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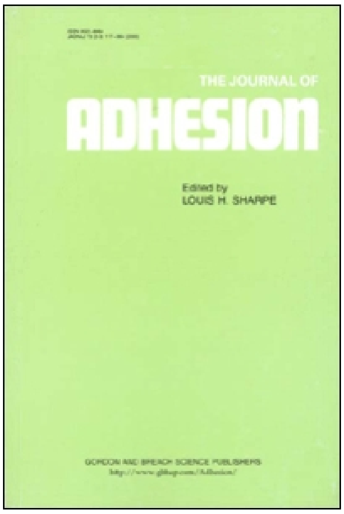

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Cracking of Short Lap Joints

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Cracking of Short Lap Joints

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INTRODUCTION

In the lap joint shown in Figure 1, the sheets of elastic material AB and CD are originally plane and joined completely over their mating surfaces with a very thin adhesive of fracture energy *R*. When tensile forces *F* are applied to test the joint, cracks propagate from the points C and B to cause eventual separation of the elastic sheets.

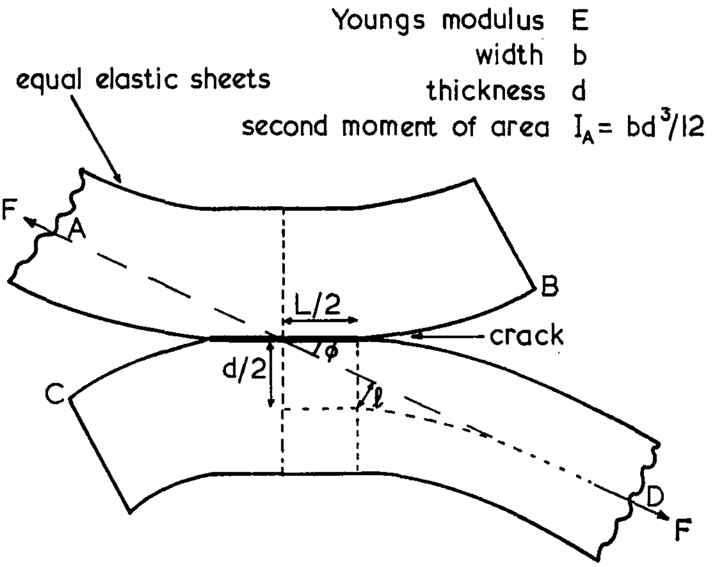

FIGURE 1 The loaded lap shear joint.

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Two extreme types of this brittle failure may be distinguished depending on the relative magnitudes of the lap-length L and the joint thickness $2d$:

When the joint is long, that is $L \gg 2d$, cracking is largely a result of stretching the elastic material, bending of the sheets being negligible, and the criterion for crack propagation is[5]

$$\left(\frac{F}{b}\right)_{\text{long joint}} = (4\,ERd)^{\frac{1}{2}} \tag{1}$$

the strength being independent of lap length, a result mentioned previously by De Brunye[1] and Sheridan and Merriman.[2]

However, when the joint is short, that is $L \ll 2d$, bending of the sheets becomes very pronounced and failure occurs by a peeling action. The purpose of this note is to describe an investigation of brittle crack propagation in this short lap joint.

THEORY

If it is assumed that brittle failure of the short lap joint is dominated by peeling, a failure criterion is readily derived. From an energy balance approach[3] peel crack propagation occurs when

$$\frac{F}{b} = \frac{R}{1 - \cos\phi} \tag{2}$$

where ϕ is the peel angle, which may be calculated from the geometry of Figure 1 where

$$\frac{d}{2} - \frac{L}{2}\tan\phi = \frac{l}{\cos\phi} \tag{3}$$

For a short joint $L \ll d$, and usually ϕ is small so that Eq. (3) becomes effectively

$$\frac{d}{2} = l \tag{4}$$

Also for the bending of long elastic sheets[4]

$$l = \left[\frac{Ebd^3}{6F}(1 - \cos\phi)\right]^{\frac{1}{2}} \tag{5}$$

so, combining Eqs. (2), (4) and (5) we obtain the failure criterion for the short lap joint,

$$\left(\frac{F}{b}\right)_{\text{short joint}} = \sqrt{\tfrac{1}{6}}\,(4\,ERd)^{\frac{1}{2}} \tag{6}$$

Comparison of Eqs. (1) and (6) shows that brittle strength in both the long and short configurations depends in the same way on fracture energy, adherend thickness and elastic modulus. However, the short joint should be weaker than the long one:

$$\left(\frac{F}{b}\right)_{\text{short joint}} = 0.408\left(\frac{F}{b}\right)_{\text{long joint}} \tag{7}$$

This prediction was tested experimentally.

RESULTS

The elastic material used in these experiments was transparent rubber (Enjay 404) crosslinked against glass to produce a smooth surface on one side as described previously.[5] Lap joints were made by bringing two such smooth surfaces together under finger pressure and leaving in contact for 5 minutes to allow appreciable autohesion to develop between the smooth sheets. When a constant tensile load was applied to the strips, cracks were observed travelling from the ends of the joint. Even for the shortest joints, failure occurred by cracking, no discernable shear failure being observed. The load required to propagate the crack at 10 μms^{-1} was measured as a function of overlap length to give the results shown in Figure 2.

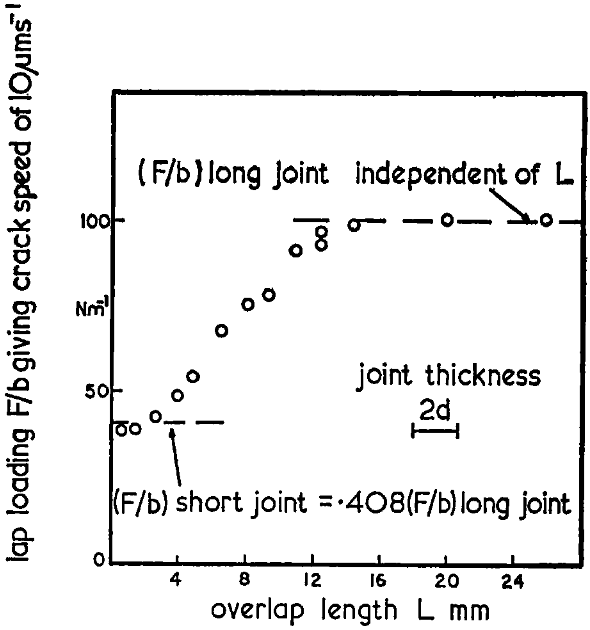

FIGURE 2 Lap loading required to produce a 10 μms^{-1} crack in joints of various overlap lengths.

Long joints, that is those longer than about four times the total joint thickness $2d$, gave a constant strength independent of overlap as predicted by the theory. The measured loading of $100\ \mathrm{Nm}^{-1}$ compared reasonably well with the strength $86\ \mathrm{Nm}^{-1}$ predicted by Eq. (1) from a value of fracture energy measured in peeling tests at the same crack speed of $10\ \mu\mathrm{ms}^{-1}$.

As the joint overlap was decreased, the load required to produce the $10\ \mu\mathrm{ms}^{-1}$ crack diminished also and for the shortest joints tested reached a limit of 0.39 times the long joint strength in fair accord with the theoretical prediction of Eq. (7).

CONCLUSION

Crack propagation in an ideal brittle lap joint has been studied both theoretically and experimentally as a function of the overlap dimension. For very long joints, that is greater than about four joint thicknesses, the brittle failure load is independent of lap length whereas for very short joints the brittle failure load falls to about 40% of the long joint value.

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