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NOTE

Mechanical Characterization of an Adhesive Layer *in situ* under Combined Load

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The mechanical behavior of an adhesive layer was characterized by a specially designed torsion-tension device which yields the shear moment displacement relationship at different levels of axial load. The derived failure envelope shows an increase in shear strength with increasing axial compression, and the opposite under tension. Small changes of the shear modulus were also observed.

INTRODUCTION

Knowledge of the mechanical properties of adhesives in a combined state of stress is essential in engineering applications of structural bonded joints in which the adhesive layer undergoes a complex state of stress even under simple loading.

Unfortunately, experimental data in this content is very scanty. Early studies of the single-lap joint model¹ tended to oversimplify the problem by assuming pure shear; subsequently, the more sophisticated closed-form solution of Goland and Reissner² envisaged a lateral normal stress component, the so-called "peel stress", while recent experimental work deals mostly with cases of pure shear³ or tension.⁴

The study reported here was undertaken with a view to a torsion-tension apparatus for measuring the mechanical properties of thin adhesive layers *in situ*, under different combinations of loading. Some preliminary results are presented, indicating the suitability of the method for the purpose in question.

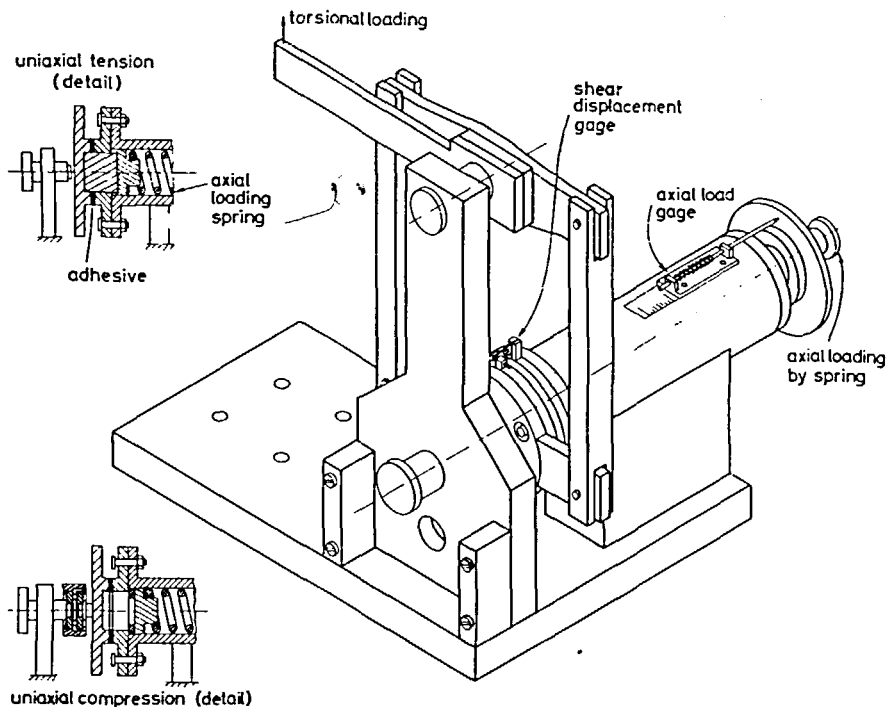


FIGURE 1 Device for combined loading of adhesive layer *in situ*.

TESTING APPARATUS (Figure 1)

The test specimen consists of a pair of 2025 aluminum flanged cylinders (adherends), *a*. The loading device consists of a torsion arm, *b*, operated from any conventional loader (*e.g.* Instron) under a controlled pattern, and a spring operated axial loading post, *c*, capable of applying tension or compression.

PROCEDURE

The test adhesive was composed of Shell epoxy resin 815 and General Mills Versamid V-140 in the ratio of 70:30 by weight. The adherends were aligned on a special fixture with a controlled gap of 1 mm, into which the resin was poured. The joint was cured for 24 hours at room temperature, plus six additional hours at 60°C. The specimens were then tested on a conventional

Instron machine at different constant shear-strain rates and under different axial load levels.

