

BUCKLING OF STRUTS. LIPPED AND UNLIPPED Z SECTIONS

1. NOTATION

c	width of lips	m	in
d	width of flanges	m	in
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	buckling stress at half-wavelength λ	N/m ²	lbf/in ²
f_{be}	elastic buckling stress at half-wavelength λ	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	m	in
m	material characteristic for strut material (see Item No. 76016)		
t	thickness of strut material	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

This Item provides curves that relate the compressive stress at buckling to the associated half-wavelength for lipped and unlipped Z-section struts of isotropic material of uniform thickness. The data include the effects of translation, rotation and distortion of the strut cross section and cover the practical range of flange and lip proportions and buckle half-wavelengths. Curves giving material plasticity factors are also provided.

Figures 1 to 9 give the elastic buckling stress, f_{be} , for struts that buckle sinusoidally along their length with a half-wavelength λ . Theoretically λ should be assumed to be an integral sub-multiple of the strut length. Local type buckles have low values of λ/h and therefore are unlikely to be influenced significantly by constraints acting at the ends of the strut. They may therefore be determined by inspection by simply locating the lowest trough of the appropriate curve.

For the range of dimensions covered by this Item the strut cross section translates and deforms but experiences no overall rotation. Flexural buckling stresses decrease with increasing λ and therefore for struts whose ends are unrestrained against flexure and warping the critical buckling stress may be taken to occur when λ equals the strut length. If the ends of the strut are fully restrained against flexure and warping, the maximum value of λ is equal to half the strut length. At the highest values of λ/h the curves merge into the straight line corresponding to the Euler stress for buckling, in the plane of least rigidity, of a pin-ended strut (see Figures 1 to 9). For this mode end restraint effects and strut eccentricity become significant and Item No. Struct 01.01.01 "The strength of struts" should be consulted.

A value of $\nu = 0.3$ has been assumed for calculating the elastic buckling stress associated with λ . 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. Figure 10 gives values of the plasticity correction factor, η , for local modes, which may be used to determine f_b , plotted against f_{be}/f_n for various values of m . For plasticity correction in the flexural mode Item No. Struct 01.01.01 should again be consulted.

3. DERIVATION

1. 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.
2. WILLIAMS, F.W. Computation of natural frequencies and initial buckling stresses of prismatic plate assemblies. *J. Sound Vib.*, Vol. 1, pp. 87-106, 1972.

4. EXAMPLE

It is required to find the initial buckling stress of a simply-supported lipped Z-section strut. The strut has a length of 427 mm, a depth of web of 66 mm, the flange widths are 34 mm, the widths of the lips are 13 mm and the thickness is 2 mm. The material properties of the strut are $f_n = 260 \text{ MN/m}^2$, $m = 14$, $E = 72\,400 \text{ MN/m}^2$ and $\nu = 0.3$.

From the dimensions given $h = 64 \text{ mm}$, $d = 32 \text{ mm}$ and $c = 12 \text{ mm}$. Hence $c/d = 0.375$, $d/h = 0.5$ and $t/h = 0.031$.

The maximum possible value of λ is 427 mm and hence $\lambda/h = 6.67$.

Figure 8 is used to obtain the buckling stress. By inspection it can be seen that buckling may occur at a lower stress and shorter wavelength than that for $\lambda/h = 6.67$. By interpolation the lowest value is

$$\frac{f_{be}}{E} = 4.4 \times 10^{-3}$$

$$\text{and therefore } f_{be} = 4.4 \times 10^{-3} \times 72\,400 = 319 \text{ MN/m}^2.$$

This will occur at about $\lambda/h = 3.8$ which is close to the theoretical value for two half-wavelengths where $\lambda/h = 6.67/2 = 3.34$.

Correcting for material plasticity, using Figure 10 with $m = 14$,

$$\frac{f_{be}}{f_n} = \frac{319}{260} = 1.23$$

giving $\eta = \frac{f_b}{f_{be}} = 0.825$

so that $f_b = 0.825 \times 319 = 263 \text{ MN/m}^2$.

