General examination rules:

1) Do not put your completed work on your desk or on the floor or on the desk next to you or anywhere it can be seen by others. If any part of your work can be seen by others it will be confiscated and you will not be permitted to rework those problems. **Place it face down on your desk under your existing work.**

2) Please remove your hat. If it is part of your head, turn it around backwards.

3) If your work not legible, or if I cannot follow your logic at a glance, or if you use a #9 nail for a pencil with 2 point font, it will receive no credit. Such work will be marked UES (Unacceptable by Engineering Standards) with appropriate deductions. This paper must be written to acceptable engineering standards for full credit.

4) All problems have the same value unless otherwise stated.

5) You are permitted to write on the back of any page (make a note on the page) or use your own paper or hat available at the front of the room.

6) If you didn’t bring a copy of the F.E. Reference Manual, you can come to the front of the room and use one of mine there. A maximum of three people can be at the front at one time. Raise your hand if you need to get in line after someone else leaves. You **cannot work at the front.** You can only copy what you need, then return to your seat.

I have read and understand all of the above instructions: ________ (Initials)

Ethical Standards: Upon accepting admission to Texas A&M University, a student immediately assumes a commitment to uphold the Honor Code, to accept responsibility for learning, and to follow the philosophy and rules of the Honor System. Students will be required to state their commitment on examinations, research papers, and other academic work. Ignorance of the rules does not exclude any member of the TAMU community from the requirements or the processes of the Honor System.

"On my honor, as an Aggie, I have neither given nor received unauthorized aid on this exam."

________________________
Signature of student

Please do not open this exam until told to do so.
Problem 1) The pipe shown has an ID = 4 inches and an OD = 8 inches. The length of the pipe is 4 feet. A load $P = 200$ kips is applied at the inside edge of the pipe. $T = 40$ kip ft. Place a postage stamp somewhere on the pipe where the stresses will be a maximum, and solve for the state of stress at that point (i.e. solve for the stresses square with the world and show the resulting stresses on the postage stamp). You are not being asked to use those stresses to determine the principal stresses. State exactly where you intend to put the stamp on the pipe – left end, right end, top, front, etc.

Stamp anywhere along far front edge
1) Max axial anywhere compressive
2) Max bending far front edge about $y$ axis compressive
3) Tension is max everywhere on outside surface.

$e = 2''$ off $y$-axis
$c = 4''$ off $y$-axis
$M = Pe = 200 \times 2'' = 400$ in k
$T = 40 \text{ kip ft} \times 12''/\text{foot}$
Properties of pipes

\[ \text{OD} = 8 \text{ inches} \]

\[ \text{ID} = 4 \text{ inches} \]

\[ c = \frac{\text{OD}}{2} \]

\[ \text{Paxial} = 200 \text{ kips} \]

\[ \text{Mom} = \text{Paxial} \cdot \frac{\text{ID}}{2} \text{ k in} \]

\[ \text{Torq} = 40 \cdot 12 \text{ k in} \]

\[ \text{pres} = 0.2 \text{ ksi} \]

\[ t = \frac{\text{OD} - \text{ID}}{2} \text{ in} \]

\[ A = \pi \cdot \left[ \frac{\text{OD}^2 - \text{ID}^2}{4} \right] \text{ in}^2 \]

\[ I = \pi \cdot \left[ \frac{\text{OD}^4 - \text{ID}^4}{64} \right] \text{ in}^4 \]

\[ J = 1 \cdot 2 \text{ in}^4 \]

\[ \Sigma\text{tau} = \text{Torq} \cdot \frac{c}{J} \]

\[ \Sigma\text{Axial} = \frac{\text{Paxial}}{A} \]

\[ \Sigma\text{Bend} = \text{Mom} \cdot \frac{c}{I} \]

\[ \Sigma\text{HoopPress} = \text{pres} \cdot \frac{c}{t} \]

\[ \Sigma\text{LongPress} = \text{pres} \cdot \frac{c}{2 \cdot t} \]

