IOP Conference Series: Materials Science and Engineering

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IOP Conf. Series: Materials Science and Engineering **549** (2019) 012035 doi:10.1088/1757-899X/549/1/012035

Test of the tensile load capacity of a timber structure joint with an inserted nail plate

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Abstract. The aim of this paper was to determine the axial tensile load capacity of timber structure elements with inserted metal plates with welded nails. The tests were performed on three specimens in the laboratory of the AdMaS centre of the Faculty of Civil Engineering, Brno University of Technology. The tensile force was applied on the specimen by increasing the force up to the specimen failure. The inductive displacement transducers continuously measured the displacement of the inserted joint plates with regard to timber prisms. The tensile load-bearing capacity of the tested joint was determined at 205.0 kN. Due to the advantages, the tested joints with inserted nail plates seem to be appropriate for joining suitable timber elements.

1. Introduction

Elements of timber structures are usually joined by mechanical means - by woodworking joints or by bonding. The basic types of mechanical connectors are divided, according to the principle of force transmission, into pin connectors and plate connectors. Pin connectors (e.g. nails, pins and screws) bend and get pressed into the wood due to the transmission of forces. Plate-type connectors (dowels and nail plates) are inserted or pressed into the elements, and the forces are therefore transferred on the surface of the structural elements. [1] An important improvement in the area of timber structure joints with plates was the shifting of the plate from the surface of the connecting elements into the grooves inside the connected solid timber parts. [2-3]

Joints with inserted plates are usually able to transfer higher loads than joints with outer plates of comparable parameters. The inserted plate contributes to an increase in fire resistance in comparison to the outer plate because the inserted connector is protected from fire by the solid timber. A disadvantage of a structure with inserted plates is the more demanding production process due to the necessity to cut the inner grooves for plates and to secure the sufficiently accurate linkup of the connectors. [1-3]

2. Specimens and method

The purpose of the measurement was to determine the axial tensile load capacity of timber structure elements with inserted nail plates. [4-5] The tests were performed on three specimens marked V1, V2 and V3.

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Each specimen consisted of two timber prisms of 80 × 160 × 830 mm joined together on both ends by an inserted nail plate marked MKD 108×200-110. These connecting plates were 10 mm thick S235 steel plates with rectangular nails welded perpendicular to the plate on both sides. The nails had a perpendicular cross-section of 3 × 4 mm and a length of 50 mm. The wider areas of the nail shafts were profiled to increase the resistance of nails against extraction. The nail shafts were reinforced by a conical shape at the point of their transition to the steel plate, which increased the load capacity and stiffness of the joint. The distance between nails in the direction parallel to timber fibres was 40 mm and perpendicular to timber fibres 12 mm, and alternating arrangement was used. The MKD connecting plates were made by welding nails to a steel plate by a welding machine. The specimens of steel-timber joint were made using a special pressing device in such a manner that the MKD connecting plates were pressed between the two layers of timber, which corresponds to the supposed procedure of girder production, see Fig. 1 and 2. [6]

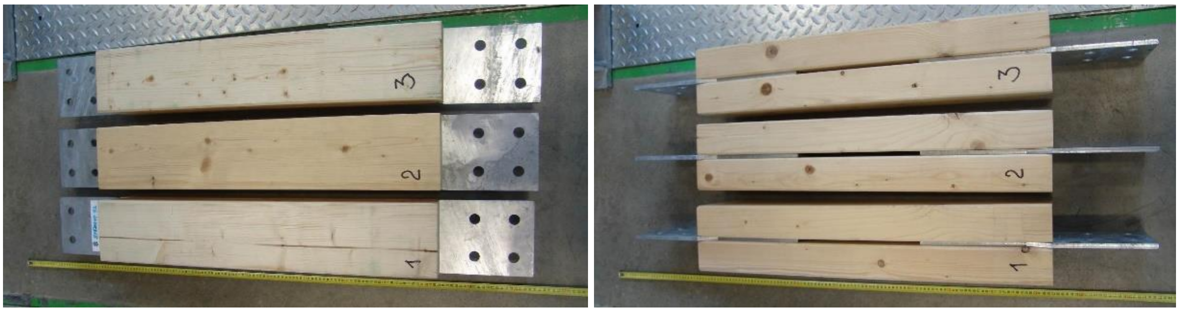

Figure 1. View of test specimens V1, V2, V3 – specimens of joints with the inserted MKD nail plates between timber prisms.

