sandwich core cell $b/a \neq 0$. However, in the figure, curves corresponding to $b/a = 0$ are plotted to show the limiting case.

Comparison of the Theory and Experiments

A general comparison of the theory with experimental values [2] is shown in Fig. 8. It is seen that the theory generally predicts a higher value of $G_x$ than obtained experimentally. The discrepancy may be due to the fact that the present theory does not take into account buckling of cell walls, nor is any bond failure considered.

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References


DISCUSSION

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The authors of the subject paper are apparently unaware of a more exhaustive treatment of the problem of determining the shear modulus of honeycomb cores which is given by Kelsey, Gellatly, and Clark (reference [3]). In that reference the shear modulus is expressed by the equation

$$G = \frac{k_{11}}{k_{22}}$$

where the symbols $k$ denote stiffnesses which are functions of core geometry and material and subscripts 1 and 2 refer to two mutually perpendicular directions. The term $k_{11}/k_{22}$ takes into account shear displacements which are not in line with the applied shear force. These displacements generally are small and were neglected in the subject paper so that for this case $G$ may be written as

$$G = k_{11}$$

In reference [3] two methods are used to calculate the stiffness quantities necessary to determine $G$. One method yields a lower limit solution for $G$ and can be interpreted as assuming a sandwich having face sheets of zero bending stiffness. The second method yields an upper limit solution for $G$ and can be interpreted as assuming a sandwich having face sheets which are rigid in bending. The method of the subject paper can be shown to be identical to the latter of these two solutions, except for the small difference which occurs between equations (18) and (19). Therefore, the method of the subject paper yields an upper limit solution.

Experimental values of $G$ should fall below the upper limit solution and this is generally the case for the points shown in Fig. 8 of the subject paper. However, there is considerable difficulty in obtaining accurate experimental values of shear stiffness and some of the problems involved are pointed out in reference [3]. Block shear tests have shortcomings because of extraneous deflections which are not easily taken into account and beam tests have certain inherent inaccuracies. It was concluded, however, that, if a large number of beam tests were made, and a statistical average made of the results, consistent values of shear stiffness could be obtained that would fall between the upper and lower limits of the theory.

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Additional Reference


Authors' Closure

Through the foregoing discussion of Mr. M. S. Anderson and private communication with the authors of reference 3, we are delighted to know that reference 3 has accomplished valuable work independently in parallel with ours. Some additional points may be of interest to the reader.

1 Our approach corresponds to the unit displacement method from equilibrium considerations while that of reference 3 is an energy method. Our method is simpler and can be extended to include the effect of bond material on the shear modulus. This generalization of equation (7) can be shown to be

\[
\frac{G_y}{G} = \frac{t}{a} \left\{ \left(1 + \frac{t}{a} \cot \alpha \right) \cos^2 \theta \right\}^{-1}
\]

where \(t\) is the bond thickness and \(G_y\) the bond material shear modulus.

2 Some interesting properties of \(G_y (= k_{11})\) and \(\frac{G_y + \gamma}{G_y} (= \frac{k_{22}}{k_{11}})\) have been demonstrated in Figs. 2 and 3 of our paper.

3 The effect of bond density is included in equation (16) of our paper. This may be an important parameter in some cases.

4 Our work was mainly done at the end of 1957 and was stimulated by the results of reference 2.