CHAPTER 2: Structural Steel Beams

2.3 Section Properties of Built-Up Steel Sections

Description

This document calculates the moment of inertia and section modulus for a steel section that has at least one axis of symmetry built-up from plates or from a combination of plates and sections with known section properties. Any number of plates or sections may be used.

Built-up sections are used when reinforcing existing members, as plate girders, and for composite steel beams using bottom plates. The application may also be used to calculate section properties for nonstandard T sections cut from I-shaped members. The properties of fillets or continuous welds may also be included when required. The required input includes the overall depth of the built-up section, plate dimensions (in the horizontal and vertical directions) and the area and moment of inertia of any sections with known properties making up the built-up section, and the dimensions from the centroids of plates or sections to the bottom of the built-up section.

Input

Notation

\[
\begin{align*}
\ y_t & \quad \text{N.A.} \quad \ y_2 \\
\ y_b & \quad \ y_1 \\
\ y_0 & \quad \ d
\end{align*}
\]
**Input Variables**

Enter depth of the built-up section, moments of inertia and areas of individual sections, horizontal and vertical dimensions of plates, and distances from the centroids of individual plates and sections to the bottom of the built-up section. Moments of inertia, areas, or plate dimensions referring to a given section or plate must have the same corresponding subscript number.

Depth of the built-up section:

\[ d := 17.81 \text{ in} \]

Moments of inertia of individual sections:

\[ I_0 := 704.5 \text{ in}^4 \]
\[ I_1 := 3.6 \text{ in}^4 \]

Areas of individual sections:

\[ A_0 := 13.24 \text{ in}^2 \]
\[ A_1 := 4.22 \text{ in}^2 \]

Horizontal plate dimensions:

\[ h := 9 \text{ in} \]

Vertical plate dimensions:

\[ v := 0.25 \text{ in} \]

Distances from the bottom of the built-up section to area centroid of any sections or plates:

\[ y_0 := 9.03 \text{ in} \]
\[ y_1 := 16.42 \text{ in} \]
\[ y_2 := 0.125 \text{ in} \]

**Note** ⇒ Section must be symmetrical about the vertical axis.
Computed Variables

The following variables are calculated in this document:

\( d \) depth of the built-up section

\( A_s \) cross section area of built-up section

\( I_s \) moment of inertia of the built-up section about the horizontal centroidal axis

\( S_t \) section modulus of the built-up section about the horizontal centroidal axis referred to the top of the section

\( S_b \) section modulus of the built-up section about the horizontal centroidal axis referred to the bottom of the section

\( y_t \) dimension form the horizontal centroidal axis to the top of the built-up section

\( y_b \) dimension form the horizontal centroidal axis to the bottom of the built-up section

Calculations

Areas of all sections and plates:

\[ i := 0 \ldots \text{last} \left( y \right) \]

\[ A_i := \text{if} \left( h_i = 0 \cdot \text{in}, A_i, h_i \cdot v_i \right) \]

\[ A^T = \begin{bmatrix} 13.24 & 4.22 & 2.25 \end{bmatrix} \text{in}^2 \]
Moments of inertia of all sections and plates:

\[ I_i := \begin{cases} h_i = 0 \cdot \text{in}, & \frac{1}{12} h_i \cdot \left( v_i \right)^3 \\ \end{cases} \]

\[ I^T = [704.5 \ 3.6 \ 0.012] \ \text{in}^4 \]

Area of the built-up section:

\[ A_s := \sum A \quad A_s = 19.71 \ \text{in}^2 \]

Dimension form the horizontal centroidal axis to the bottom of the built-up section:

\[ y_b := \sum \frac{A_i \cdot y_i}{A_s} \quad y_b = 9.596 \ \text{in} \]

Dimension form the horizontal centroidal axis to the top of the built-up section:

\[ y_t := d - y_b \quad y_t = 8.214 \ \text{in} \]

Moment of inertia of the built-up section about the horizontal centroidal axis:

\[ I_s := \sum I + \sum \left( A_i \cdot \left( y_i - y_b \right)^2 \right) \]

\[ I_s = 1110.691 \ \text{in}^4 \]

Section modulus of the built-up section about the horizontal centroidal axis referred to the top of the built-up section:

\[ S_t := \frac{I_s}{y_t} \]

\[ S_t = 135.214 \ \text{in}^3 \]
Section modulus of the built-up section about the horizontal centroidal axis referred to the bottom of the built-up section:

\[ S_b := \frac{I_s}{y_b} \]

\[ S_b = 115.749 \text{ in}^3 \]