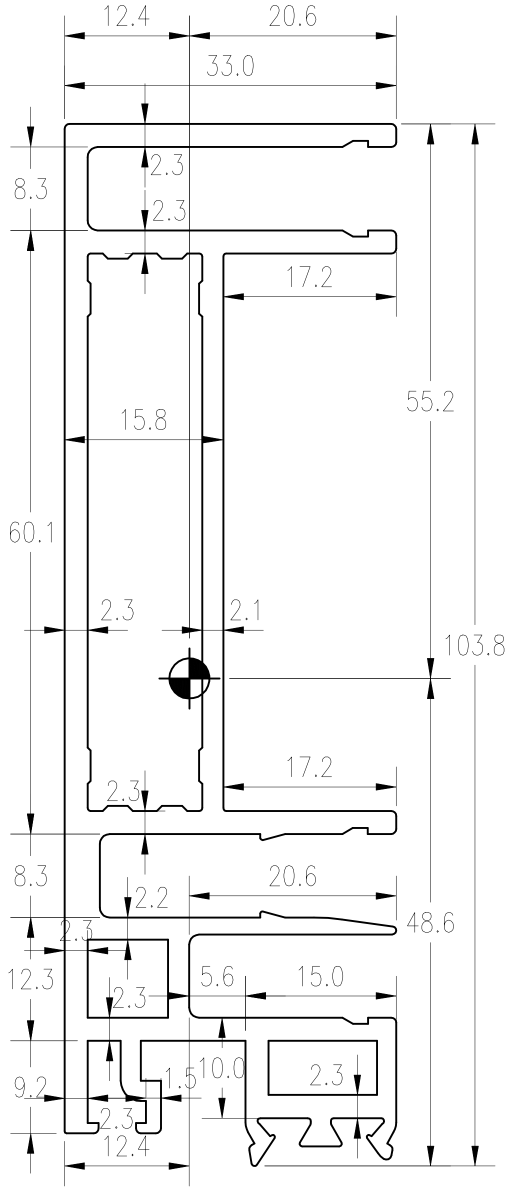
SECTION PROPERTIES OF THE SILL TRANSOM ALUMINUM EXTRUSION

TRIBECA SQUARE ELEPHANT ROAD (Capped Glazed Curtainwall)
London



Input CAD file: mullion-elephant-road.dxf

Area of Cross-Section = 819.271

Width of Section (in X direction): 33

Depth of Section (in Y direction): 103.632

Coordinates of Centroid (x, y): 44.7997, 76.5214

Distance from Centroid to Extreme Left Hand Fibre: 12.4241

Distance from Centroid to Extreme Right Hand Fibre: 20.5759

Distance from Centroid to Extreme Top Fibre: 55.1349

Distance from Centroid to Extreme Bottom Fibre: 48.4973

Ixx = 929562

Iyy = 79736.7

Radius of Gyration about Centroidal X-Axis, Rx = 33.6841

Radius of Gyration about Centroidal Y-Axis, Ry = 9.86542

Coordinates of Intersection of Plastic Neutral Axes (x, y) : 45.3462, 65.6338

Plastic Modulus About X Axis = 24156.8

Plastic Modulus About Y Axis = 6877.01

Distance from Plastic Axis to Extreme Left Hand Fibre: 12.9707

Distance from Plastic Axis to Extreme Right Hand Fibre: 20.0293

Distance from Plastic Axis to Extreme Top Fibre: 66.0225

Distance from Plastic Axis to Extreme Bottom Fibre: 37.6097

Polar Moment of Inertia = 1.0093e+006

Section Properties Computed Using 'x-section'

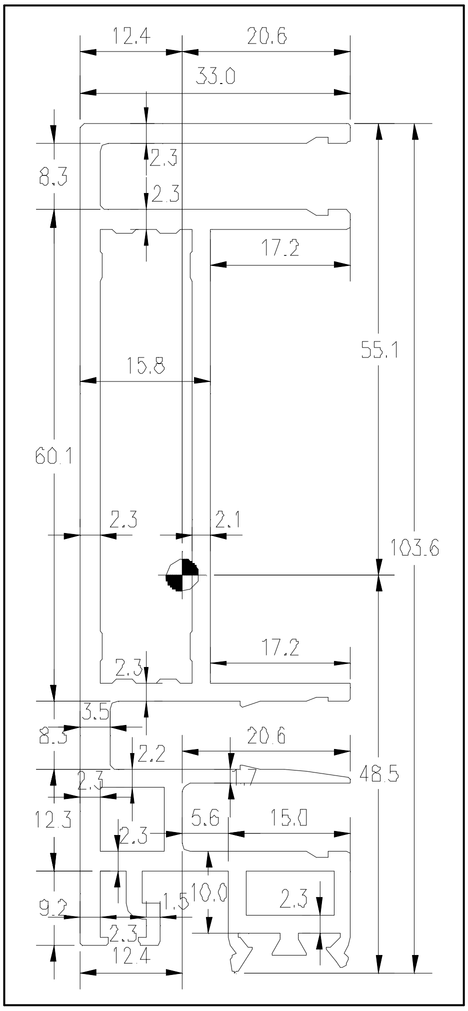
Software Author: Adam Lee <adamlee@torstencalvi.com>

Version: 05 February 2009. Beta status.

