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Tests and models for engineered wood product connections using small steel tube fasteners

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ABSTRACT

Laminated Strand Lumber (LSL) is a type of engineered wood product widely used as a substitute for sawn structural lumber. This is because LSL can be manufactured to have superior mechanical and physical performance to competing products, including high resistance to splitting, high strength and dimensional stability. The authors studied connections in LSL with behaviour of similar connections in sawn Spruce lumber as a benchmark. Proneness to splitting is the Achilles heel of most wood-based construction materials and especially products like sawn lumber and glued-laminated-timber. This characteristic makes it especially difficult to make connections that are mechanically efficient. However, when constructing with LSL it is possible to create connections that not only have desirable response characteristics, but also achieve labour efficiencies. The particular type of connection studied by the authors uses small diameter steel tube fasteners inserted in tight-fitting holes in conjunction with steel plate elements located in slots in ends of joined members and links them together. Tube fasteners are driven perpendicular to the axes of wood members and pass through both those members and steel link elements. Tests were conducted under static tensile loads with multiple-fastener arrangements obeying spaced and end distance rules typical for solid bolts in sawn softwood lumber. The response was highly ductile and failure occurred mainly in the fasteners. Consequently the so-called European Yield Model (EYM) for doweled timber connections yields good predictions of connection strengths. A detailed finite element analysis was also performed to assist interpretation of test results and validate predictions from the EYM beyond the range of test data. The finite element model was developed using the ABAQUS software and results from that model agreed closely with experimental findings in both qualitative and quantitative aspects.

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1. Introduction

Connections play an important role in determining the overall performance of any engineering structure. Ability to provide ductile connections gives designers scope to better prevent collapse of overall structural systems, to provide energy absorption in the case of partial collapses or capacity reserves in the case of statically redundant systems. How to select an appropriate combination of member (type of material, size and geometry), fasteners (e.g. nails, screws, plain dowels, bolts) and fastener layout to achieve ductility is arguably the most challenging part of engineering design in wood. Commonly wood connections fail prematurely by wood splitting, that is before each fastener can achieve the failure mode, which is the upper bound on strength per fastener [1]. This reflects that solid wood (sawn lumber, glued-laminated-timber) and engineered wood products like laminated veneer lumber and parallel strand lumber have low fracture toughness for modes where fracture planes lie parallel to the strong axis of material symmetry [2]. Laminated Strand Lumber (LSL) is a structural composite lumber product manufactured from sliced wood strands that are aligned mostly, but not only, parallel to the longitudinal axis of the manufactured member and bonded together with isocyanate-based adhesives [3]. Because of cross-laminating between cells in wood strands, LSL has high fracture toughness relative to most other solid wood products and is therefore much more resistant to splitting than say sawn lumber.

The aim of the work discussed here was to identify combinations of wood like member materials and fasteners capable of resulting in high performance connections. In generic qualitative terms, high performance equates to relatively high initial stiffness, well-defined yielding (in terms of the envelope defining the load–displacement response), high ultimate load capacity and high levels of inelastic deformation (as expressed in terms of the ductility ratio). LSL was chosen as the member material because of its high fracture toughness. Sawn Spruce lumber (*Picea mariana*) was used as a comparison member material.

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