Beam Bending Problem Analysis - FEM Method

1. Physical Constants:

Young's Modulus (E): 210 x 10^9 Pa (Steel)

Beam Width (b): 0.1 m

Beam Height (h): 0.02 m

Second Moment of Area (I) = b * h^3 / 12

2. Problem Setup:

Length of the Beam (L): 10.0 m

Concentrated Load (q): 1000 N

Number of Elements (N): 20

Element Length (h_elem): L / N

3. Stiffness Matrix Calculation:

The stiffness matrix for a beam element is calculated as:

```
K_e = (E * I / h_elem^3) * [ [12, 6*h_elem, -12, 6*h_elem],
                      [6*h_elem, 4*h_elem^2, -6*h_elem, 2*h_elem^2],
                      [-12, -6*h_elem, 12, -6*h_elem],
                      [6*h_elem, 2*h_elem^2, -6*h_elem, 4*h_elem^2] ]
```

4. Displacement Calculation:

The displacement vector is solved using the global stiffness matrix and load vector:

```
displacements[free] = np.linalg.solve(K_ff, F_f)
```

5. Theoretical Displacement:

The theoretical displacement can be calculated using the following formula:

```
delta_max_theoretical = (q * L^3) / (3 * E * I)
```

6. Results:

Theoretical Maximum Displacement: 2.3810e+01 m

Maximum FEM Displacement: -2.3810e+01 m