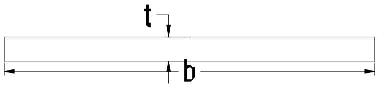
SECTION 3.12

CALCULATION OF TORSION CONSTANT OF THE SILL TRANSOM

TRIBECA SQUARE ELEPHANT ROAD (Capped Glazed Curtainwall) - London



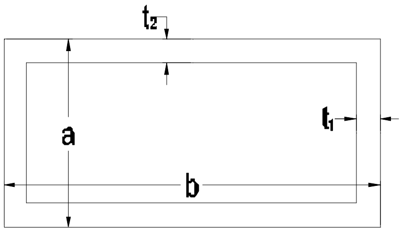
- **Torsion Constant for Plate Elements**



$$J = k \cdot b \cdot t^3$$

$$k = \begin{cases} \dfrac{1}{3} & \text{if } \dfrac{b}{t} \geq 10 \\ \dfrac{1}{3} - 0.20\dfrac{t}{b} & \text{otherwise} \end{cases}$$

- **Torsion Constant for Tube Elements**



$$J = \frac{2\, t_1\, t_2 \left(a - t_2\right)^2 \left(b - t_1\right)^2}{a\, t_2 + b\, t_1 + t_2^{\,2} - t_1^{\,2}}$$

- **Tabulation of Torsion Constant Computation**

Plate #	b (mm)	t (mm)	b / t	k	J (mm^4)
1	33.00	2.30	14.35	0.33	133.84
2	8.30	2.30	3.61	0.28	28.07
3	17.20	2.30	7.48	0.31	64.16
4	17.20	2.30	7.48	0.31	64.16
5	8.30	3.50	2.37	0.25	88.61
6	20.60	1.70	12.12	0.33	33.74
7	5.60	2.30	2.43	0.25	17.11
8	9.20	2.30	4.00	0.28	31.72
9	9.20	1.50	6.13	0.30	9.34

Tube #	b (mm)	t_1 (mm)	a (mm)	t_2 (mm)	J (mm^4)
1	60.10	2.30	15.80	2.20	38397.20
2	12.40	2.20	12.30	2.25	2309.13
3	15.00	2.10	10.00	2.25	2121.22

J_m = 43298.29

SECTION 3.13

SECTION CLASSIFICATION FOR THE MAJOR PRINCIPAL AXIS OF THE HEAD TRANSOM

BS 8118-1:1991 STRUCTURAL USE OF ALUMINUM PART 1: CODE OF PRACTICE FOR DESIGN

TRIBECA SQUARE ELEPHANT ROAD (Capped Glazed Curtainwall) - London

- **Element Classification for Beams**

Limiting Values of Elements

Alloy_Temper = "6060-T6" — Alloy and temper designation of aluminum extrusion

$p_o = 150.00 \cdot MPa$ — Limiting stress for bending and overall yielding
Refer to Section 3.05

$\varepsilon := \sqrt{\frac{250MPa}{p_o}} = 1.29$ — Parameter for limiting values

Table 4.3 Limiting Values of β

Elements	β_o Unwelded	β_o Welded	β_1 Unwelded	β_1 Welded
Outstand elements	7ε	6ε	6ε	5ε
Internal elements	22ε	18ε	18ε	15ε

Classification for beam elements (moment resistance):

