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Strength of t-joints in wooden constructions

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Abstract:

This paper is focused on the determination of mechanical properties and loading capacity for T-joints used in wooden construction. The results can be adapted both in the furniture construction and in the large wooden structure construction. A console like model is used in case of massive wooden furniture structures, MDF or particle board furniture's, dovetail or dowel joints to test the resistance of the connection. Because of the large size of structural elements, only few durability tests of T-joints in larger wooden structures have been performed using real-size samples. However, the obtained test results can easily be homologated. In our experiment the connection of wooden structural elements is realized by means of a metallic bolt with two nuts and two washers. In order to achieve a good shape of the hole the drilling on wood is made by a well sharpened drilling bit. The structural elements tested are made from Abies Alba mill wood, with a density of 0.35 g/cm³, and a humidity of 12%. The samples are tested in a Controlab testing device. The force is applied at regular intervals and the displacement of the samples during testing was measured by means of a LVDT. The performance graphs obtained from the tests show a scaled curve performance of the structural elements tested. The various maximum values achieved are explained by the anisotropy of wood and the presence of defects such as joints, which are inevitable. Wood anisotropy also explains the different times needed for the destruction of the samples.

Keywords: Wood, bolt, strength, mechanical, tests

1. Introduction

Generally, the evaluation of the mechanical characteristics and allowed strains values in the joints of the wooden elements are made taking into account the T-shaped or the L-shaped connections. The results can be adapted both in the construction of furniture as well as in the construction of larger structures of wood. A console like model is used in case of massive wooden furniture structures, MDF or particle board furniture's, dovetail or dowel joints to test the resistance of the connection. For massive wooden furniture structures, MDF or particle board furnitures, dove-tails or dowel joints are made a lot of tests [2; 5; 12]. In some cases, when we deal with the visual evaluation of wood material we have to consider the fact that the evaluator must be a skilled and experienced professional [13]. Because of the large size of structural elements (figure 1), few tests have been performed with real-size samples. The woods are classified according to their mechanical characteristics in resilient classes of resistance, to make possible their interchangeability in the project and to enable based on resistance design [6]. With ever-growing demands for environmental protection, people are addressing ecological materials such as wood. According to the National Inventory of Forestry, sawn timber production is the main function of the forested areas 3 (71%) [1]. It is advisable to use certified and tested products for better safety in the realization of projects. However, sawn timber used in construction is characterized by the presence of structural defects (joints, cracks) and for this reason it is important to make a preliminary classification based on classes of sustainability [7]. Design information is empirical and available for only simple cases. Improvement procedures needs a lot of information about wooden stresses and the stresses that act near the bolt position. Typically is assumed that connectors are placed in such positions that allow them to express the full strength of each (National Forest Products Association 1986). However, in practice space and load requirements often needs the use of multiple fasteners whose end distance and/or bolt spacing is less than sufficient to develop the maximum strength of each bolt individually.

2. Material and Methods

The evaluation and the methods used are defined in the European Standards, such determination of destructive strains (fm, 384) the modulus of elasticity in bending E (m, g, 384) and the density of the wood [4; 11]. Nowadays, the use of wood material is scientifically based and highly efficient [9]. Despite the use of various types of coupling elements such as nails, pins and staples for joining timber elements according to the case of use, the bonds between the elements of mass joints are realized with mechanical elements. Mechanical fasteners are common in timber constructions, as we can see in figure 1.

Figure 1. An example of mechanical fasteners used in wooden constructions

In our case we considered T-joints connections. Johansen's yielding theory [3] assuming plasticity in both the wood and the fastener is the basis of the engineering methods for the design of bolted or nailed joints in timber. Samples are obtained by Abies Alba mill wood, with density of 0.35 g/cm³, with a humidity of 12%, have four sideways perpendicular to each other [8]. Samples are prepared as it is shown in the figure 2. There we can see the two horizontal elements of dimensions 245 x 90 x 42 mm and the vertical element of dimensions 170 x 90 x 35 mm. The screw-bolt diameter is 8 mm.

Figure 2. T-joints taken into consideration for testing

As a testing device we used the Controlab. It can measure the force applied by means of pressure transducer. The force is applied at regular intervals, because of the equipment we have in our disposal. We measure the displacement of the sample during testing by means of a LVDT (Linear Variable Displacement Transformer). It is worth mentioning that wood as an anisotropic material, at a certain point presents different physical-mechanical characteristics in different directions [10]. Joint consist in three wood members: a centre member loaded in compression parallel-to-grain direction and two side members loaded perpendicular-to-grain direction (figure 3).

