LOCAL BUCKLING OF COMPRESSION PANELS WITH FLANGED STRINGERS

1. NOTATION

b	stringer pitch	m	in
d	stringer flange width	m	in
E	Young's modulus of panel and stringer material	N/m^2	lbf/in^2
E_t	tangent modulus of panel and stringer material	N/m^2	lbf/in^2
f_b	compressive stress in panel at which local buckling occurs	N/m^2	lbf/in^2
$(f_b)_e$	compressive stress in panel at which elastic local buckling would occur	N/m^2	lbf/in^2
f_n	stress at which $E_t = ½E$	N/m^2	lbf/in^2
h	depth of stringer	m	in
K	elastic buckling stress coefficient defined by $(f_b)_e = KE(t/b)^2$		
m	material characteristic for panel and stringer (see Item No. 76016)		
t	thickness of skin	m	in
t_d	thickness of stringer flange	m	in
t_s	thickness of stringer web	m	in
η	plasticity reduction factor defined by $f_b = \eta(f_b)_e$		
ν	Poisson's ratio for panel material		

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

2. NOTES

Figures 1 to 6 show the local buckling coefficient, K, for panels having integrally manufactured single or double flanged stringers, plotted against h/b for various values of t_s/t; each figure applies to a fixed value of d/h and of t_d/t_s. Figures 7 to 9 are similar to Figures 1 to 6 but relate to panels reinforced by separate stringers: these stringers are of constant section having equal length flanges and are manufactured from similar material to the skin. Figure 10 shows η plotted against $(f_b)_e/f_n$ for various values of m. If $(f_b)_e$ is beyond the limit of proportionality of the panel material the appropriate values of f_n and m together with $(f_b)_e$ may be used to estimate η from Figure 10.

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The data were calculated using the method set out in Item No. Struct. 02.01.28. The application of this method to a panel reinforced by Z-section stringers is illustrated in Item No. Struct. 02.01.35.

When h/b is less than about 0.4 the effect of the stringer flanges on K is small and differences between the curves of Figures 1 to 9 are negligible. Also, differences between the single and double flanged stringer constructions of Figures 1 to 6 are significant only in Figures 3 and 5.

The method of attachment of Z-section stringers can influence the local buckling stress. The data of Figures 7 to 9 are sufficiently accurate for a single line of fasteners or welds providing attachment close to the heel. However, if the stringer flange is constrained to deflect with the skin, as for example with bonded-on stringers, then the buckling stress will be above that given by this Item. The increase in the buckling stress is likely to be small excepting in the region where the curves of Figures 7 to 9 are dotted. In this region the data are no longer applicable to bonded-on stringers.

The data of Figures 1 to 9 are sufficiently accurate provided that b/t , h/t_s and d/t_d are all greater than about 5. A value of $\nu = 0.3$ has been assumed for calculating the elastic deformation of the panel material. It is sufficiently accurate to factor the buckling stress by $0.91(1-\nu^2)$ to obtain results for other values of ν between 0.25 and 0.35. The method of calculation takes full account of the rotational coupling that occurs between the component flats but does not allow for translation of the flats in their own plane. Therefore, torsional and flexural buckling modes must be checked separately. It should be noted that while local instability does not necessarily lead to total collapse it will have an effect on the torsional and overall instabilities of the panel.

The local buckling stress for panels with unflanged stringers is given in Item No. 70003 “Local buckling of compression panels with unflanged integral stiffeners”.

3. DERIVATION

1.	ROSSMAN, C.A. BARTONE, L.M. DOBROWOSKI, C.V.	Compressive strength of flat panels with Z-section stiffeners. NACA ARR 4B03, (RD.TIC/589), February 1944.
2.	SCHUETTE, E.H.	Charts for the minimum-weight design for 24S-T aluminum-alloy flat compression panels with longitudinal Z-section stiffeners. NACA Rep. 827, July 1945.
3.	LABRAM, E.E.	An experimental study of the influence of methods of attachment on skin buckling and failure of stringer-skin panels. Thesis, College of Aeronautics, Cranfield, May 1950.
4.	COX, H.L.	Computation of initial buckling stress for sheet-stiffener combinations. *J. R. aeronaut. Soc.*, Vol.58, pp. 634-638, September 1954.
5.	GERARD, G. BECKER, H.	Handbook of structural stability. Part I – Buckling of flat plates. NACA tech. Note 3781, October 1954.

4. EXAMPLE

It is required to find the local buckling stress of a panel having integrally manufactured flanged stiffeners with the dimensions $b = 65$ mm, $h = 33$ mm, $d = 15$ mm, $t = 2$ mm and $t_d = t_s = 3$ mm. The material properties of the panel are $E = 73\ 600$ MN/m^2 , $\nu = 0.34$, $f_n = 317$ MN/m^2 and $m = 15$.

Checking the width to thickness ratios of the component flats of the panel gives, $b/t = 32.5 \ (> 5)$, $h/t_s = 11 (> 5)$ and $d/t_s = 5 \ (= 5)$. Therefore, the data are applicable.

Then, $t_s/t = 1.5$, $h/b = 0.507$, $t_d/t_s = 1.0$ and interpolating for $d/h = 0.455$ from Figures 1, 3 and 5, $K = 5.33$. Therefore,

$$(f_b)_e \;=\; 5.33 \times 73\ 600 \times \left(\frac{2}{65}\right)^2 \;=\; 371 \ \text{MN/m}^2 \ .$$

Correcting $(f_b)_e$ for Poisson's ratio gives

$$(f_b)_e \;=\; \frac{0.91}{(1 - 0.34^2)} \times 371 \;=\; 382 \ \text{MN/m}^2 \ .$$

Now, $$(f_b)_e/f_n = \frac{382}{317} = 1.21 \ .$$

Therefore, from Figure 10 at $m = 15$, $\eta = 0.832$.

