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EFFECTS OF MOISTURE ON BOLT EMBEDMENT AND CONNECTION PROPERTIES OF GLULAM

KEYWORDS: Bolts, connections, creep deformation, relaxation, glulam, moisture conditioning, numerical modelling

OVERVIEW OF PROJECT

Deformation incompatibilities occur when interconnected parts of structural systems in timber hybrid buildings distort differently under influences affecting them as a whole or in part. For example,wood and steel deform differently while they come into equilibrium with, or respond to, loading, changes in temperature or relative humidity of surrounding air. This potentially causes damaging stresses to build up in one or more parts connected together in a structural system. Current practices for avoiding deformation incompatibility problems in timber buildings have been learned empirically and can be unreliable. Need exists for scientific understanding and modelling of deformations in timber hybrid buildings, especially at the connections. Applications for which knowledge is required include buildings employing heavy-frame structural systems with glulam members and bolted connections, which was the topic of the research.

Primary research objectives of the project were:

- To understand the causes and develop the ability to predict temporally varying movements/deformations in structural components of glulam heavy-frame hybrid buildings.
- To create numerical models capable of predicting how moisture content condition of glulam influence load-displacement curves for bolted connections.
- To facilitate application of advanced understanding in support of using glulam as a mid- and high-rise construction material which can be used in combination with other material to optimize system performance.

Methods employed in this research recognized that the central technical challenge and contribution to knowledge is to integrate how individual components made of glulam or other materials within hybrid buildings respond to individual effects of parameters like applied force, moisture load and flux, temperature and time, to predict the combined effects at the level of a building system. Focus was placed on the deformation behaviour of connections rather complete superstructure systems, because behaviour of connections is the dominant factor in how complete superstructure systems will behave during normal or overload service conditions.

The research activities encompassed the following:

1) Tests on axially loaded splice connections that had a steel plate slotted into the ends of joined glulam members and secured to those members using high strength steel bolts (Figure 1). During those tests primary variables were the methods of post-connection fabrication moisture conditioning of the glulam members, glulam moisture content at the time of loading, and size and number of bolts.

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2) Embedment tests wherein bolts loaded glulam. Such tests yielded so-called embedment strength properties that are basic wood member parameters on which design capacities of bolted connections are based. A feature of the research was that it considered the effects of moisture content on embedment strengths.

3) Material test on glulam and other connection components to determine their physical and mechanical properties. This became primary input to numerical models built to replicate test behaviour of connections, and/or to predict the behaviour of connections of types not tested as part of the research.

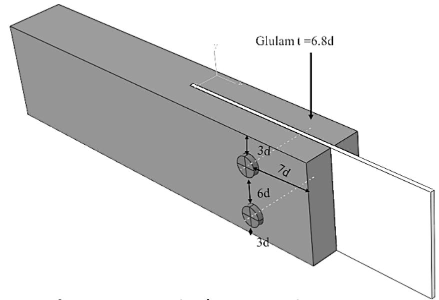

Figure 1 - Typical connection

4) Development of numerical models for glulam connections and embedment specimens, of the types or similar to those investigated by testing, based on application of advanced finite element approximation methods. Those models have ability to predict deformation due to short-term and medium-term loading for situations where bolts load glulam parallel or perpendicular to grain, including influences of post-connection fabrication moisture conditioning and moisture content of glulam at the time of loading.

KEY RESULTS

In scientific terms, the research led to greatly improved understanding of how stresses develop within bolted connections as a result of moisture variations associated with drying or wetting of glulam members. Practical importance of the research is that it gives a reliable foundation for formulating design and construction guidelines that will facilitate use of glulam in non-traditional applications like high-rise buildings. Development of numerical modelling techniques was a crucial achievement because, for example, that enables determination of best practice ways of accounting for combined effects that initial moisture content of glulam and building service classifications have on mechanical properties of bolted connections. The numerical modelling also enables prediction of bolt embedment strengths based on computer simulations rather than physical testing (Figure 2).

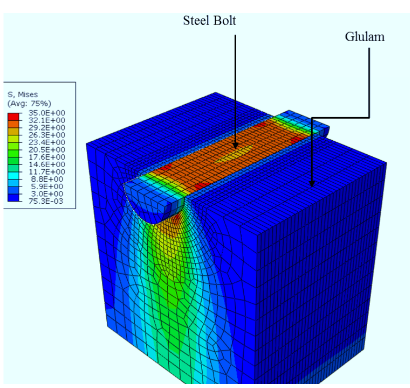

Figure 2 - Finite element model of von Mises stresses in an embedment specimen

Important to acknowledge is that additional research is still necessary because not all possible construction and design scenarios were dealt with. In particular it is important that future investigations determine effects of longer term and cyclic loadings that occur in combination with drying and wetting of glulam (as occurs on diurnal and seasonal bases) have on mechanical properties of connections. Future attention should also be directed toward determination of what types of connection details mitigate the possibility of unwanted phenomena like shrinkage cracks and brittle failure mechanisms.

THESIS

Henry Meleki Kiwelu. 2013. Finite Element Models of Effects of Moisture on Bolt Embedment and Connection Properties of Glulam. PhD Thesis, University of New Brunswick, Fredericton, NB.