Maybe engineering is the pursuit of an unattainable perfection.

Maybe it's impossible to create something bug-free.

Maybe the tyranny of Murphy is the penalty for hubris.

But I just can't shake the feeling.

With all those supplies, I could have caught that roadrunner.
9.53 A W310 × 60 steel beam (see Appendix B) in an existing structure is to be strengthened by adding a 250 mm wide by 16 mm thick cover plate to its lower flange, as shown in Fig. P9.53. The cover plate is attached to the lower flange by pairs of 24-mm-diameter bolts spaced at intervals of $s$ along the beam span. Bending occurs about the $z$ centroidal axis.

(a) If the allowable bolt shear stress is 96 MPa, determine the maximum bolt spacing interval $s$ required to support an internal shear force in the beam of $V = 50$ kN.

(b) If the allowable bending stress is 150 MPa, determine the allowable bending moment for the existing W310 × 60 shape, the allowable bending moment for the W310 × 60 with the added cover plate, and the percentage increase in moment capacity that is gained by adding the cover plate.

---

**Solution**

**Centroid location in $y$ direction:**

<table>
<thead>
<tr>
<th>Shape</th>
<th>Width ($b$)</th>
<th>Height ($h$)</th>
<th>Area ($A$)</th>
<th>$y$ from bottom ($y_i$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>W310 × 60</td>
<td>7,550</td>
<td>167</td>
<td>1,260,850</td>
<td>111.935 mm</td>
</tr>
<tr>
<td>cover plate</td>
<td>250</td>
<td>16</td>
<td>4,000</td>
<td>8</td>
</tr>
</tbody>
</table>

**Moment of inertia about the $z$ axis:**

$$I_C = \frac{y_i^2 A_i}{d^2}$$

<table>
<thead>
<tr>
<th>Shape</th>
<th>$I_C$</th>
<th>$d$</th>
<th>$I_C + d^2 A$</th>
</tr>
</thead>
<tbody>
<tr>
<td>W310 × 60</td>
<td>128,000,000</td>
<td>55.065</td>
<td>150,892,764</td>
</tr>
<tr>
<td>cover plate</td>
<td>85,333.33</td>
<td>103.935</td>
<td>43,295,270</td>
</tr>
</tbody>
</table>

(a) Maximum bolt spacing

---

Consider the cover plate, which is connected to the W310 × 60 shape with two bolts:

$$Q = VQ = \frac{50,000 \text{ N}}{415,740 \text{ mm}} = 107.0457 \text{ N/mm}$$

Relate the shear flow and the bolt shear stress with Eq. (9.14):

$$q_s n A = 2 \times 24 \text{ mm} \times 96 \text{ N/mm} \times 452.389 \text{ mm} = 811 \text{ mm}$$

**Fig. P9.53**
9.50 A wooden beam is fabricated by bolting together three members, as shown in Fig. P9.50a. The cross-sectional dimensions are shown in Fig. P9.50b. The 8-mm-diameter bolts are spaced at intervals of $s = 200$ mm along the $x$ axis of the beam. If the internal shear force in the beam is $V = 7$ kN, determine the shear stress in each bolt.

![Fig. P9.50a](image1)

![Fig. P9.50b](image2)
Homework

- Problem P9.51
- Problem P9.54
- Problem P9.56