For calibration, shear displacements of specimens with "zero adhesive thickness" were recorded and deducted from the overall shear displacement of the bonded specimens. The shear strain and stresses are computed from recorded moment-displacement curves.

RESULTS

Typical shear stress-strain curves in Figure 2 indicate that normal uniaxial loading has a clear-cut effect on the inelastic behavior of the adhesive. Axial tension tends to reduce the initial modulus, shear strength and ultimate strain, while axial compression tends to increase them. However, because of the lower *in situ* strength of the adhesive, and its brittle mode of failure under tension load, the range of applicability is limited. Failure under combined load may be described by means of the apparent ultimate-stress combination plotted in the shear-normal axial stress plane (Figure 3). The failure envelope thus obtained also shows reduction of the shear strength with increasing tensile load, and increase with compression.

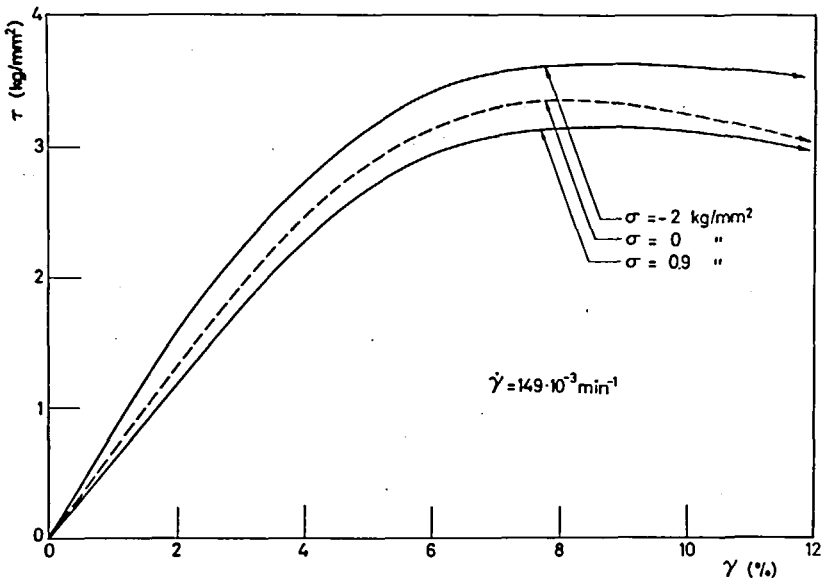


FIGURE 2 Typical shear stress-strain curves of adhesive layer *in situ* under combined shear and axial normal loading.

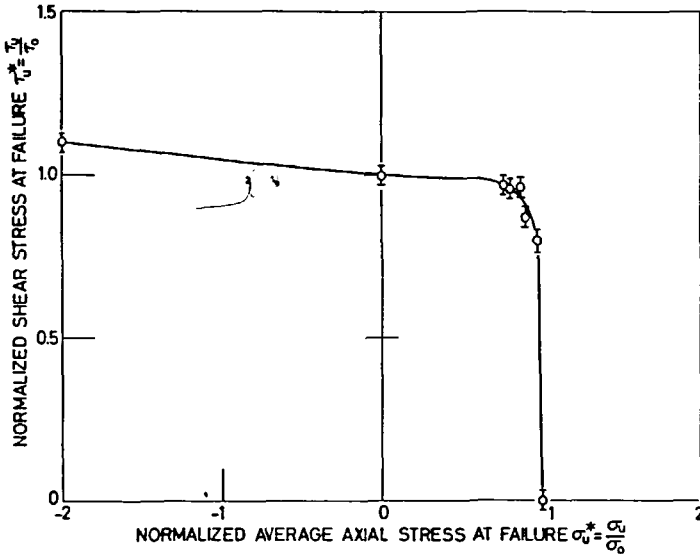


FIGURE 3 Failure envelope for adhesive layer *in situ* (loaded under combined shear and axial normal stress).

CONCLUSIONS

Instrumentation and methods for evaluation of *in situ* adhesive failure characteristics under combined load was successfully tested. Results yielded shear stress-strain relationships for the adhesive at different axial load levels. The failure envelope shows that at the average normal stress level, the ultimate shear strength is reduced under tension and increased under compression.

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