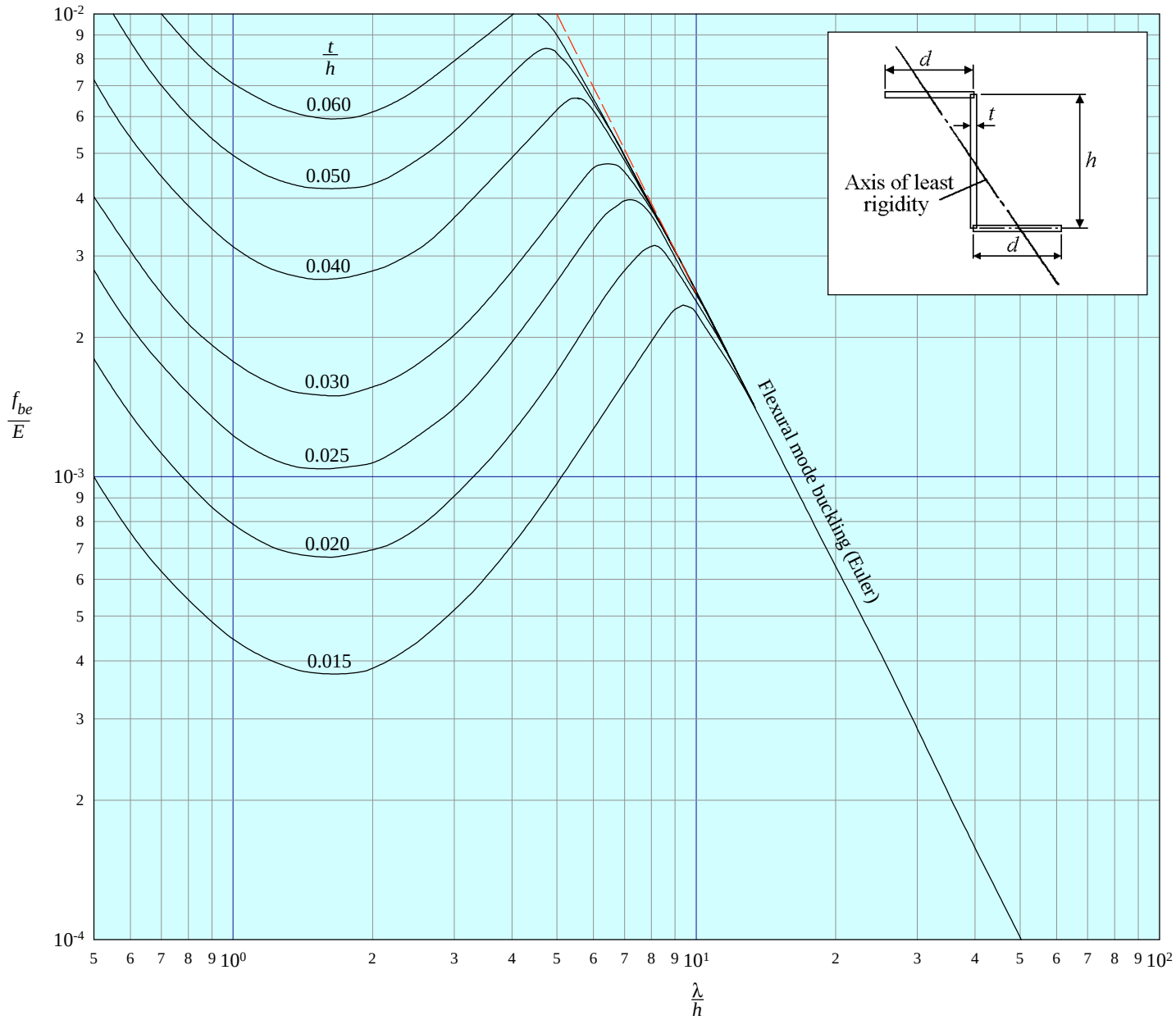


FIGURE 1 $\frac{c}{d} = 0, \frac{d}{h} = 0.667$

