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DETERMINATION OF PANEL SHEAR STRENGTH AND PANEL SHEAR MODULUS OF BEECH-PLYWOOD IN STRUCTURAL SIZES

by

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Introduction

High quality beech plywood is a usable material in timber engineering, e.g. for reinforcing glulam structures under perpendicular-to-grain tensile stresses or for plywood gussets in nailed or glued trusses. Beech plywood may also be used as a web of I- or box-beams or in similar structural applications.

Therefore, it is necessary - among others - to make available data of the panel shear strength and the panel shear modulus. In a study made in the "Versuchsanstalt für Stahl, Holz und Steine" of the University of Karlsruhe (FRG) such data were collected using shear tests with beech plywood panels of 10 to 40 mm panel thickness. This task gave the opportunity of using the RILEM-recommended test method developed for testing plywood in structural sizes. This RILEM-Recommendation /1/ was approved by CIB-W18 and forwarded to ISO as a basis for a draft ISO Standard. In a joint committee of ISO/TC 139 and 165 this recommendation was discussed. A draft proposal of this ISO Joint Committee will be under discussion at the main meetings of the technical committees TC 139 and TC 165. It was considered useful to perfom tests using high strength plywood panels at this stage in order to propose additional or modified test methods if necessary.

Test Specimen

The test specimen and test set-up described in the RILEM-Recommendation are shown in Figs. 1 and 2. A method of measuring the shear deformation is given in ASTM Standard D 2719-76 /2/ and will be proposed also in the ISO draft. This principle is given in Fig. 3. When using this loading apparatus, the external loads act to the test specimen in a manner shown in Fig. 4.

The panel shear strength is

$$f_p = \frac{F_{t,u}}{L \times t} \qquad (1)$$

with $F_{t,u}$ = ultimate applied tensile load of the testing machine; L = length of panel; t = panel thickness.

In former investigations MÖHLER and EHLBECK /3/ used small test specimens and found panel shear strengths for beech plywood in the range of 18 to 20 N/mm² (Mpa). According to that, ultimate tensile loads in the range of 430 to 480 kN had to be expected for test specimens of 600 mm length and 40 mm panel thickness. At the same time shear stresses will occur in the timber rails of 115 x 35 mm cross-section. These stresses amount to

$$f = \frac{H}{2 \times 35 \times 115} \qquad (2)$$

with $H \approx F_t/4$ (see Fig. 4). With $F_{t,u}$ = 480 kN, shear stresses in the rails will figure up to about 15 N/mm² (Mpa) with the failure of the test specimen certainly to occur in the rails instead of shear failure in the plywood panel. These considerations made sure that the proposed timber rails of the RILEM-Recommendation are not practicable for high quality hardwood plywood of a more than 20 mm - panel - thickness. Moreover, it seemed to be too time-consuming to use steel rails instead of timber rails.

So, the timber rails were replaced by beech plywood rails of the same thickness as the test panel thickness. With a rail width of 150 mm instead of 115 mm the shear stress in the rails amounts only to half the shear stress in the test panel:

$$f = \frac{H}{2 \times t \times 150} = \frac{f_p \times t \times 600}{4 \times 2 \times t \times 150} = 0,5 \times f_p \qquad (3)$$

With the plywood rails taken from the same panel under scrutiny, it could be expected that a failure in the rails would never occur. From these considerations the test specimens were modified as shown in Fig. 5. In no case of altogether 72 tests failure occurred in the rails.

Test Set-up

Ultimate test loads up to 500 kN require heavy and unwieldy test equipment when the test set-up according to Fig. 2 is used. The steel bars and pins and yokes as well as the steel link connected to the crosshead of the testing machine are only used to transform the tensile loads of the testing machine to compressive loads acting on the test specimen. Why not imposing compression loads of the testing machine directly to the test specimen?

A stationary test equipment was developed (see Fig. 6). It proved to be time-saving, because only the test specimen had to be moved into or out of the testing apparatus. The test load F, as shown in Fig. 4, acts directly on the test specimen. It has to be taken into account that the panel shear strength in this case amounts to

$$f_p = \frac{F_u \cdot \cos 14°}{L \times t} \qquad (4)$$

with F_u = ultimate compressive load of the testing machine.

