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Investigation on mechanical connections with birch plywood gusset plates



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Background

The construction industry is increasingly driven by sustainability concerns, prompting a search for alternative materials with a low environmental footprint, such as engineered wood products. Nowadays, connections of timber elements are still performed by the use of steel plates. However, steel plates can be replaced by plywood made of birch since it has superior mechanical properties compared to plywood made from softwood (Wang et al. 2021, 2022; Crocetti et al. 2021; Werner Åström, 2019). Besides, the capacity calculation for this connection according to the standards is conservative, meaning that the efficiency is low and the actual capacity could be much higher than the design value (Rossi et al. 2016). This research aims to enhance the knowledge and the design process of timber-to-timber connections with birch plywood (BP) plates.

Keywords: birch plywood, mechanical connection, rope effect.

Experimental

In this study, both screwed and dowelled timber-to-timber connections in double shear with two BP gusset plates were tested under uniaxial tension with grain angle parallel to the loading direction. The tests were performed according to standard ISO 6891-1983 (E) (ISO, 1983). Each specimen was designed to achieve a ductile failure with the bending of the connectors, as shown in Figure 1. In the capacity calculations, the input values used, such as the yielding moment of the connector and the embedment strength of the timber, were obtained through laboratory tests.

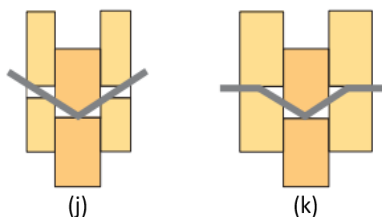


Figure 1. Ductile failure modes in timber-to-timber joints (Swedish Wood).

The failure mode with the formation of one plastic hinge (j) was predicted for thinner BP plates, while the failure mode with the formation of three plastic hinges (k) was predicted for

both screwed and dowelled connections only for the thickest BP plate, i.e. 42mm. For each type of connection, four different birch plywood plate thicknesses were tested, i.e. 15, 21, 30 and 42mm, to check their influence on the capacity and the failure mode. Each test series consists of 3 replicates.

Results and Discussion

In Table 1 and Figure 2, the predicted capacity for each test series is compared to the mean value of the test results.

Table 1. Comparison between predicted capacity and test results

BP thickness, mm	Screwed connection			Dowelled connection		
	Predicted capacity, kN	Mean test results, kN	Ratio	Predicted capacity, kN	Mean test results, kN	Ratio
15mm BP	21.0	26.6	1.26	21.3	23.7	1.11
21mm BP	24.1	27.1	1.12	23.2	23.8	1.02
30mm BP	29.7	43.5	1.47	27.4	32.7	1.20
42mm BP	34.4	46.0	1.34	31.7	35.7	1.13

It is possible to see that for the dowelled connections the predictions are very similar to the test results. The highest difference is about 20% for the BP plate of 30mm thickness, while it is around 10% or less for the others. The screwed connections showed a higher difference between the predicted and test capacity, up to almost 50% for the BP plate of 30mm. The higher difference for the screw connection could be explained by the rope effect given by the threaded part of the screw that is activated when the connector bends under loading. This effect is already taken into account in the calculations, however, it is calculated through an empirical formula which is conservative to avoid overestimation of the capacity.

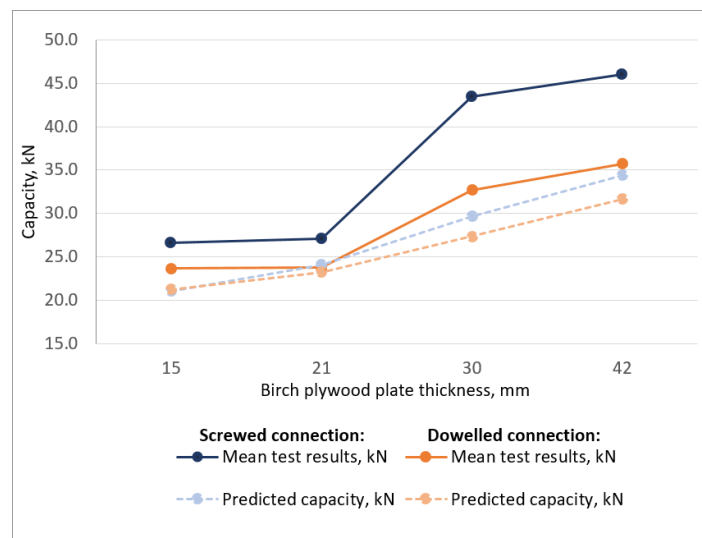


Figure 2. Predicted capacity and mean test results.

The failure mode is according to the predictions, however, the external plastic hinges are sometimes not clearly visible in the screwed connection for 42mm BP.

Conclusions

The test results have shown higher capacity than the prediction, especially for the screwed connections due to the rope effect. This means that there is a need for a more accurate model to predict the contribution of the rope effect to the connection capacity.

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