NOTE

FAILURE OF *PINUS RADIATA* VENEER IN TENSION ACROSS THE GRAIN

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INTRODUCTION

Preliminary tests on small pieces of veneer under room conditions were used to determine the tensile strength of *Pinus radiata* D.Don perpendicular to the grain in the radial direction. These tests were undertaken to provide failure information for devising loading tests at elevated temperatures with veneer sheets. The use of veneer has attractions in that, firstly, replication of samples is simple as the properties of flat-sliced veneer change relatively slowly along a veneer sheet or between adjacent veneers and, secondly, the loads at failure are relatively small, so making any test apparatus comparatively simple in construction.

MATERIAL AND METHOD

The material used was nominally 0.6-mm-thick veneer of *P. radiata* from a 28-year-old pruned managed stand in Southland, New Zealand, and was produced by slicing in a tangential direction to the rings. Samples were cut from sheets to give visually homogeneous test pieces of earlywood from 15 to 200 mm long and 50 mm wide. Thickness of each sample was measured with a vernier gauge and ranged between 0.575 and 0.6 mm.

The test apparatus was designed to allow a variable load to be applied to a piece of veneer in tension. The veneer was securely held in place between a pair of clamps, with the bottom clamp attached to the lower edge of an I-shaped frame. This frame supported a system of two pulleys over which a single cord connected the top clamp to a pan on the other side of the frame through a spring balance. The load was increased by progressively placing small weights (steel shot) in the pan and was measured by the spring balance.

A sample of veneer was placed between the clamps in the testing rig and the load was increased until the veneer failed. The corresponding stress was calculated according to the apparent cross-sectional area of the veneer, and not the area occupied by cell wall tissue.

Tensile strengths perpendicular to the grain were determined for both green veneer and air-dried veneer at 12% moisture content.

RESULTS

Initial tests on 100-mm-long veneer samples showed some variation in the calculated stress (Fig. 1). The coefficient of variation was 0.13. Failure locations were statistically random along the "gauge length" of the samples and any pieces on which failure occurred within the clamps were rejected. There was no indication of preferential failure adjacent to the clamps, which would indicate stress concentrations due to the clamps themselves. However, the failure stresses measured were much smaller than those reported in tests on a similar species, *Pinus sylvestris* L., in which large samples 10 mm thick had been used (Siimes 1967). These results may also have been affected by the different loading method used which, being load-controlled rather than deflection-controlled, possibly influenced the nature of crack growth in the specimen. The work done by Siimes (1967) was with wood loaded at a constant rate of about 50 kp/minute with tensiometer readings being taken every 5 or 10 kp. Bier (1986) also gave much higher values for failure stress for *P. radiata* in bending tests perpendicular to the grain. Samples 100 mm long × 180 mm wide × 45 mm thick had a failure stress of 3.60 MPa.

Initially it was thought that the low values for failure stress were due to apparent defects in the veneer, possibly microchecks which had developed during slicing, but when samples

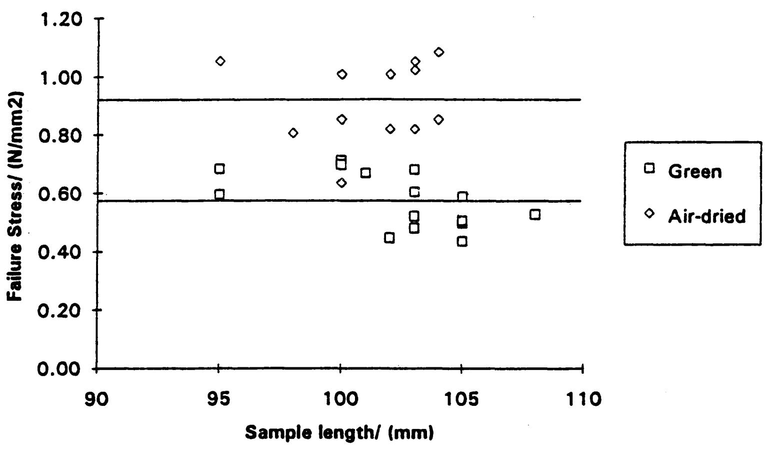

FIG. 1–Failure stress of air-dried and green *Pinus radiata* veneer samples.

of different lengths were tested, the shorter the sample the greater was the stress at failure (Fig. 2).