Figure 3. T-joints sample during test procedure

3. Results and Discussion

The results are based on the testing results of 50 samples in total and are presented in the table 1 as the average values for all samples tested for their strengths.

Table 1. The results of the tests

Sample number	Fmax	Tmax	SFmax	Fmes	SD	Median
	kN	s	mm	kN		kN
1	**2**	**3**	**4**	**5**	**6**	**7**
1-50	16,33	102	12,5	13,56	1,16	12,41

Where:

Sample number - Samples from 1 to 50

Fmax – average maximum force at which elements destruction occurs

Tmax – average time required to achieve this force value and the destruction of element

SFmax - average maximum displacement of the element

Fmes - average strength exercised during the test

SD - standard deviation

Median - a characteristic value (corrected average force)

In the figure 4 is given a picture of a t-joint element tested after the destruction of the element occured

Figure 4. T-joint elemens after destruction

Below in the figure 5 is presented the graph illustrating the tested performance for the sample no. 4. We can see the force-deformation curve that demonstrates the application of force by given intervals, depending by the stroke of the Lucas cylinder.

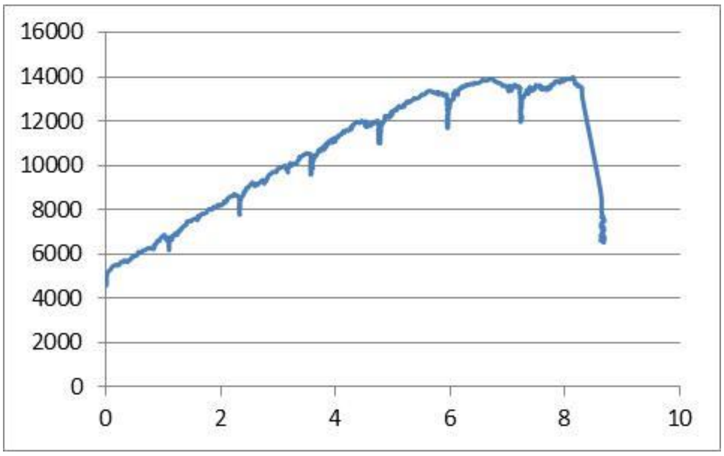

Figure 5. Force – Displacement chart for the sample no. 4

In about 80% of the tested t-joints, the destruction of a connection occurred as a consequence of bolt destruction, because of the exerted force P. The deformation of the bolt and of the t-joint wood elements, starts when the exerted force P exceeds over 3000 to 4000 N. The bolt is deformed in bending, cause the upper part of it works in compression while the rest works in retraction and the deformation grows with the magnitude of the exerted force. Analyzing the fracture mechanics and the results of the measurements it showed out that the bolt or screws are destroyed in retraction as the consequence of the exercise of the force P in bending. In about 20% of the tested t-joints, the destruction of a connection occurred as a consequence of t-joint wood elements destruction. The deformation of the t-joint wood elements, starts when the exerted force P exceeds over 4000 N and occurred in the bolt holes, in transversal bending perpendicular to the fibers of the horizontal wood elements of the t-joint and in axial bending in the horizontal wood element, where the destruction occurred. The bolt embedded into the horizontal wood element of the t-joint, causing the emergence of perpendicular tensionwith the grain. As a consequence the grain starts to break off and the destruction of the wood element continues parallel with grain along the low resistance areas between the spring and autumn wood in the annual ring and the rays parenchyma.

4. Conclusions

From a quick view of the graphs obtained by data processing from the transducers we can see a scaled performance. This is caused by the fact that the pressure is applied manually. Lucas pump should be recycled after each application of force until the end of its range. If we apply the pressure quickly then we will have another, more slopped and unrealistic curve, as force will be exercised at greater speeds. This will also bring the plastic behavior of the element under test as the force will cease to be active. The various maximum values are explained by the anisotropy of wood as well as the presence of different defects in various elements, which are inevitable. Anisotropy also explains the different durability of the bond. To be taken into consideration is also the position of the bolts and tightening them with the connecting elements. The more fixed the bolt will be, the more stable it will be the connection. Frequent and prudent checks should be carried out at regular intervals, as destruction and deformation may arise at any time and measures must be taken to prevent them.

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