

LOCAL BUCKLING AND CRIPPLING OF I-, Z- AND CHANNEL-SECTION STRUTS

1. NOTATION

d	width of flange (see Figures 1 and 2)	m	in
c_2	0.2 per cent compressive proof stress of strut material	N/m ²	lbf/in ²
E	modulus of elasticity of strut material	N/m ²	lbf/in ²
E_t	tangent modulus of strut material	N/m ²	lbf/in ²
f_b	compressive stress at onset of local buckling	N/m ²	lbf/in ²
f_{be}	compressive stress at which elastic local buckling would occur	N/m ²	lbf/in ²
f_c	crippling stress	N/m ²	lbf/in ²
f_n	stress at which $E_t = \frac{1}{2}E$	N/m ²	lbf/in ²
h	depth of web (see Figures 1 and 2)	m	in
K	buckling stress coefficient defined by $f_{be} = KE(t_h/h)^2$		
m	material characteristic for strut		
t_d	thickness of flange	m	in
t_h	thickness of web	m	in
η	plasticity reduction factor defined by $f_b = \eta f_{be}$		
λ	half-wavelength of buckle	m	in
ν	Poisson's ratio for strut material		

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

2. NOTES

In Figures 1 and 2 the coefficient K is plotted against d/h for values of t_d/t_h for I-section and for Z- and channel-section struts, respectively. For a given value of t_d/t_h and low values of d/h the web is primarily responsible for buckling and requires some restraint from the flange in order to delay the buckling until the load is reached for which the cross section as a whole becomes unstable; the half-wavelength of the buckle will be comparable with h . For higher values of d/h the flange is primarily responsible for buckling and the wavelength will be greater. An estimate of the buckle half-wavelength, λ , for a particular strut may be obtained from the broken-line curves on Figures 1 and 2 which represent approximate values of λ/h . Figure 3 shows η plotted against f_{be}/f_n for various values of m . If f_{be} is beyond the limit of proportionality of the

strut material the appropriate values of f_n and m together with f_{be} may be used to estimate η from Figure 3. The curves have been obtained using a value of $\nu = 0.3$; it is sufficiently accurate to multiply the buckling stress by $0.91/(1 - \nu^2)$ to obtain values of f_{be} for other values of ν between 0.25 and 0.35.

After buckling the section can carry more load before failure finally occurs either by crippling or by flexural or flexural-torsional buckling (see Item No. 78021). The crippling stress may be estimated using the equation

$$f_c = (c_2 f_b)^{1/2}. \quad (2.1)$$

Values so obtained are likely to be within 10 per cent of those given by test results.

Flexural or flexural-torsional buckling may occur at lower stresses than that for local buckling if the strut is sufficiently long. For the particular case $t_d = t_h$ data on these modes of buckling are given in Item Nos 76023 and 77030 for channel and Z-sections, respectively. If f_b is close to the flexural or flexural-torsional buckling stress the strut stiffness may be reduced with consequent reduction in the flexural or flexural-torsional buckling stress.

3. DERIVATION

1. SECHLER, E.E. The ultimate strength of thin flat sheets in compression. California Institute of Technology, Publication No. 27, 1933.
2. GERARD, G. BECKER, H. Handbook of structural stability. Part I – Buckling of flat plates. NACA tech. Note 3781, October 1954.
3. GERARD, G. Handbook of structural stability. Part IV – Failure of plates and composite elements. NACA tech. Note 3784, October 1954.
4. WITTRICK, W.H. A unified approach to the initial buckling of stiffened panels in compression. *Aeronaut. Q.*, Vol. XIX, Part 3, pp. 265-283, August 1968.
5. WILLIAMS, F.W. Computation of natural frequencies and initial buckling stresses of prismatic plate assemblies. *J. Sound Vib.*, Vol. 21, pp. 87-106, 1972.

4. EXAMPLE

It is required to find the local buckling and crippling stresses of a short I-section strut. The strut has a web depth of $h = 50$ mm, flange width of $d = 25$ mm and web and flange thicknesses of $t_h = 2.0$ mm and $t_d = 2.5$ mm, respectively. The material properties of the strut are $E = 73\,800$ MN/m², $c_2 = 310$ MN/m², $\nu = 0.3$, $m = 11.5$ and $f_n = 264$ MN/m².

From the given dimensions,

$$\frac{d}{h} = 0.5 \text{ and } \frac{t_d}{t_h} = 1.25.$$

Hence from Figure 1, $K = 3.23$.

$$\text{Therefore } f_{be} = 3.23 \times 73\,800 \times 10^6 \left(\frac{2.0 \times 10^{-3}}{50 \times 10^{-3}} \right)^2 = 381 \text{ MN/m}^2$$

$$\text{so that } \frac{f_{be}}{f_n} = \frac{381}{264} = 1.44.$$

Hence from Figure 3, at $m = 11.5$,

$$\eta = 0.745$$

$$\text{Thus } f_b = 0.745 \times 381 = 284 \text{ MN/m}^2.$$

Using Equation (2.1) the crippling stress is therefore estimated at

$$f_c = (310 \times 10^6 \times 284 \times 10^6)^{1/2} = 297 \text{ MN/m}^2.$$

Also from Figure 1, $\lambda/h \approx 1.7$.

Therefore the approximate buckle half-wavelength will be

$$\lambda = 1.7 \times 50 = 85 \text{ mm}.$$