**Question:** For a round beam carrying a constant axial load of 50 kN in a hostile environment of a field firm, we have two material alternatives: Material A and Material B. The field firm is to serve for 10 years, and then demolish the equipments. Using the given specifications of two materials, select the most suitable material on the basis of combination of following criteria:

- No failure with a strength safety factor of 2
- Maximum elastic deflection of 0.5 mm
- Minimized overall cost

**Material Specifications:**

<table>
<thead>
<tr>
<th></th>
<th>Material A</th>
<th>Material B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw material cost (TL/kg)</td>
<td>10</td>
<td>28</td>
</tr>
<tr>
<td>Production cost (TL/kg)</td>
<td>1.5</td>
<td>4.5</td>
</tr>
<tr>
<td>Assembly cost (TL/kg)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Elastic modulus (GPa)</td>
<td>200</td>
<td>250</td>
</tr>
<tr>
<td>Yield strength (MPa)</td>
<td>450</td>
<td>650</td>
</tr>
<tr>
<td>Density (ton/m³)</td>
<td>7</td>
<td>5.5</td>
</tr>
<tr>
<td>Service life (year)</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

**Solution:** The material selection procedure is given below. The following nomenclature is used throughout calculations:

- $D$: Diameter of beam
- $F$: Force applied on the beam
- $\delta$: Elastic deflection of beam
- $C_m$: Raw material cost
- $C_p$: Production cost
- $C_a$: Assembly cost
- $A$: Sectional area of beam
- $S_y$: Yield strength of material
- $E$: Elastic modulus of material
- $\rho$: Density of material
- $Q$: Req. number of part

**Step 1:** Determine diameter of beam based on the safety factor (the dimension of diameter will be rounded to an integer value):

$$D \leq \frac{\sqrt{\frac{4(F/A)(S_y)}{\pi \eta}}} \Rightarrow D \geq \frac{\sqrt{4(F/A)(S_y)}}{\pi \eta} \equiv 16.82 \text{ mm} \rightarrow 17 \text{ mm}$$

**Step 2:** Determine length of beam based on the elastic deflection (the dimension of length will be rounded to an integer value):

$$L \leq \frac{\delta E A}{\pi F} \Rightarrow L \leq \frac{\delta E A}{\pi F} \rightarrow L \leq \frac{(0.5 \text{ mm})(200 \times 10^3 \text{ N/mm}^2)(\pi (17 \text{ mm})^2)/4}{50 \times 10^3 \text{ N}} \equiv 453.96 \text{ mm} \rightarrow 450 \text{ mm}$$

**Step 3:** Calculate mass of beam:

$$m = \rho \ast V = \rho \ast A \ast L = \rho \ast \left(\pi D^2/4\right) \ast L$$

$$m_a = (7 \times 10^{-6} \text{ kg/mm}^3) \ast \left[\pi (17 \text{ mm})^2/4\right] \ast (450 \text{ mm}) \equiv 0.715 \text{ kg}$$

$$m_b = (5.5 \times 10^{-6} \text{ kg/mm}^3) \ast \left[\pi (14 \text{ mm})^2/4\right] \ast (380 \text{ mm}) \equiv 0.321 \text{ kg}$$

**Step 4:** Calculate the overall cost:

$$C_{\text{part}} = C_{\text{total}} \ast m \ast Q = (C_m + C_p + C_a) \ast m \ast (\text{req. life/service life})$$

$$C_{a} = \left[(10+1.5+1) TL/\text{kg}\right] \ast (0.715 \text{ kg}) \ast (10/2 \rightarrow 5) = 44.6875 \text{ TL}$$

$$C_{b} = \left[(28+4.5+1) TL/\text{kg}\right] \ast (0.321 \text{ kg}) \ast (10/4 \rightarrow 3) = 32.2605 \text{ TL}$$

**Step 5:** The most suitable material is Material B.