SOLUTION

Unit Settings: SI C kPa kJ mass deg

\[ A = 37.7 \]

\[ J = 377 \]

\[ \text{pres} = 0.2 \]

\[ \Sigma\text{Axial} = 5.305 \]

\[ \Sigma\text{Bend} = 8.488 \]

\[ \Sigma\text{HoopPress} = 0.4 \]

\[ \Sigma\text{LongPress} = 0.2 \]

\[ c = 4 \]

\[ \text{Mom} = 400 \]

\[ \text{SigAxial} = 5.305 \]

\[ \text{SigBend} = 8.488 \]

\[ \text{SigHoopPress} = \]

\[ l = 188.5 \]

\[ \text{OD} = 8 \]

\[ \text{Paxial} = 200 \]

\[ \text{Torq} = 480 \]

\[ t = 2 \]
Problem 2) An A36 structural steel W12x50 beam is to be reinforced by welding two 1"x12" plates of the same material, to the beam as shown. The allowed bending stress is specified as 0.6 times the yield strength of the steel. Determine which of the two configurations will give the greatest increase in strength over the original unreinforced beam, and by how much.
For un reinforced \( W \times 50 \) of A36:

\[
Tall = 36 \text{ksi} \times 0.6 = 21.6 \text{ksi}
\]

\[
I = 391 \text{in}^4, \quad d = 12.2", \quad c = 6.1"
\]

\[
T = \frac{Mc}{I} \quad \text{so} \quad M_{all} = \frac{5TI}{d/2} = \frac{(21.6 \text{ ksi})(391 \text{in}^4)}{12.2/2} = 1385 \text{in-k}
\]

\[
= 115.4 \text{ k-ft}
\]

For plates on side:

\[
I = 391 \text{in}^4 + 2 \left( \frac{b \cdot h^3}{12} \right) = 391 \text{in}^4 + 2 \left( \frac{1"}{12} \right) (12")^3 = 391 \text{in}^4 + 288 \text{in}^4 = 679 \text{in}^4
\]

So \( M_{all} = \frac{(21.6 \text{ ksi})(679 \text{in}^4)}{12.2/2} = 2404 \text{in-k} \]

\[
= 200.3 \text{ k-ft}
\]

For an increase of \( 2404 - 1385 = \)

For plates on top & bottom:

\[
I = 391 \text{in}^4 + 2(12") (1")^3/12 + 2(1" \times 12") (6.1" + 0.5") = 391 \text{in}^4 + 2 \text{in}^4 + 1045 \text{in}^4 = 1438 \text{in}^4
\]

So \( M_{all} = \frac{(21.6 \text{ ksi})(1438 \text{in}^4)}{12.2 + 2 \left( \frac{1"}{2} \right)} = 4375 \text{in-k} \]

\[
= 364.6 \text{ k-ft}
\]

For an increase of \( 4375 - 1385 = 2990 \text{in-k} \)

Plates on top/bottom much stronger
Problem 2) An A36 structural steel W12x50 beam is to be reinforced by welding two 1"x12" plates of the same material, to the beam as shown. The allowed bending stress is specified as 0.6 times the yield strength of the steel. Determine which of the two configurations will give the greatest increase in strength over the original unreinforced beam, and by how much.

\[ \sigma_{\text{bend}} = 0.6 \sigma_{\text{yield}} = 21.6 \text{ ksi} \]
\[ \sigma_{\text{yield}} = 36 \text{ ksi} \]

1. \[ I = I_1 + 2I_2 \]
\[ I = 391 \text{ in}^4 + 2 \left[ \frac{1}{12} (12)(12^3) \right] = 679 \text{ in}^4 \]
\[ c = 6.1" \]
\[ \sigma_8 = \frac{M_c}{I} \Rightarrow 21600 = \frac{M_c}{679} \Rightarrow M_{\max} = 24043.27 \text{ lb} \cdot \text{in} = 2404.3 \text{ kip} \cdot \text{in} \]

2. \[ I = I_1 + 2I_2 \]
\[ c = 7.1" \]
\[ I = 391 + 2 \left[ \frac{1}{12} (12)(12^3) + 12(1)(12.1+0.5)^2 \right] = 1438.44 \text{ in}^4 \]
\[ \sigma_8 = \frac{M_c}{I} \Rightarrow 21600 = \frac{M_c}{1438.44} \Rightarrow M_{\max} = 4376099.15 \text{ lb} \cdot \text{in} = 4376.1 \text{ kip} \cdot \text{in} \]