Hence, $$f_n = 0.832 \times 382 = 318 \ \text{MN/m}^2 \ .$$

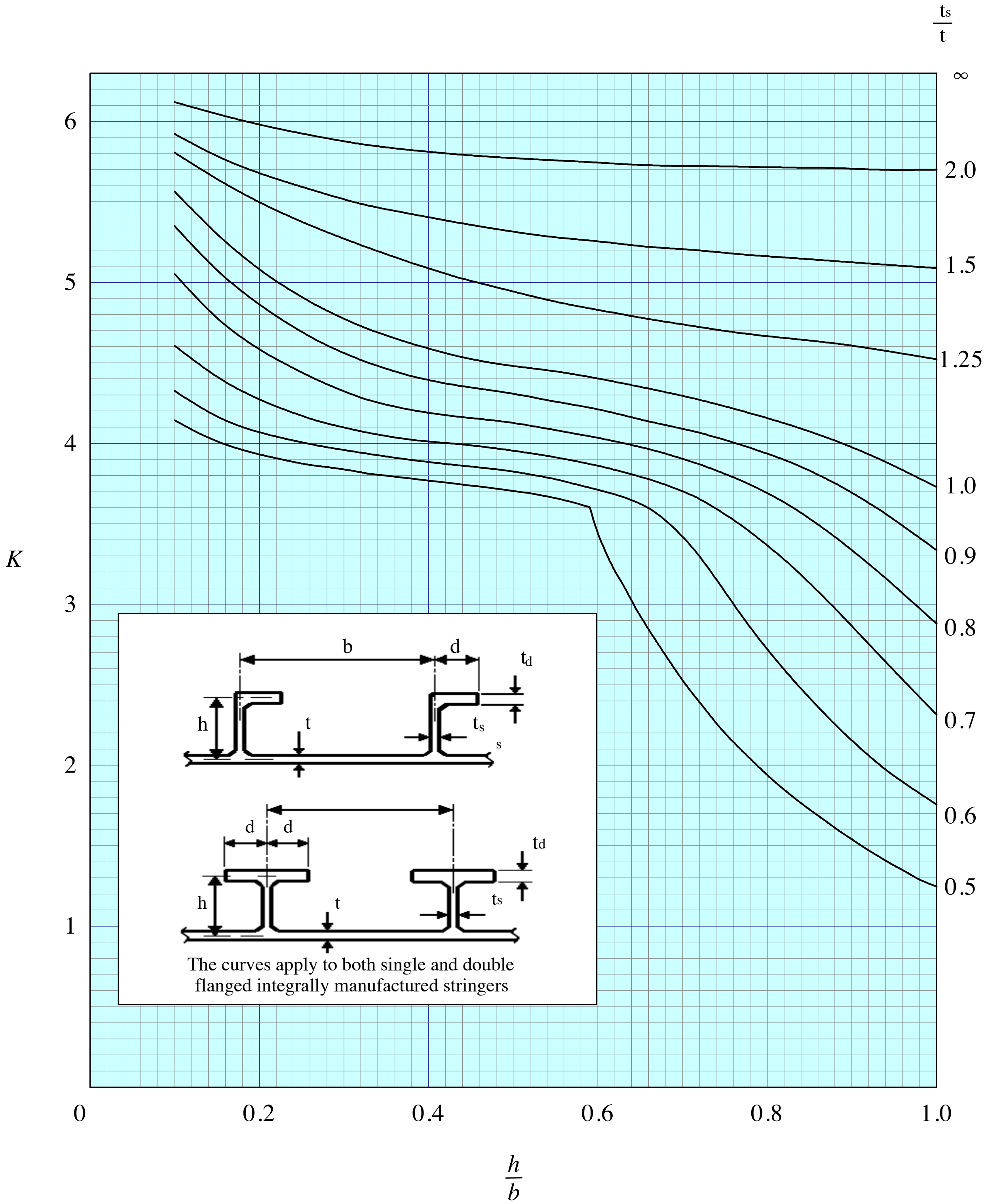

FIGURE 1 $\frac{d}{h} = 0.3$ AND $\frac{t_d}{t_s} = 1.0$

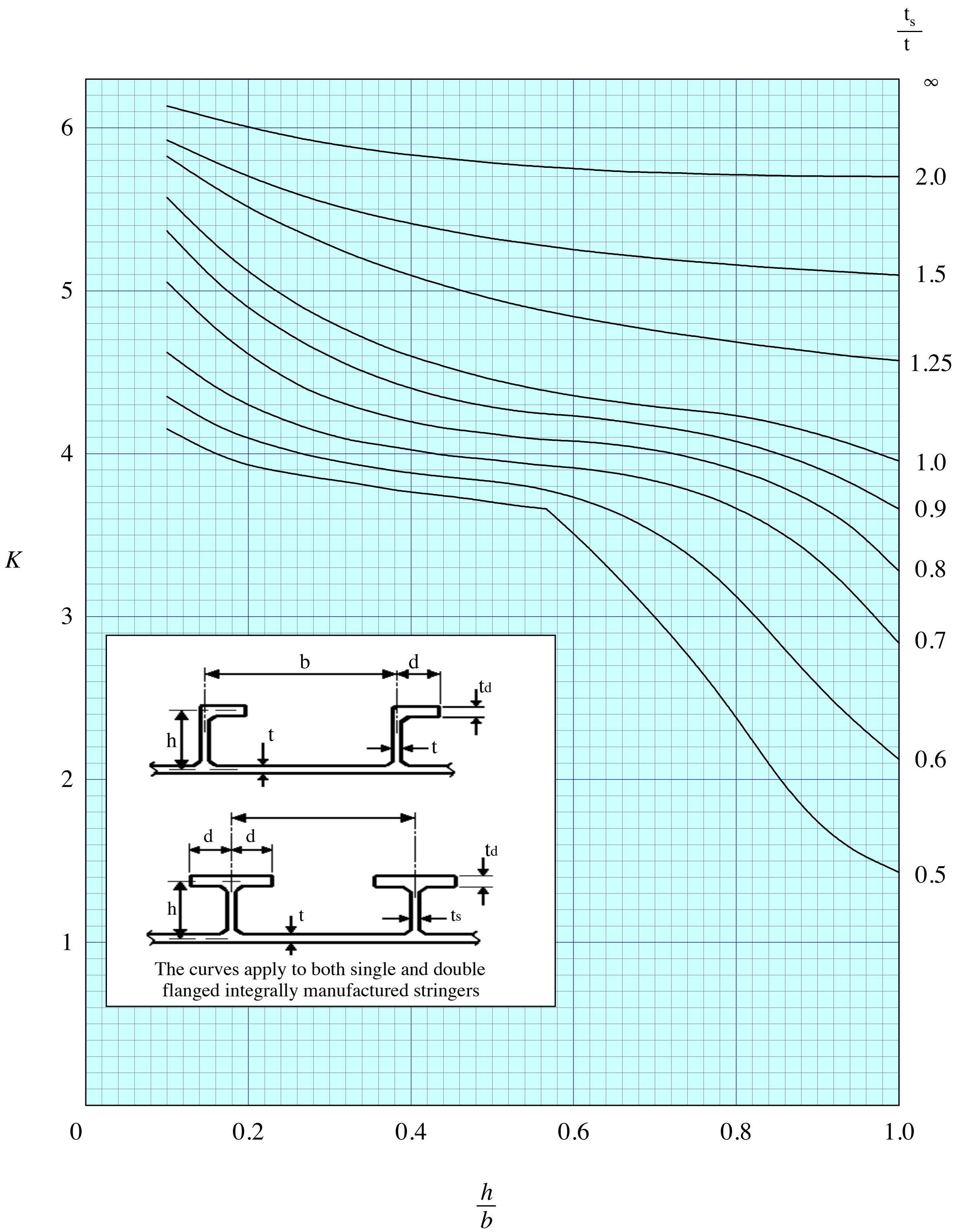

