Ecole Polytechnique Fédérale de Lausanne

Semi-Rigidity of Through-Tenon Joints under Tension and Shear Loads and Perpendicular-to-Grain Compression

Experimental Tests Report

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May 15, 2019

1 Introduction

This report presents the results of experimental tests performed on through-tenon joints used in double-layered and double-curved timber plate shells recently developed [1, 2]. Three tests were carried out to determine the semi-rigidity of these wood-wood connections in their three translational degrees-of-freedom. The objective of these tests is to obtain values of axial, shear and perpendicular-to-grain compression stiffness of the connections used in large-scale assemblies tested [2], as well as their maximum capacity in all three directions.

2 Material and Methods

2.1 Material

All specimens tested were made out of Baubuche-Q panels which are 40 mm-thick beech laminated veneer lumber (LVL) made of 2 crosswised layers [3]. This material was used in large-scale assemblies tested [2]. Its properties are presented in Tables 1 and 2.

Table 1: Characteristic stiffness and density values of 40 mm thick BauBuche Q panels [3]

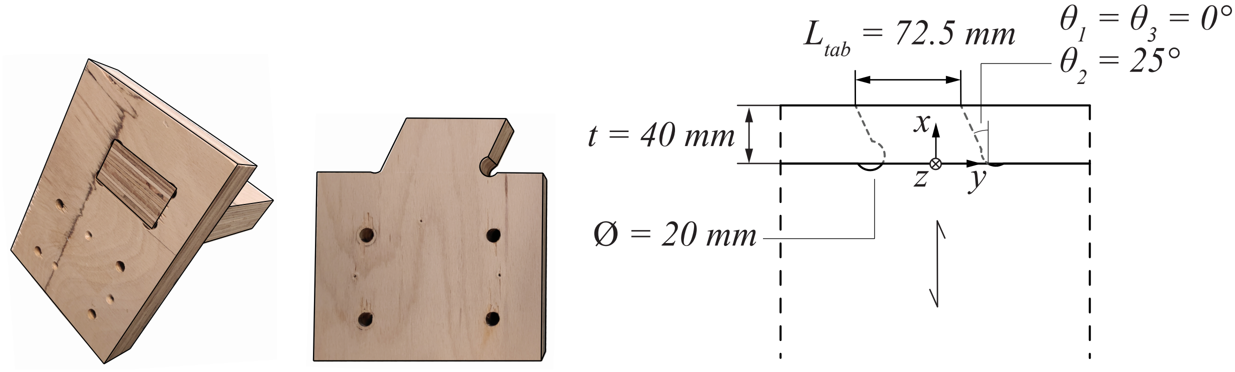
Property	**Symbol**	**Value**		**Units**
		flatwise	edgewise	
Elastic modulus	$E_{0,05}$	12 200	12 200	N/mm^2
	$E_{90,05}$	2 000	2 000	N/mm^2
Shear modulus	G_{05}	540	360	N/mm^2
Density	ρ_{k}	730		kg/m^3

Table 2: Characteristic strength values of 40 mm thick BauBuche Q panels [3]

Strength	**Symbol**	**Value**		**Units**
		flatwise	edgewise	
Bending	$f_{m,0,k}$	75	60	N/mm^2
	$f_{m,90,k}$	20	10	N/mm^2
Compression	$f_{c,0,k}$	53.3	53.3	N/mm^2
	$f_{c,90,k}$	13.0	19.0	N/mm^2
Tension	$f_{t,0t,k}$	51	51	N/mm^2
	$f_{t,90,k}$		8	N/mm^2
Shear	$f_{v,k}$	3.8	7.8	N/mm^2

2.2 Geometry of the Tested Specimens

The geometry of the through-tenon joints tested is the one of the large-scale assemblies tested [2]. These joints (see Figures 1a and 1b) are characterized by a tab length L_{tab} of 72.5 mm and Bryant angles θ_1, θ_2 and θ_3 equal to 0, 25 and 0° respectively, as illustrated in Figure 1c.



(a) (b) (c)

Figure 1: Geometry of the through-tenon joints tested: wood-wood connection (a) panel with tenon (b) and geometry of the connection (c)

2.3 Experimental Procedure

Three different experimental tests were performed to retrieve the stiffness of the connection in its three translational degrees-of-freedom (x, y and z in Figure 1c). The loading procedure applied for the three tests was as described in the European Standards EN 26891 [4].