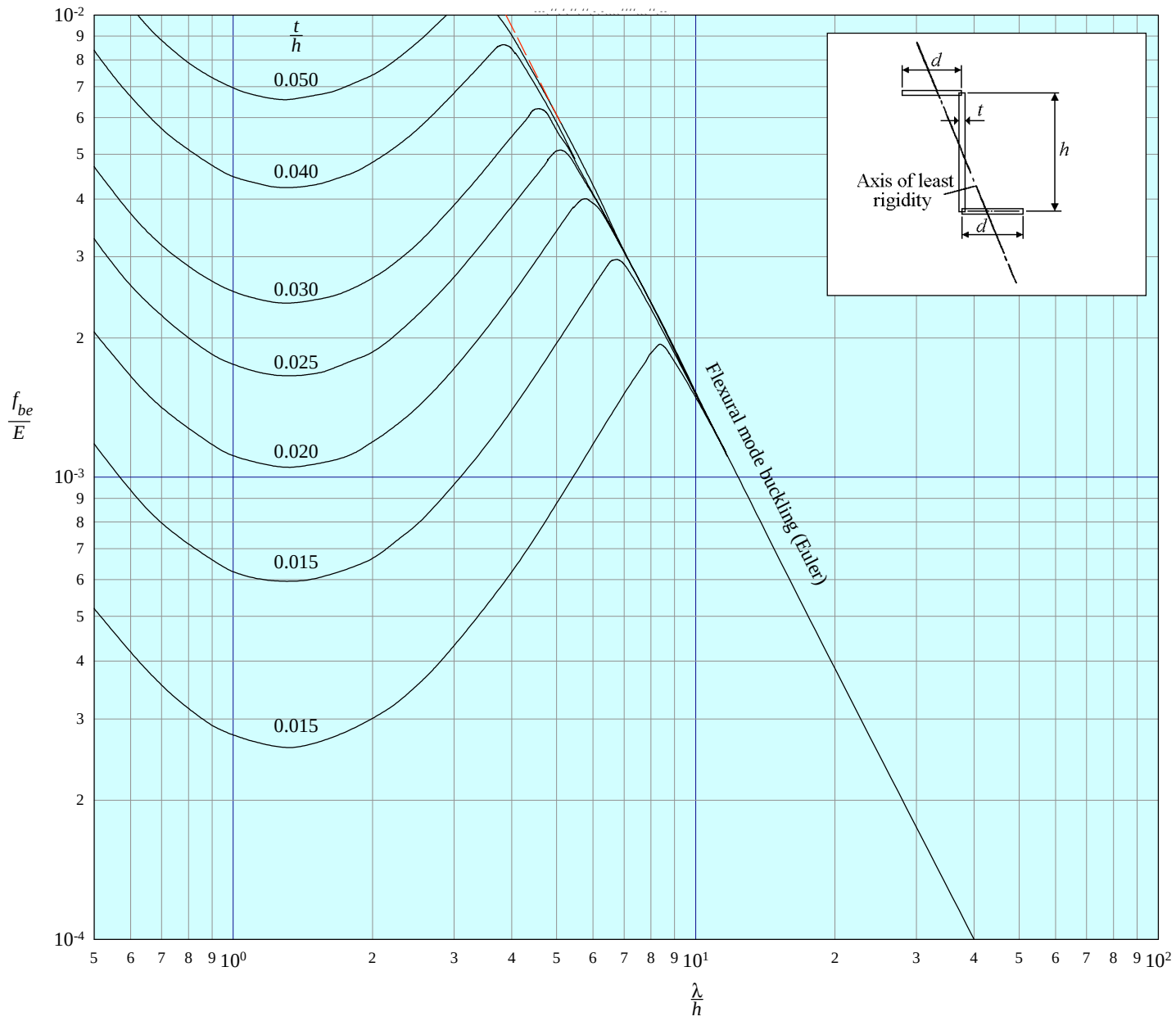


FIGURE 2 $\frac{c}{d} = 0, \frac{d}{h} = 0.5$