When the apparent defects on the surface of the veneer were examined under a scanning electron microscope, they were not checks as anticipated. The rounded depressions on the surface of the veneer (Fig. 3) indicated that they were randomly dispersed axial resin canals, between 0.3 and 0.4 mm diameter, with some on the surface and others embedded in the veneer. It was also possible to see some small radial resin canals, 0.04 mm diameter,

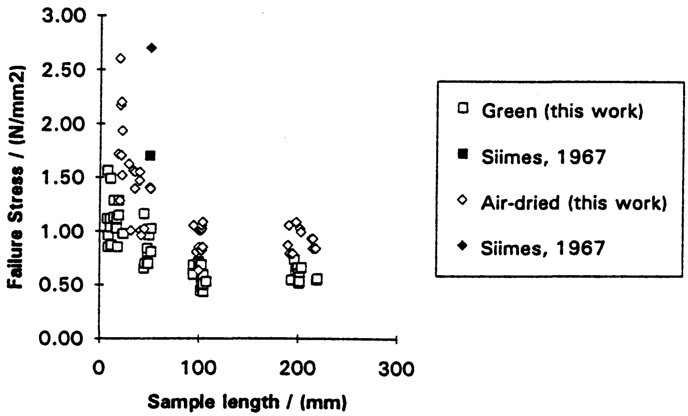

FIG. 2–Variation of failure stress of air-dried and green *Pinus radiata* samples with sample length.

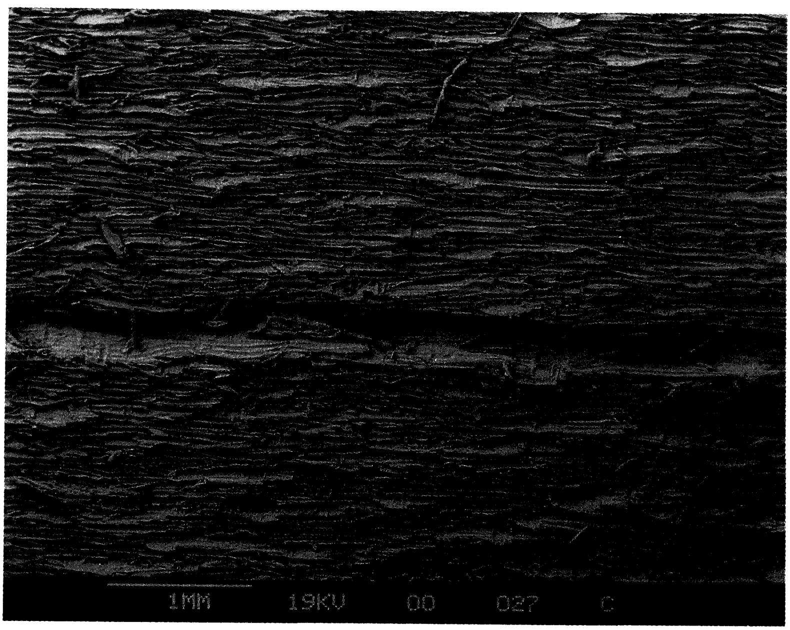

FIG. 3–An axial resin canal on the surface of the veneer.

completely penetrating through the veneer (Fig. 4). The embedded axial resin canals would probably be the dominant weaknesses in the veneer; their size suggests that the true value for the failure stress is greater than the apparent failure values for 100-mm-long samples—a consequence of the canals weakening the test sample. If the veneer was 0.6 mm thick and a resin canal was 0.3 mm in diameter, there would be a 0.3-mm skin of veneer at the thinnest place. Such material would exhibit a two-fold decrease in the apparent tensile strength measured over the whole cross-section.