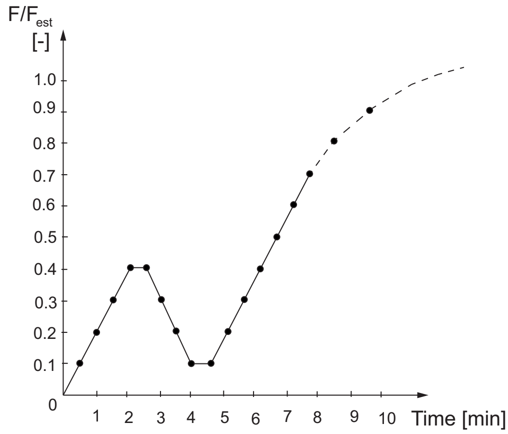


Figure 2: Loading procedure as described in EN 26891:1991 [4]

1. Test n°1: Tension

   The test setup used for the determination of the maximum capacity and stiffness of the connection in tension is presented in Rad et al. [5].

2. Test n°2: In-Plane Shear

   The test setup used for the determination of the maximum capacity and stiffness of the connection in in-plane shear is presented in Rad et al. [6].

3. Test n°3: Perpendicular-to-Grain Compression

   The test setup used for the determination of the maximum capacity and stiffness of the connection in perpendicular-to-grain compression is illustrated in Figure 3. As for the second test setup, symmetric specimens with two connections were fabricated and placed on a concrete support, considered rigid. Force was applied through a hydraulic jack and four linear variable differential transducers (LVDTs) were placed to measure the deformation of the samples.

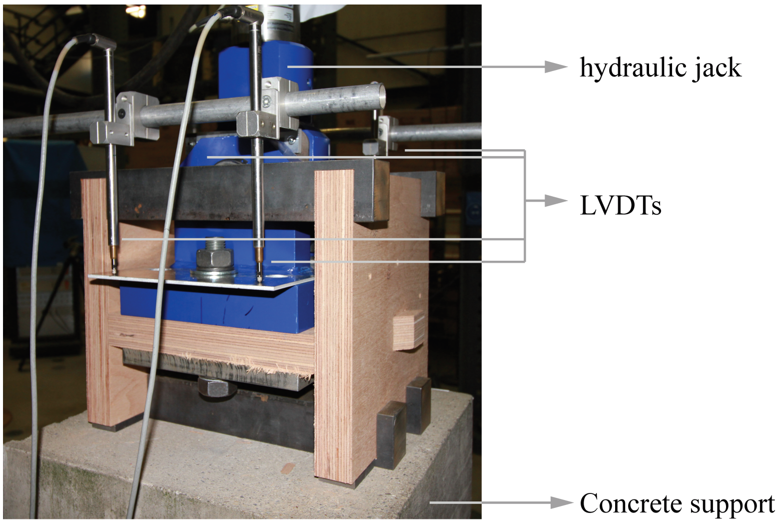


Figure 3: Experimental setup for the determination of the maximum capacity and stiffness of the connection in perpendicular-to-grain compression

3 Results

Results for the three tests are presented in Figure 4, 5 and 6 and are summarized in Table 3. The coefficient of variation c_v was analyse to assess the variability of the results for the maximum force F_{max} and stiffness of the connection k. It is defined as the ratio between the average μ and the standard deviation σ:

$$c_v = \frac{\mu}{\sigma} \quad (1)$$

For all three tests, the coefficient of variation for the maximum capacity F_{max} and stiffness k of the connections was found to be below 10%.