$\beta \le \beta_1$ — Fully compact element

$\beta_1 \le \beta \le \beta_o$ — Semi-compact element

$\beta > \beta_o$ — Slender element

Slenderness Parameter for Unreinforced Flat Elements

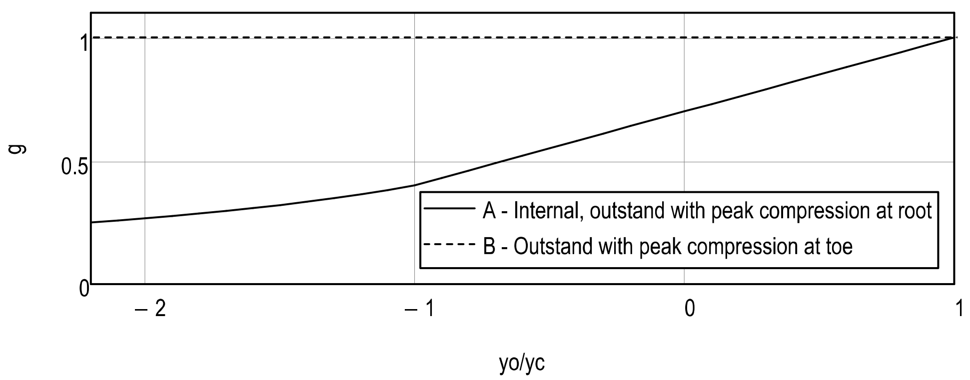
b — Width or depth of element

t — Thickness of element

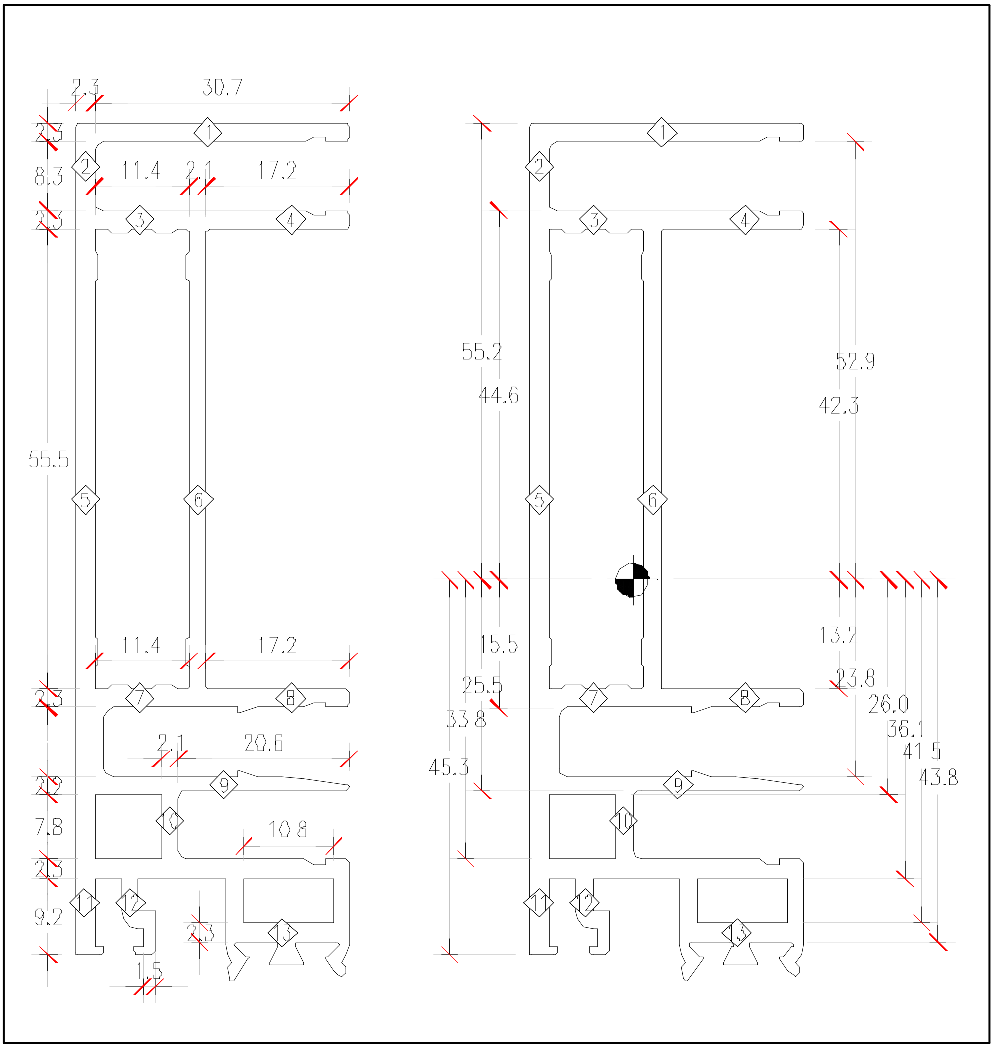
y_o — Distance of less compressed fiber from neutral axis

y_c — Distance of more compressed fiber from neutral axis

Figure 4.2 Flat elements under stress gradient, value of g



$\beta = g \cdot \frac{b}{t}$ — Slenderness parameter
g = 1.00 if element is under uniform compression



Classification of Unreinforced Flat Beam Elements

#	Element Type	b	t	yc	yo	g	β	β1	βo	Classification
1	O	30.70	2.30	55.20	52.90	0.988	13.181	7.746	9.037	**SLENDER**
2	I	8.30	2.30	52.90	44.60	0.953	3.439	23.238	28.402	COMPACT
3	I	11.40	2.30	44.60	42.30	0.985	4.880	23.238	28.402	COMPACT
4	O	17.20	2.30	44.60	42.30	0.985	7.363	7.746	9.037	COMPACT
5	I	55.50	2.30	42.30	-13.20	0.606	14.632	23.238	28.402	COMPACT
6	I	55.50	2.10	42.30	-13.20	0.606	16.026	23.238	28.402	COMPACT
7	I	11.40	2.30	15.50	13.20	0.955	4.736	23.238	28.402	COMPACT
8	O	17.20	2.30	15.50	13.20	0.955	7.145	7.746	9.037	COMPACT
9	O	20.60	2.20	25.50	23.80	0.980	9.176	7.746	9.037	**SLENDER**
10	I	7.80	2.10	33.80	23.80	0.911	3.385	23.238	28.402	COMPACT
11	O	9.20	2.30	45.30	36.10	0.939	3.756	7.746	9.037	COMPACT
12	O	9.20	1.50	45.30	36.10	0.939	5.760	7.746	9.037	COMPACT
13	I	10.80	2.30	43.80	41.50	0.984	4.622	23.238	28.402	COMPACT

Element Type: O – Outstand; I – Internal

THEREFORE, THE SECTION IS SLENDER.

