Effect of Rolling Shear Modulus and Geometric Make up on the Out-Of-Plane Bending Performance of Cross-Laminated Timber Panel

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Abstract : Cross-laminated timber (CLT) is made from layers of timber boards orthogonally oriented in the thickness direction, and due to this, CLT can withstand bi-axial bending in contrast with most other engineered wood products such as laminated veneer lumber (LVL) and glued laminated timber (GLT). Wood is cylindrically anisotropic in nature and is characterized by significantly lower elastic modulus and shear modulus in the planes perpendicular to the fibre direction, and is therefore classified as orthotropic material and is thus characterized by 9 elastic constants which are three elastic modulus in longitudinal direction, tangential direction and radial direction, three shear modulus in longitudinal tangential plane, longitudinal radial plane and radial tangential plane and three Poisson's ratio. For simplification, timber materials are generally assumed to be transversely isotropic, reducing the number of elastic properties characterizing it to 5, where the longitudinal plane and radial planes are assumed to be planes of symmetry. The validity of this assumption was investigated through numerical modelling of CLT with both orthotropic mechanical properties and transversely isotropic material properties for three softwood species, which are Norway spruce, Douglas fir, Radiata pine, and three hardwood species, namely Victorian ash, Beech wood, and Aspen subjected to uniformly distributed loading under simply supported boundary condition. It was concluded that assuming the timber to be transversely isotropic results in a negligible error in the order of 1 percent. It was also observed that along with longitudinal elastic modulus, ratio of longitudinal shear modulus (GL) and rolling shear modulus (GR) has a significant effect on a deflection for CLT panels of lower span to depth ratio. For softwoods such as Norway spruce and Radiata pine, the ratio of longitudinal shear modulus, GL to rolling shear modulus GR is reported to be in the order of 12 to 15 times in literature. This results in shear flexibility in transverse layers leading to increased deflection under out-of-plane loading. The rolling shear modulus of hardwoods has been found to be significantly higher than those of softwoods, where the ratio between longitudinal shear modulus to rolling shear modulus as low as 4. This has resulted in a significant rise in research into the manufacturing of CLT from entirely from hardwood, as well as from a combination of softwood and hardwoods. The commonly used beam theory to analyze the performance of CLT panels under out-of-plane loads are the Shear analogy method, Gamma method, and k-method. The shear analogy method has been found to be the most effective method where shear deformation is significant. The effect of the ratio of longitudinal shear modulus and rolling shear modulus of cross-layer on the deflection of CLT under uniformly distributed load with respect to its length to depth ratio was investigated using shear analogy method. It was observed that shear deflection is reduced significantly as the ratio of the shear modulus of the longitudinal layer and rolling shear modulus of cross-layer decreases. This indicates that there is significant room for improvement of the bending performance of CLT through developing hybrid CLT from a mix of softwood and hardwood.

Keywords : rolling shear modulus, shear deflection, ratio of shear modulus and rolling shear modulus, timber
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