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A series of tests aimed at establishing the effect of temperature upon the tensile strength parallel-to-grain of finger jointed laminae for glulam has been conducted in the Fire Research Laboratory at Aalborg University Centre. The objective of this report is to present the background to and the results of these experiments.

Introduction

Previous tests in the laboratory with full size glulam beams exposed to fire while loaded in four point bending [1] has indicated that the strength of finger joints in the tension side laminae might well have an effect on the load carrying capacity of glulam structures exposed to fire.

In one of the beams tested a partial failure occurred in a finger joint in the third lamina from the edge of the tension side. This resulted in splitting along the beam axis from the point of failure causing a significant increase in the charring of the wood in the failure zone.

The failure in the finger joint was not anticipated and it was suspected that it could be caused by a reduction in strength due to the increase in temperature.

It was decided to investigate this effect by determining the tensile strength of unjointed and finger jointed laminae at four different temperature levels.

Test program

A sample of 38×150 mm Swedish Whitewood (Picea Abies) from one sawmill was graded visually according to the Nordic grading rules. A total of 150 boards of grade T30 were chosen and divided into 3 groups.

Group 1 was used for tests with unjointed boards. The boards in group 2 were finger jointed end-to-end and cut half-way between joints thus forming a group of test specimens with a finger joint in the centre. Group 3 was used for another part of the test program, still underway, dealing with tensile strength of laminae exposed to a standard fire.

The specimens in group 1 and 2 were planed to 33×140 mm and cut to a length of 3100 mm to fit the tension testing machine developed by the Structures Laboratory of the Institute [2].

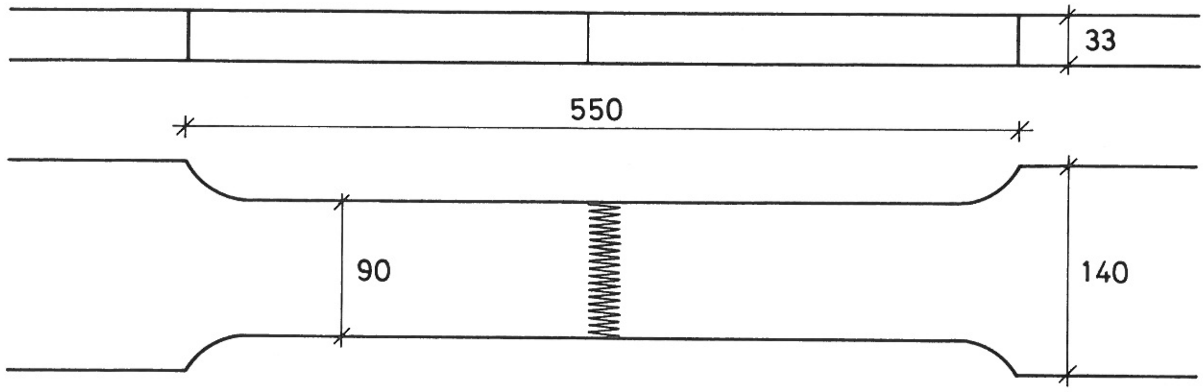

Figure 1. Top and side view of test specimen with finger joint. Dimensions in mm.

In order to confine the failure to the centre of the boards all specimens were machined to a width of 90 mm over a length of about 500 mm, cf. figure 1.

All boards were conditioned to a moisture content of about 0.12.

A heating unit was built to fit into the tension testing machine. Electric heating elements were mounted on the back of two steel plates to create an approximately constant temperature field on the front side of these plates, cf. figure 2. Maximum effect 1200 W. The plates were made 500 mm long. The unit was constructed to allow adjustment of the gap between the steel plates. During testing the plates were brought in contact with the test specimen. Temperature was controlled by means of a variable power supply. The unit was

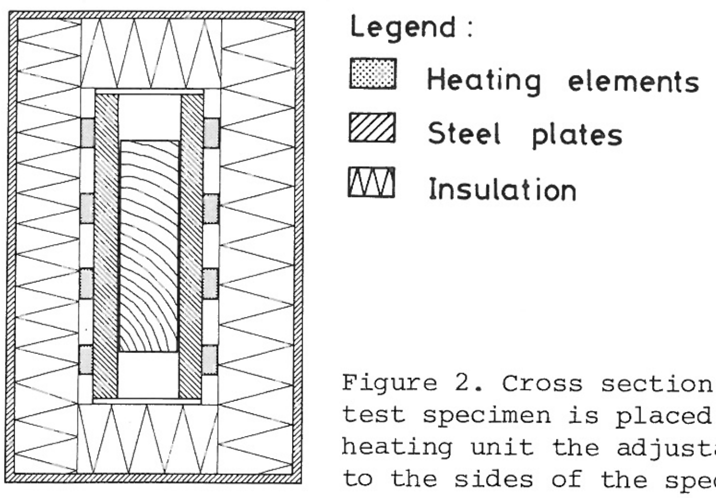

Figure 2. Cross section in heating unit. After the test specimen is placed with the centre part in the heating unit the adjustable steel plates are clamped to the sides of the specimen.

insulated and built into a housing with holes in the end allowing for insertion of the test specimen. A detailed description of the unit can be found in [3].

