ABSTRACT: In Australia CLT has a big potential but has to be imported from overseas to date for quite high prices. Milling of Pinus Radiata using optimised sawing patterns for yield and consecutive mechanical grading lead to a substantial amount of boards, which cannot be used for structural purposes directly. Therefore it should be economically interesting to produce CLT using this resource. The authors performed a considerable amount of mechanical tests using various setups and optimised layups in order to investigate the mechanical properties of Pinus Radiata CLT using non-structural boards. The results showed that depending on the layup of the CLT the used resource leads to a product that performs similarly to the ones on the market in Europe.

KEYWORDS: CLT, Pinus Radiata, material testing, low grade timber

1 INTRODUCTION

Cross laminated timber (CLT) is quite established in Europe and finds many applications in housing and multi-story timber construction transmitting high loads in floors and walls. In Australia CLT is only used scarcely and has to be imported to quite high prices for the time being. The Australian housing construction differs quite a lot from the European construction types and most timber houses are built from small standard sections. As all construction timber in Australia is mechanically graded quite a substantial amount of the timber is down-graded as non-structural and has to be sold at low prices. The applied sawing patterns also result in a considerable amount of wing boards presenting nearly defect free timber, boards including the pith and short boards unsuitable for standard construction purposes. Such boards and certain dimensions cannot be used for structural applications.

2 OBJECTIVES

It should be economically interesting to produce CLT using this resource. This however asks for optimised layups using the given, at times extremely low mechanical properties of the available resource trying to match strength and stiffness requirements of the final product for structural applications. The objective of the presented research was to investigate in statistically sufficient quantity the very rough input material, the minimum override grading rules, the properties of used boards and the resulting properties of CLT products carrying load flat and on edge. Furthermore various layups should lead to similar strength and stiffness as standard European CLT using C24 / C20 input material.

3 MATERIAL AND METHODS

Four different types of Australian Pinus Radiata boards were used to produce the CLT: 35x70mm non-structural boards, 35x70mm machine grade MGP12, 25x150mm “wing boards” and 40x200mm “heart-in” boards. Only a small quantity of MGP 12 boards was used for best properties and in order to allow a comparison of the results with CLT produced with C24 and C16 Picea Abies boards. All panels and layers were produced without edge-gluing. The Pinus Radiata CLT was produced using an industrial production facility in Switzerland. Various grading rules were applied to the non-structural and wing boards with the goal to increase the strength and to ensure a smooth production process.

Tension tests were done in order to estimate the strength and the potential of the different board types. The specimens had a length of two metres and the full cross section was tested. Based on these tests some basic grading rules were established and the attribution of the boards to inner or outer layers in the panel section was defined.
The CLT panels were tested in four point bending and shear-bending according to the draft version of prEN 16351 “Timber structures – Cross laminated timber - Requirements” (WI 124.128). The four point bending tests proposed in this standard correspond to the EN 408 (Figure 1) requirements. The CUAP in order to possibly achieve an ETA for solid wood slab elements was also considered. The local and global bending stiffness, the bending strength and the shear strength were determined. The CLT was tested for plate and panel action as proposed in the WI 124/128. The specimens for plate action presented a minimum with of 300mm or three times the board width. The specimens for panel action had a height of 300mm.

**Figure 1: Test setup as used for the four point bending tests**

The shear-bending test proposed in WI 124.128 is a four point bending with reduced distances (2.5h) between the support and the loading point. To simulate the case that the layers are produced without edge-gluing the outermost layers present a horizontal cut at the neutral axes to provoke shear failure for tests in panel action.

**Figure 2: Test setup as used for shear-bending for specimens tested in plate action and common failure mode**

The tests on the CLT panels were done in two series. The aim of the first series was to investigate several layups and grading regimes. At this stage eight different layups were produced and tested. In a second series the three most promising layups were produced and tested. For each layup 5 to 10 panels with the dimensions of 1.5 to 6 meters were produced. From each panel all test specimens were cut. 70 panels with eleven different layups and/or qualities of CLT were tested that adds up to 280 bending tests.

**4 RESULTS**

The tension tests on non-structural boards showed that in view of the production a minimum grading has to be applied. A rough visual override and the docking of the largest defects leads to a substantial improvement of the tension strength of non-structural boards. Such material is placed in the core layers only if high bending strength is requested. In order to reach high strength surface layers a more thorough grading has to be done, but the yield is quite low. The wing boards showed very promising properties and can be used as surface layer for all applications. The heart-in boards showing low density and poor mechanical properties are only used as core layer for CLT used in plate action. MGP12 boards substantially increase CLT properties that meet the expectations.

MGP should be used if a high bending resistance is requested (e.g. for floors). The three layer boards showed a clear tendency to fail due to rolling shear in the core layer even in the bending test. All layups failed due to rolling shear if the shear-bending setup was used. The stiffness of the CLT especially for three layer boards is promising (Figure 3).

**Figure 3: MOE (section regarded as homogeneous material) of specimens tested for plate action. P11 => 3 layer 70mm; P13 => 5 layer 134mm; P14 => 7 layer 202mm**

The results and measurements of this tests series allow calculating the properties of the CLT in transversal direction. Furthermore loadbearing capacities of other layups may be estimated.

**5 CONCLUSIONS**

This investigation showed that it is possible to produce CLT using Australian non-structural *Pinus Radiata* mainly. In order to get high performance MGP12 or wing boards have to be used for the surface layer. The non-structural boards have to undergo a coarse grading in order to get a smooth production process and to ensure minimum quality requirements of the final product. If the bending strength is not critical (e.g. for walls) coarse graded non-structural boards can also be used as surface layer.

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