Test Procedure

A constant rate of loading was chosen so that the ultimate load was reached within 3 ± 1 minutes. The load-deformation curves were recorded. A typical graph is given in Fig. 7. The shear modulus can be calculated from the straigth line portion of the load-deformation-curve. The elastic range extends to about 40 % of the ultimate load.

Test Results

Shear failure occured always along the weakest cross-section of the test panel. The shear strength achieved was not influenced by the location of the failure section. The coefficient of variation of the panel shear strength was rather low, ranging from 9 to 10 %. Compared with shear strength values obtained from small specimen, a reduced shear strength of about 80 % must be taken into consideration for plywood panels in structural sizes.

The mean panel shear strength of the beech plywood under scrutiny amounts to 11,5 N/mm²; the shear modulus ranges from 700 to 800 N/mm². A detailed research report is in preparation /4/.

Conclusions

The RILEM-Rēcommendations for testing the panel shear strength of plywood in structural sizes may be usable for softwood plywood. If the panel shear strength increases, however, e.g. for hardwood plywood, timber rails in the dimension proposed by the RILEM-Recommendations turn out to be the weakest part of the test specimen. In such cases the rails should be of the same material and of such a cross-section that the shear stresses in the rails do not cause early failure of the test specimen.

The test equipment described in the RILEM-Recommendations becomes heavy and unwieldy when high tensile loads have to be applied. A simple stationary test set-up, easy to handle and of big advantage when testing many replications, proved to be a useful alternative with compressive loads of the testing machine directly applied to the test specimen.

References

/1/ International Union of Testing and Research Laboratories for Research and Testing (RILEM): Testing Methods for Plywood in Structural Grades for Use in Load-Bearing Structures. RILEM-Recommendation TT2, 1st Edition, Paris, 1976.

/2/ American Society for Testing and Materials (ASTM): Standard Methods of Testing. Plywood in Shear Through-The-Thickness. ANSI/ASTM Standard D 2719-76. Philadelphia, Penn., USA, 1976.

/3/ Möhler, K. und J. Ehlbeck: Kurzzeit- und Dauerstandversuche zur Ermittlung der statischen und Dauerstandfestigkeit von Bau-Furnierplatten. Berichte aus der Bauforschung, Heft 92, Holzbau-Versuche V. Teil. W. Ernst u. Sohn, Berlin 1974.

/4/ Ehlbeck, J. und F. Colling: Ermittlung der Scherfestigkeit und des Schubmoduls von Buchenfurnierplatten rechtwinklig zur Plattenebene. HOLZ als Roh- und Werkstoff 42 (1984); in preparation.