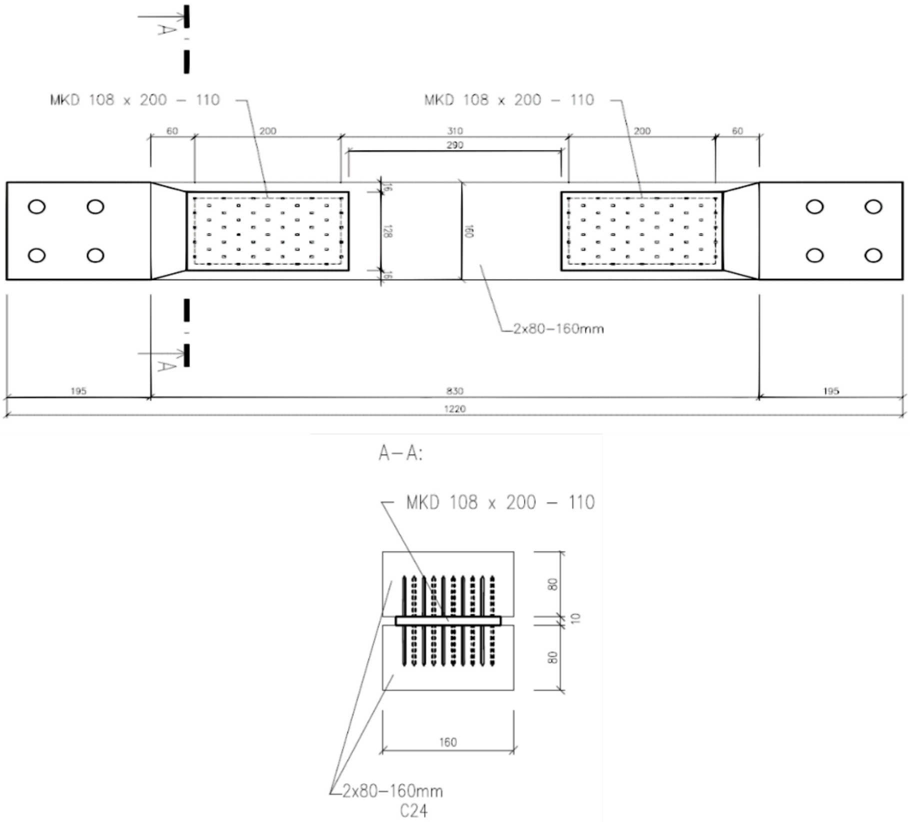

Figure 2. Diagram of the test specimen with an MKD nail plate (above) and the cross-section of the element (below).

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The experiments were performed in the laboratory of the AdMaS centre of the Faculty of Civil Engineering, Brno University of Technology. The testing tensile load was applied by a hydraulic cylinder of the automatic electrohydraulic loading system called INOVA with a range of the loading cylinder of up to 500 kN and a strain gauge displacement transducer (displacement of the cylinder). The specimens were anchored in the test frame for static loading tests. The lower part of the test specimen was fastened to the breaking path with an articulated pin joint in the tested joint plates. The upper part of the specimen was fastened to the loading cylinder in a similar way. The tensile force was applied on the specimen by increasing the force of 0.45 kNs^{-1} up to the specimen failure.

In the tensile test, the HBM WA/50mm inductive displacement transducers continuously measured the displacement of the inserted joint plates with regard to timber prisms. Deformations were measured in four measuring bases, by two transducers near the upper nail plate and by two transducers near the lower nail plate. The location of transducers is apparent in Fig. 3.