FIGURE 2 $\frac{d}{h} = 0.3$ **AND** $\frac{t_d}{t_s} = 2.0$

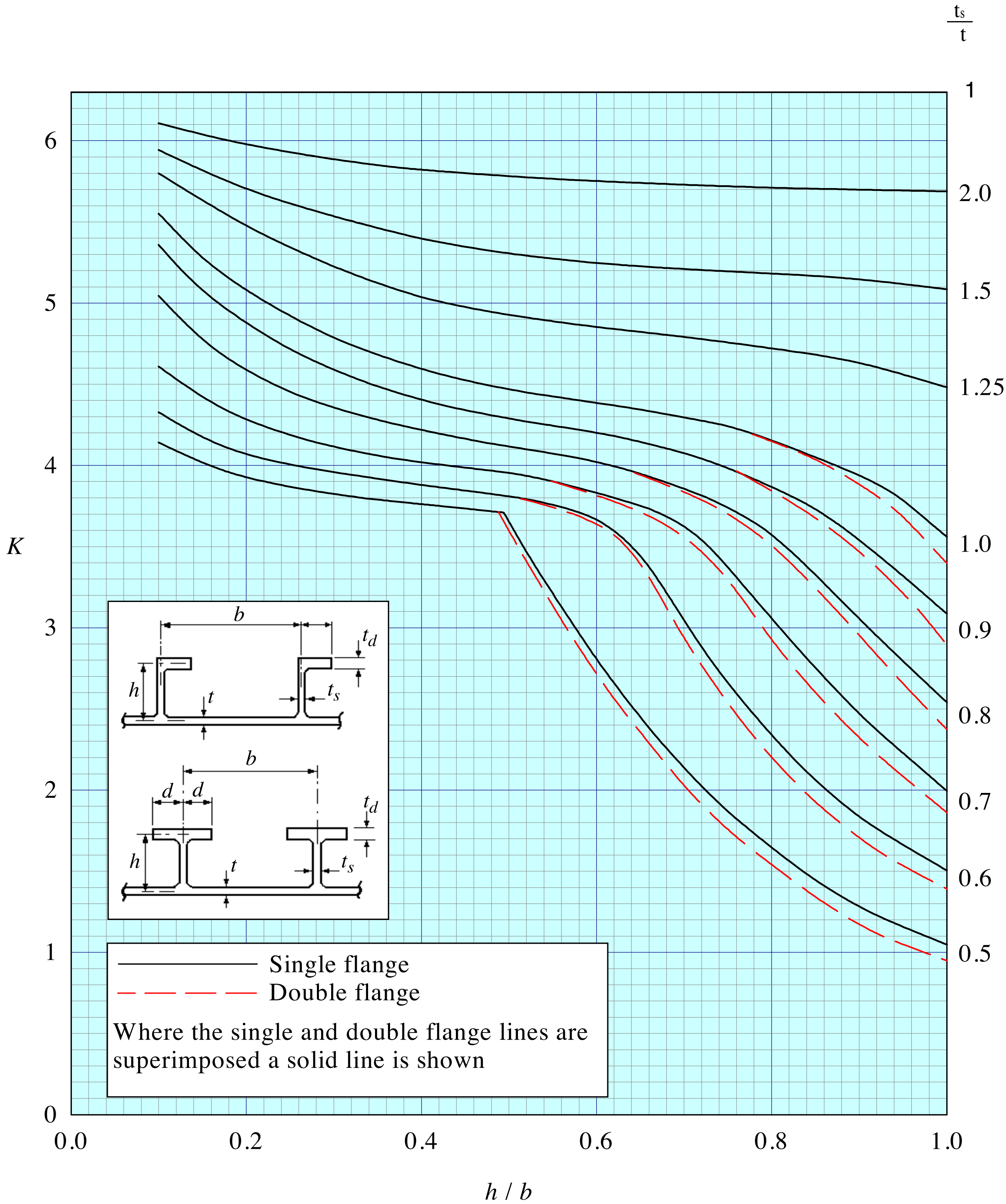

FIGURE 3 $\frac{d}{h} = 0.4$ **AND** $\frac{t_d}{t_s} = 1.0$

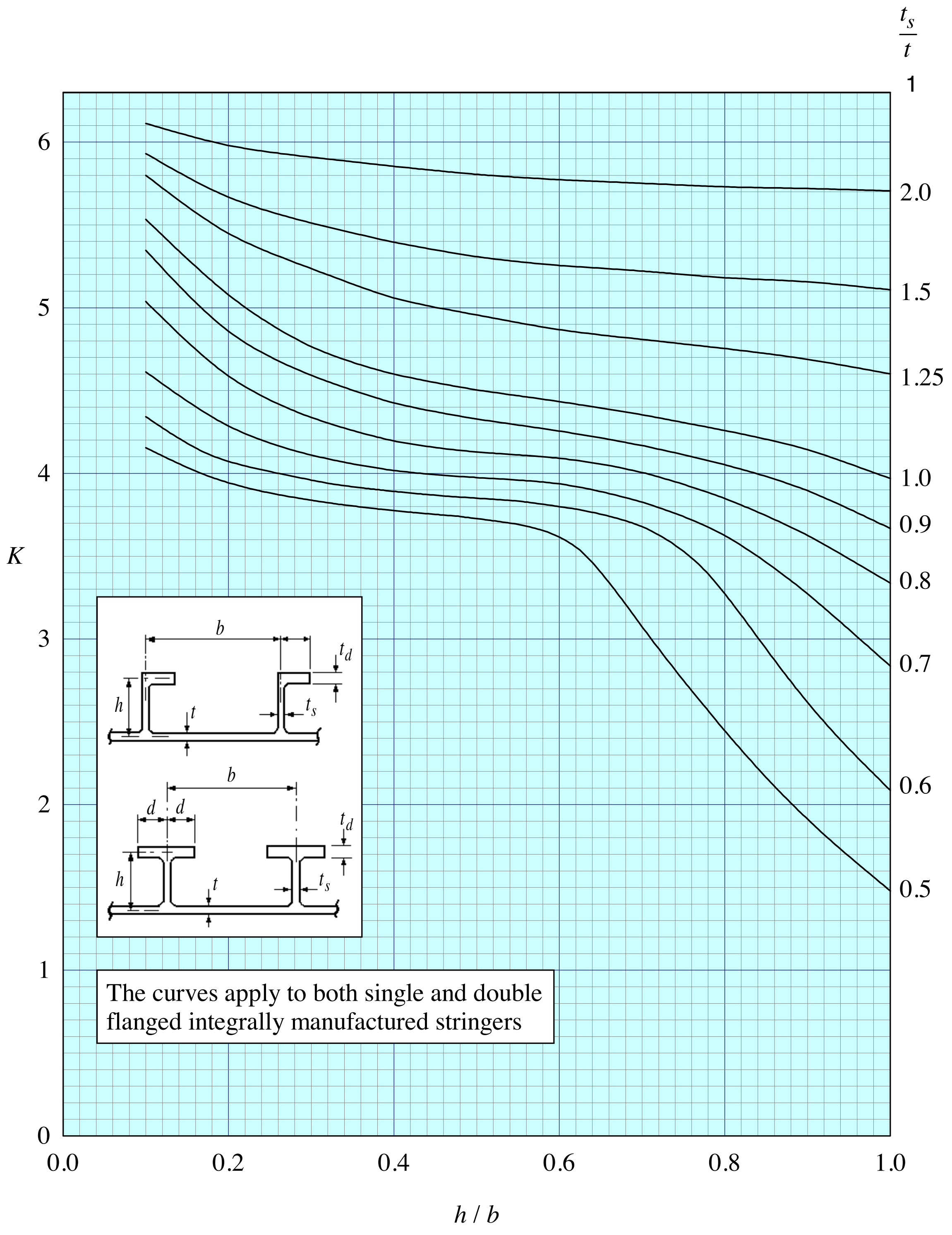