An outline of the test set-up with tension testing machine and heating unit is shown in figure 3.

Tests were conducted on 4 temperature levels: 20, 90, 160 and 230^{0} C with the two groups of unjointed and finger jointed boards, thus creating a total of 8 subgroups containing 8 test specimens each.

Before a test specimen was inserted into the tension testing machine a thermocouple (NiCr-Ni) was placed in the centre of the cross-section through a small hole drilled from the narrow face of the board. A second thermocouple was fixed to the surface of the board. Moisture content was measured with a resistance type moisture meter. Finally cross sectional dimensions were recorded.

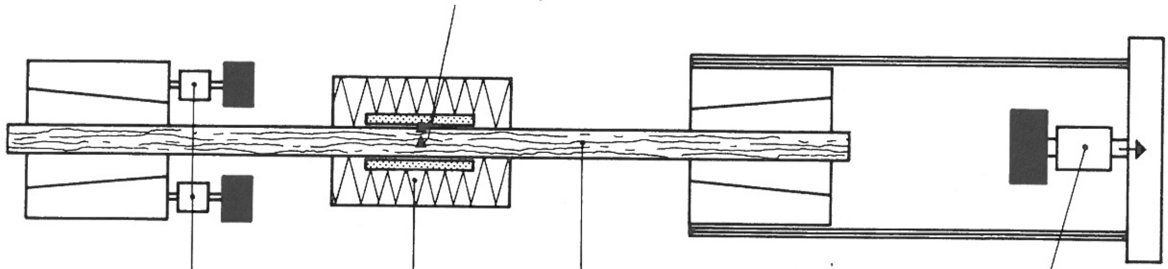

Figure 3. Outline of test set-up with a specimen fitted into the tension testing machine and the heating unit.

When the test specimen was centered in the testing machine the steel plates of the heating unit were adjusted to make contact with the wood. The temperature of the steel plates was kept at the predetermined level until the temperature in the center and on the surface of the cross-section had reached the desired level. This operation was controlled with a strip chart recorder.

When equality in temperatures was achieved a tensile load was applied to the specimen until failure occurred. The failure load was recorded. In a few instances the failure occurred partly outside the heated section of the test specimen. These specimens were discarded and replaced.

<u>Discussion of test results</u>

All failures were examined. Typical failure types at 90^{0} C and 230^{0} C are shown in figure 4.

The ultimate tensile stress was calculated for all test specimens. The test results are tabulated in appendix A. Mean values for the eight subgroups investigated were calculated. The results were plotted against temperature, cf. figure 5A. A 3-parameter Weibull distribution was fitted to each set of data to determine the lower 5-percentile values. These data points were also plotted against temperature, cf. figure 5B. Except for the value of unjointed boards at 20^0 C the results show the same trend in the two presentations. The