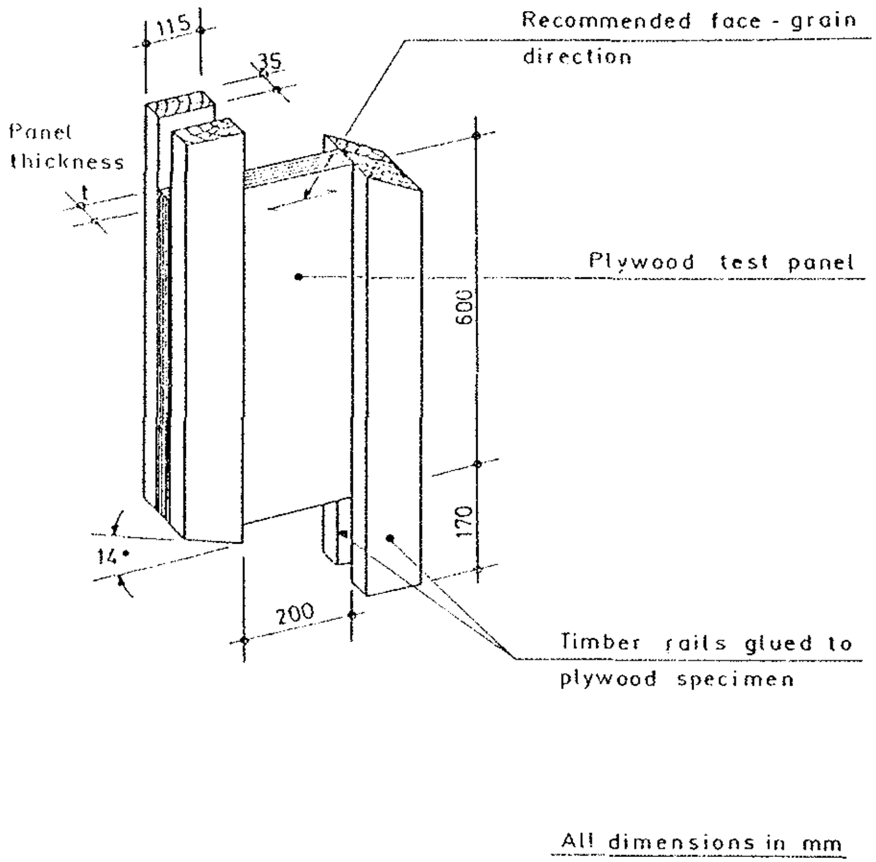

Fig. 1: Test Specimen According to RILEM - Recommendation and ISO - Proposal 1983 (Joint Committee TC 139/165)