FIGURE 4 $\frac{d}{h} = 0.4$ AND $\frac{t_d}{t_s} = 2.0$

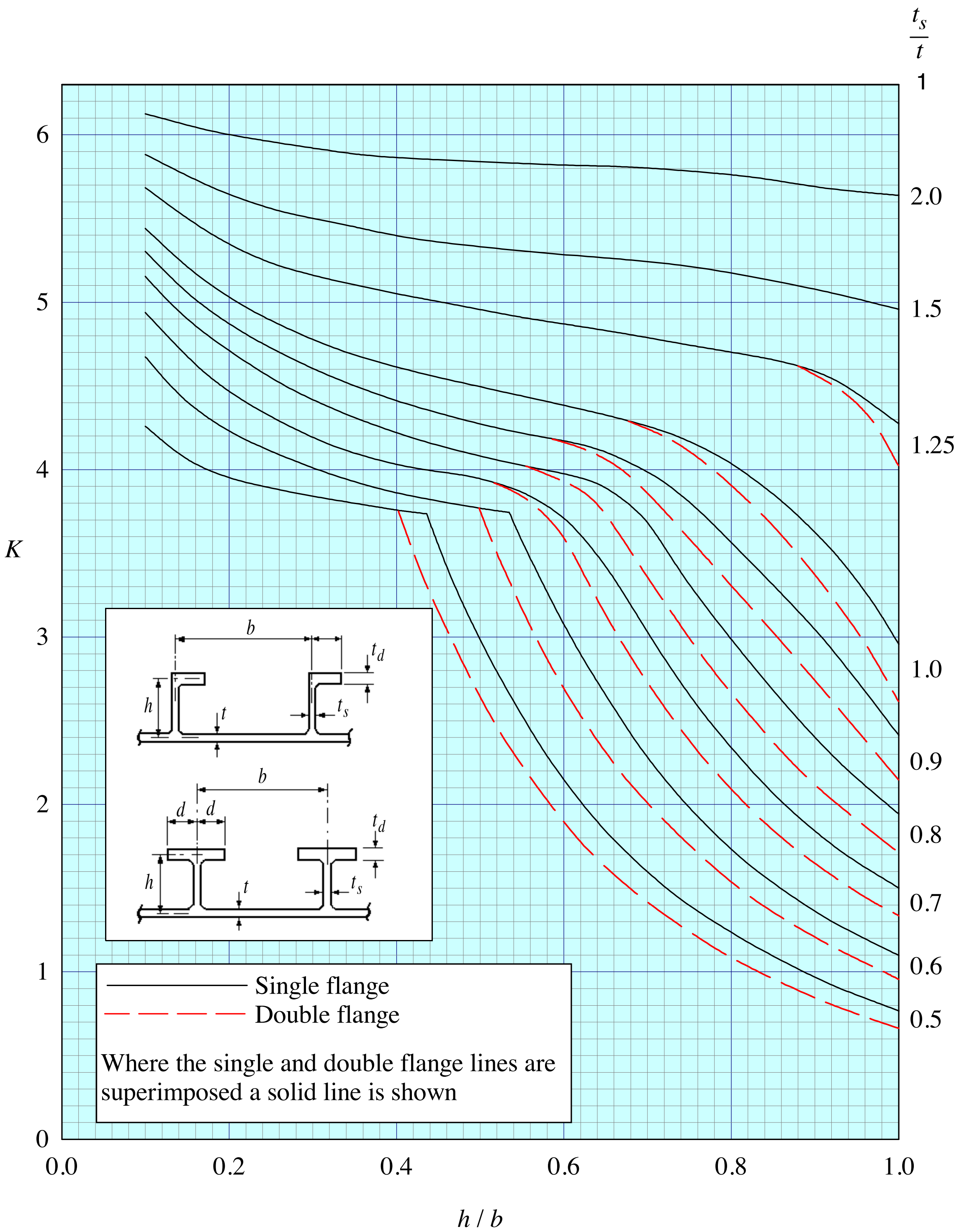

FIGURE 5 $\frac{d}{h} = 0.5$ AND $\frac{t_d}{t_s} = 1.0$

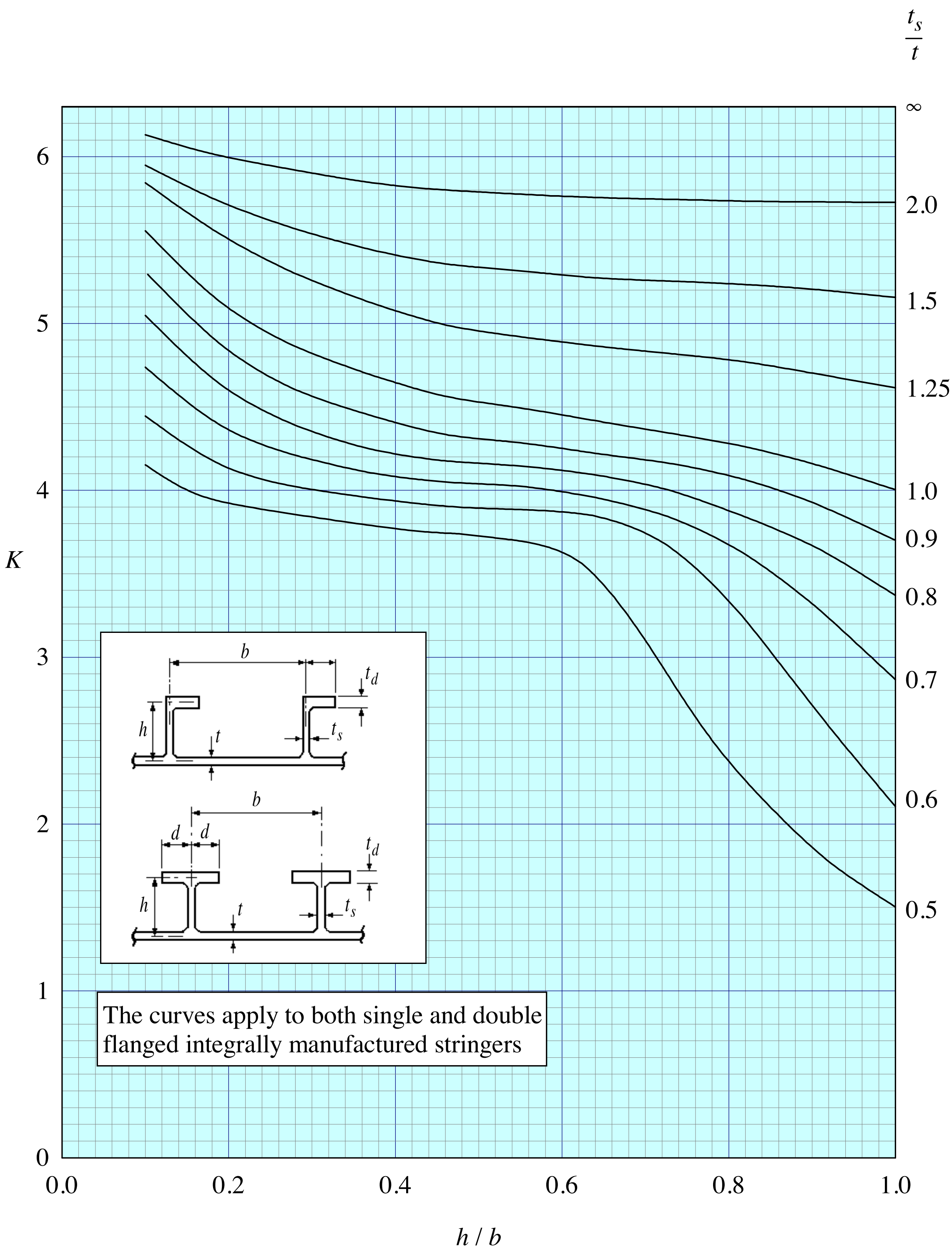