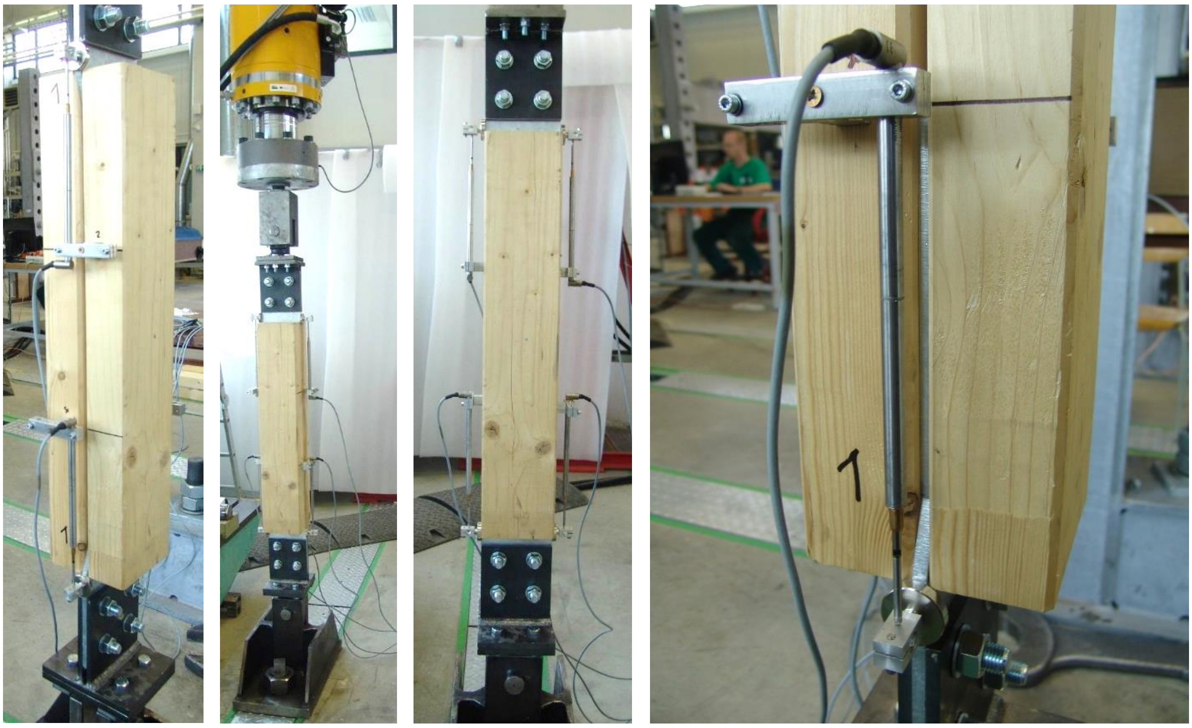

Figure 3. View of the testing setup for determining the tensile load capacity and the detail of the inductive transducer of a selected lower nail plate.

The data were measured by means of the HBM QUANTUM X system and processed in the computer using software for retrieving data called catman Easy version 3.5.1, and subsequently exported to a text file. The record contains data of the time course of the test, of the applied force, and of the displacement of MKD joint plates with regard to timber prisms measured by inductance transducers.

3. Results

The results of experimental measurement of the tensile load capacity are shown in the following working diagrams of joints in Fig. 3, which demonstrate the dependence of the nail plate displacement with regard to the timber prisms on the value of load. The values marked as *displ_up* and displ_bott are calculated as average values of the displacement measured on two sides near the upper and lower joint.

The load capacities of nail plate specimens inserted between timber prisms are summarized in Table 1. The tensile load capacity of the tested element $F_{max,m}$ was determined as the arithmetic mean of the forces of the failure limit of the three test specimens. The load capacity of the tested joint was determined at 205.0 kN (with a standard deviation of 13.7 kN and a coefficient of variation of 6.7 %). The character of specimen failure after reaching the tensile load capacity is apparent from the Fig. 4 and 5.

