

STRENGTH OF STRINGERS IN PANEL IN COMPRESSION

1. NOTATION

A_s	cross-sectional area of stringer	m ²	in ²
b	plate width between stringers, measured as distance between adjacent rivet lines	m	in
E	modulus of elasticity of material of sheet and stiffener	N/m ²	lbf/in ²
E_{te}	tangent modulus of stringer material at stress f_{edge}	N/m ²	lbf/in ²
E_{ts}	tangent modulus of stringer material at stress f_s	N/m ²	lbf/in ²
f_a	average stress in plate at edge stress f_{edge}	N/m ²	lbf/in ²
f_b	stress at which plate first buckles in compression	N/m ²	lbf/in ²
f_{edge}	edge stress at failure of stiffened panel	N/m ²	lbf/in ²
f_s	failing stress of stringer alone, constrained to fail by flexure in direction normal to sheet	N/m ²	lbf/in ²
I_s	second moment of area of stringer section about axis through stringer centroid parallel to sheet	m ⁴	in ⁴
I_x	second moment of area of stringer section about axis in median plane of sheet	m ⁴	in ⁴
l	panel length	m	in
t	sheet thickness	m	in
η	slope of the curve of f_a against f_{edge} from Data Item No. Struct 02.01.03 or 02.01.23		

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

2. NOTES

In Figure 1 the ratio f_{edge}/f_s is plotted against the ratio $A_s/(\eta bt)$ for various values of I_x/I_s . The curves apply only to failure of the stringers due to flexural instability. The possible failure due to local or torsional instability must also be considered.

The effect of buckling of the sheet has been taken into account in assessing the contribution of the sheet to the flexural stiffness of the stringer. The effects of any tendency for the stringer and the panel to buckle in different forms and of inter-rivet buckling along the length of the stringer have been ignored; this will be permissible if the stringer is of greater wall thickness than the sheet, but may not apply to heavy gauge

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sheet with relatively light stringers.

The curves have been plotted for stresses in the elastic range; as a first approximation they may be used in the plastic range by replacing the ratio f_{edge}/f_s by $(f_{edge}/f_s)(E_{ts}/E_{te})$.

3. DERIVATION

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

$$\frac{f_{edge}}{f_s} = \frac{\frac{A_s}{\eta bt} \left(\frac{A_s}{\eta bt} + \frac{I_x}{I_s} \right)}{\left(\frac{A_s}{\eta bt} + 1 \right) \left(\frac{A_s}{\eta bt} + 1.5 \right)} \quad (3.1)$$

1. FARRAR, D.J.
JONES, C.H. Investigation of skin buckling, Part III – Compression tests on flat panels with stringer edge supports, with conclusions from Parts I, II and III. Aeronautical Research Council, UK, Scientific and Technical Memorandum, S & TM No. 12C/47, October 1945.

4. EXAMPLE

It is required to determine the sheet edge stress at failure in a simply-supported panel loaded in uniaxial compression. The material properties of both the sheet and stringer are $E = 63\,400 \text{ MN/m}^2$, Poisson's ratio is 0.3 and, in the notation of Item No. 76016*, the inelastic properties are given by the reference stress $f_n = 275 \text{ MN/m}^2$ and $m = 15$. The panel dimensions are, $l = 375 \text{ mm}$, $b = 135 \text{ mm}$, $t = 1.0 \text{ mm}$, $A_s = 65 \text{ mm}^2$, $I_s = 9160 \text{ mm}^4$ and $I_x = 24\,100 \text{ mm}^4$.

The value of f_s is determined using Item No. Struct 01.01.01 assuming no eccentricity of loading. Thus, in the notation of that Item,

$$\frac{l'}{k} \left(\frac{f_n}{E} \right)^{1/2} = \frac{375 \times 10^{-3}}{(9160 \times 10^{-12} / 65 \times 10^{-6})^{1/2}} \left\{ \frac{275 \times 10^6}{63\,400 \times 10^6} \right\}^{1/2} = 2.08$$

and from Figure 1 of that Item, at $m = 15$, $f/f_n = 1.02$ giving

$$f = 1.02 \times 275 \times 10^6 = 280.5 \text{ MN/m}^2 \equiv f_s$$

in the notation of this Item.

The value of f_b is determined using Figure 2 of Data Item No. 72019. Thus, in the notation of that Item $f_{xe}/f_0 = 1.0$ so that

$$f_{xe} = \frac{\pi^2 \times 63\,400 \times 10^6}{3(1 - 0.3^2)} \left(\frac{1 \times 10^{-3}}{135 \times 10^{-3}} \right)^2 = 12.6 \text{ MN/m}^2 \equiv f_b$$

* Data Item No. 76016 "Generalisation of smooth continuous stress-strain curves for metallic materials".