FIGURE 6 $\frac{d}{h} = 0.5$ **AND** $\frac{t_d}{t_s} = 2.0$

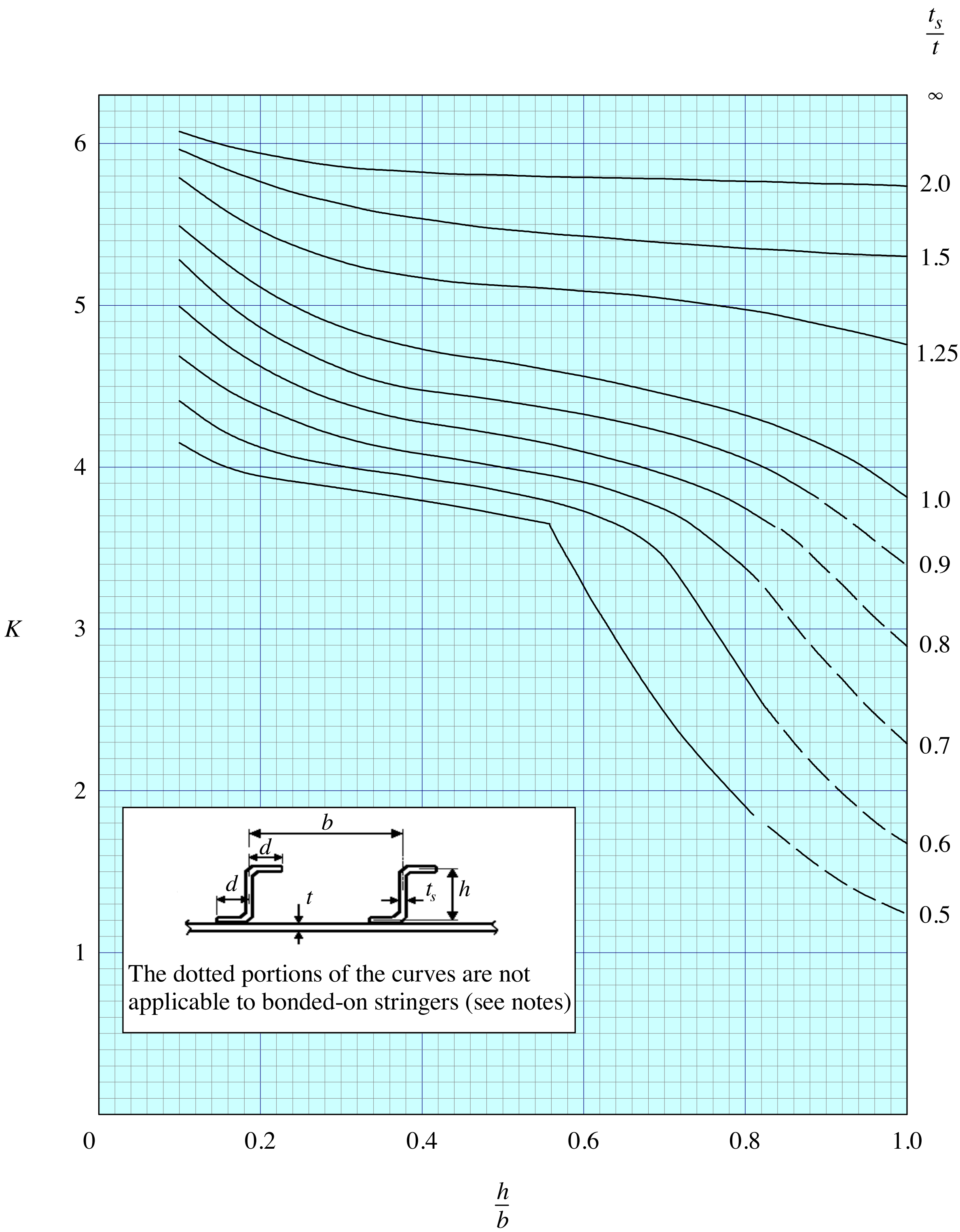

FIGURE 7 $\frac{d}{h} = 0.3$

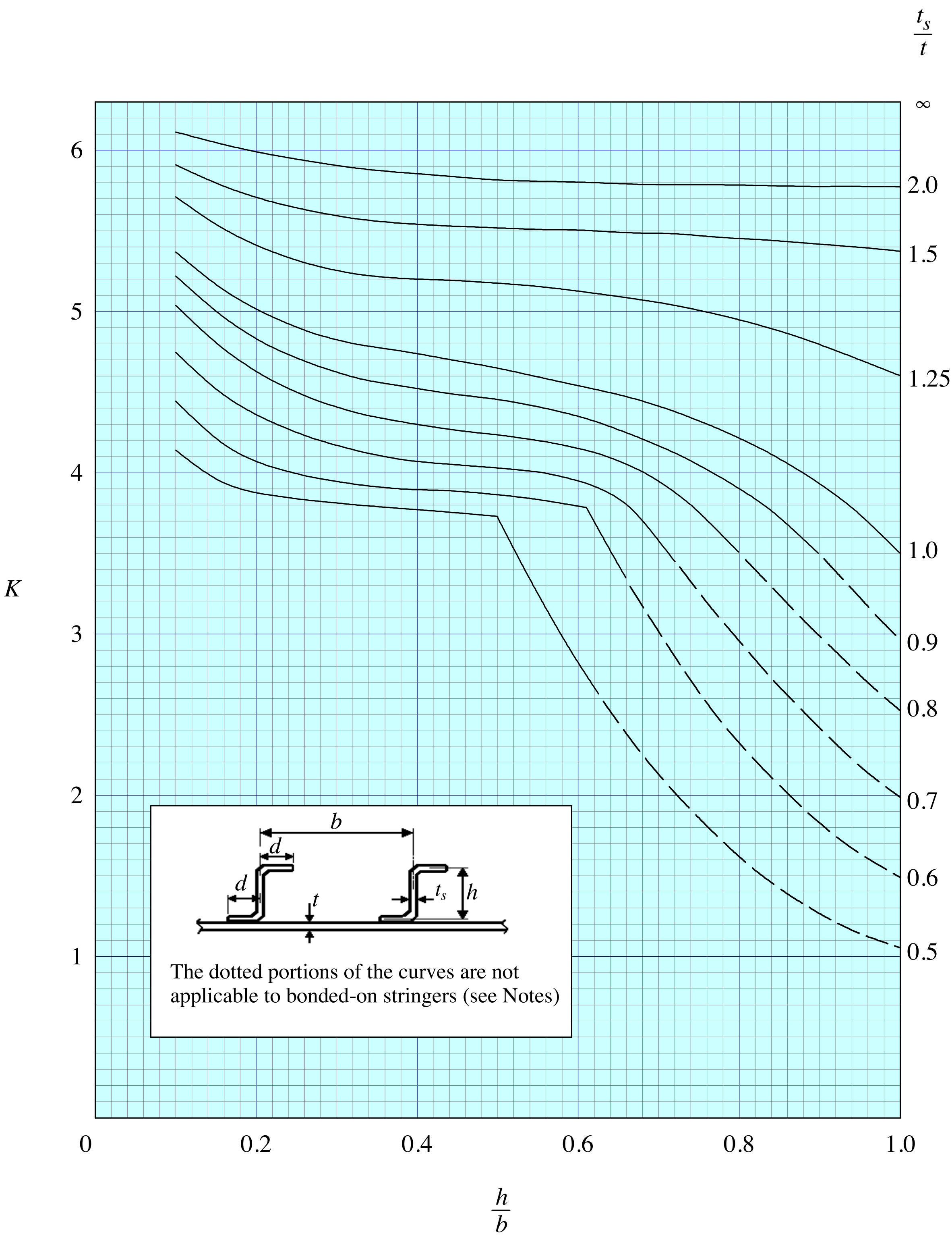

FIGURE 8 $\frac{d}{h} = 0.4$

