

---

**Antonín LOKAJ<sup>1</sup>, Kristýna KLAJMONOVÁ<sup>2</sup>****CARRYING CAPACITY OF ROUND TIMBER BOLTED JOINTS  
WITH STEEL PLATES UNDER STATIC LOADING****ÚNOSNOST SVORNÍKOVÝCH SPOJŮ KULATINY S VLOŽENÝMI OCELOVÝMI  
PLECHY PŘI JEDNORÁZOVÉM STATICKÉM NAMÁHÁNÍ****Abstract**

Aim of this article is in presentation of results of static tests of round timber bolted connections with steel plates. Round timber connections tests in tension were made on pressure machine EU100 in laboratory of the Faculty of Civil Engineering VSB-TU Ostrava. Results of laboratory tests have been statistically evaluated and completed by graphical records of deformation response on loading.

**Keywords**

Round timber, bolt, joint, carrying capacity.

**Abstrakt**

Obsahem příspěvku je prezentace výsledků statických testů svorníkových spojů dřevěné kulatiny s vloženými ocelovými styčnickovými plechy. Testy spojů vzorků kulatiny v tahu byly prováděny staticky v lisu EU100 v laboratoři FAST VŠB-TU Ostrava. Výsledky testů byly statisticky vyhodnoceny a doplněny o grafické záznamy deformační odezvy spoje na zatížení.

**Klíčová slova**

Kulatina, svorník, spoj, únosnost.

**1 INTRODUCTION**

Timber constructions made of round timber become increasingly popular nowadays. It concerns footbridges, bridges, watchtowers ( the tallest round timber watchtower in central Europe was built at Lázně Bohdaneč in 2011, tower height is almost 53 m – Fig. 1 and [2]) or playground equipment. If these constructions are designed with truss supporting system, element connections are often made of bolts with embedded steel plates.

Issue of timber-to-timber joints and steel-to-timber joints is solved by means of bolts in current European standards for design of timber structures ([1]), but this applies only to connections from squared timber. Connections from round timber don't have sufficient support in existing Eurocodes. Problem is also in determination of cyclically loaded round timber joints (fatigue loading in wood e.g. [3] and [4]) or their combination with steel components. Static carrying capacity of

---

<sup>1</sup> Doc. Ing. Antonín Lokaj, Ph.D., Department of Building Structures, Faculty of Civil Engineering, VSB-Technical University of Ostrava, Ludvika Podeste 1875/17, 708 33 Ostrava, tel.: (+420) 597 321 302, e-mail: antonin.lokaj@vsb.cz.

<sup>2</sup> Ing. Kristýna Klajmonová, Department of Building Structures, Faculty of Civil Engineering, VSB-Technical University of Ostrava, Ludvika Podeste 1875/17, 708 33 Ostrava, tel.: (+420) 597 321 925, e-mail: kristyna.klajmonova@vsb.cz.

bolted joints of round timber was explored by researchers in Great Britain, at the Czech Technical University in Prague ([6]) and in another research centres. Bolted joints of steel beams and glulam elements tests results are showed in [7].

It is necessary to know the response of the construction and their connections to static and dynamic loading for reliable structural design of constructions (such as bridges, footbridges, towers or watchtowers) which are subjected to dynamic loading. In the first phase, the most common type of joint was chosen: bolted joint with embedded steel plate subject to axial tension. Test samples were produced then. Samples bolt connections of round timber elements with embedded steel plates were tested for carrying capacity and deformation of a single tension – up to the destruction of joints. carrying capacity and deformation of joints under static loading was measured in this test, results were compared with the calculation of carrying capacity according to current applicable European standard for design of timber structures - [1] (indicating relations for steel-to-timber joint of squared timber). These tests were performed on machinery in laboratory of the Faculty of Civil Engineering at VŠB - Technical University of Ostrava. Based on these tests results, intensity of dynamic loading will be set and joints will be tested under cyclic loading on pulsator.



Fig. 1: Watchtower near Lázně Bohdaneč made of round timber

## 2 DESCRIPTION OF THE TEST SAMPLES

It was necessary to adapt dimensions of the test samples by possibilities of machinery in laboratory of the Faculty of Civil Engineering at VŠB - Technical University of Ostrava. Spruce round timber with diameter 120 mm and sample length 450 mm was used. We used the bolts that were made from HS (High Strength) steel category 8.8 ( $f_y = 640 \text{ MPa}$ ,  $f_u = 800 \text{ MPa}$ ) with diameter 20 mm. Joint plates were from steel category S235 with thickness 8 mm and width 70 mm, holes for bolts had diameter 22 mm. Holes for bolts with diameter 20 mm were made in the round timber. Nine test samples were produced reasonably (Figure 2-A). Tensile tests were conducted on the press EU100 with a recording system (Figure 2-B).