- **Section Property Adjustment Factor**

$y_1 := c_{y.m} = 55.20\,mm$ Distance of section extreme fiber from neutral axis

$y_2 = 0.5 \cdot (y_c + y_o)$ Distance of element from section neutral axis

Local Buckling Coefficient

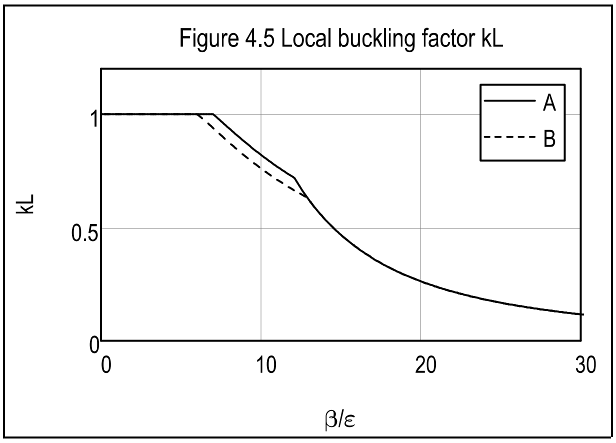
$p_o = 150.00 \cdot MPa$ Limiting stress for bending and overall yielding

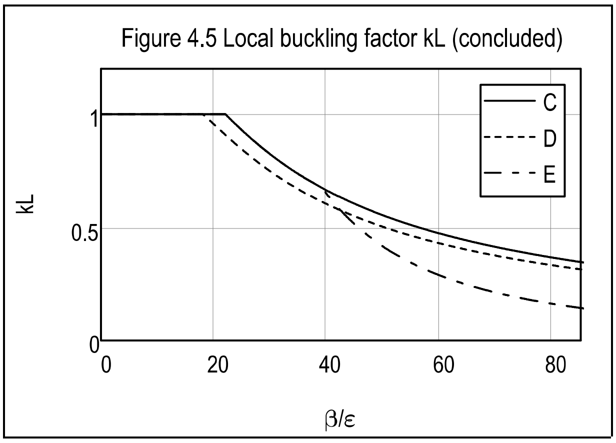
$$\varepsilon_e = \sqrt{\frac{(250MPa)\,y_1}{p_o \cdot y_2}}$$ Modified parameter for limiting values

β Slenderness parameter

Table 4.4 Curve selection for figure 4.5 (local buckling)

Elements	Unwelded	Welded
Flat outstand elements	curve A	curve B
Internal elements	curve C	curve D
Round tubes	Lower of curves C and E	Lower of curves D and E





Area Adjustment Factor Due to Element Slenderness

$A_m = 819.27 \cdot mm^2$ Area of extrusion

$$\xi = \frac{A_m - (b \cdot t - b \cdot k_L \cdot t)}{A_m}$$ Area adjustment factor due to single element

Area Adjustment Factor

#	Element Type	b	t	y_2	ε_e	β	β / ε_e	Curve	k_L	$k_L t$	ξ
1	O	30.70	2.30	54.05	1.305	13.181	10.103	A	0.814	1.873	0.9840
9	O	20.60	2.20	24.65	1.932	9.176	4.750	A	1.000	2.200	1.0000

Element Type: O – Outstand; I – Internal

$\Pi\xi$ = 0.9840

SECTION 3.14

SECTION CLASSIFICATION FOR THE MINOR PRINCIPAL AXIS OF THE SILL TRANSOM

BS 8118-1:1991 STRUCTURAL USE OF ALUMINUM PART 1: CODE OF PRACTICE FOR DESIGN

TRIBECA SQUARE ELEPHANT ROAD (Capped Glazed Curtainwall) - London

- **Element Classification for Beams**

Limiting Values of Elements

Alloy_Temper = "6060-T6" — Alloy and temper designation of aluminum extrusion

$p_o = 150.00 \cdot MPa$ — Limiting stress for bending and overall yielding
Refer to Section 3.05

$\varepsilon := \sqrt{\frac{250MPa}{p_o}} = 1.29$ — Parameter for limiting values

Table 4.3 Limiting Values of β

	β_o		β_1	
Elements	Unwelded	Welded	Unwelded	Welded
Outstand elements	7ε	6ε	6ε	5ε
Internal elements	22ε	18ε	18ε	15ε