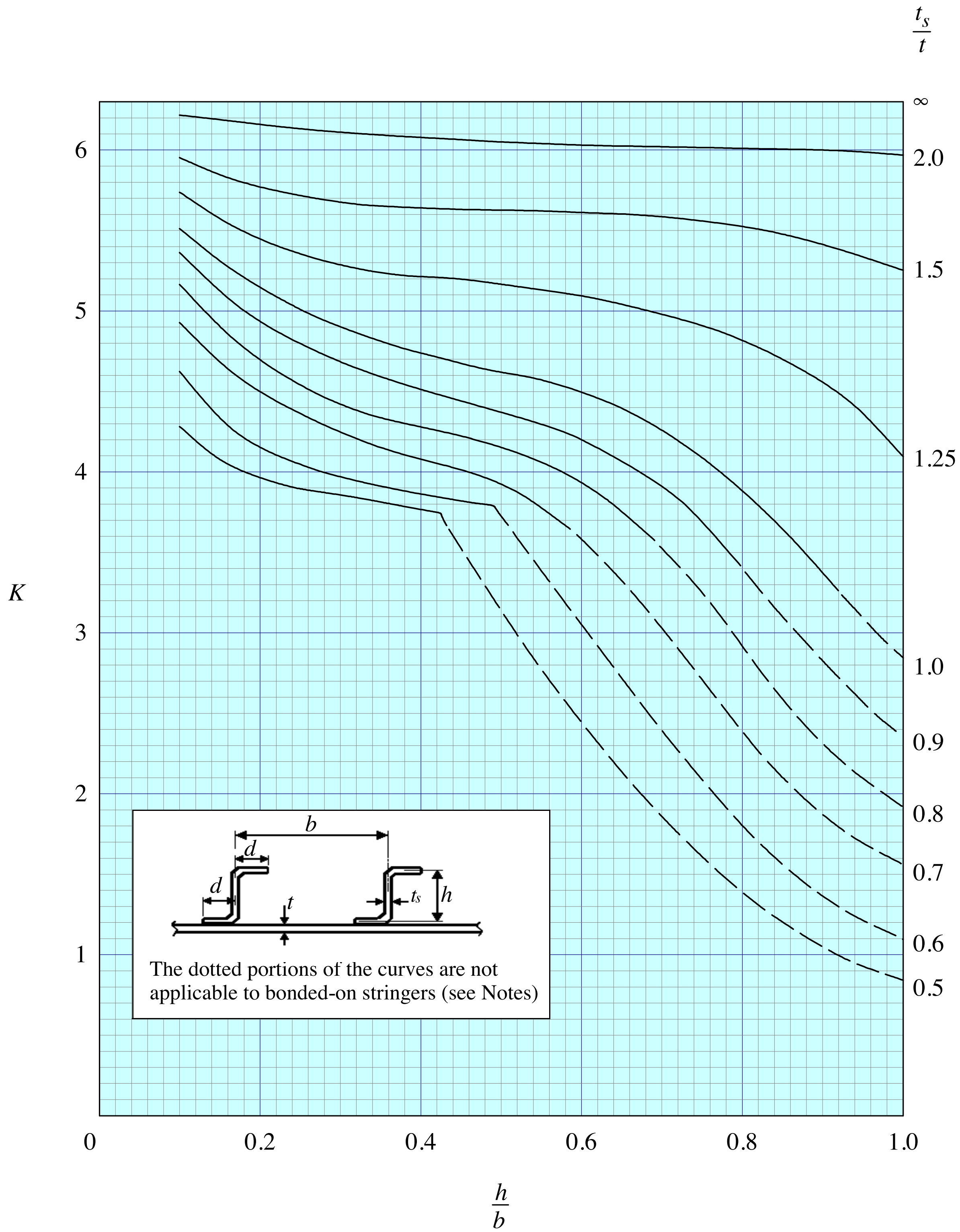

FIGURE 9 $\frac{d}{h} = 0.5$

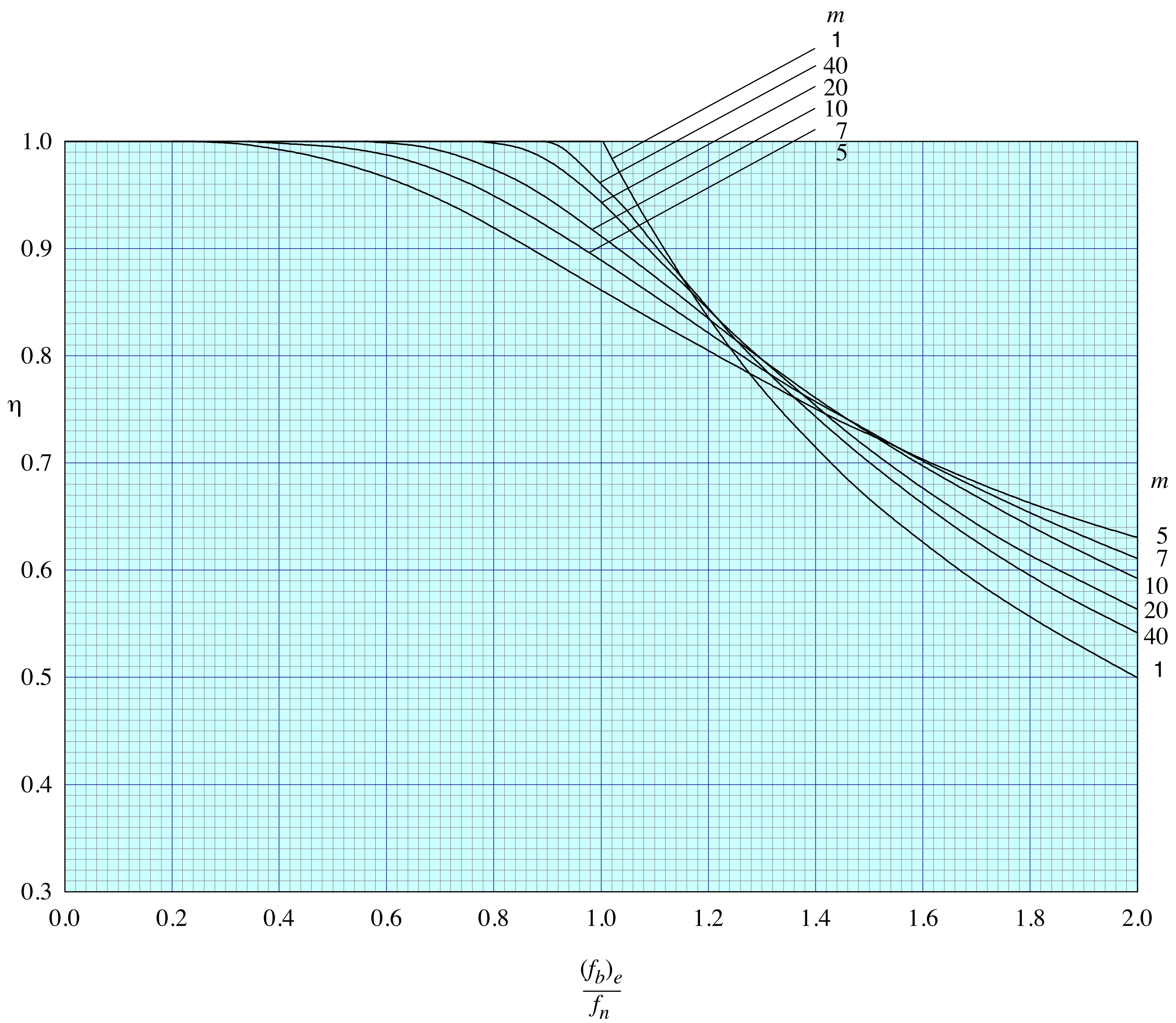
m
1
40
20
10
7
5
1.0
0.9
0.8
η
0.7
0.6
0.5
0.4
0.3
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
m
5
7
10
20
40
1
$\frac{(f_b)_e}{f_n}$

FIGURE 10

THE PREPARATION OF THIS DATA ITEM

The work on this particular Item, which supersedes Item No. Struct. 02.01.25, was monitored and guided by the Aerospace Structures Committee which has the following constitution:

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The member of staff concerned was

Mr M.E. Grayley – Head of Strength Analysis Group.