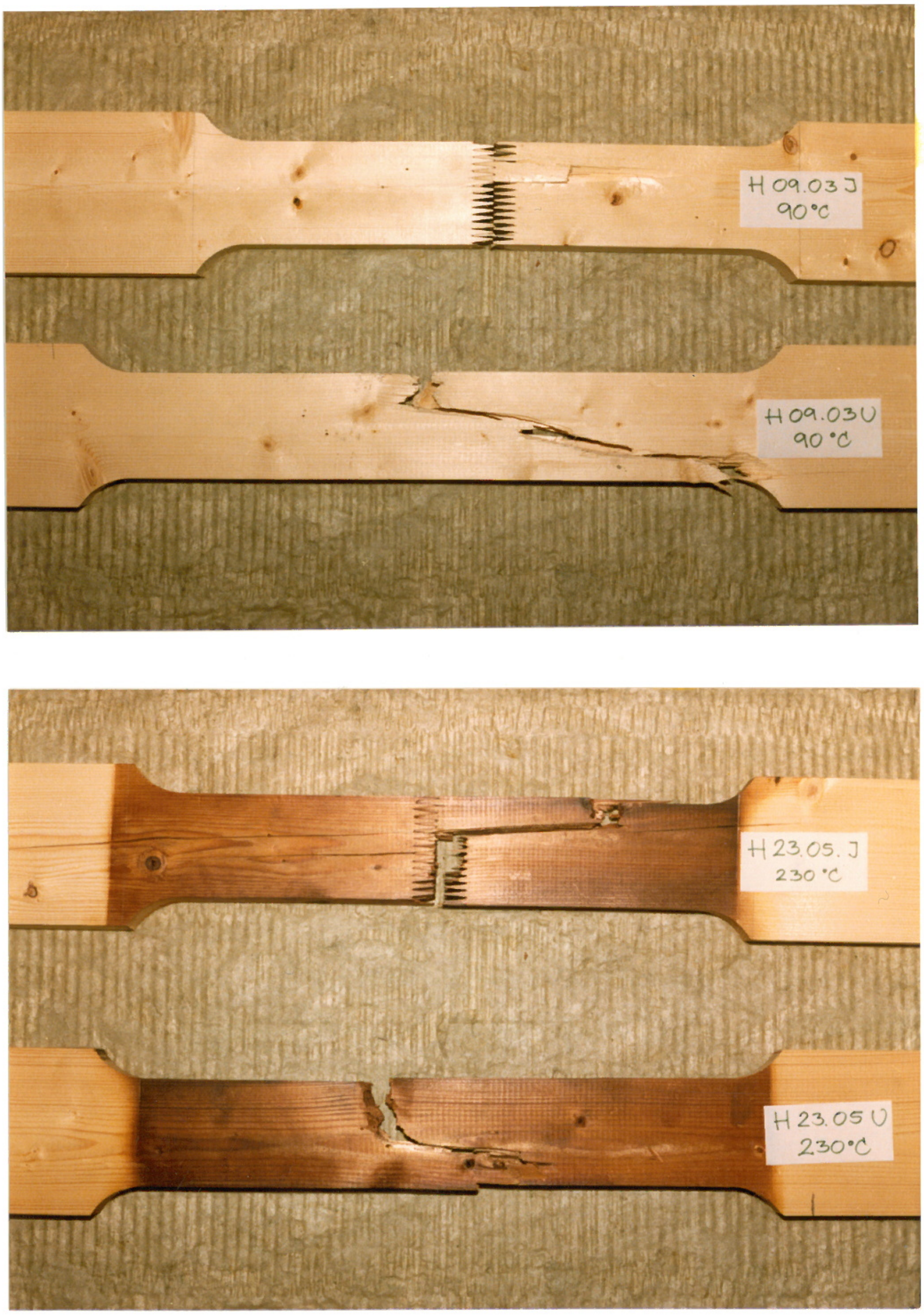

Figure 4. Failed test specimens. Typical failures are shown at 90^0 C (top) and at 230^0 C (bottom) for finger jointed (J) and unjointed (U) specimens.

difference found at 20^0 C is caused by two very low strength values in the subgroup of unjointed boards.

There is a very significant temperature effect on the tension strength of both unjointed and finger jointed laminae. This effect has been investigated by Nyman [4] for small clear specimens. At 230^0 C he found a tension strength of about 0.6 relative to the strength at 20^0 C. The present results show a much more severe strength reduction to about 0.2 for the unjointed specimens of structural grade material. However, the strength difference in absolute terms between 20^0 C and 230^0 C is about 35 MPa in both investigations.

As can be seen from figure 5A the strength ratio between finger jointed and unjointed specimens at 20^0 C was found to be about 0.92. It should be noted that this value is somewhat higher than the corresponding ratio of 0.78 found by Larsen [5] in an extensive test program with finger jointed laminae. This difference is mainly caused by the two low values found in the subgroup of unjointed boards.

