Reply by Authors to R. A. Gellatly

JOSEPH PENZIEN*
University of California, Berkeley, Calif.

AND

THEODOR DIDRIKSSON†
Municipal Office of Reykjavik, Reykjavik, Iceland

THE writers would like to first express their apologies to Dr. Gellatly for not having referenced his contributions[1, 2] in their recent paper[3] dealing with the effective shear modulus of honeycomb cellular structure. They did not, of course, wish to give the impression that their work represented the first venture into this field of analysis.

The writers presented in Ref. 3 a rigorous method of analysis which gives the correct theoretical shear modulus of honeycomb core material under pure shear assuming that 1) the facing sheets have zero bending stiffness, i.e., warpage of cells is permitted without restraint, or 2) the facing sheets have infinite bending stiffness, i.e., no warpage of cells is allowed. By using Eq. (41) of Ref. 3, the writers obtained the final result given by Eq. (44) which is the correct solution based on assumption 1. This solution corresponds to the "unit load" solution given by Eq. (2.20) of Ref. 1. If, however, one uses Eq. (37) of Ref. 3 rather than Eq. (41), an expression for (G_c/G) can easily be obtained which is somewhat more complex than that given by Eq. (44). For the special case of $\phi = 0, R = 1, \theta = 60°, \mu_\eta = 0.33$, this solution yields values for (G_c/G) equal to those given by Eq. (44) but increased by the percentage shown in Fig. 6 of Ref. 3. This solution corresponds to the conditions of assumption 2.

Since facing sheets normally have finite bending stiffness, the foregoing two solutions are considered by the writers as proper bounds to the correct solution. The writers have shown by the curve of Fig. 6 of Ref. 3 that these bounds are very close together except when (L/H) becomes very small. It should be made clear to the reader that the lower bound, as given by Eq. (44) of Ref. 3, corresponds exactly with the lower bound given by Eq. (2.20) of Ref. 1. However, the upper bound resulting from the use of Eq. (37) of Ref. 3 does not correspond with the "unit displacement" value as given by Eq. (2.21) of Ref. 1, which is considered an upper bound by Gellatly. The writers cannot accept the "unit displacement" value as a proper upper bound, since it is based on a method that does not satisfy conditions of statics and must therefore be incorrect. It is believed, however, by the writers that a correct upper bound is obtained through the use of Eq. (37) of Ref. 3, as previously indicated.

The writers are aware of the various test procedures used in the past to measure effective shear modulus of honeycomb materials. The double-block method has the disadvantage that loading of the specimen is not pure shear due to shear lag effects and improper boundary conditions. The flexure tests have the bad feature that flexural deformations and local compressive deformations at concentrated load points tend to overshadow the shear deformations of the core, thus making it difficult to measure shear modulus accurately. Gellatly himself has pointed out these difficulties. The rectangular frame method of testing, as suggested by the writers, places the core under essentially a pure shear condition, which is exactly what one wishes to do. The fact that this method requires a somewhat deeper core (dimension L of Ref. 3) than standard methods is not considered a weakness of the method. Theory clearly shows that only for a very small ratio of (L/H) does the depth L of the core have an influence on effective shear modulus.

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* Professor of Civil Engineering.

† Structural Engineer.

References

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[2] Gellatly, R. A., "Buckling of sandwich panels with particular reference to thermal effects," Ph.D. Thesis, Univ. of London, (1958).

[3] Penzien, J. and Didriksson, T., "Effective shear modulus of honeycomb cellular structure," AIAA J. **2**, 531–535 (1964).