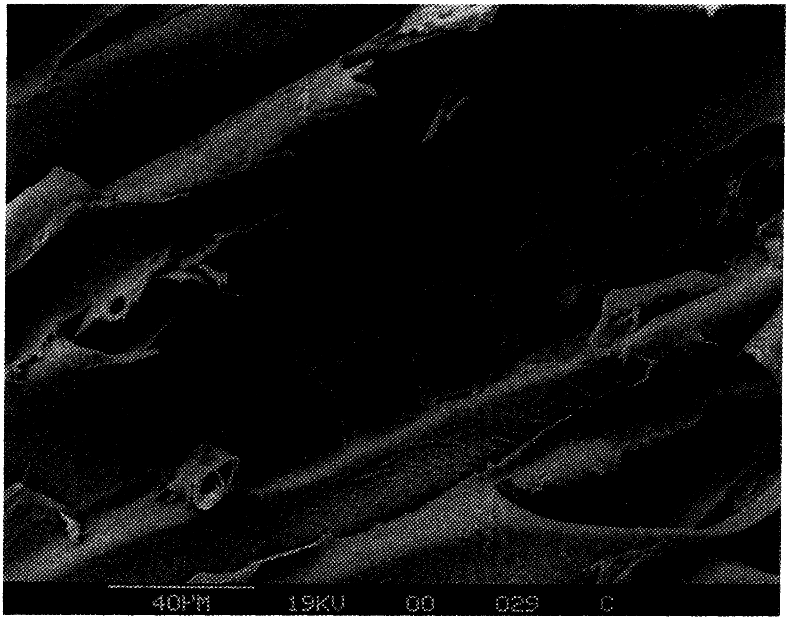

FIG. 4–Radial resin canals.

Occupation of some of the volume by resin canals causes a decrease in the effective cross-sectional area, giving rise to stress concentrations in the material. As the elastic stress concentration factor is approximately 2.2 (Benham & Crawford 1987), the maximum stress adjacent to the resin canals is likely to be approximately 4.4 times larger than the apparent stress (load divided by apparent veneer cross-section). Elastic and plastic deformations will lead to a reduction in the value of the stress concentration factor. However, the true failure stress will still be larger than the apparent stress, as indicated by the data.

Scanning electron micrographs were taken of the failure surfaces (Fig. 5). Both axial and radial resin canals appeared on the failure surfaces as rounded grooves. A piece of veneer that had failed at very high load had no trace of an axial resin canal (Fig. 6), but some radial resin canals were visible on the failure surface. This suggests that the small radial canals rather than the larger axial canals were the strength-limiting defect in this case, resulting in the higher failure stress. Barrett (1974) showed that size effects in samples in tension perpendicular to the grain can be explained by the failure behaviour being governed by the "weakest link". The apparent stress is a function of sample volume for geometrically similar specimens. In

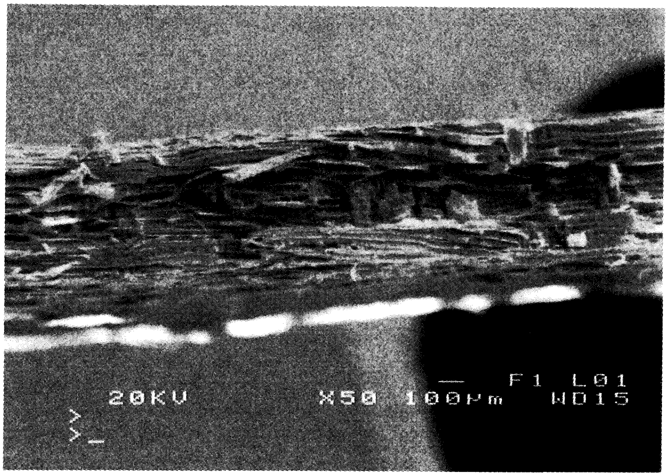

FIG. 5–The fracture surface with remnants of an axial resin canal.