Original

\[ I = 391 \text{ in}^4 \]
\[ c = 6.1" \]
\[ \sigma_8 = \frac{M_c}{I} \Rightarrow 21600 = \frac{6.1M}{391} \Rightarrow M_{\max} = 1384524.6 \text{ lb} \cdot \text{in} = 1384.5 \text{ kip} \cdot \text{in} \]

Configuration 2 gives the largest increase in strength over the original unreinforced beam, allowing the configuration to tolerate a moment 2991.6 kip\cdot in.
<table>
<thead>
<tr>
<th>Shape</th>
<th>Area A</th>
<th>Depth d</th>
<th>Web t_w</th>
<th>Flange b_f</th>
<th>Axis X-X l</th>
<th>S r</th>
<th>Z</th>
<th>Axis Y-Y l</th>
<th>r</th>
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Table 1 - Typical Material Properties
(Use these values if the specific alloy and temper are not listed on Table 2 below)

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<tr>
<th>Material</th>
<th>Modulus of Elasticity, E [Mpsi (GPa)]</th>
<th>Modulus of Rigidity, G [Mpsi (GPa)]</th>
<th>Poisson’s Ratio, ν</th>
<th>Coefficient of Thermal Expansion, α [10^-6°F (10^-6°C)]</th>
<th>Density, ρ [lb/in^3 (Mg/m^3)]</th>
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<tr>
<td>Steel</td>
<td>29.0 (200.0)</td>
<td>11.5 (80.0)</td>
<td>0.30</td>
<td>6.5 (11.7)</td>
<td>0.282 (7.8)</td>
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<td>Aluminum</td>
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<td>3.8 (26.0)</td>
<td>0.33</td>
<td>13.1 (23.6)</td>
<td>0.098 (2.7)</td>
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<tr>
<td>Cast Iron</td>
<td>14.5 (100.0)</td>
<td>6.0 (41.4)</td>
<td>0.21</td>
<td>6.7 (12.1)</td>
<td>0.246–0.282 (6.8–7.8)</td>
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<td>Wood (Fir)</td>
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<td>0.6 (4.1)</td>
<td>0.33</td>
<td>1.7 (3.0)</td>
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<td>14.8–18.1 (102–125)</td>
<td>5.8 (40)</td>
<td>0.33</td>
<td>10.4 (18.7)</td>
<td>0.303–0.313 (8.4–8.7)</td>
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<td>0.322 (8.9)</td>
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<td>5.0 (9.0)</td>
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<td>Polyvinyl Chloride (PVC)</td>
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<td>28.0 (50.4)</td>
<td>0.047 (1.3)</td>
<td>0.141 (3.9)</td>
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<tr>
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<td>58 (400)</td>
<td></td>
<td></td>
<td>0.083 (2.3)</td>
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<tr>
<td>Aramid Fiber</td>
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<td>0.083 (2.3)</td>
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<td>0.083 (2.3)</td>
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<tr>
<td>Carbon Fiber</td>
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<td>0.116 (3.2)</td>
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<td>Silicon Carbide Fiber</td>
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<td></td>
<td>0.083 (2.3)</td>
<td>0.116 (3.2)</td>
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Table 2 - Average Mechanical Properties of Typical Engineering Materials
(U.S. Customary Units)
(Use these values for the specific alloys and temperature listed. For all other materials refer to Table 1 above.)

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<td>0.30f</td>
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</table>

a Specific values may vary for a particular material due to alloy or mineral composition, mechanical working of the specimen, or heat treatment. For a more exact value reference books for the material should be consulted.
b The yield and ultimate strength for ductile materials can be assumed equal for both tension and compression.
c Measured perpendicular to the grain.
d Measured parallel to the grain.
e Deformation measured perpendicular to the grain when the load is applied along the grain.

