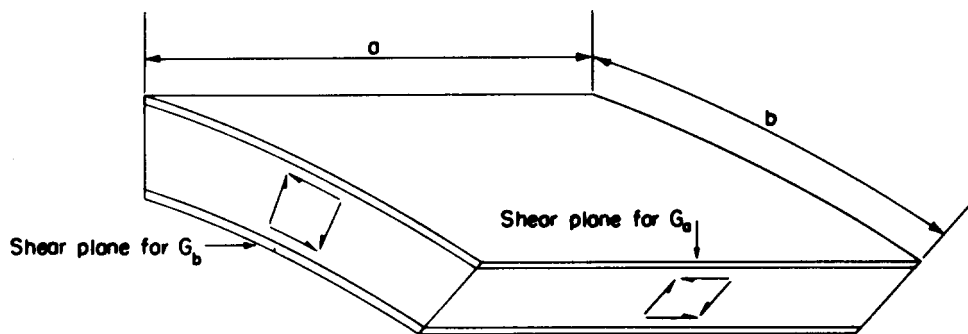


NATURAL FREQUENCIES OF FLAT OR SINGLY-CURVED SANDWICH PANELS WITH CORES OF ZERO FLEXURAL STIFFNESS

1. NOTATION

a	longer dimension of flat panel, or length of curved panel straight edge	m	in
b	shorter dimension of flat panel or arc length of curved panel	m	in
C_1, C_2, C_3	non-dimensional parameters (see Section 3)		
E	Young's modulus of face-plate material	N/m ²	lbf/in ²
F	non-dimensional parameter (see Section 3)		
f_c	natural frequency of curved panel	Hz	Hz
f_f	natural frequency of flat panel	Hz	Hz
f_u	natural frequency of uniform flat plate of thickness equal to distance between midplanes of face plates and having density and Young's modulus equal to those of face plates	Hz	Hz
G	shear modulus of honeycomb-core material	N/m ²	lbf/in ²
G_a, G_b	transverse shear moduli of core in planes defined in sketch below	N/m ²	lbf/in ²



G_c	effective shear modulus of core	N/m ²	lbf/in ²
G_x, G_y	transverse shear moduli of core in planes defined in sketch in Section 2	N/m ²	lbf/in ²
h	core thickness	m	in
K_1, K_2	non-dimensional parameter (see Section 3)		
l	length of honeycomb cell wall	m	in

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m	number of half-waves parallel to side of length a		
n	number of half-waves parallel to side of length b		
R	radius of curvature of panel	m	in
t	face-plate thickness	m	in
t_c	thickness of honeycomb core material	m	in
ν	Poisson's ratio of face-plate material		
ρ_c	core density	kg/m ³	*
ρ_f	face-plate density	kg/m ³	*

* In this Item, density is used only in the form of the ratio ρ_c/ρ_f . Therefore, any consistent units may be used for these quantities. For example, in British units density may be expressed either in units of lb/in³ or lb s⁻²/in⁴ [i.e. (lb/in³)/386.4]. (A force of 1 lbf acting on a mass of 1 lb produces an acceleration of 386.4 in/s².)

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

2. NOTES

This Data Item gives a method of calculating the natural frequencies of initially unstressed flat or curved rectangular panels of sandwich construction with identical face plates. The core is assumed to have zero flexural stiffness and to be isotropic, but a moderate degree of orthotropy, i.e. $1/3 < G_a/G_b < 3$, can be taken into account. The data have been derived for application to honeycomb sandwich panels, but may be used for other types of sandwich panel having cores of negligible flexural stiffness provided that their properties comply with the assumptions stated later in these notes.

The natural frequency of the sandwich panel is obtained by factoring the natural frequency, f_u , of a solid flat plate of thickness equal to the distance between the mid-planes of the face plates, $h + t$, according to the following expressions.

For a flat panel:

$$f_f = f_u C_1 C_2.$$

For a curved panel:

$$f_c = f_f \left\{ 1 + \left(\frac{b^2}{n^2 R (h + t)} \right)^2 \frac{C_3}{C_2^2} \right\}^{1/2}.$$

The values of f_u , C_1 , C_2 , C_3 and f_c are obtained as shown in the following Table.

