Investigating out-of-plane strength & stiffness of a nailed glulam connection

Rebecka Kvist, Oskar Ranefjärd*, Hiba Alyaseen, Sven Thelandersson

Lund University, Sweden

***Contact:** oskar.ranefjard@kstr.lth.se

Abstract

During March 2020 a large-span arena, Tarfalahallen, collapsed. The main load-bearing girders with a 54 m span were high and slender glulam trussed beams, supported from below by a cable system via vertical struts. Investigations concluded that the failure was initiated by out-of-plane buckling of the struts and slender beam, in spite of lateral stabilization by steel roof sheeting at the top edge of the beam and by glulam rods at the lower end of the strut where the cable system was attached. The nailed connection between strut and main glulam beam was not stiff enough to prevent buckling. In this study a nailed connection similar to that used in the arena, though on a smaller scale, was tested under combined bending and axial loading. The biaxial testing simulates vertical loading in the strut combined with out-of-plane loading created by second order effects. It was found that the out-of-plane stiffness is reduced when vertical loading is at high levels.

Keywords: lateral stabilization, biaxial, out-of-plane stiffness, lateral torsional buckling, nailed joint, Tarfalahallen, experimental testing

1 Introduction

1.1 Background

Glue-laminated timber or glulam is a commonly used material for larger load-bearing structures. In comparison to structural timber, glulam is stiffer and has higher strength with a lower variability [1]. Compared to other materials, glulam is one of the stiffest in relation to its weight, which is why it is used for building long span structures. One way of building longer spans is to use trussed glulam beams [2]. This means that the beam is being optimized by introducing a tensioning cable or rod, with one or more intermediate support struts loaded in compression as seen in Figure 1. A trussed beam system could be seen as a hybrid between a truss and an ordinary beam. The supporting struts are commonly made of glulam and the tensioning system is made of steel. The practical maximum span for trussed beams is approximately 50 meters [2].

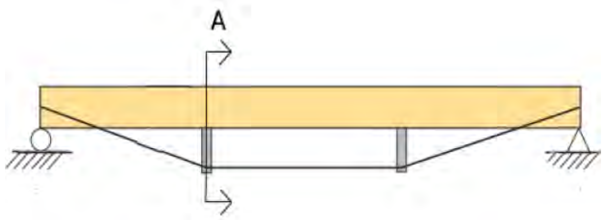

Figure 1. Trussed beam with two intermediate supports

To show the principle of how a trussed beam structure could increase the span, one can look at the moment distribution of a simply supported beam. When the beam is loaded by a uniformly distributed load, the bending moment is largest in mid-span, with the top edge being at risk of lateral torsional buckling. When introducing a supporting strut, the beam could conceptually be seen as a continuous beam over three supports. The strut reduces the free span of the beam and changes its moment distribution by introducing a moment over the intermediate strut-support. This moment instead makes the lower edge of the beam subjected to the risk of lateral torsional buckling.