<table>
<thead>
<tr>
<th>Figure</th>
<th>Area &amp; Centroid</th>
<th>Area Moment of Inertia</th>
<th>(Radius of Gyration)$^2$</th>
<th>Product of Inertia</th>
</tr>
</thead>
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<tr>
<td><img src="image" alt="Circle" /></td>
<td>$A = \pi a^2$</td>
<td>$I_x = I_y = \frac{\pi a^4}{4}$</td>
<td>$r_x^2 = r_y^2 = \frac{a^2}{4}$</td>
<td>$I_{x,y} = 0$</td>
</tr>
<tr>
<td><img src="image" alt="Circle" /></td>
<td>$A = \pi(a^2 - b^2)$</td>
<td>$I_x = I_y = \frac{\pi a^4 - \pi b^4}{4}$</td>
<td>$r_x^2 = r_y^2 = \frac{(a^2 + b^2)^2}{4}$</td>
<td>$I_{x,y} = 0$</td>
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<tr>
<td><img src="image" alt="Circle" /></td>
<td>$A = \frac{\pi a^2}{2}$</td>
<td>$I_x = \frac{\pi a^4}{8}$</td>
<td>$r_x^2 = \frac{a^2}{4}$</td>
<td>$I_{x,y} = 0$</td>
</tr>
<tr>
<td><img src="image" alt="Circular Sector" /></td>
<td>$A = a^2 \theta$</td>
<td>$I_x = \frac{a^4(\theta - \sin \theta \cos \theta)}{4}$</td>
<td>$r_x^2 = \frac{a^2(\theta - \sin \theta \cos \theta)}{4}$</td>
<td>$I_{x,y} = 0$</td>
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<tr>
<td><img src="image" alt="Circular Segment" /></td>
<td>$A = a^2 \left[ \frac{\theta - \sin 2\theta}{2} \right]$</td>
<td>$I_x = Aa^2 \left[ \frac{1 - 2\sin^2 \theta \cos \theta}{3\theta - 3\sin \theta \cos \theta} \right]$</td>
<td>$r_x^2 = \frac{a^2}{4} \left[ 1 - \frac{2\sin^2 \theta \cos \theta}{3\theta - 3\sin \theta \cos \theta} \right]$</td>
<td>$I_{x,y} = 0$</td>
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</table>

Problem 3) Draw shear and moment diagrams for members AB and BC for the following frame. The sketch is not to scale. L1 = 10 ft, L2 = 6 ft, L3 = 8 ft, $W = 2$ kips/foot.
Draw V & M diagrams for

\[ \Sigma M_A = 0 = (-2 \text{ kft})(10')(5') + R_{CV}(16') \]
\[ R_{CV} = 6.25 \text{ k} \]

\[ \Sigma F_V = 0 = A_V - 2(10) + 6.25 \]
\[ A_V = 13.75 \text{ k} \]

\[ \Sigma F_H = 0 = A_H \]

\[ \Sigma M_B = 0 = M_B - 13.75 \text{ k}(10') + (2 \text{ kft})(10')(5') \]
\[ M_B = 37.5 \text{ kft} \]

\[ A_1 = \frac{1}{2}(6.875 \text{ ft})(13.75 \text{ k}) = 47.27 \text{ kft} \]
\[ A_2 = \frac{1}{2}(3.125')(6.25 \text{ k}) = -9.77 \]
\[ \sum M_B = 0 = -M_B + 6.25 \text{k}(6') \]
\[ M_B = 37.5 \text{k} \]
\[ \sum F_V = 0 = -R_{BV} + 3.75 \text{k} \]
\[ R_{BV} = 3.75 \text{k} \]
\[ \sum F_H = 0 = R_{BH} - 6.25 \text{k} \]
\[ R_{BH} = 6.25 \text{k} \]

\[ R_{BH} = 3.75 \text{k} \]

\[ R_{BV} = 3.75 \text{k} \]

\[ \text{Axial Load} = 6.25 \text{k} \]

\[ \text{Bending Load} = 6.25 \text{k} \]

\[ 6.25 \cos 53.1^\circ = 3.75 \text{k} \]

\[ A_3 = 3.75 \text{k}(6') = -37.5 \text{k\,ft} \]
General examination rules:

1) Do not put your completed work on your desk or on the floor or on the desk next to you or anywhere it can be seen by others. If any part of your work can be seen by others it will be confiscated and you will not be permitted to rework those problems. Place it face down on your desk under your existing work.

2) Please remove your hat. If it is part of your head, turn it around backwards.

3) If your work not legible, or if I cannot follow your logic at a glance, or if you use a #9 nail for a pencil with 2 point font, it will receive no credit. Such work will be marked UES (Unacceptable by Engineering Standards) with appropriate deductions. This paper must be written to acceptable engineering standards for full credit.

4) All problems have the same value unless otherwise stated.

5) You are permitted to write on the back of any page (make a note on the page) or use your own paper or that available at the front of the room.

