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Analysis of the fracture behavior of Radiata Pine timber and Laminated Veneer Lumber

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ABSTRACT

The investigation of the failure mechanism of the fracture mode I and II and the mixed mode of New Zealand Radiata Pine timber and of Radiata Pine Laminated Veneer Lumber is presented. Different test setups were compared and used for the determination of the material parameters fracture toughness and fracture energy. Furthermore, the differences, advantages and disadvantages of Radiata Pine Laminated Veneer Lumber versus solid wood are presented. The investigations show that Radiata Pine Laminated Veneer Lumber is more ductile than Radiata Pine timber.

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1. Background

Typical timber constructions consist of members and also joints, notches or holes which can lead to high stress singularities in the structure. Fracture mechanic gives the possibility to characterize situations with stress singularities which can lead to a failure including crack initiations and crack propagations. For the prediction of failures or load capacities, the fracture mechanics methods are used in new design proposals. However, important material parameters such as the critical fracture energy or the fracture toughness have to be known. International research results are published for solid wood e.g. in Radiata Pine by King et al. [1], in European Spruce e.g. by Franke [2], Aicher et al. [3], Valentin et al. [4], Larsen and Gustafsson [5] or in Canadian Spruce by Smith et al. [6] or Vasic [7]. For engineered wood products, only a portion of the values are published, e.g. Stanzl-Tschegg and Navi [8], Niemz et al. [9,10]. The trend to large scale and multistory timber constructions requires high performance wood products with increased strengths and stiffness. In order to allow the analysis of failures in structures made of Radiata Pine timber (RP) or Laminated Veneer Lumber (LVL), a study to determine the fracture energy and fracture toughness was initiated. The research results presented include the investigation of the failure behavior of New Zealand Radiata Pine LVL compared to timber. The difference, possible advantages or maybe disadvantages of LVL versus timber are investigated and compared with published international experimental test results.

When investigating the failure behavior, different test setups are available to study the different fracture modes. The fracture mechanic method distinguishes three different failure modes, as shown in Fig. 1. They are: failure mode I – cracking under transverse tension stress in relation to the crack plane, mode II – cracking under in plane shear stress and mode III – the failure under out of plane shear stress. The so-called mixed mode failure is a combination of the mode I and mode II. The fracture modes I and II and for some cases, the mixed mode failure were investigated in experimental test series. None

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Nomenclature

E'	specific modulus of elasticity (MPa)
F	load (N)
F_c	critical load (N)
G	shear modulus (MPa)
G_f	energy release rate (Nm/m^2)
G_c	critical fracture energy (Nm/m^2)
K	stress intensity factor (SIF) (kN/m$^{3/2}$)
K_c	fracture toughness (kN/m$^{3/2}$)
Y	form function of the geometry (–)
a	crack length (mm)
a_c	corresponding crack length at critical load (mm)
d	thickness of the specimen (mm)
h	depth of the specimen (mm)
u	displacement (mm)
α	loading angle of the system (°)
β	annual growth ring (°)
σ	stress (MPa)
ρ	density (kg/m^3)
I	index for fracture mode I (–)
II	index for fracture mode II (–)
III	index for fracture mode III (–)

of the test setups available for the different failure modes are approved or standardized for wood. Therefore different methods were used and are compared for the same stress situation.

2. Material and method

2.1. Material and specimens

New Zealand Radiata Pine timber and LVL were used for the analysis of the failure behavior of solid wood and wood product respectively. New Zealand Radiata Pine is a relatively fast growing plantation pine species which is fully grown after approximately 20–30 years. The timber used grew in a relatively constant climate on the North Island of New Zealand. The growth ring width was 10 mm on average and the specimens were without major defects. The timber was conditioned in an environment with a temperature of 20° Celsius and a relative humidity of 65%. At testing, the average moisture content from the test specimens was 11.4% and the mean density was 486 kg/m^3.

LVL is a wood product manufactured from rotary peeled veneer layers glued together to form slabs. The veneers are 3–4 mm thick and in general laid up with parallel to grain direction. Natural defects such as knots are more homogenously distributed, which lead to higher strength and less variation in comparison to timber. Even if there are small derivations between the grain directions of the veneers due to the practical production, which might influences the properties and e.g. the response in the post peak-resistance behavior; LVL shows no behavior related to cross-laminations and the influences are respected in the variations of the properties. LVL products are used in houses and large span buildings as structural members. The hyspan90 product from the Carter Holt Harvey company from the North Island of New Zealand was used. The LVL specimens were also stored in the conditioned environment chamber. The average moisture content of the LVL test specimens was 8.9% and the mean density was 600 kg/m^3.

For the consideration and investigation of the influence of the anisotropic material behavior of solid wood on the fracture energy in the different material directions, three different crack systems, RL, TL and NL were tested, as shown in Fig. 2. The

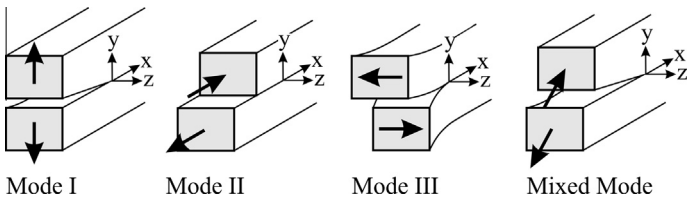

Fig. 1. Different test setups for the fracture mode I, II and III and the mixed mode.

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