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ESTIMATION OF YIELD LOAD OF BOLTED TIMBER JOINTS

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ABSTRACT: Four approaches for estimation of yield load of bolted timber joints based on US 5% bolt diameter offset, Karacabeyli and Ceccotti, CEN and CSIRO have been analyzed. Single double-shear bolted timber joints with wood (Bulgarian Scots pine) and steel side members have been tested in compression perpendicular to the axes and parallel to the grain. The yield loads from experimental load-displacement curves have been determined graphically according to mentioned methods and the percentages of yield load to the maximum load were calculated. Investigated methods can be shown to predict the yield load relatively well. The method of Karacabeyli and Ceccotti, Germany and method of CSIRO, Australia could be used to predict the yield load of bulgarian wood-wood and wood-steel bolted timber joints from Scots pine with the same degree of accuracy. Eurocode 5 method predicts maximum values for yield load compared to the other methods.

KEYWORDS: yield load, load-displacement curves, bolted joints, timber structures

❖ INTRODUCTION

The basis of the plastic theory for determining the strength of bolted timber joints is the determination of the yield load. This approach is employed all over the world, even in Asia [1-8]. Load at the yield point is used for calculation of yield strength. Also, the bearing strength of the wood beneath the bolt is determined at the yield point. This factor is used for estimation of the influence of the ratio of the bearing length c to the bolt diameter (c/D) on the bolt-bearing stress at the yield limit state (yield point) [2, 5, 7].

Nowadays prediction of yield load has been accepted as basis for the limit state method of the design. Currently, there are many different methods in determining yield loads for timber joints including examples, cited in [4] by Jumaat, Z. and Murty, B.(2004): Johansen (Heine 2001), Foschi (1974), Smith (1987), the US 5% dowel diameter offset, and examples, cited in [1] by Chui, Y., Smith, I. and Chen, Z (2006): Harding and Fowkes (1884), Karacabeyli and Ceccotti (1996), Eurocode 5 (2004) and CSIRO (1996).

The objectives of this study include analyzing of four methods for estimation of yield load and comparing the suitability of these methods for predicting yield load of “wood-wood” and “wood-steel“ bolted timber joints from bulgarian Scots pine.

❖ MATERIALS AND METHODS

Single double-shear bolted joints with wood and steel side members have been tested in compression perpendicular to the axes of bolts and parallel to the grain [7-9]. The joint sample is presented on Fig.1. The sizes of the members are described in [7-9]

Wooden joint members were cut from Scots pine and were conditioned to a moisture content of 12% before being machined to final dimensions within a tolerance of ±0,4 mm. As side members matched pairs of cold-rolled mild steel (ASt3 BDS 2592-71) plates were used. Bolt holes were cut in both wooden and steel plates with a bolt clearance of 0,4 mm. Steel bolts M8, M10 and M12 were used. Washers were used beneath bolt heads and nuts.

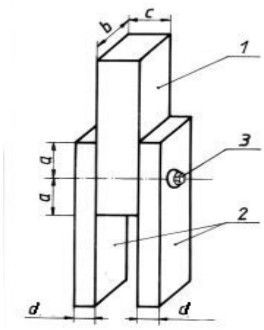

Figure1. Bolted joint sample

Bolted timber joints were tested in compression perpendicular to the axes and parallel to the grain on the test stand which is described in detail in [9]. Joint slips have been measured and load-displacement curves have been plotted. They are presented on Fig.2 for bolted joints with wood side members (wood-wood joints) and on Fig.3 for joints with steel side members (wood-steel joints).