A few nondestructive tests were carried out before start of tests in the press. Aim was to determine the quality of the round timber material, particularly its moisture and density. Test samples were weighed on a laboratory scale, their moisture and dimensions were measured (Figure 3-A). Apparent density and mass density was determined from measured values. The average moisture

was 11,3%. Average value of apparent density reached  $542 \text{ kg/m}^3$ . Average thickness of annual rings was 12,4 mm, it confirms the relatively high measured density values and the quality of the tested round timber. Average penetration depth measured with penetration device PILODYN 6J was 10,9 mm, this corresponds to mass density of round timber  $430 \text{ kg/m}^3$  (according to the relations in [5]).



Fig. 2-A/B: Tested sample in the press (A - left), the press EU 100 with sample (B - right)

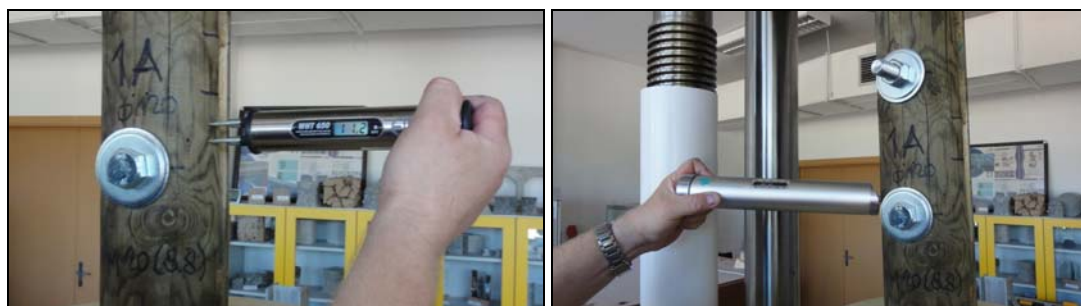


Fig. 3-A/B: Humidity measuring of sample (A – left), testing with PILODYN 6J (B –right)

### 3 COURSE OF TESTS

Testing was proceeded in the press EU100, while tension force was increasing gradually. The choosen rate of displacement of jaws of the press seems to be optimal, because destruction of all tested samples appeared in time-boundary  $300 \pm 120 \text{ sec}$ , which corresponds to interval of laboratory tests for short-time strength according current European standards for timber structures.

Diagram of increasing of tension force during time is in Fig. 4. Fig. 5. shows relation between displacement (eg. elongation) of the joint and tension force working in the joint.

The weakest part of the joint should be steel bolt, according to relations for double shear joints steel to timber type with steel plate inside, even if this bolt is designed from high strength steel. Destruction of the joint should have been caused by achievement of plastic carrying capacity of bolt in bending and by setting of plastic hinge. Deceleration of increase of the force during testing time can be observed on Fig. 4 and a similar clearly deceleration of increase of force in relation to increase of displacement can be observed on Fig. 5. It indicates plastic reshaping of the bolt. All testing samples collapsed by disruption of the sample (Fig. 6). Disruption of the sample was caused by exceeding of timber strength in tension perpendicular to the grains, but a block shear collapse was not observed. Fracture of the bolt was not observed in any test.

