

Representation of Conductor Sag, Rotating and Twisting for Transposition

Conductor Sag

$$H_{tower} := 77\text{ft}$$

$$Mid := 33\text{ft}$$

$$sag := H_{tower} - Mid \quad sag = 44 \cdot \text{ft}$$

$$H_{ave1} := H_{tower} - \frac{2}{3} \cdot sag \quad H_{ave1} = 47.66667 \cdot \text{ft}$$

$$H_{ave2} := Mid + \frac{1}{3} \cdot sag \quad H_{ave2} = 47.66667 \cdot \text{ft}$$

$$H_{ave3} := \frac{H_{tower}}{3} + \frac{2}{3} \cdot Mid \quad H_{ave3} = 47.66667 \cdot \text{ft}$$

Rotation

$$Z_{123} := \begin{pmatrix} 100 & 12 & 13 \\ 21 & 200 & 23 \\ 31 & 32 & 300 \end{pmatrix} \quad V_{123} := \begin{pmatrix} 1 \\ 2 \\ 3 \end{pmatrix}$$

$$R_p := \begin{pmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{pmatrix}$$

$$V_{312} := R_p \cdot V_{123} \quad V_{312} = \begin{pmatrix} 3 \\ 1 \\ 2 \end{pmatrix}$$

$$V_{231} := R_p^{-1} \cdot V_{123} \quad V_{231} = \begin{pmatrix} 2 \\ 3 \\ 1 \end{pmatrix}$$

$$\mathbf{R}_p \cdot \mathbf{Z}_{123} = \begin{pmatrix} 31 & 32 & 300 \\ 100 & 12 & 13 \\ 21 & 200 & 23 \end{pmatrix}$$

$$\mathbf{Z}_{123} \cdot \mathbf{R}_p^{-1} = \begin{pmatrix} 13 & 100 & 12 \\ 23 & 21 & 200 \\ 300 & 31 & 32 \end{pmatrix}$$

$$\mathbf{Z}_{312} := \mathbf{R}_p \cdot \mathbf{Z}_{123} \cdot \mathbf{R}_p^{-1} \quad \mathbf{Z}_{312} = \begin{pmatrix} 300 & 31 & 32 \\ 13 & 100 & 12 \\ 23 & 21 & 200 \end{pmatrix}$$

$$\mathbf{R}_p^{-1} \cdot \mathbf{Z}_{123} = \begin{pmatrix} 21 & 200 & 23 \\ 31 & 32 & 300 \\ 100 & 12 & 13 \end{pmatrix}$$

$$\mathbf{Z}_{123} \cdot \mathbf{R}_p = \begin{pmatrix} 12 & 13 & 100 \\ 200 & 23 & 21 \\ 32 & 300 & 31 \end{pmatrix}$$

$$\mathbf{Z}_{231} := \mathbf{R}_p^{-1} \cdot \mathbf{Z}_{123} \cdot \mathbf{R}_p \quad \mathbf{Z}_{231} = \begin{pmatrix} 200 & 23 & 21 \\ 32 & 300 & 31 \\ 12 & 13 & 100 \end{pmatrix}$$

$$f_1 := \frac{1}{3} \quad f_2 := \frac{1}{3} \quad f_3 := \frac{1}{3}$$

$$\mathbf{Z}_{\text{eq}} := f_1 \cdot \mathbf{Z}_{123} + f_2 \cdot \mathbf{Z}_{231} + f_3 \cdot \mathbf{Z}_{312} \quad \mathbf{Z}_{\text{eq}} = \begin{pmatrix} 200 & 22 & 22 \\ 22 & 200 & 22 \\ 22 & 22 & 200 \end{pmatrix}$$

- Note that it is balanced, the numbers themselves don't have meaning

• **Twisting**

$$T_{23} := \begin{pmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{pmatrix} \quad T_{23}^{-1} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{pmatrix}$$

$$T_{13} := \begin{pmatrix} 0 & 0 & 1 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \end{pmatrix} \quad T_{13}^{-1} = \begin{pmatrix} 0 & 0 & 1 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \end{pmatrix}$$

$$T_{12} := \begin{pmatrix} 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{pmatrix} \quad T_{12}^{-1} = \begin{pmatrix} 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

$$T_{12} \cdot Z_{123} \cdot T_{12} = \begin{pmatrix} 200 & 21 & 23 \\ 12 & 100 & 13 \\ 32 & 31 & 300 \end{pmatrix} \quad \text{Element 3,3 doesn't move}$$

$$T_{13} \cdot Z_{123} \cdot T_{13} = \begin{pmatrix} 300 & 32 & 31 \\ 23 & 200 & 21 \\ 13 & 12 & 100 \end{pmatrix} \quad \text{Element 2,2 doesn't move}$$

$$T_{23} \cdot Z_{123} \cdot T_{23} = \begin{pmatrix} 100 & 13 & 12 \\ 31 & 300 & 32 \\ 21 & 23 & 200 \end{pmatrix} \quad \text{Element 1,1 doesn't move}$$

$$f1 := 0 \quad f2 := \frac{1}{3} \quad f3 := \frac{1}{3} \quad f4 := \frac{1}{3}$$

$$Z_{tw} := f1 \cdot Z_{123} + f2 \cdot (T_{12} \cdot Z_{123} \cdot T_{12}) + f3 \cdot (T_{13} \cdot Z_{123} \cdot T_{13}) + f4 \cdot (T_{23} \cdot Z_{123} \cdot T_{23})$$

$$Z_{tw} = \begin{pmatrix} 200 & 22 & 22 \\ 22 & 200 & 22 \\ 22 & 22 & 200 \end{pmatrix}$$

- Note that it is now balanced, note that the numbers themselves don't have meaning