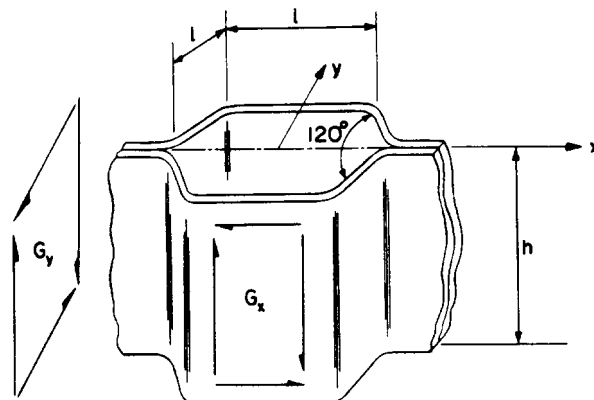
Parameter:	obtained from:	as a function of:
f_u	Data Item Nos 75030 or 87002	$\frac{h+t}{b^2}, \frac{a}{b}, m, n$, edge conditions
C_1	Figure 1	$\frac{\rho_c}{\rho_f} \frac{h}{t}$
G_c/G_a	Figure 2	$\frac{mb}{an}, \frac{G_b}{G_a}$
C_2	Figure 3	$\left(\frac{E}{G_c}\right)\left(\frac{t}{h}\right)\frac{(h+t)^2m^2}{a^2}, \frac{mb}{an}$
C_3	Figure 4	$\frac{mb}{an}, \nu$
f_c/f_f	Figure 5	$C_2, C_3, \frac{b^2}{n^2R(h+t)}$

The shear moduli of the core, G_a and G_b , can be obtained from manufacturers' data or test or they can be calculated for honeycomb cores. A suitable test method is described in Data Item No. 66025 (Structures Sub-series) and a calculation method for hexagonal honeycomb cores is given in Data Item No. 67022 for the case of deep hexagonal honeycomb cores with $h/l > 2$, and included angle of 120° .

$$G_y = 0.577 \frac{t_c G}{l}$$

and

$$G_x = 1.5 G_y$$



Shear moduli of different samples of core may be expected to vary by up to about 25 per cent, but the effect on natural frequency is significant only when C_2 is much less than unity.

The data are based on an exact solution of the simplified differential equation of motion of an idealised slightly-curved panel described in Derivation 1. Panels may be considered to be slightly curved if the ratio of panel length, a , to radius of curvature is very much less than 1.0.

It is assumed that the orthotropic core carries no in-plane loading, but carries all the transverse shear. The method of accounting for orthotropy has been simplified to allow graphical presentation, but the errors arising from this simplification do not exceed 1 per cent over the range of variables covered by the Figures.

The panel is assumed to be simply-supported at all edges but it is suggested that, provided C_2 is close to unity, the fundamental natural frequency for panels with fixed edges can be found approximately by

taking f_u as the value corresponding to fixed-edge conditions for a uniform plate.

The frequencies of the higher modes of curved panels are obtained approximately by assuming that the frequencies are the same as for a simply-supported panel having dimensions of one half wavelength in each direction, *i.e.* by substituting a/m and b/n for a and b . Frequencies calculated this way compare well with the few experimental results that are available for modes up to (3, 1) or (1, 3).

It is assumed that the half-wavelengths are large compared with the cell-size of the honeycomb core, and that there is no strain in the through-thickness (radial) direction. These assumptions are not expected to lead to serious errors for conventional sandwich panels covered by the ranges of variables given in Figures 1 to 4, but any extrapolation outside these ranges should be treated with caution.

Figure 3 is drawn for a value of $\nu = 0.3$. The error arising from this assumption does not exceed 1.5 per cent for values of Poisson's ratio between 0.25 and 0.35.

A computer-based prediction procedure for the estimation of curved panel natural frequencies is given in Item No. 85037. Although primarily intended for sandwich panels with laminated face plates, Item No. 85037 may be used to evaluate natural frequencies of sandwich panels having isotropic face plates. The method of analysis used in Item No. 85037 is also based on Derivation 1 but does not include the simplifying assumptions required to allow a graphical solution.

3. DERIVATION

The frequency expressions are:

$$f_f = f_u C_1 C_2.$$

and

$$f_c = f_f \left\{ 1 + \left(\frac{b^2}{n^2 R(h+t)} \right)^2 \frac{C_3}{C_2^2} \right\}^{1/2},$$

where f_u is given in Item No. 75030 and

$$C_1 = \left\{ \frac{6}{2 + \frac{\rho_c h}{\rho_f t}} \right\}^{1/2},$$

$$C_2 = \left[\left(\frac{E}{G_c} \right) \left(\frac{t}{h} \right) \frac{(h+t)^2 m^2}{a^2} \frac{\pi^2}{2(1-\nu^2)} \left\{ 1 + \frac{a^2 n^2}{m^2 b^2} \right\} + 1 \right]^{-1/2}$$

and

$$C_3 = \frac{4}{\pi^4} \frac{\left\{ 1 - \frac{an}{mb} (K_2 + \nu K_1) \right\}}{\left\{ 1 + \frac{m^2 b^2}{a^2 n^2} \right\}^2},$$