Classification for beam elements (moment resistance):

$\beta \le \beta_1$ — Fully compact element

$\beta_1 \le \beta \le \beta_o$ — Semi-compact element

$\beta > \beta_o$ — Slender element

Slenderness Parameter for Unreinforced Flat Elements

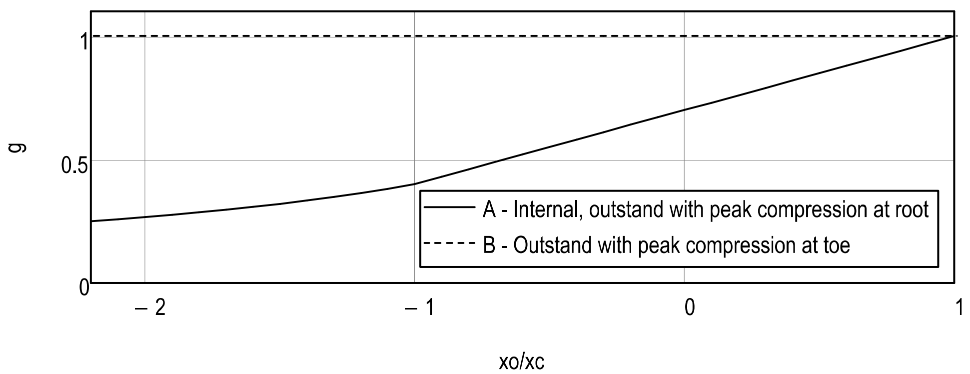
b — Width or depth of element

t — Thickness of element

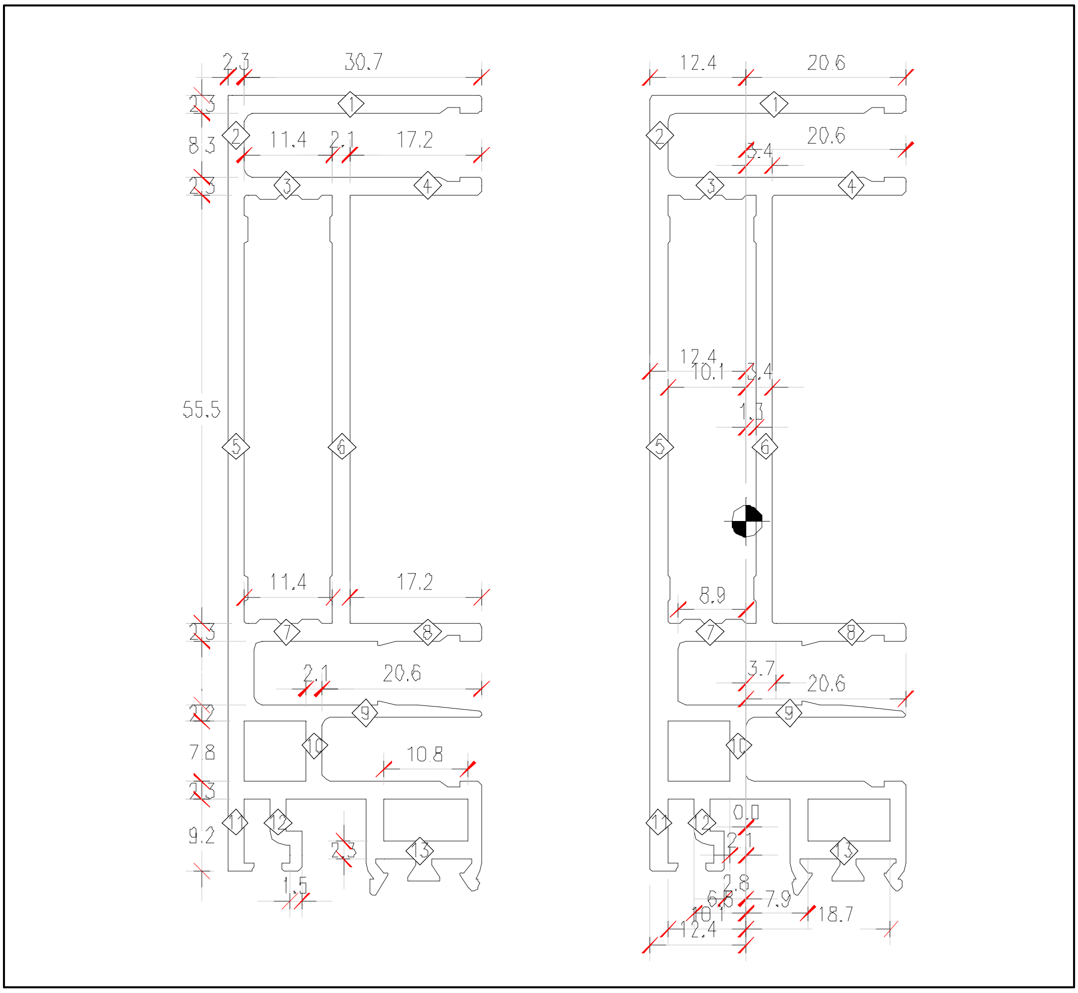
x_o — Distance of less compressed fiber from neutral axis

x_c — Distance of more compressed fiber from neutral axis

Figure 4.2 Flat elements under stress gradient, value of g



$\beta = g \cdot \frac{b}{t}$ — Slenderness parameter
g = 1.00 if element is under uniform compression



