs.

Initial Assumption

The weight of the pipe (32,000 kN) is evenly distributed over the eight legs, resulting in a force of 4,000 kN per contact point.

Step 1: Free Body Diagram

The contact forces on the frame need to be decomposed, primarily focusing on the x-components for the inner legs. I have depicted these decomposed forces in the free body diagram.

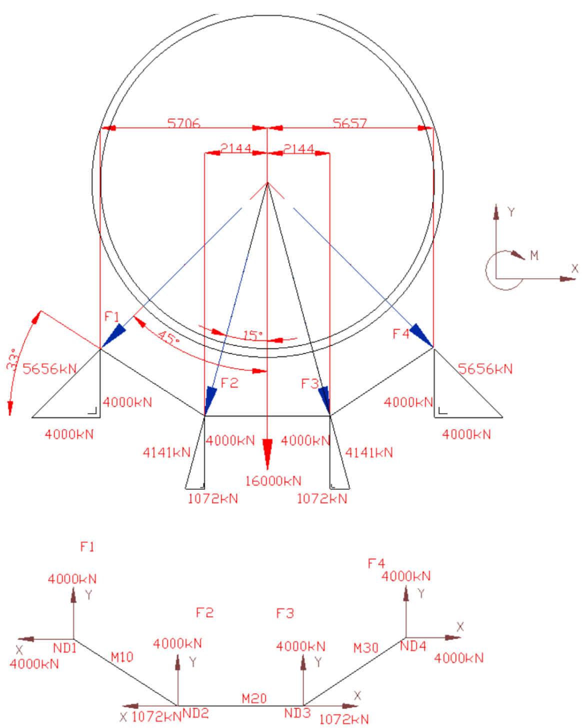

Figure 1: Free body diagram

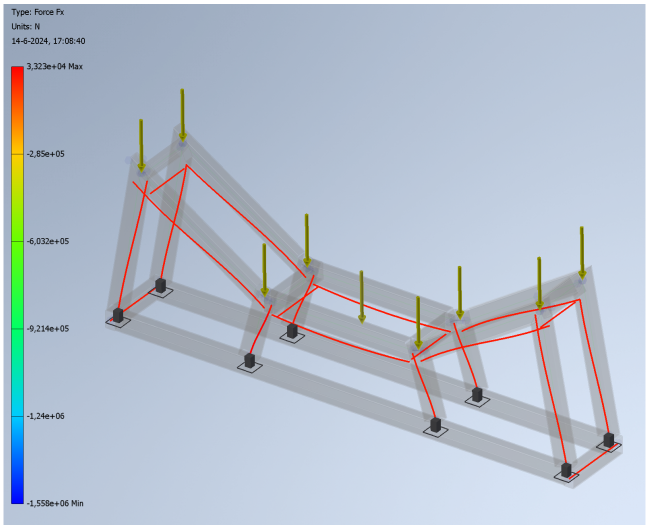

Figure 2: Inventor drawing

Free Body Diagram

Here are the resolved forces, as referenced in the free-body diagram in Figure 1.

For F_1:

$$\frac{4000\,\text{kN}}{\sin(45^\circ)} = 5656\,\text{kN}$$

$$\begin{aligned} &\text{X-component:} \quad -4000\,\text{kN} \\ &\text{Y-component:} \quad 4000\,\text{kN} \end{aligned}$$

For F_2:

$$\frac{4000\,\text{kN}}{\cos(15^\circ)} = 4141\,\text{kN}$$

$$\begin{aligned} &\text{X-component:} \quad 4141\,\text{kN} \times \sin(15^\circ) = -1072\,\text{kN} \\ &\text{Y-component:} \quad 4000\,\text{kN} \end{aligned}$$

For F_3 (same as F_2 but in the opposite direction):

$$\frac{4000\,\text{kN}}{\cos(15^\circ)} = 4141\,\text{kN}$$

$$\begin{aligned} &\text{X-component:} \quad 4141\,\text{kN} \times \sin(15^\circ) = 1072\,\text{kN} \\ &\text{Y-component:} \quad 4000\,\text{kN} \end{aligned}$$

For F_4 (same as F_1 but in the opposite direction):

$$\frac{4000\,\mathrm{kN}}{\sin(45^\circ)} = 5656\,\mathrm{kN}$$

$$\text{X-component:} \quad 4000\,\mathrm{kN}$$

These forces are shown in the free-body diagram in Figure 2. The vertical forces must be projected onto members M10, M20, and M30.

Detailed Projection of Forces

I have resolved and projected the x and y forces to determine the forces in M10 and M20. This can be seen in the following free-body diagram and the corresponding calculations.