6) If you didn’t bring a copy of the F.E. Reference Manual, you can come to the front of the room and use one of mine there. A maximum of three people can be at the front at one time. Raise your hand if you need to get in line after someone else leaves. You cannot work at the front. You can only copy what you need, then return to your seat.

I have read and understand all of the above instructions: ________ (Initials)

Ethical Standards: Upon accepting admission to Texas A&M University, a student immediately assumes a commitment to uphold the Honor Code, to accept responsibility for learning, and to follow the philosophy and rules of the Honor System. Students will be required to state their commitment on examinations, research papers, and other academic work. Ignorance of the rules does not exclude any member of the TAMU community from the requirements or the processes of the Honor System.

"On my honor, as an Aggie, I have neither given nor received unauthorized aid on this exam."

____________________________
Signature of student

Please do not open this exam until told to do so.
Problem 1) The following sketch is not to scale. \( L_1 = 8 \) ft, \( L_2 = 12 \) ft, \( L_3 = 6 \) ft, \( W = 4 \) kips/foot. Draw shear and moment diagrams for members AB and BC.

\[ \sum M_A = 0 = -\left(4 \text{ k/ft}\right)(12')(14') + R_{CV}(20') \]

\[ R_{CV} = 33.6 \text{ k} \]

\[ \sum F_V = 0 = 33.6 \text{ k} - 4(12) + R_{AV} \]

\[ R_{AV} = 14.4 \text{ k} \]

\[ \sum F_{V+B} = 0 = R_{AH} \]

\[ 14.4 \text{ k} \left( \sin 36.87^\circ \right) = 7.88 \text{ k} \]

\[ R_B = 14.4 \text{ k} \cos 36.87^\circ = 11.53 \text{ k} \]

\[ R_{AV} = 14.4 \text{ k} \]

\[ M = 115.3 \text{ k-ft} \]

\[ 115.3 \text{ k-ft} \]

\[ 115.3 \text{ k-ft} \]
\[ \Sigma M_B = 0 = (33.6^k)(12\text{ ft}) - (4^k/\text{ft})(12')(6') - M_B \]

\[ M_B = 115.2^k/\text{ft} \]

\[ \Sigma F_V = 0 = R_{BV} - 4^k/\text{ft}(12') + 33.6^k \]

\[ R_{BV} = 14.4^k \]

\[ X = \frac{14.4^k}{4^k/\text{ft}} = \]

\[ A_1 = \frac{1}{2}(14.4^k)(3.6') = 25.92^k/\text{ft} \]

\[ A_2 = \frac{1}{2}(8.4')(33.6^k) = 141.12^k/\text{ft} \]
Problem 2) Place a postage stamp somewhere on the pipe where the stresses will be a maximum, and solve for the state of stress at that point (i.e. solve for the stresses square with the world and show the resulting stresses on the postage stamp). The pipe has an ID = 2 inches and an OD = 4 inches. The length of the pipe is 5 feet. A load P = 100 kips is applied at the inside edge of the pipe. T = 10 kip ft. State exactly where you intend to put the stamp on the pipe – left end, right end, top, front, etc. You are not being asked to use those stresses to determine the principal stresses.
Properties of pipes

