

**Appendix 1:** Calculations for areal and density-weighted bending strength indices: moment of inertia ( $I_{\min}$ ,  $I_{\max}$ ) and section modulus ( $S_{\min}$ ,  $S_{\max}$ ).

*Step 1:* determine center of mass (COM) positions for each cross-sectional slice.

Areal bending strength indices:

Density-weighted bending strength indices:

$$X_{COM} = \frac{\sum_i(x_i * A_i)}{\sum_i A_i}$$

$$X_{COM} = \frac{\sum_i(x_i * BMD_i * A_i)}{\sum_i BMD_i * A_i}$$

$$Y_{COM} = \frac{\sum_i(y_i * A_i)}{\sum_i A_i}$$

$$Y_{COM} = \frac{\sum_i(y_i * BMD_i * A_i)}{\sum_i BMD_i * A_i}$$

*Step 2:* determine moments of inertia (I) using the X-Y axes for each cross-sectional slice.

Areal bending strength indices:

Density-weighted bending strength indices:

$$I_{xx} = \sum_i (Y_i - Y_{COM})^2 * A_i$$

$$I_{xx} = \sum_i (Y_i - Y_{COM})^2 * BMD_i * V_i$$

$$I_{yy} = \sum_i (X_i - X_{COM})^2 * A_i$$

$$I_{yy} = \sum_i (X_i - X_{COM})^2 * BMD_i * V_i$$

$$I_{xy} = \sum_i (X_i - X_{COM})(Y_i - Y_{COM}) * A_i$$

$$I_{xy} = \sum_i (X_i - X_{COM})(Y_i - Y_{COM}) * BMD_i * V_i$$

*Step 3:* determine the minimum ( $I_{\min}$ ) and maximum ( $I_{\max}$ ) moments of inertia from  $I_{xx}$ ,  $I_{yy}$ , and  $I_{xy}$ :

$$I_{max,min} = \frac{I_{xx} + I_{yy}}{2} \pm \sqrt{\left(\frac{I_{xx} - I_{yy}}{2}\right)^2 + I_{xy}^2}$$

Step 4: calculate the minimum ( $S_{min}$ ) and maximum ( $S_{max}$ ) section moduli from  $I_{min}$ ,  $I_{max}$ , and the periosteal radius ( $R_o$ ).

$$S_{min} = \frac{I_{min}}{R_o}$$

$$S_{max} = \frac{I_{max}}{R_o}$$

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