

BUCKLING OF OUTSTANDING FLANGES DIRECT STRESSES VARYING LINEARLY OR PARABOLICALLY

1. NOTATION

a	length of outstanding flange	m	in
b	width of outstanding flange	m	in
E	modulus of elasticity of outstanding flange material	N/m ²	lbf/in ²
f_b	elastic buckling stress of outstanding flange under uniform compression	N/m ²	lbf/in ²
f_F, f_O	values of f_x at $y/b = 1.0$ and $y/b = 0$, respectively	N/m ²	lbf/in ²
f_{Fb}, f_{Ob}	critical values of f_F and f_O , respectively, at which outstanding flange buckles	N/m ²	lbf/in ²
f_x	axial stress in outstanding flange at distance y from supported edge, positive if compressive	N/m ²	lbf/in ²
K	buckling stress coefficient defined by $f_{Fb} = KE(t/b)^2$		
M	elastic restraint per unit length against rotation of edge $y = 0$	(N m/rad)/m	(lbf in/rad)/in
t	outstanding flange thickness	m	in
x, y	axes of outstanding flange (see sketch on Figure 1 or Figure 2)		
μ_R	coefficient of rotational restraint acting along edge $y = 0$ defined by		
	$\mu_R = \frac{12M(1 - \nu^2)b}{Et^3}$		
ν	Poisson's ratio of outstanding flange material		

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

2. NOTES

This Item provides data on the buckling of outstanding flanges subjected to stresses that vary linearly or parabolically across their width. Data are given for long thin rectangular plates ($a/b \geq 4$) in which one of the long edges is elastically restrained against rotation and the other is free and in which both ends perpendicular to the loading are simply-supported. The data presented are strictly only applicable to cases where the stress and its distribution across the section remain constant along the length of the outstanding flange. The data may be used where stresses are sensibly constant along a length greater than about $4b$. The data are not applicable to external distributions that diffuse rapidly into the outstand.

Poisson's ratio, ν , has been assumed to be 0.3. For all other values of ν , buckling stresses may be calculated by multiplying the value of K obtained from Figure 1 by $0.91/(1 - \nu^2)$.

2.1 Stresses that Vary Linearly Across the Width

Figure 1 gives K plotted against f_O/f_F for a range of values of μ_R . Data are provided for linear stress distributions between the limits of $f_O/f_F = -1$ and 2. The buckling stress coefficient, K , relates to the stress at the free edge of the outstanding flange. The value of f_b is calculated using $f_O/f_F = 1$ and a value of μ_R corresponding to that in the specific problem.

The limiting value of $\mu_R = 0$ corresponds to a simply-supported attachment and $\mu_R = \infty$ corresponds to a clamped attachment. The finite value of μ_R is the ratio of the rotational restraint provided along the edge $y = 0$ to the stiffness of the outstanding flange. It has been assumed that the value of μ_R is constant along the length.

2.2 Stresses that Vary Parabolically Across the Width

Figure 2 shows the variation of f_{Fb}/f_b with f_O/f_F for a range of values of μ_R for outstanding flanges subjected to the family of parabolically distributed stresses that have zero stress gradient at the free edge, as illustrated in Figure 3. When calculating f_b in cases where the stress distribution has arisen from thermal strain, allowance should be made for possible variations with temperature in the modulus of the outstanding flange material. The value of E selected should be appropriate to the mean temperature over the range $y/b = 0.65$ to $y/b = 1.0$. The data may be used for stress distributions that do not strictly conform to Figure 3, but in which the region of the curve $y/b = 0.65$ to $y/b = 1.0$ is a close fit to one of the distributions provided. The value of f_O/f_F for the appropriate curve may then be used to estimate f_{Fb} .

3. DERIVATION

This section lists selected sources that have assisted in the preparation of this Item.

1. LUNDQUIST, E.C.
STOWELL, E.Z. Critical compressive stress for outstanding flanges. NACA tech Rep. 734, 1942.
2. TIMOSHENKO, S.P.
GERE, J.M. *Theory of elastic stability*. Second edition, pp. 360-362. McGraw-Hill, New York, 1961.
3. BENOY, M.B. An energy solution to the buckling of rectangular plates under non-uniform in-plane loading. *Jl R. aeronaut. Soc.*, Vol. 73, pp. 974-977, November 1969.
4. BULSON, P.S. *The stability of flat plates*, pp. 34-39, 71. Chatto and Windus, London, 1970.

4. EXAMPLES

4.1 Example 1

It is required to determine the buckling stress of the outstanding flanges reinforcing a panel. The outstands are subjected to combined bending and compression such that the stress at the free edge is three times that at the attached edge when the stress is assumed to vary linearly across the width. The principal dimensions

of the flanges are $a = 300$ mm, $b = 35$ mm, $t = 1.5$ mm and the modulus of elasticity, E , is $74\,500$ MN/m² and Poisson's ratio is 0.33. The elastic restraint provided along the attached edge has been calculated as 36.5 (kN m/rad)/m.

From the notation

$$\mu_R = \frac{12 \times 36.5 \times 10^3 \times (1 - 0.33^2) \times 35 \times 10^{-3}}{74\,500 \times 10^6 \times (1.5 \times 10^{-3})^3} = 54.3.$$

Interpolation from Figure 1 for $f_O/f_F = 0.33$ and $\mu_R = 54.3$ gives

$$K = 1.25.$$

Correcting for Poisson's ratio gives

$$K = 1.25 \times 0.91 / (1 - 0.33^2) = 1.28.$$

Therefore,

$$f_{Fb} = 1.28 \times 74\,500 \times 10^6 \left(\frac{1.5 \times 10^{-3}}{35 \times 10^{-3}} \right)^2 = 175 \text{ MN/m}^2$$

so that
$$f_{Ob} = \frac{175 \times 10^6}{3} = 58.3 \text{ MN/m}^2.$$

4.2 Example 2

During deceleration from supersonic flight, transient thermal compressive stresses are set up in the outstanding flanges on a panel similar to that in Example 1. It is required to determine whether or not at any time during the deceleration buckling occurs.

It is necessary to check the stability of the outstands at a number of temperature and stress distributions. One of these distributions is illustrated below. It has $f_F = 160$ MN/m², $f_O/f_F = 0.2$ and the mean temperature over the range $0.65 \leq y/b \leq 1.0$ of the plate is 100°C .