Classification of Unreinforced Flat Beam Elements

#	Element Type	b	t	x_c	x_o	g	β	$β_1$	$β_o$	Classification
1	O	30.70	2.30	20.60	-10.10	0.553	7.380	7.746	9.037	COMPACT
2	I	8.30	2.30	12.40	10.10	0.944	3.408	23.238	28.402	COMPACT
3	I	11.40	2.30	10.10	-1.30	0.661	3.278	23.238	28.402	COMPACT
4	O	17.20	2.30	20.60	3.40	0.750	5.605	7.746	9.037	COMPACT
5	I	55.50	2.30	12.40	10.10	0.944	22.788	23.238	28.402	COMPACT
6	I	55.50	2.10	3.40	1.30	0.815	21.532	23.238	28.402	COMPACT
7	I	11.40	2.30	8.90	-1.30	0.656	3.252	23.238	28.402	COMPACT
8	O	17.20	2.30	20.60	3.40	0.750	5.605	7.746	9.037	COMPACT
9	O	20.60	2.20	20.60	0.00	0.700	6.555	7.746	9.037	COMPACT
10	I	7.80	2.10	2.10	0.00	0.700	2.600	23.238	28.402	COMPACT
11	O	9.20	2.30	12.40	10.10	0.944	3.777	7.746	9.037	COMPACT
12	O	9.20	1.50	6.80	2.80	0.824	5.051	7.746	9.037	COMPACT
13	I	10.80	2.30	18.70	7.90	0.827	3.882	23.238	28.402	COMPACT

Element Type: O – Outstand; I – Internal

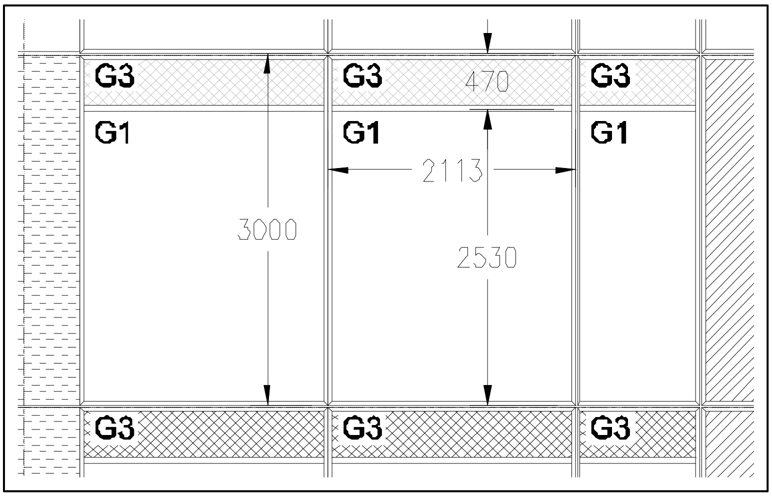
<u>THEREFORE, THE SECTION IS COMPACT.</u>

SECTION 3.15

STRESS AND DEFLECTION ANALYSIS OF THE SILL TRANSOM

BS 8118-1:1991 STRUCTURAL USE OF ALUMINUM PART 1: CODE OF PRACTICE FOR DESIGN

TRIBECA SQUARE ELEPHANT ROAD (Capped Glazed Curtainwall) - London



Reference Drawing: 3330-WT-EL-0111

- **Length Parameters**

$L := 2113.00\text{mm}$ — Length of transom

$L_b := 2113.00\text{mm}$ — Unbraced length of transom span

$d_a := 2530.00\text{mm}$ — Panel module height above the transom

$d_b := 0.00\text{mm}$ — Panel module height below the transom

- **Strength Parameters for Analysis**

Material Factors

$\gamma_m := 1.2$ — Material factor for riveted and bolted members
Refer to BS 8118-1:1991 Table 4.1 to Table 4.2

Mechanical Properties of Wrought Aluminum Product

Refer to BS 8118-1:1991 Appendix D and Table 2.5

Alloy_Temper = "6060-T6" — Alloy and temper designation of aluminum extrusion

$f_{0.2} = 150.00\text{MPa}$ — Minimum tensile 0.2% proof stress

$f_u = 190.00\text{MPa}$ — Tensile strength

$$p_o = \begin{cases} f_{0.2} & \text{if } f_u \le 1.4f_{0.2} \\ 1.28f_{0.2} - 0.2f_u & \text{otherwise} \end{cases}$$ — Limiting stress for bending and overall yielding