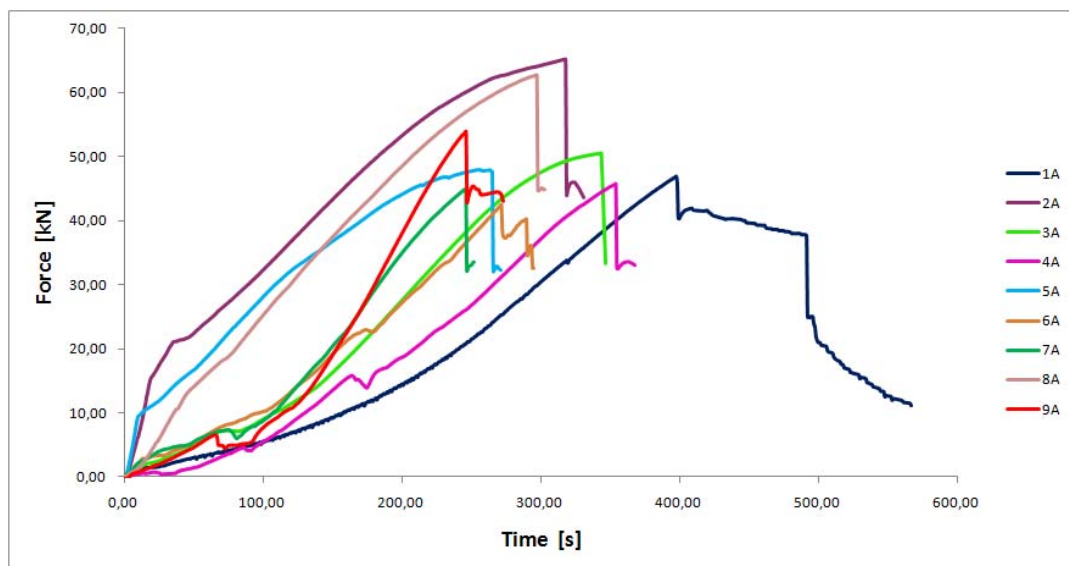


Fig. 4: Tension force increase in the joint during time

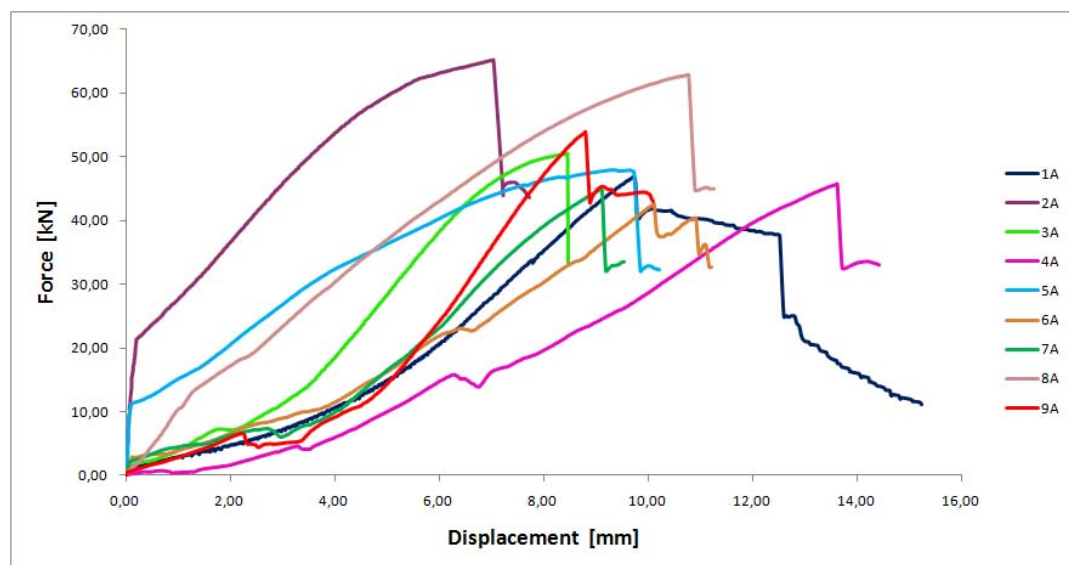


Fig. 5: Relation between tension force in the joint and displacement of the the joint



