

DESIGN FOR MINIMUM WEIGHT. STRUTS OF UNIFORM SECTION. THIN-WALLED SQUARE TUBES

1. NOTATION

d	mean width of side of strut	m	in
d_0	mean width of side of elastic strut of least weight	m	in
E	Young's modulus of strut material	N/m ²	lbf/in ²
E_t	tangent modulus at stress f	N/m ²	lbf/in ²
f	average stress in strut at failure	N/m ²	lbf/in ²
f_n	stress at which $E_t = \frac{1}{2}E$	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
m	material characteristic (see Item No. 76016)		
P	end load in strut at failure	N	lbf
t	thickness of wall of strut	m	in
t_0	thickness of wall of elastic strut of least weight	m	in
W	weight of strut	N	lbf
W_{min}	minimum weight of strut	N	lbf

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

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2. INTRODUCTION

This Data Sheet gives the cross-sectional dimensions for minimum weight of thin-walled struts of uniform square section and given length. Information is also presented on the weight penalty incurred by restricting either of the cross-sectional dimensions.

Figure 1 gives values of d_0/l' and t_0/l' against P/EI'^2 . Figures 2 and 3 give values of d/d_0 and t/t_0 against f_0/f_n for various values of m . Figures 4 and 5 give values of W/W_{min} and the unspecified dimensional ratio against d/d_0 or t/t_0 respectively for elastic struts with a restriction on the choice of dimensions.

In deriving Figure 1, no allowance has been made for eccentricity or overall curvature of the strut. The effect of a practical degree of local irregularity of the walls is negligible. In deriving Figures 2 and 3, the appropriate modulus effective in each mode of plastic buckling has been used (Derivation 1).

Item No. 66008 gives information on the minimum weights of struts of uniform section in various materials.

3. DIMENSIONS OF STRUT OF LEAST WEIGHT

To determine the dimensions of a strut of least weight, the material is first assumed to be perfectly elastic. The cross-sectional dimensions d_0 and t_0 are obtained from Figure 1 for the appropriate value of P/EI'^2 . The stress f_0 is then obtained from the relation

$$f_0 = \frac{P}{4d_0t_0}.$$

If f_0 is above the elastic limit, the values of f_n and m appropriate to the strut material are used to obtain d/d_0 and t/t_0 from Figures 2 and 3. The actual dimensions d and t may then be evaluated.

4. WEIGHT PENALTY FOR ELASTIC STRUTS WITH DIMENSIONAL RESTRICTION

In particular cases, one of the cross-sectional dimensions may be dictated by considerations other than design for minimum weight. Figures 4 and 5 show the least value of W/W_{min} that can be achieved when one dimension is initially specified. Each figure also gives the value of the remaining section dimension that must be used and indicates the initial buckling mode.

If d is specified, d/d_0 is evaluated. Then W/W_{min} and t/t_0 are obtained from Figure 4, noting the change of scale of t/t_0 as the value of d/d_0 passes through unity. Initial instability occurs in the overall mode if $d/d_0 < 1$ and in the local mode if $d/d_0 > 1$.

For the given value of P/EI'^2 , t_0 is the absolute minimum thickness of a square tubular strut. Thus for any admissible design, t can only be specified so that $t/t_0 \geq 1$. In this case W/W_{min} and d/d_0 are obtained from Figure 5. Initial instability occurs in the overall mode.

Figures 4 and 5 apply only to elastic struts. In particular, the value of W_{min} is that appropriate to an elastic strut of least weight. If the dimensionally restricted strut is indeed elastic but the strut of least weight inelastic, the quoted value of W/W_{min} is misleading. In this case the unspecified cross-sectional dimension is obtained from either Figure 4 or Figure 5. The average stress in the dimensionally restricted strut can then be calculated and so can the stress in the strut of least weight. The realistic weight penalty for the

dimensionally restricted strut is then given by

$$\frac{W}{W_{min}} = \frac{\text{stress in strut of least weight}}{\text{stress in dimensionally restricted strut}}.$$

5. DERIVATION

1. BECKER, H. Handbook of structural stability. Part II: Buckling of composite elements. NACA TN 3782, 1955.
2. COX, H.L. *The design of structures of least weight*. Pergamon, Oxford, 1965.