$p_o = 150.00\cdot\text{MPa}$

$$p_a = \begin{cases} 0.5\left(f_{0.2} + f_u\right) & \text{if } f_u \le 1.4f_{0.2} \\ 1.2f_{0.2} & \text{otherwise} \end{cases}$$ — Limiting stress for local capacity of the section in tension or compression

$p_a = 170.00\cdot\text{MPa}$

$p_v := 0.6p_o = 90.00\cdot\text{MPa}$ — Limiting stress in shear

$E := 70000\text{MPa}$ — Modulus of elasticity of aluminum

$G := 26600\text{MPa}$ — Shear modulus of aluminum

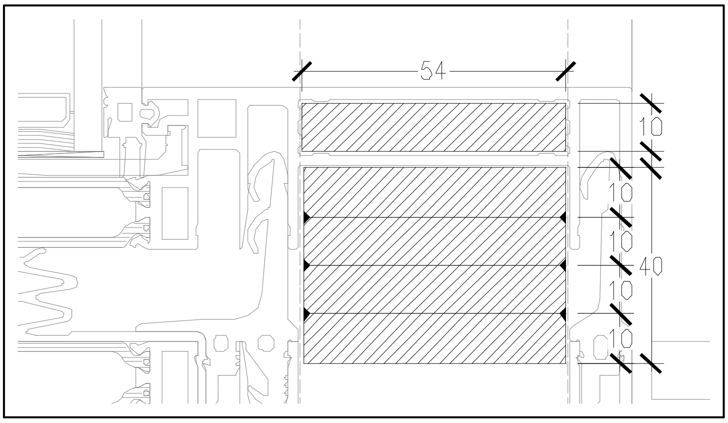
- **Transom Section Properties**

$Classification_{x.m} = \text{"Slender"}$	Section classification of aluminum extrusion for major axis bending
$Classification_{y.m} = \text{"Compact"}$	Section classification of aluminum extrusion for major axis bending
$A_m = 819.27 \cdot mm^2$	Cross-sectional area
$I_{x.m} = 929562.00 \cdot mm^4$	Moment of inertia about the major axis
$c_{y.m} = 55.20\,mm$	Distance of extreme fiber along the minor axis
$Z_{x.m} := \frac{I_{x.m}}{c_{y.m}} = 16839.89 \cdot mm^3$	Elastic modulus about the major axis
$I_{y.m} = 79736.07 \cdot mm^4$	Moment of inertia about the minor axis
$c_{x.m} = 20.60\,mm$	Distance of extreme fiber along the major axis
$Z_{y.m} := \frac{I_{y.m}}{c_{x.m}} = 3870.68 \cdot mm^3$	Elastic modulus about the minor axis
$J_m = 43298.29 \cdot mm^4$	Torsional constant
$S_{x.m} = 24156.80 \cdot mm^3$	Plastic modulus about major axis
$S_{y.m} = 6877.01 \cdot mm^3$	Plastic modulus about minor axis
$r_{y.m} := \sqrt{\frac{I_{y.m}}{A_m}} = 9.87\,mm$	Radius of gyration about the weak axis
$H_m := 0.00mm^6$	Warping constant
$d_m = 103.80\,mm$	Depth of section

Effective Section Properties

$\Pi\xi_{x.m} = 0.9840$	Product of the area adjustment factors per element
$Z_{xe.m} := \Pi\xi_{x.m} \cdot Z_{x.m} = 16570.61 \cdot mm^3$	Effective elastic section modulus about major axis
$S_{xe.m} := \Pi\xi_{x.m} \cdot S_{x.m} = 23770.52 \cdot mm^3$	Effective plastic section modulus about major axis
$\Pi\xi_{y.m} = 1.0000$	Product of the area adjustment factors per element
$Z_{ye.m} := \Pi\xi_{y.m} \cdot Z_{y.m} = 3870.68 \cdot mm^3$	Effective elastic section modulus about minor axis
$S_{ye.m} := \Pi\xi_{y.m} \cdot S_{y.m} = 6877.01 \cdot mm^3$	Effective plastic section modulus about minor axis

- **Steel Stiffener Properties**



Reference Drawing: Sketch

Material Properties

$Grade := "S275"$	Steel grade
$p_{y.st} = 275.00 \cdot MPa$	Design strength of steel Refer to BS 5950-1:2000 Clause 3.1.1
$E_{st} := 205000.00MPa$	Modulus of elasticity of steel Refer to BS 5950-1:2000 Clause 3.1.3
$n := \frac{E_{st}}{E}$	Modular ratio
$E = 70000.00 \cdot MPa$	Modulus of elasticity of aluminum
$n = 2.93$	