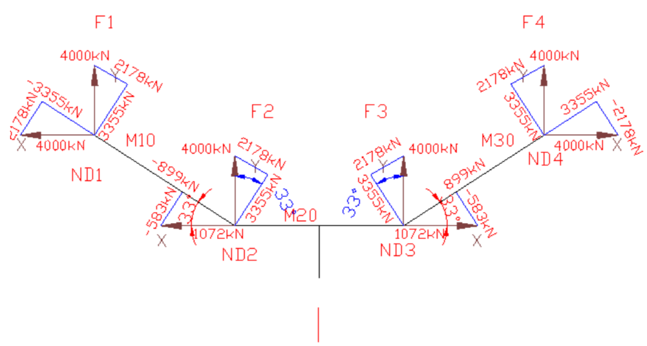

Figure 3: Free body diagram

Node ND1

- Vertical Vector F_1:

$$F_{1y_x} = 4000\,\text{kN} \times \sin(33^\circ) = 2178\,\text{kN}$$
$$F_{1y_y} = 4000\,\text{kN} \times \cos(33^\circ) = 3354\,\text{kN}$$

- Horizontal Vector F_1:

$$F_{1x_x} = 4000\,\text{kN} \times \cos(33^\circ) = -3354\,\text{kN}$$
$$F_{1x_y} = 4000\,\text{kN} \times \sin(33^\circ) = -2178\,\text{kN}$$

Node ND2

- Vertical Vector F_2:

$$F_{2y_x} = 4000\,\text{kN} \times \sin(33^\circ) = 2178\,\text{kN}$$
$$F_{2y_y} = 4000\,\text{kN} \times \cos(33^\circ) = 3354\,\text{kN}$$

- Horizontal Vector F_2:

$$F_{2x_x} = 1072\,\text{kN} \times \cos(33^\circ) = -899\,\text{kN}$$
$$F_{2x_y} = 1072\,\text{kN} \times \sin(33^\circ) = -583\,\text{kN}$$

Node ND3

- Vertical Vector F_3:

$$F_{3y_x} = 4000\,\text{kN} \times \sin(33^\circ) = 2178\,\text{kN}$$
$$F_{3y_y} = 4000\,\text{kN} \times \cos(33^\circ) = 3354\,\text{kN}$$

- Horizontal Vector F_3:

$$F_{3x_x} = 1072\,\text{kN} \times \cos(33^\circ) = -899\,\text{kN}$$
$$F_{3x_y} = 1072\,\text{kN} \times \sin(33^\circ) = -583\,\text{kN}$$

Node ND4

- Vertical Vector F_4:

$$F_{4y_x} = 4000\,\text{kN} \times \sin(33^\circ) = 2178\,\text{kN}$$
$$F_{4y_y} = 4000\,\text{kN} \times \cos(33^\circ) = 3354\,\text{kN}$$

- Horizontal Vector F_4:

$$F_{4x_x} = 4000\,\text{kN} \times \cos(33^\circ) = -3354\,\text{kN}$$
$$F_{4x_y} = 4000\,\text{kN} \times \sin(33^\circ) = -2178\,\text{kN}$$

Analysis for Member M20

The axial force in member M20 can be directly influenced by the horizontal components from nodes ND1 and ND2 (left) and ND3 and ND4 (right) see figure 1:

Total X-component in M20 $= -1072\,\mathrm{kN} + 1072\,\mathrm{kN} + 4000\,\mathrm{kN} - 4000\,\mathrm{kN} = 0\,\mathrm{kN}$

The axial force in M20 is therefore:

$$T_{M20} = 5072\,\mathrm{kN}$$

The axial forces in members M10 and M30 must be projected along the beam, as depicted in the two free-body diagrams. Also, the shear force are the F2y and F3y combined so that is 8000 kN.

Analysis for Member M10

The forces at nodes ND1 and ND2 affect each other.The sum of forces in the x-direction:

$$\sum F_x = F_{1y_x} + F_{1x_x} + F_{2y_x} + F_{2x_x} = 0$$

The sum of forces in the y-direction:

$$\sum F_y = F_{1y_y} + F_{1x_y} + F_{2y_y} + F_{2x_y} = 0$$

The sum of forces in the y-direction:

$$\sum F_X = -3355kN - 2178kN + 2178kN - 899kN = ?$$

$$\sum F_y = 3355kN - 2178kN + 3355kN - 583kN = ?$$

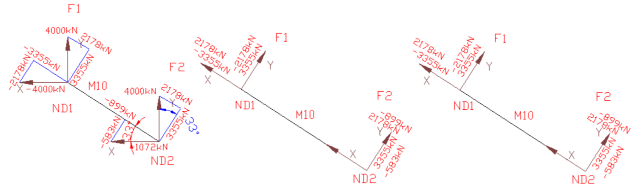

Figure 4: Inventor drawing

Question

I like to have the same result as the other one. How should I approach this? There should be some balance with the sum of the moments that I currently don't have. If I simplify, I could say that 5072 kN is the x-component of M20, so M10 equals 5072 kN / cos(33deg) = 6047 kN.

- My first question is: How do I resolve this? Is there a method for it?
- My second question is: How do I determine the size of my profiles? Is it based on tension/compression and, I believe, buckling?"