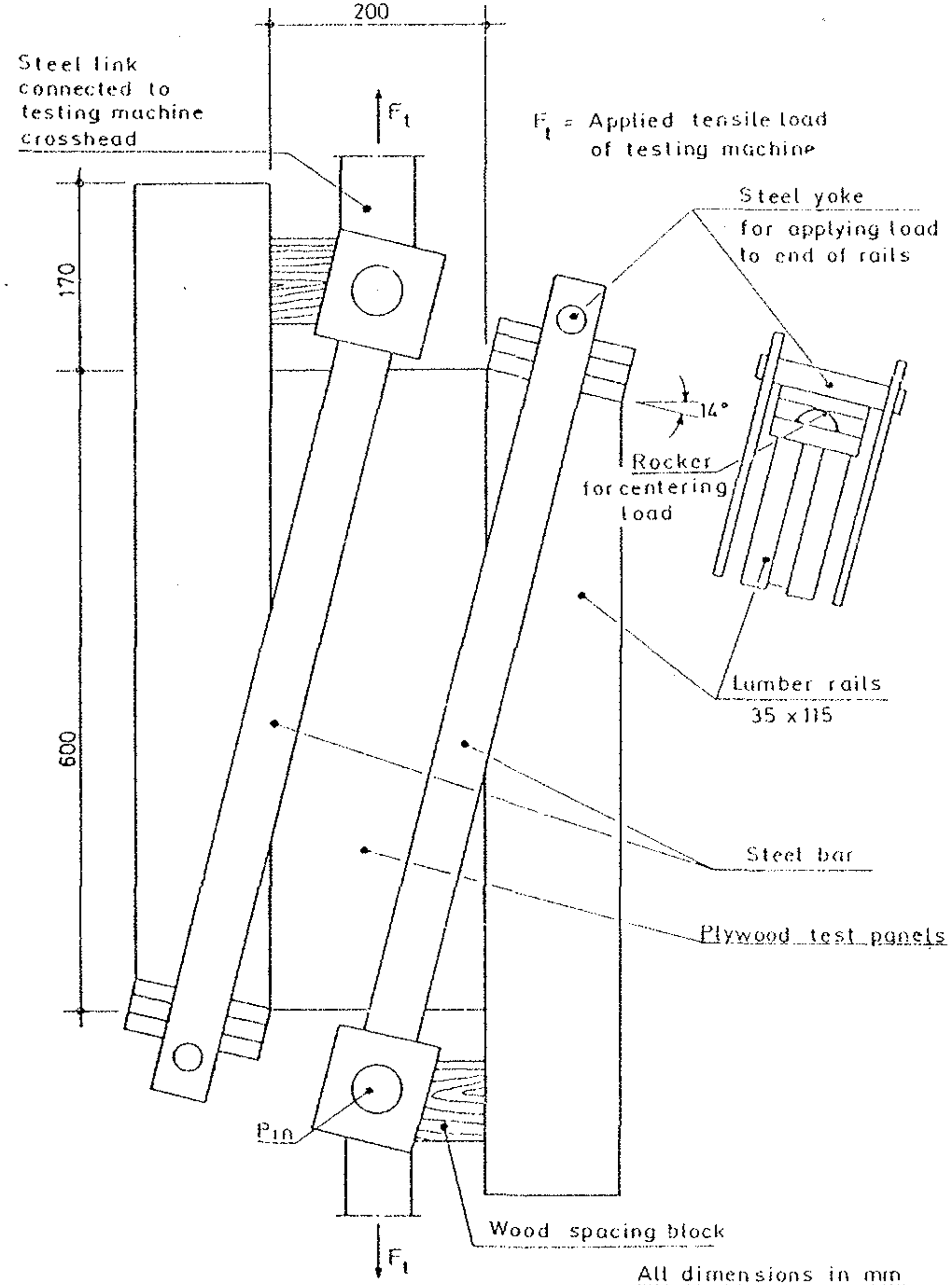

Fig. 2: Test Set - up According to RILEM - Recommendation and ISO - Proposal 1983 (Joint Committee TC 139/165)