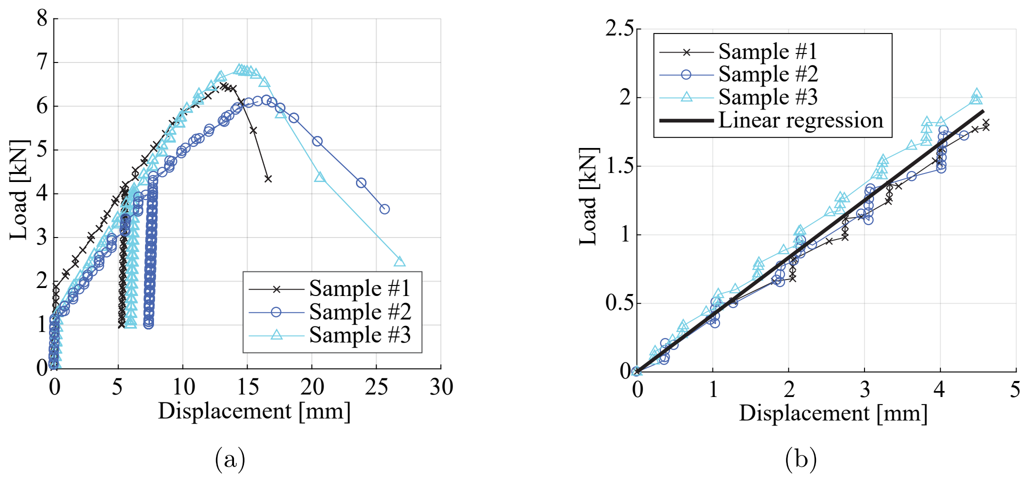
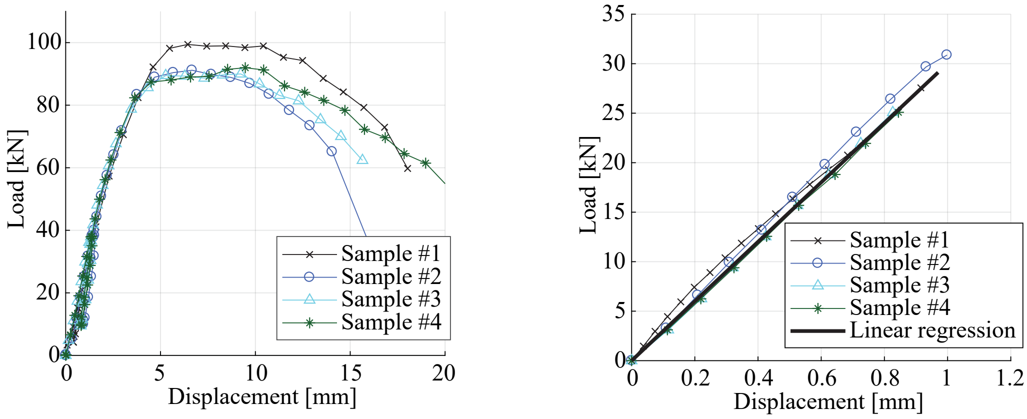
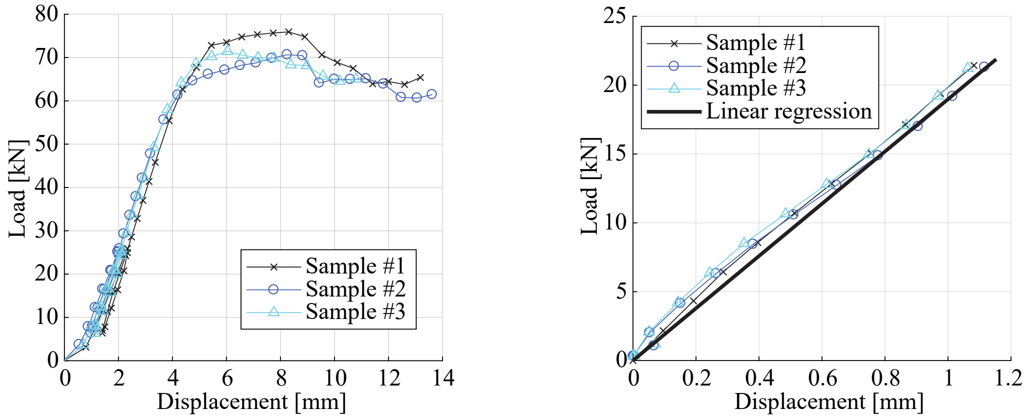


Figure 4: Force-deformation curves for test n°1: entire tests (a) and linear range between 10 and 40 % of F_{max} (b)



(a) (b)

Figure 5: Force-deformation curves for test n°2: entire tests (a) and linear range between 10 and 40 % of F_{max} (b)



(a) (b)

Figure 6: Force-deformation curves for test n°3: entire tests (a) and linear range between 10 and 40 % of F_{max} (b)

Table 3: Results of the three tests performed

	Total samples	$F_{\text{max,avg}}$ [kN]	$c_{v,F_{\text{max}}}$ [%]	k_{avg} [N/mm]	$c_{v,k}$ [%]
Test n°1	3	6.47	5.32	416.81	6.16
Test n°2	4	46.83	4.48	15 0009.24	1.79
Test n°3	3	36.55	3.88	9489.04	2.74

4 Conclusions

Experimental tests allowed to determine the maximum capacity and stiffness of through-tenon joints, which were used in large-scale assemblies of double-layered timber plate structures tested [2], in the their three translational degrees-of-freedom. Coefficient of variations lower than 10% and were considered acceptable for this material. The connections were shown to have a much lower resistance and stiffness in the axial direction and the highest resistance and stiffness in shear. The values obtained can be used in numerical models of large-scale assemblies [2].

References

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