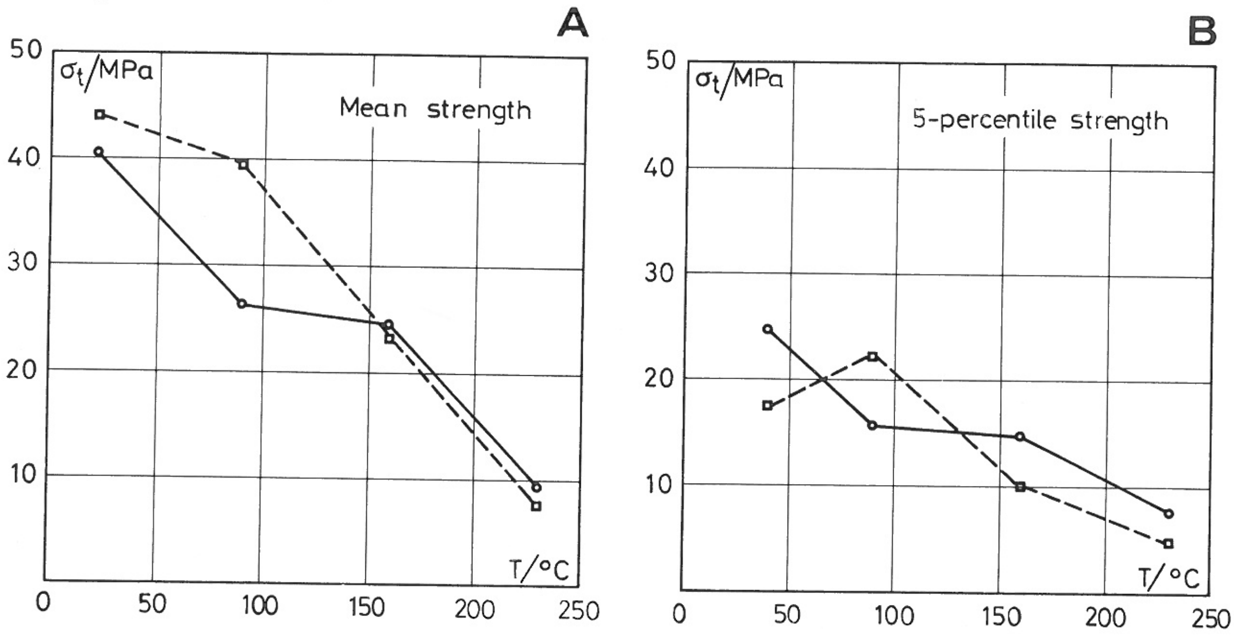

Figure 5. Tensile strength at different temperature levels for unjointed boards (□------) and for finger jointed boards (o————). Variation in mean strength (A) and 5-percentile strength (B) is shown.

There was a significant strength reduction from 20^0 C to 90^0 C for the finger jointed specimens whereas the significant drop for the unjointed boards was observed from 90^0 C to 160^0 C. A statistical analysis showed that only at 90^0 C a significant difference could be found between the strength of unjointed and finger jointed specimens. This difference might be explained by assuming that shear strength is governing the failures in the finger jointed specimens at lower temperatures. Nyman [4] has shown that the shear strength is less dependant of temperature than tension strength. Consequently the failure mode at higher temperatures is governed by the tension strength.

The fact that no strength difference was found between unjointed and finger jointed specimens at 160° C and 230° C supports this hypothesis.

Further Nyman [4] found that the wood strength was more sensitive to an increase in temperature than a glueline of resorcinol glue. This is supported by the observation that all finger jointed specimens tested at 230° C had 100% failure in the wood material.

Conclusions

The test results support the following conclusions:

- A major temperature effect on the tensile strength exists for both unjointed and finger jointed laminae.
- At 90° C the tensile strength of unjointed laminae is significantly higher that the tensile strength of finger jointed laminae.
- The finger joints have no influence on the tensile strength of laminae at 160° C and 230° C.

Acknowledgements

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[4] Nyman, C., The Influence of Temperature and Moisture on the Strength of Wood and Glue Joints. Symposium on Fire Resistance of Wood Structures, VTT Symposium 9, Technical Research Centre of Finland, 1980.

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Appendix A - Test results

Results from tests with unjointed and finger jointed boards are given in tables A1 and A2 respectively.

Specimen no.	Tensile strength (MPa) T=20°C	T=90°C	T=160°C	T=230°C
01	40.7	48.1	23.5	7.65
02	49.7	33.8	19.1	10.7
03	27.8	42.5	31.7	4.71
04	41.5	42.3	25.0	5.61
05	67.5	47.5	21.4	6.45
06	52.2	44.8	31.4	6.54
07	25.2	26.1	19.4	6.02
08	47.3	33.0	12.6	15.0
Mean strength	44.0	39.8	23.0	7.84
Standard deviation	13.6	7.89	6.44	3.41
5-percentile strength	17.8	22.0	10.0	4.51

Table A1. Tensile strength of unjointed boards.

Specimen no.	Tensile strength (MPa) T=20°C	T=90°C	T=160°C	T=230°C
01	44.9	25.6	18.6	11.8
02	43.8	30.9	25.8	8.33
03	42.0	33.1	28.1	9.15
04	36.1	18.3	18.7	12.7
05	35.8	24.6	30.8	9.11
06	50.5	25.3	24.6	8.04
07	28.0	26.2	26.5	7.75
08	41.7	25.1	25.2	8.28
Mean strength	40.4	26.2	24.8	9.40
Standard deviation	6.88	4.44	4.25	1.84
5-percentile strength	24.7	15.9	15.0	7.68

Table A2. Tensile strength of finger jointed boards.