Risk analysis in the design of timber portal frames with semi-rigid knee joints

Lilita Ozola, Janis Fabriciuss

Latvia University of Life Sciences and Technologies, Jelgava, LATVIA

Contact: Lilita.ozola@llu.lv

Abstract

The complex behaviour of anisotropic wood material and semi-rigid connections in knee joints of timber portal frames leads to a discussion on additional design conditions entailing strength failure criteria. Also the assessment of the consequences of deformation development and increase of global displacements of a system due to the load duration impact in semi-rigid connections is essentially important for a sustainable design. Some important affecting factors: the resistance of wood in tension perpendicular to the direction of the grain, development of deformations in semi-rigid connections and uncertainty of bearing capacity are examined regarding their role in a safety format.

Keywords: tension perpendicular to the direction of the grain; strength criterion for wood; failure mode; rotational stiffness modulus.

1 Introduction

Timber portal frames with mechanical fasteners in knee joints are a more appropriate solution regarding transportation and assembling conditions compared with the prefabricated glued units. At the same time by replacing rigid glue finger-joint connection in a knee with the semi-rigid mechanically fastened junction the model of distribution of transferring forces changes considerably. Setup of bolted knee joint presents complicated system formed by bolts and members of wood material into which they are embedding under loads during service life. It is designed that resisting shear forces transferred by bolts balance the applied moment in a knee. Real behaviour of connection is non-linear due to plastic embedment deformation of wood, as well as bending deformation of bolt. There are many cases of crack development observed during inspection of the portal frames which have been in service for some decades. That suggests that some important specifics of stress-strain behaviour of anisotropic timber material are not considered in the design codes. In order to avoid the risks of failure a new framework was created for more comprehensive design conditions. The rafter section near the knee joint appears to be heavy loaded by bending moment and shear force, as well as tensile stresses perpendicular to the direction of the grain arise due to forces transferred by the individual bolts.

In some aspects design conditions provided by Eurocode 5 appear quite poor as regards predictive abilities of semi-rigid connections.

In this current study three aspects of the portal frame risk problems are discussed: 1) splitting capacity of wood, 2) strength of wood in tension perpendicular to the grain direction at the end sections of members beyond bolts and 3) reducing rigidity of bolted connections.

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