Steel Plate Stiffener Section Properties

$b_{st1} := 54.00mm$	Overall width of steel plate
$t_{st1} := 10.00mm$	Thickness of steel plate
$A_{st1} := b_{st1} \cdot t_{st1}$	Cross-sectional area of steel plate
$A_{st1} = 540.00 \cdot mm^2$	
$S_{x.st1} := \frac{b_{st1}^2 t_{st1}}{4}$	Plastic modulus about transom major axis
$S_{x.st1} = 7290.00 \cdot mm^3$	
$S_{y.st1} := \frac{b_{st1} \cdot t_{st1}^2}{4}$	Plastic modulus about transom minor axis
$S_{y.st1} = 1350.00 \cdot mm^3$	
$y_{c.st1} := 0.5b_{st1} = 27.00\,mm$	Distance of major axis extreme compression fiber
$x_{c.st1} := 0.5 \cdot t_{st1} = 5.00\,mm$	Distance of minor axis extreme compression fiber
$I_{x.st1} := \frac{b_{st1}^3 \cdot t_{st1}}{12}$	Moment of inertia about major axis of transom
$I_{x.st1} = 131220.00 \cdot mm^4$	

$I_{y.st1} := \frac{b_{st1} \cdot t_{st1}^3}{12}$ Moment of inertia about minor axis of transom

$I_{y.st1} = 4500.00 \cdot mm^4$

$Z_{x.st1} := \frac{I_{x.st1}}{y_{c.st1}} = 4860.00 \cdot mm^3$ Section modulus about major axis of transom

$Z_{y.st1} := \frac{I_{y.st1}}{x_{c.st1}} = 900.00 \cdot mm^3$ Section modulus about minor axis of transom

Built-up Rectangular Stiffener Section Properties

$b_{st2} := 4 \times (10mm) = 40.00\,mm$ Overall width of steel section

$d_{st2} := 54.00mm$ Overall depth of steel section

$A_{st2} := b_{st2} \cdot d_{st2}$ Cross-sectional area of steel section

$A_{st2} = 2160.00 \cdot mm^2$

$S_{x.st2} := \frac{b_{st2} \cdot d_{st2}^2}{4}$ Plastic modulus about transom major axis

$S_{x.st2} = 29160.00 \cdot mm^3$

$S_{y.st2} := \frac{b_{st2}^2 \cdot d_{st2}}{4}$ Plastic modulus about transom minor axis

$S_{y.st2} = 21600.00 \cdot mm^3$

$y_{c.st2} := 0.5d_{st2} = 27.00\,mm$ Distance of major axis extreme compression fiber

$x_{c.st2} := 0.5 \cdot b_{st2} = 20.00\,mm$ Distance of minor axis extreme compression fiber

$I_{x.st2} := \frac{b_{st2} \cdot d_{st2}^3}{12}$ Moment of inertia about major axis of transom

$I_{x.st2} = 524880.00 \cdot mm^4$

$I_{y.st2} := \frac{b_{st2}^3 \cdot d_{st2}}{12}$ Moment of inertia about minor axis of transom

$I_{y.st2} = 288000.00 \cdot mm^4$

$Z_{x.st2} := \frac{I_{x.st2}}{y_{c.st2}} = 19440.00 \cdot mm^3$ Section modulus about major axis of transom

$Z_{y.st2} := \frac{I_{y.st2}}{x_{c.st2}} = 14400.00 \cdot mm^3$ Section modulus about minor axis of transom

- **Combined Section**

$A_{total} := A_m + n \cdot A_{st1} + n \cdot A_{st2}$ — Total cross-sectional area

$A_m = 819.27 \cdot mm^2$ — Cross-sectional area of transom

$A_{st1} = 540.00 \cdot mm^2$ — Cross-sectional area of steel plate stiffener

$A_{st2} = 2160.00 \cdot mm^2$ — Cross-sectional area of steel built-up stiffener

$n = 2.93$ — Modular ratio

$A_{total} = 8726.41 \cdot mm^2$

$I_{x.total} := I_{x.m} + n \cdot I_{x.st1} + n \cdot I_{x.st2}$ — Total moment of inertia about major axis

$I_{x.m} = 929562.00 \cdot mm^4$ — Moment of inertia of transom about major axis

$I_{x.st1} = 131220.00 \cdot mm^4$ — Moment of inertia of steel plate stiffener about transom major axis

$I_{x.st2} = 524880.00 \cdot mm^4$ — Moment of inertia of steel built-up stiffener about transom major axis

$I_{x.total} = 2850997.71 \cdot mm^4$

$I_{y.total} := I_{y.m} + n \cdot I_{y.st1} + n \cdot I_{y.st2}$ — Total moment of inertia about minor axis

$I_{y.m} = 79736.07 \cdot mm^4$ — Moment of inertia of transom about minor axis

$I_{y.st1} = 4500.00 \cdot mm^4$ — Moment of inertia of steel plate stiffener about transom minor axis

$I_{y.st2} = 288000.00 \cdot mm^4$ — Moment of inertia of built-up stiffener about transom minor axis

$I_{y.total} = 936343.21 \cdot mm^4$