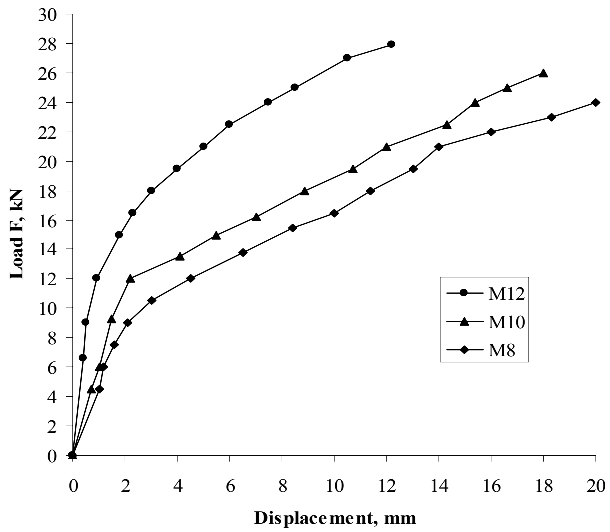

Figure 2. Load-displacement curves for wood-wood joints

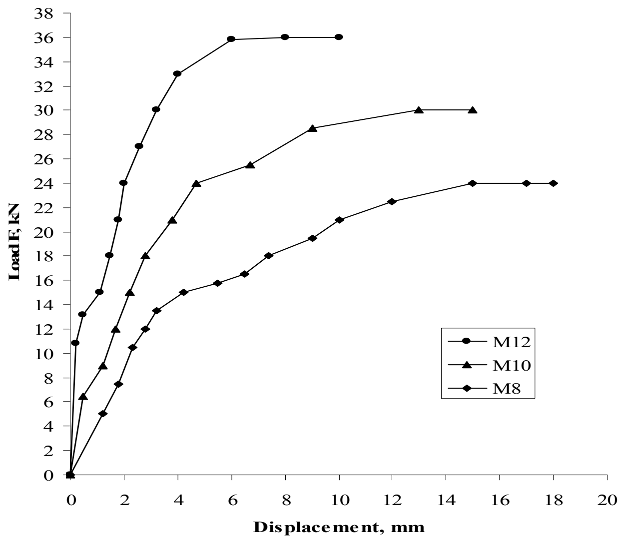

Figure 3. Load-displacement curves for wood-steel joints

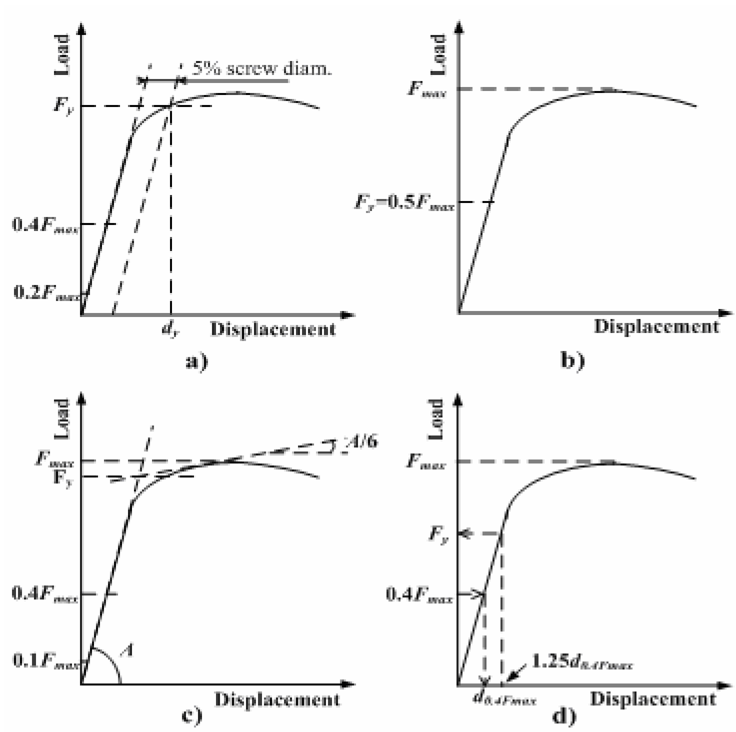

Figure 4. Methods to estimate yield load

Four approaches for determining yield loads of investigated bolted timber joints, were used in this study. The first is the US 5% dowel diameter offset according to [6], the others are according to [1, 3] - methods by Karacabeyli and Ceccotti (1996), Eurocode 5 (2004) and CSIRO (1996). The principle of each of these four approaches for determining yield loads is illustrated in Fig.4.