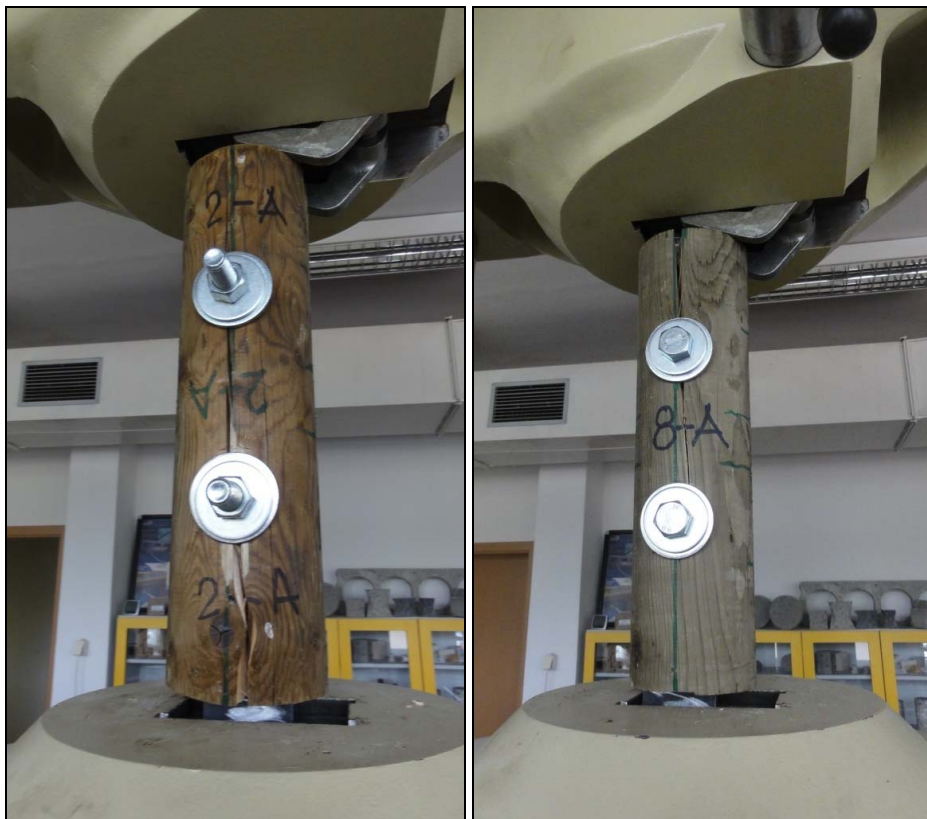


Fig. 6: Collapse of testing samples in the press EU100

#### 4 TESTS RESULTS

Results of the joints carrying capacity obtained from laboratory tests and values calculated by [1] with actual values of timber density are shown in Tab. 1. We are not able to explicit conclusions due to limited number of samples, but response of all tested samples of joints to loading shows some similar signs. After initial displacement of the joint (displacement about 5 mm), which was caused by different diameter of bolt and a hole in steel plate, there follows almost linear phase of “working diagram“ of the joint up to 80% of maximal carrying capacity. Audible cracking was observed over this border and “plastic“ phase of the joint displacement occurred, e.g. displacement of the joint was increasing more than adequate increasing of force (see Fig. 5). Rapid disruption of timber element in the area between bolt and the end of round timber occurred in final phase (Fig. 6). Although joints carrying capacity of all tests shows relatively large variability (from 43 kN to 65 kN), we are able to conclude, that measured joints carrying capacity values are relatively well corresponding with values calculated according to [1] with actual values of round timber density.

Tab. 1: Results of the joints carrying capacity obtained from laboratory tests and calculating

	$F_{V,Rk,1}$ [kN]	$F_{V,Rk,2}$ [kN]	$F_{V,Rk,3}$ [kN]	$F_{V,Rd,VYP}$ [kN]	$F_{V,Rd,TEST}$ [kN]
$\mu$	35,54	32,03	49,64	<b>49,28</b>	<b>50,29</b>
$SD$	0,96	0,52	0,71	<b>0,80</b>	<b>5,95</b>
$V$ [%]	2,71	1,63	1,44	<b>1,63</b>	<b>11,82</b>

Where:

$F_{V,Rk,i}$  are characteristic values of double shear joint (steel to timber) in one shear for particular way of destruction calculated according to [1] ;

$F_{V,Rd,VYP}$  is design value of double shear joint (steel to timber) calculated for  $k_{mod} = 1,0$  and  $\gamma_M = 1,3$ ;

$F_{V,Rd,TEST}$  is design value of double shear joint (steel to timber) obtained from laboratory tests;

$\mu$  is mean value of corresponding variable;

$SD$  is standard deviation of corresponding variable;

$V$  is variation coefficient of corresponding variable.

## 5 CONCLUSION

These results of static testing of round timber bolted joints with inserted steel plates indicate well corresponding with calculated values, in spite of relatively large variability of measured values. Obtained values will be used during following tests of these joints, which will be exposed to multicyclic (passing) loading.

## ACKNOWLEDGEMENT

This outcome has been achieved with funds of conceptual development of science, research and innovation for the year 2012 assigned to VŠB-TU Ostrava by Ministry of Education Youth and Sports of the Czech Republic.

## REFERENCES

- [1] ČSN EN 1995-1-1. Eurocode 5: Design of Timber Structures – Part 1-1: Common rules and rules for buildings. Czech Standards Institute, Praha, 12/2006.
- [2] STRAKA, B., ŠMAK, M. Joints with steel elements in timber structures. In Proceedings of International conference *Timber structures 2011 (in Czech)*. Volyně, 20. and 21. of . 2011. Pp. 151-158. ISBN 978-80-86837-33-8.
- [3] MALO, K. A. et al. Fatigue Tests of Dowel Joints in Timber Structures, Part II: Fatigue Strength of Dowel Joints in Timber Structures. Nordic Timber Bridge Project, ISBN 82-7120-035-6. Nordic Timber Council AB, Stockholm, Sweden, 2002.
- [4] SMITH, I. et al. *Fracture and Fatigue in Wood*. John Wiley & Sons, England, 2003.
- [5] KUKLÍK, P., KUKLÍKOVÁ, A. Nondestructive Testing of Solid Timber. In Proceedings of *International Conference on Wood and Wood Fiber Composites*, Stuttgart, 2000, Pp. 303-312.
- [6] KUKLÍK, P. *Timber Structures (in Czech)*, Praha 2005, ISBN 80-86769-72-0.
- [7] LOKAJ, A. et al. *Timber Houses and Timber Structures, I. and II. chapter (in Czech)*. CERM Brno, 2010, ISBN 978-80-7204-732-1.

## Reviewers:

Doc. Ing. Bohumil Straka, CSc., Institute of Metal and Timber Structures, Faculty of Civil Engineering, Brno University of Technology.

Doc. Ing. Jaroslav Sandanus, PhD., Department of Steel and Timber Structures, Faculty of Civil Engineering, Slovak University of Technology in Bratislava.