OD = 4 inches

ID = 2 inches

c = \frac{OD}{2}

P axial = 100 kips

Mom = P axial \cdot \frac{ID}{2} k in

Torq = 10 \cdot 12 k in

pres = 0.2 ksi

t = \frac{OD - ID}{2} in

A = \pi \cdot \left[ \frac{OD^2 - ID^2}{4} \right] in^2

I = \pi \cdot \left[ \frac{OD^4 - ID^4}{64} \right] in^4

J = I \cdot 2 in^4

SigTau = Torq \cdot \frac{c}{J}

SigAxial = \frac{P axial}{A}

SigBend = Mom \cdot \frac{c}{I}

SigHoopPress = pres \cdot \frac{c}{t}

SigLongPress = pres \cdot \frac{c}{2 \cdot t}

SOLUTION

Unit Settings: SI C kPa kJ mass deg

A = 9.425 in^2

J = 23.56 in^4

pres = 0.2 ksi

SigLongPress = 0.2 ksi

SigAxial = 10.61 ksi

SigBend = 16.98 ksi

SigHoopPress = 0.4 ksi

OD = 4 inches

Mom = 100 kips

Torq = 10 \cdot 12 k in

pres = 0.2 ksi

t = 1 in

ID = 2 inches

P axial = 100 kips

C = 2

l = 11.78 in

SigTau = 10.19 ksi

ID = 2 inches

P axial = 100 kips

C = 2

l = 11.78 in

SigTau = 10.19 ksi

Torq = 120 k in
Problem 3) A Stainless 304 steel W16x50 beam is to be reinforced by welding two 1"x16" plates of the same material, to the beam as shown. Determine which of the two configurations will give the greatest increase in strength over the original unreinforced beam, and by how much. The allowed bending stress is specified as 0.6 times the yield strength of the steel.
Ibeam = 659 "I of original beam"
Tplates = 1.0 "thickness of reinforcing plate"
Lplates = 16.0 "Height of plates"
Sallowed = 30*0.6 "Allowed stress in steel"

c = 16.3/2 "c for beam or plates, whichever is taller"
c1 = c + Tplates "c for plates on top and bottom"
MomentOriginal = Sallowed*Ibeam/c

IbeamPlatesOnSides = Ibeam + 2*Tplates*Lplates^3/12
MomentPlatesOnSides = Sallowed*IbeamPlatesOnSides/c

IbeamPlatesOnTops = Ibeam + 2*Lplates*Tplates^3/12 + 2*Tplates*Lplates*(c+Tplates/2)^2
MomentPlatesOnTops = Sallowed*IbeamPlatesOnTops/c1

SOLUTION
Unit Settings: SI C kPa kJ mass deg
c = 8.15
IbeamPlatesOnSides = 1342
MomentOriginal = 1455
Sallowed = 18

c1 = 9.15
IbeamPlatesOnTops = 3056
MomentPlatesOnSides = 2963
Tplates = 1

Ibeam = 659
Lplates = 16
MomentPlatesOnTops = 6012

No unit problems were detected.
Problem 3) A Stainless 304 steel W16x50 beam is to be reinforced by welding two 1"x16" plates of the same material, to the beam as shown. Determine which of the two configurations will give the greatest increase in strength over the original unreinforced beam, and by how much. The allowed bending stress is specified as 0.6 times the yield strength of the steel.

A) \[ I_1 = I_{W16x50} = 659 \text{ in}^4 \]
\[ I_2 = \frac{1}{12}(16 \text{ in})(1 \text{ in})^3 + (1 \text{ in})(16 \text{ in})(8.65 \text{ in})^2 = 1198.49 \text{ in}^4 \]
\[ I_{\text{total}} = I_1 + 2I_2 = 659 \text{ in}^4 + 2(1198.49 \text{ in}^4) = 3055.97 \text{ in}^4 \]
\[ G_y = 30 \text{ KSI tension + compression (Table 2)} \]
\[ G_{\text{all}} = G_y \times 6 = 30 \text{ KSI}(6) = 180 \text{ KSI} \]
\[ G = \frac{Mc}{I} \quad M = \frac{659 (18.65 \text{ kip})(16 \text{ in})}{8.15 \text{ in}} = 6011.78 \text{ kip-in} \]

B) \[ I_1 = I_{W16x50} = 659 \text{ in}^4 \]
\[ I_2 = \frac{1}{12}(1 \text{ in})(16 \text{ in})^3 = 341.333 \text{ in}^4 \]
\[ I_{\text{total}} = I_1 + 2I_2 = 659 \text{ in}^4 + 2(341.333 \text{ in}^4) = 1341.67 \text{ in}^4 \]
\[ G_{\text{all}} \text{ still 18 KSI} \]
\[ G = \frac{Mc}{I} \quad M = \frac{659 (1341.67 \text{ in}^4)}{8.15 \text{ in}} = 2963.2 \text{ kip-in} \]

\[ 6011.78 \text{ kip-in} > 2963.2 \text{ kip-in} \]

A stronger than B

\[ I_{\text{original}} = 659 \text{ in}^4 \]
\[ M = \frac{659 (18 \text{ kip})}{8.15 \text{ in}} = 1455.46 \text{ kip-in} \]
\[ \frac{6011.78}{1455.46} = 4.15546 \quad \frac{2963.2}{3048.58} = 0.9718 \]

A stronger than original by
A stronger than B by

Good

Wasn't sure which you wanted.