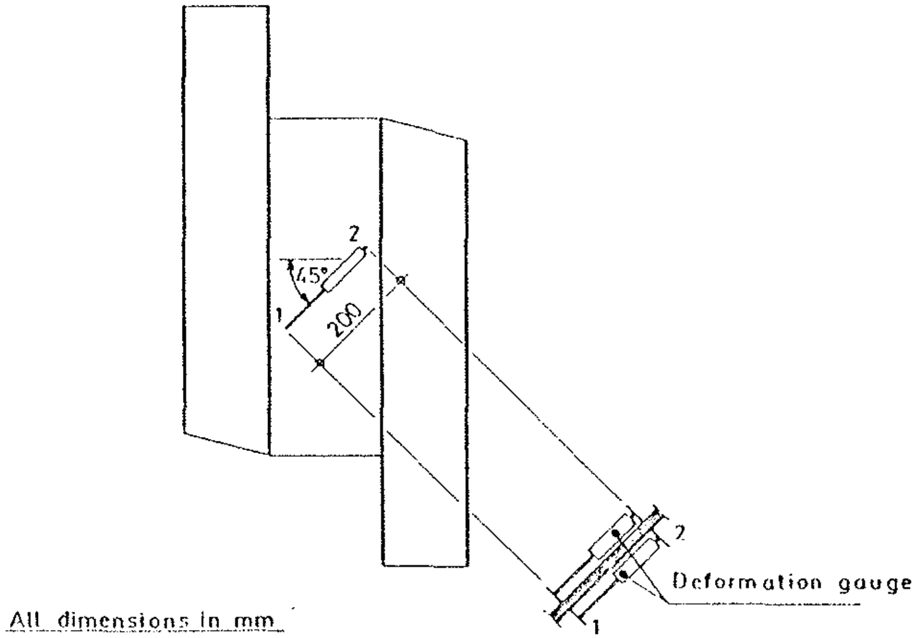

Fig. 3: Measuring Device for Determination of Shear Modulus

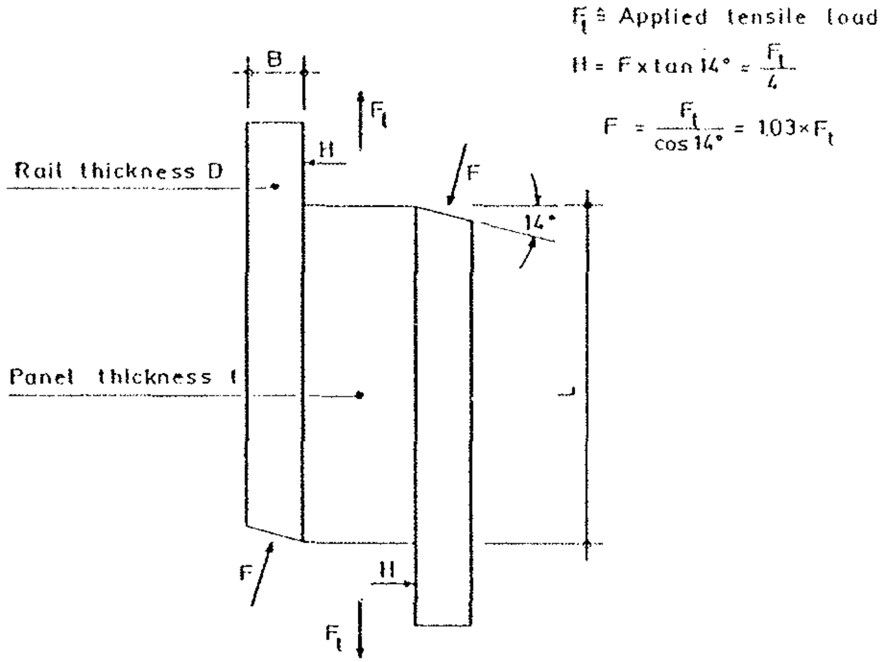

Fig. 4: Loads Acting to Test Specimen

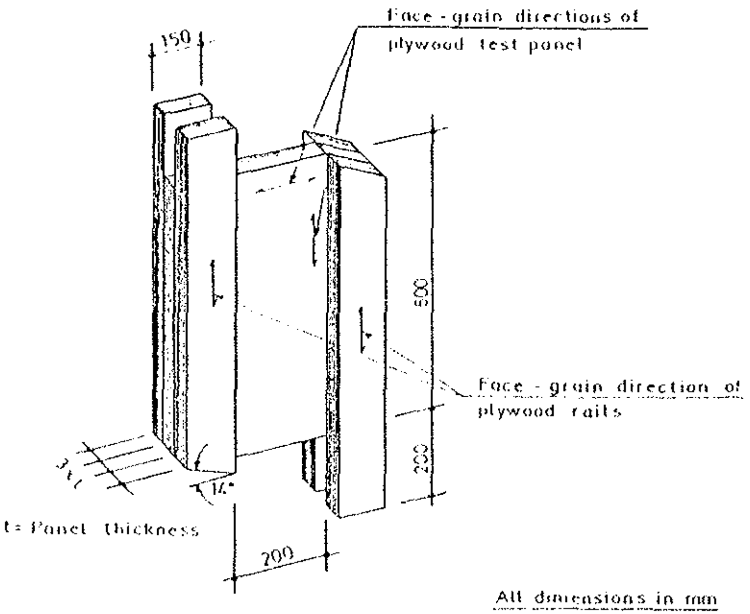

Fig 5 : Modified Test Specimen with Plywood Rails of Same Thickness as Test Panel