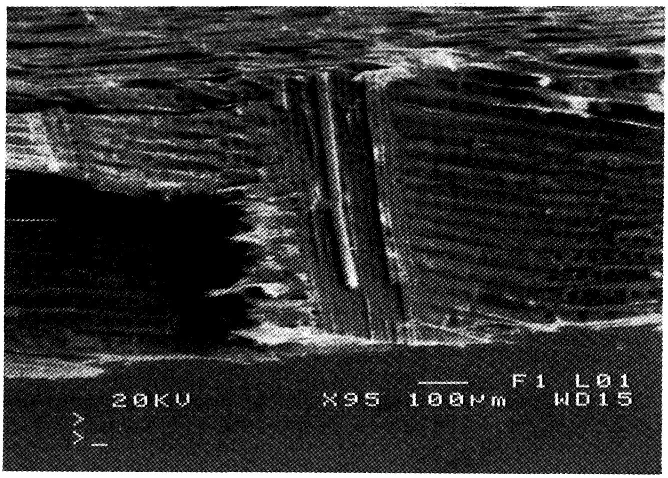

FIG. 6–The fracture surface without remnants of an axial resin canal.

our tests, the axial resin canals formed the weakest link, and the apparent stress exhibited a linear relationship with sample volume on a log-log plot (Fig. 7).

CONCLUSION

The differences in failure stress with variation in sample length can be explained by the natural distribution of axial resin canals within the veneer. Failure stress might be expected to be influenced by the probability of finding one or more axial resin canals within the veneer (which increases with sample length), by the natural distribution and the dimensions of axial

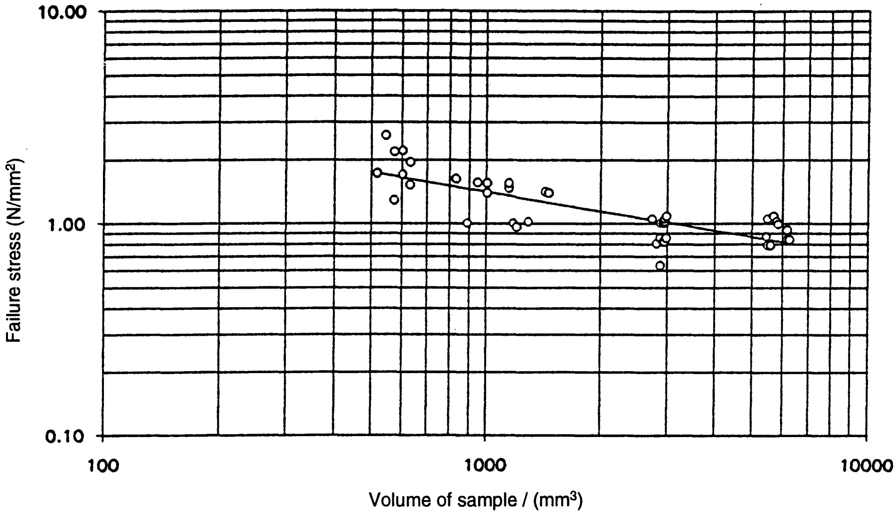

FIG. 7–Variation of failure stress of air-dried and green *Pinus radiata* samples with sample volume.

resin canals, and by the location of the axial resin canal relative to the veneer surface (Gordon 1978). Short veneer samples (<20 mm) may be free of axial resin canals, and their strength should approximate that for "clear" samples. In thicker samples resin canals are still present but their effect on the strength of the sample has been reduced as the ratio of canal diameter to sample thickness is reduced. The limiting values of the failure stress correspond to reported values for *P. sylvestris* reported by Siimes (1967).

This conclusion is demonstrated by the failure surface of the veneer, since all failure surfaces except those with a high stress at failure showed traces of axial resin canals (Fig. 5). Therefore, the cause of most failures was the presence of the embedded axial resin canals.

The original premise for this work was the suggestion that tests of thin veneers would obviate some of the difficulties in sampling and natural variation that occur when working with larger specimens. However, the distribution of axial resin canals means that unless the specimen is very short (<20 mm) this approach would be impractical.

ACKNOWLEDGMENTS

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