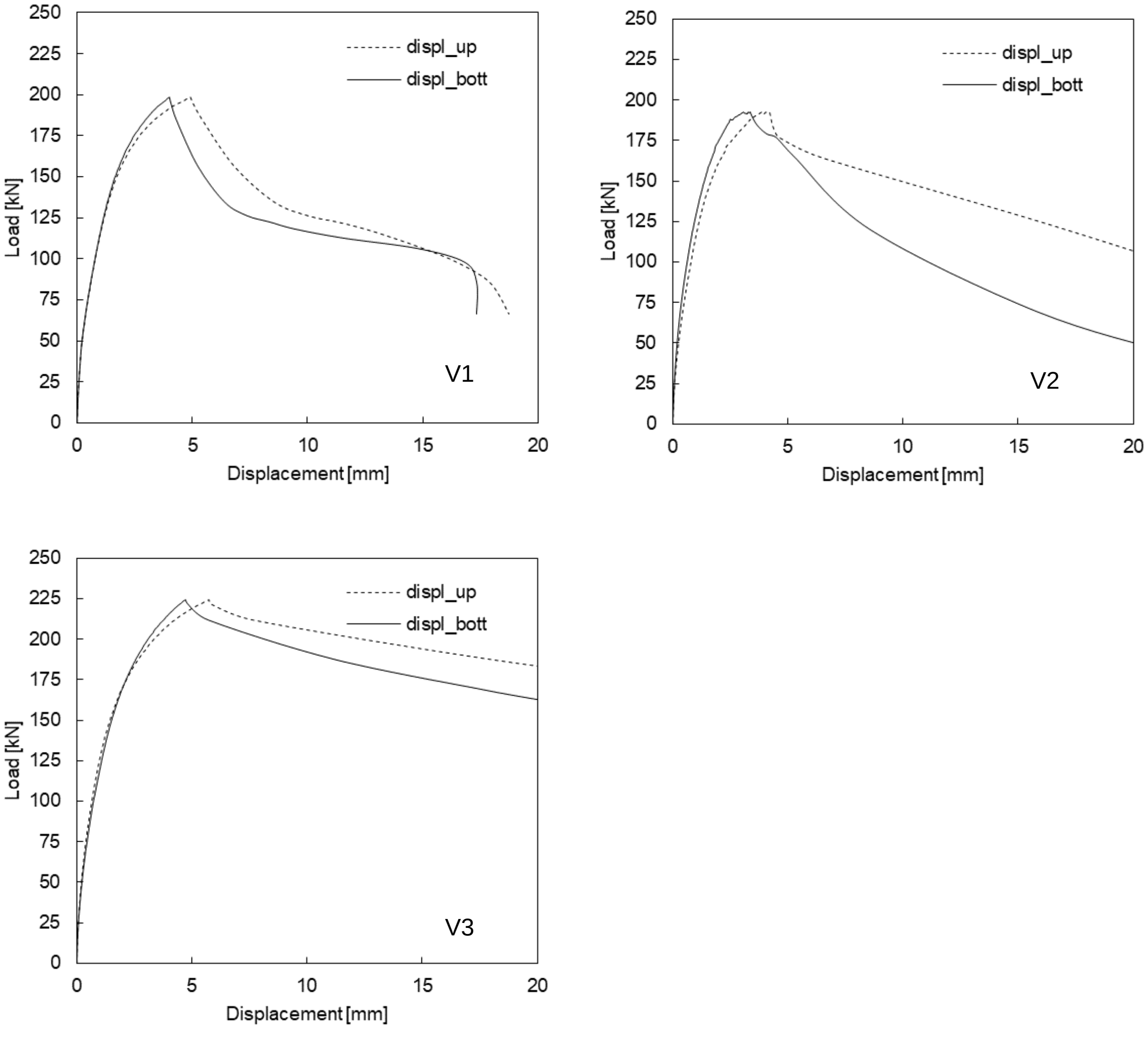

Figure 4. Working diagrams of the specimens of joints V1, V2 and V3 in the tensile test.

Table 1. Tensile load capacities of the examined specimens (incl. diameter, standard deviation and coefficient of variation).

Specimen	$F_{max,i}$ [kN]	$F_{max,m}$ [kN]	σ [kN]	CV [%]
V1	198.2			
V2	192.6	205.0	13.7	6.7
V3	224.1			

Figure 5. Damaged specimens – overall view and important details of the specimens V1 (1st row), V2 (2nd row) and V3 (3rd row).

4. Conclusion

The paper is a contribution to the knowledge in the field of timber structures and load capacity of joints. The experiment determined the tensile load capacity of a timber structure joint with an inserted metal plate with welded nails. All the three elements tested in the laboratory showed similar behaviour, the average tensile load capacity of specimens was 205.0 kN. All the tested elements behaved in a similar way under tensile loading, which was also supported by the records of deformations of the plates in the area of timber-steel contact. Due to their advantages, the tested joints with inserted nail plates seem to be appropriate for joining suitable timber elements.

Acknowledgement

This paper was created under the support of project No. LO1408 “AdMaS UP - Advanced Materials, Structures and Technologies", supported by the Ministry of Education, Youth and Sports under the „National Sustainability Programme I”.

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