

DESIGN FOR MINIMUM WEIGHT. STRUTS OF UNIFORM SECTION. MINIMUM WEIGHTS FOR VARIOUS SECTIONS

1. NOTATION

E	Young's modulus of strut material	N/m ²	lbf/in ²
f_0	average stress at failure in elastic strut of least weight	N/m ²	lbf/in ²
l	actual length of strut	m	in
l'	equivalent length of strut (see Data Sheet Struct. 01.01.01)	m	in
P	end load in strut at failure	N	lbf
W_{min}	minimum weight of strut	N	lbf
w	weight per unit volume of strut material	N/m ³	lbf/in ³

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

2. NOTES

Values of $W_{min}E/Plw$ ($= E/f_0$) are plotted against P/EI'^2 for elastic struts of thin-walled circular, square and I-section.

If f_0 exceeds the elastic limit for the particular material considered, this Data Sheet under-estimates the value of W_{min} . A closer estimate may then be obtained by using Item No. 66006, 66007 or 85014.

3. DERIVATION

1. COX, H.L. *The design of structures of least weight*. Pergamon, Oxford, 1965.

4. EXAMPLE

It is required to determine the least weight of a square tubular strut to carry a load of 4500 lbf over a distance of 10 in. One end of the strut is fixed and the other is free. The material is a titanium alloy with properties

$$w = 0.165 \text{ lbf/in}^3, \quad E = 17.5 \times 10^6 \text{ lbf/in}^2, \\ \text{stress at elastic limit} = 55\,000 \text{ lbf/in}^2.$$

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From Data Sheet 01.01.01,

$$l' = 2l = 20 \text{ in.}$$

Hence,

$$\frac{P}{El'^2} = \frac{4500}{17.5 \times 10^6 \times 20^2} = 6.43 \times 10^{-7}.$$

From the curve labelled "square tube" in Figure 1,

$$\frac{W_{min}}{Pl} \frac{E}{w} = \frac{E}{f_0} = 3.3 \times 10^2 = 330.$$

Hence,

$$W_{min} = \frac{330 \times 4500 \times 10 \times 0.165}{17.5 \times 10^6} = 0.140 \text{ lbf},$$

$$f_0 = \frac{17.5 \times 10^6}{330} = 53\,000 \text{ lbf/in}^2.$$

This value of W_{min} can be achieved in the given material since the stress of 53 000 lbf/in² does not exceed the elastic limit.