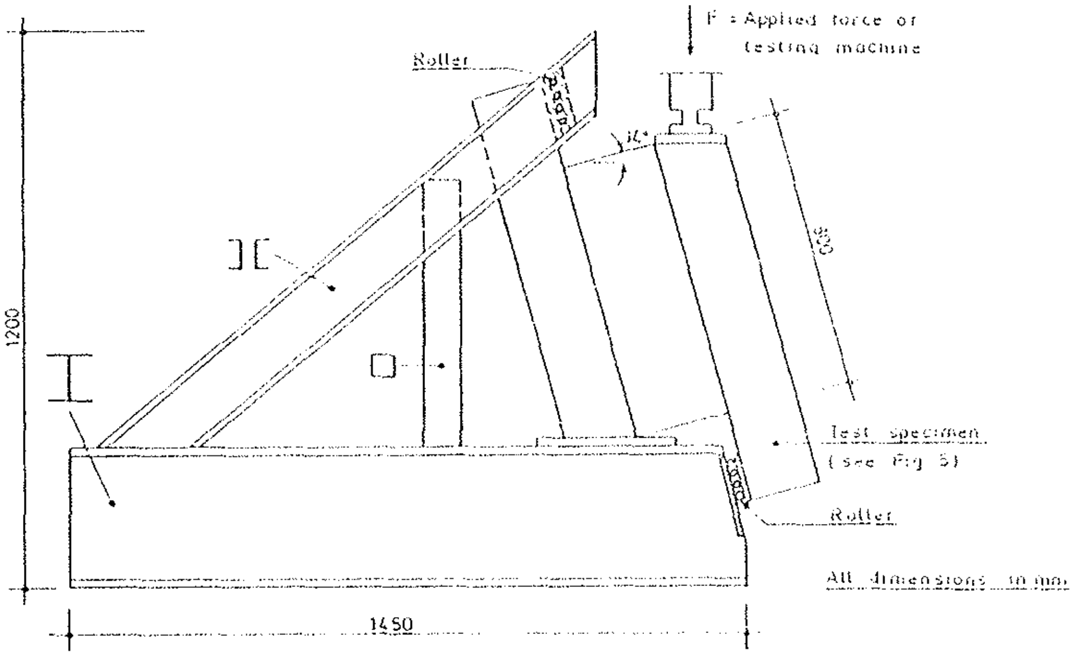

Fig. 6 Test Set-up Using Compressive Applied Loads

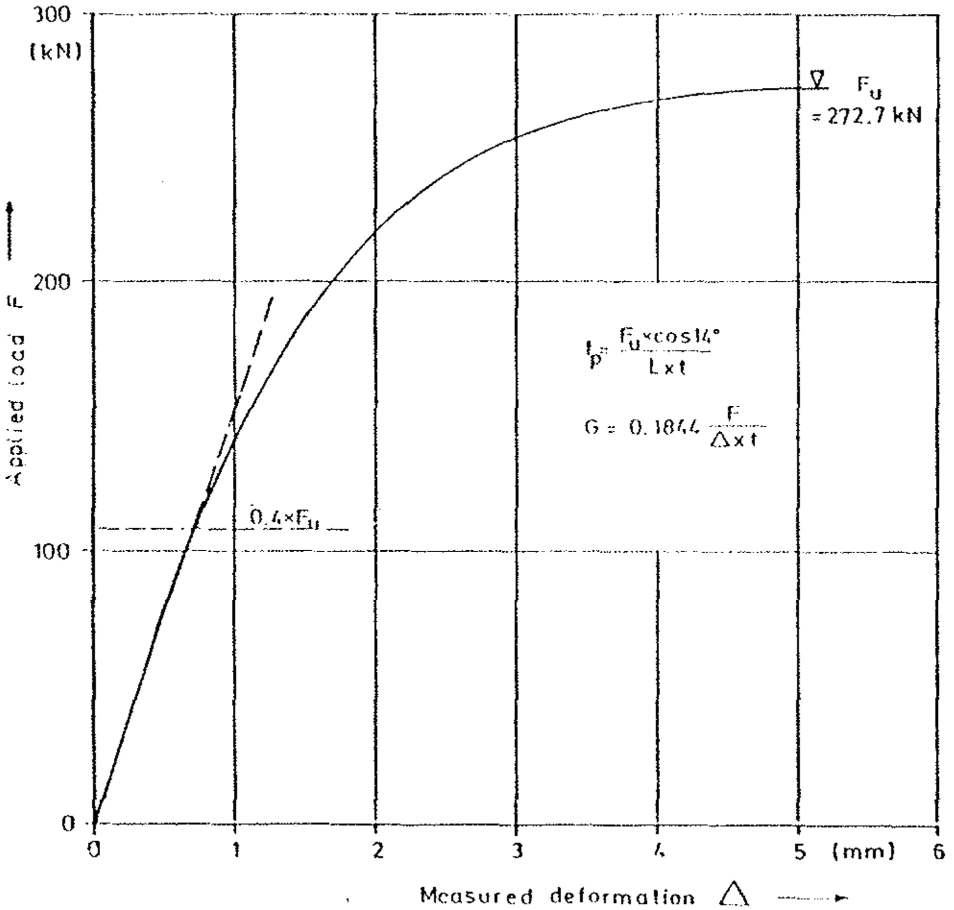

Fig. 7: Load-Deformation-Curve of a Test Specimen which Failed within the Measuring Range, Panel Thickness 40 mm