

PRIMARY WARPING CONSTANT FOR Z-SECTIONS WITH BULBS

1. NOTATION

B	area of one bulb measured from centreline of flange (see sketch on Figure 1)	m^2	in^2
d	width of each flange measured between bulb centre and centreline of web (see sketch on Figure 1)	m	in
e	distance of bulb centroid from centreline of flange (see sketch on Figure 1)	m	in
F	area of each corner fillet (see sketch on Figure 1)	m^2	in^2
h	depth of web	m	in
t	thickness of web	m	in
t_1	effective thickness of web = $t + 2(F/h)$	m	in
t_2	thickness of each flange	m	in
Γ_1	primary warping constant as defined in Data Item No. Struct. 00.07.00	m^6	in^6

Both SI and British units are quoted but any coherent system of units may be used.

2. NOTES

The ratio $\Gamma_1/(t_1 h^3 d^2/12)$ is plotted against $d/t_2/(h/t_1)$ on Figure 1 for various values of $B/(h/t_1)$ and e/h . For intermediate values of $B/(h/t_1)$ and e/h , double linear interpolation gives good accuracy. These data may be compared with those given by Data Item No. 77023* which gives Γ_1 for lipped Z-sections.

3. DERIVATION

1. KAPPUS, R. Twisting failure of centrally loaded open section columns in the elastic range. NACA tech Memor. 851, 1938.
2. ARGYRIS, J.H.
DUNNE, P.C. Work done for Structures Committee leading to the formula,

$$\Gamma_1 = \frac{t_1 h^3 d^2}{12} \frac{p(2+p) + 2\beta(3+2p) + 24\epsilon\beta[(1+p) + \epsilon(1+2p)]}{1+2p+2\beta}, \quad (3.1)$$

* Data Item No. 77023, "Shear centre and primary warping constant for lipped and unlipped channel and Z-sections."

where $\rho = \frac{dt_2}{ht_1}$, $\beta = \frac{B}{ht_1}$ and $\varepsilon = \frac{e}{h}$.

4. EXAMPLE

It is required to find the primary warping constant, Γ_1 , for a Z-section with bulbs where:

$$h = 30 \text{ mm}, d = 12 \text{ mm}, t = 1.5 \text{ mm}, t_2 = 2 \text{ mm}$$

$$B = 11 \text{ mm}^2, e = 1.4 \text{ mm}, F = 2 \text{ mm}^2.$$

Now $t_1 = t + 2(F/h) = 1.63 \text{ mm},$

$$\frac{dt_2}{ht_1} = 0.491,$$

$$\frac{B}{ht_1} = 0.225$$

and $e/h = 0.0467.$

From Figure 1, by interpolation,

$$\Gamma_1 / \left(\frac{t_1 h^3 d^2}{12} \right) = 1.40$$

Hence, since $t_1 h^3 d^2 / 12 = 528\,000 \text{ mm}^6$

then $\Gamma_1 = 1.4 \times 528\,000$
 $= 739\,000 \text{ mm}^6$
 $= 0.739 \times 10^{-12} \text{ m}^6.$