

STRESSES IN THE CORE OF A SANDWICH PANEL UNDER LOCAL NORMAL LOADING (TENTATIVE)

1. NOTATION

a	radius of circular loading area	m	in
D	flexural rigidity of face plates defined by $D = Et^3/12(1 - \nu^2)$	N m	lbf in
E	Young's modulus for material of face plates	N/m ²	lbf/in ²
E_{cz}	Young's modulus in compression of core material in z-direction	N/m ²	lbf/in ²
f	maximum core compressive stress in z-direction	N/m ²	lbf/in ²
f_c	maximum core compressive stress in z-direction for zero face plate flexural rigidity (see Figure 3)	N/m ²	lbf/in ²
G_c	shear modulus of core in rz-planes	N/m ²	lbf/in ²
h	depth of core	m	in
P	total local load applied normal to panel	N	lbf
p_a	average pressure acting over area within radius a defined by $p_a = P/\pi a^2$	N/m ²	lbf/in ²
$p(r)$	pressure at radius r	N/m ²	lbf/in ²
q	maximum core shear stress in rz-planes	N/m ²	lbf/in ²
q_a	reference core shear stress acting in rz-planes defined by $q_a = P/2\pi ah$	N/m ²	lbf/in ²
q_c	maximum core shear stress in rz-planes for zero face plate flexural rigidity (see Figure 2)	N/m ²	lbf/in ²
r	radius measured from loading axis	m	in
t	thickness of face plates	m	in
z	coordinate measured normal to face plate	m	in
ν	Poisson's ratio for material of face plates		

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

2. NOTES

This Item provides data that may be used to assess the performance of sandwich panels subjected to a local loading remote from the panel edges. The data are tentative since they are based upon a theoretical study of sandwich panels under specified load distributions without direct supporting experimental evidence.

The data relate to panels constructed from two identical isotropic face plates with a core that has equal shear stiffnesses in all planes through its depth. The load is assumed to be axisymmetrically distributed over a small circular area of one face plate as shown in the sketch on Figure 1. Provision is made for a choice of load distributions between the flat or stepped forms and the peaked or bell forms defined by the value of the shape parameter, $p(0)/p_a$. A selection of distributions is shown in Figure 1.

Under loading the core is subjected to a combination of shear and compressive stresses. The maximum values of these stresses are provided in Figures 2 and 3, as ratios to q_c and f_c , respectively, in terms of the core and face plate properties and dimensions for various values of the loading shape parameter, $p(0)/p_a$. These curves demonstrate the influence of the face plates in reducing the stresses in the core.

3. DATA APPLICATION

No data that relate the pressure distributions given in Figure 1 to typical load situations are currently available. Generally the user should attempt to select a distribution that will satisfy the loading specifications. However, when no knowledge of the applied distribution exists either a step loading or a bell loading of low $p(0)/p_a$ should be used. In cases where the load applicator is more flexible than the panel, there will be a consequent spreading of the load and this should be allowed for by choosing a lower value for $p(0)/p_a$. An example of this situation arises when the load is transmitted to an aircraft floor panel through a carpet or similar covering.

For any load distribution defined by $p(0)/p_a$ the data of Figures 2 and 3 are expected to provide a guide to the effects of core and face plate properties on the shear and compressive stresses in a sandwich panel. Such test data as are available indicate that the shear and the compressive stresses obtained from this Item are likely to be higher than those occurring in practice. However, it is strongly advised that the allowable stresses for comparison with this Item should be determined by experiment. Even when core failure may be tolerated, for example in secondary structural applications, the parametric relationships of Figures 2 and 3 may be used directly as a guide to the performance of panels.

Where a moderate degree of orthotropy exists in the core, it is reasonable to assume the modulus of rigidity to be equivalent to the root mean square of the orthotropic values, which may be obtained as described in Item No. 66025, "Experimental determination of the shear and flexural stiffnesses of a sandwich panel". For cellular core constructions, *e.g.* honeycombs, the data apply only if the diameter $2a$ is more than twice the core cell size. Values of G_c for the honeycomb type of construction are given in Item No. 67022, "Modulus of rigidity of sandwich panels with hexagonal cell cores".

4. DERIVATION

1. ARMSTRONG, K.B. Cost effective design of indentation resistant sandwich panels. British Overseas Airways Corporation Rep. EEA. S.4.8644, December 1969.
2. MARTIN, D.W.
PICKEN, S.M.
HINDE, B.T. Axisymmetric local loading on sandwich panels. NPL Rep. DNAM 86, July 1970.

3. RAIMONDO, J.V. The resistance of sandwich panels to lateral indentation. RAF College, Cranwell, Project Report, June 1971.

5. EXAMPLE

It is required to halve the core thickness of a sandwich panel without seriously affecting its local load-carrying capacity. The original panel consists of a 10 mm balsa core sandwiched between two aluminium alloy face plates each of thickness 0.6 mm. It is subjected to a maximum load of 1 kN that is fairly evenly distributed over an area of radius 5 mm. It is suggested that the panel strength can be retained if the thickness of each face plate is increased. The two alternative face plates available are of thickness 1.2 mm and 0.9 mm. The material properties for the aluminium alloy are $E = 68\,900 \text{ MN/m}^2$ and $\nu = 0.34$ and for the balsa $E_{cz} = 227 \text{ MN/m}^2$ and $G_c = 110 \text{ MN/m}^2$.

From consideration of Figure 1, the shape of the load distribution will be assumed to be represented by $p(0)/p_a = 2$.

The non-dimensional constants used in the following calculations are

$$6(1 - \nu^2) \frac{G_c}{E} = 0.00847,$$

and
$$24(1 - \nu^2) \frac{E_{cz}}{E} = 0.0699.$$

The calculations are given in tabular form as follows.

Parameter	Original Panel	Replacement Panel 1	Replacement Panel 2
a (mm)	5	5	5
h (mm)	10	5	5
t (mm)	0.6	1.2	0.9
a/h	0.5	1	1
h/t	16.7	4.17	5.56
$6(1 - \nu^2) \frac{G_c}{E} \left(\frac{h}{t}\right)^3 \left(\frac{a}{h}\right)^2$	9.86	0.614	1.46
$24(1 - \nu^2) \frac{E_{cz}}{E} \left(\frac{h}{t}\right)^3 \left(\frac{a}{h}\right)^4$	20.3	5.07	12.0
q/q_c (Figure 2)	0.837	0.345	0.51
f/f_c (Figure 3)	0.522	0.36	0.459
$q_c = q_a = P/2\pi ah$ (MN/m ²)	3.18	6.37	6.37
$f_c = p_a = P/\pi a^2$ (MN/m ²)	12.73	12.73	12.73
Core shear stress, q (MN/m ²)	2.66	2.20	3.25
Core compressive stress, f (MN/m ²)	6.65	4.58	5.84