

AVERAGE AND EDGE STRESSES FOR SLIGHTLY CURVED PLATES WITH CLAMPED EDGES IN COMPRESSION WITH INITIAL IRREGULARITIES

1. NOTATION

b	plate width, measured circumferentially	m	in
E	modulus of elasticity of plate material	N/m ²	lbf/in ²
f_a	average stress in plate = $\frac{\text{total load on plate}}{t \times b}$	N/m ²	lbf/in ²
f_e	stress at edges of plate parallel to direction of applied load	N/m ²	lbf/in ²
R	radius of curvature	m	in
t	plate thickness	m	in
δ	maximum initial inward deviation from any generator measured over length b	m	in

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

2. NOTES

The ratio $f_a/\{E(t/b)^2\}$ is plotted against $f_e/\{E(t/b)^2\}$ for various values of the parameter $b^2/(Rt)$ for four values of δ/t that represent the degree of initial irregularity. The depth of the bulge, that is the maximum distance from the plate surface to the plate chord, equals $b^2/(8R)$.

The curves apply to isotropic plates of uniform curvature, with clamped edges but with negligible lateral restraint, and long enough to render negligible the influence of any restraint at the loaded edges.

One principal factor affecting the buckling stress of curved plates is the depth, δ , of initial irregularities, and their shape and disposition. The effect of the latter has been partially taken into account by the particular definition adopted for δ , that is the maximum initial inward deviation of the surface of the plate measured from a straight edge of length b placed anywhere on the outside of the plate in an axial plane. Appreciable variation in the f_a/f_e curves must still be expected for plates having the same δ/t ratio but with differently shaped and differently located initial irregularities.

The curves are based on a simplified theory in which certain numerical constants are left undetermined. The constants have been assigned values such that for $b^2/(Rt) = 0$ the resultant curves agree with those given by existing theory for flat plates, and for $b^2/(Rt) = 78$ they fit the curves given by theoretical results as closely as possible within the range considered of most practical importance, see Derivation 4. In the case when $b^2/(Rt) = 78$ it may be noted that the trough of the curve, where the difference between the values indicated by the more exact and the simplified theories is greatest, will always be suppressed, because under practical loading conditions the strain, represented by the edge stress, cannot actually decrease as the load is increased. The intermediate curves have been interpolated.

Owing to the simplifying assumptions made, the slope of the f_a/f_e curve after buckling is underestimated

for values of $b^2/(Rt) > 30$. In this region the buckle form will probably change soon after the initial buckling, leading to a further sudden fall in the load carried by the plate, and the curve drawn is intended to represent a lower envelope to the discontinuous values obtained (see Figure 3 of Derivation 2.)

In the higher range of $b^2/(Rt)$, permanent deformation extending over part of the buckles is likely to develop immediately at or very soon after buckling. No allowance has been made for the effects of this yielding in the plate material on the value of f_a .

3. DERIVATION

1. LEGGETT, D.M.A. The buckling of a long curved panel under axial compression. ARC R & M 1899, 1942.
2. LEGGETT, D.M.A. The behaviour of a cylindrical shell under axial compression when the
JONES, R.P.N. buckling load has been exceeded. ARC R & M 2190, 1942.
3. JACKSON, A.P. Curved plates in compression. National Research Council of Canada,
HALL, L.F. Report No. MM-180, 1945.
4. COX, H.L. The elements of the buckling of curved plates. *Jl R. aeronaut. Soc.*,
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4. EXAMPLE

It is required to find the average stress in a plate in compression at an edge stress of 70 MN/m^2 when $t = 1 \text{ mm}$, $b = 141 \text{ mm}$, $R = 500 \text{ mm}$, $\delta = 0.07 \text{ mm}$ and $E = 66\,000 \text{ MN/m}^2$.

Then, $b^2/(Rt) = 40$, $E(t/b)^2 = 3.32 \text{ MN/m}^2$, $f_e/\{E(t/b)^2\} = 21$ and $\delta/t = 0.07$. From the figures, by interpolation, $f_a/\{E(t/b)^2\} = 16.6$ giving $f_a = 55 \text{ MN/m}^2$.

Due to the underestimate of the slope after buckling (see the fifth paragraph of the notes) the value obtained in practice is likely to be higher than that obtained from the figures.