The US 5% dowel diameter offset method is accepted by ASTM in 1996. This standard defines the yield load at the intersection of the initial stiffness line (0,2P_{max} and 0,4P_{max}), defined in the linear portion of the load-displacement curve offset by 5 percent of the dowel diameter with the load-displacement curve – Fig.4, a).

Karacabeyli and Ceccotti (1996, Germany) offer yield load of ½ from the maximum load - Fig.4, b).

According to Eurocode 5, the yield load is determined as intersection of the initial line defined from 0,1P_{max} and 0,4P_{max} points with the line under inclination A/6 to the point P_{max} – Fig.4, c).

CSIRO (Commonwealth Scientific and Industrial Research Organization) method (1996, Australia) determines yield load at 1,25.$d_{0,4Pmax}$ – Fig.4, d).

❖ RESULTS AND DISCUTION

The yield loads have been determined graphically by the mentioned above four methods for investigated wood-wood and wood-steel timber joints and are shown in Table 1. The percentages of yield load to the maximum load were also calculated and shown in Table 1.

It is obviously from Table 1 that yield loads, determined by the method of Karacabeyli and Ceccotti (Fig.4, b) and the method of CSIRO (Fig.4, d) are close especially for both kind of bolted timber joints: wood-wood and wood-steel.

For wood-wood joints the values of yield load determined by US 5% method (Fig.4, a) are close to these, determined by methods of Karacabeyli and Ceccotti and CSIRO. For wood-steel joints the values of yield load for US 5% method and Eurocode 5 are close, especially for bigger dowel diameters.

The maximum values of yield loads are obtained for method Eurocode 5 for all kind of bolted timber joints. Also, percentages of yield load to the maximum load are the biggest for this method

The percentages of yield load to the maximum load are close for methods of Karacabeyli and Ceccotti and CSIRO for all kind of bolted timber joints.

Table1. Comparison of methods for estimation of yield load

Kind of joint	Dowel diameter, mm	P_{max}, kN	Yield load P_y , kN				P_y / P_{max}, %			
			US 5%	Karacabeyli and Ceccotti	Eurocode 5	CSIRO	US 5%	Karacabeyli and Ceccotti	Eurocode 5	CSIRO
wood-wood	8	24	9	12	18,4	10,4	37,5	50	76,7	43,3
	10	26	12	13	20,4	12,2	46,1	50	78,5	46,9
	12	28	15,5	14	23,7	15,2	55,3	50	84,6	54,3
steel - wood	8	24	14	12	20,4	11,0	58,3	50	85	45,8
	10	30	20	15	25,5	14,2	66,7	50	85	47,3
	12	36	30	18	33,7	17,8	83,3	50	93,6	49,4

From Table 1 it appears that the method of Karacabeyli and Ceccotti and CSIRO method could be used to predict the yield load of bulgarian wood-wood and wood-steel bolted timber joints from Scots pine with the same degree of accuracy. Obviously, Eurocode 5 method predicts the maximum values for yield load and maximum percentages of yield load to the maximum load compared to the other methods.

❖ CONCLUSIONS

From comparisons all investigated methods can be shown to predict the yield load of Bulgarian bolted timber joints relatively well.

The method of Karacabeyli and Ceccotti, Germany and method of CSIRO, Australia could be used to predict the yield load of bulgarian wood-wood and wood-steel bolted timber joints from Scots pine with the same degree of accuracy.

US 5% method, the methods of Karacabeyli and Ceccotti and CSIRO predict the values of yield load with the same degree of accuracy for wood-wood joints, but for wood-steel joints the US 5% method and Eurocode 5 predict close results for values of yield load.

Eurocode 5 method predicts the maximum values for yield load and maximum percentages of yield load to the maximum load compared to the other methods.

Clearly, estimates of yield load are sensitive to the method of their estimation, and there is no uniformity in international practice in that respect.

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