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Evaluation of bending tests on composite glulam–CLT beams connected with double-sided punched metal plates and inclined screws

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HIGHLIGHTS

- Bending tests on glulam–CLT composite beams were performed.
- Different types of mechanical shear connections were used.
- Double-sided punched metal plates (DSNP), inclined screws, individually and combined.
- DSNP shear connectors combined with inclined screws exhibit a satisfactory behaviour.

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ABSTRACT

Composite beam elements made of glulam beams and cross laminated timber (CLT) panels, and connected with a new shear connection system were tested under four point bending. The beams tested represent a section of a cassette floor element to be used in a multi-storey CLT construction system. The shear connection is primarily made of double-sided punched metal plate fasteners, connecting the CLT and glulam members to form a T-cross-section. Due to the uncertainty about the capacity of the double-sided nail plates to resist possible separation forces between the timber members, the shear connection may be secured with screws. Bending tests were performed with three shear connection configurations: double-sided punched metal plate fasteners only, inclined screws only, and double-sided punched metal plate fasteners combined with inclined screws. An additional test with a screw-glued connection was made for comparison. The results show that a shear connection with double-sided nail plates can be designed to provide a sufficiently high level of composite action and load-carrying capacity and represents an alternative shear connection system for glulam–CLT composite floors.

1. Introduction

This article presents the evaluation of a connection system for build-up floor elements made with cross laminated timber (CLT) panels and glulam beams. Fig. 1 shows an example of glulam–CLT floor element where the CLT panel is fastened underneath four glulam beams. This orientation is the one intended to be used in practice for this floor solution. The typical spacing between the beams for this application ranges between 450 and 750 mm, for assemblies made with 4–6 glulam beams on a CLT panel of 2450 mm width. The load-bearing part of the floor element consists of the CLT panel and glulam beams only, which are assembled with shear connectors. In this study, the connection system which is evaluated is made of double-sided punched metal plate fasteners and inclined screws.

Double-sided punched metal plate fasteners, also called double-sided nail plates for short (DSNP), are proprietary fasteners which have been developed for fire protected and aesthetic joints in light timber trusses [1]. Double-sided nail plates are usually pressed in-between two timber members and are supposed to transfer forces between the members in the same manner as traditional punched metal plate fasteners. Despite the fact that it is not their intended original function, double-sided nail plates can be used for shear load transfer when pressed between two timber members subjected to relative sliding, i.e. in a layered composite structure. The large timber area mobilised by this type of fastener compared to nails or screws can provide high values of load-carrying capacity and slip modulus and can be beneficial in timber composite structures.

The shear behaviour of joints with double-sided nail plates has been evaluated in a previous study [2], individually and in combination with self-tapping screws in order to compensate the low withdrawal capacity of double-sided nail plates. The combination

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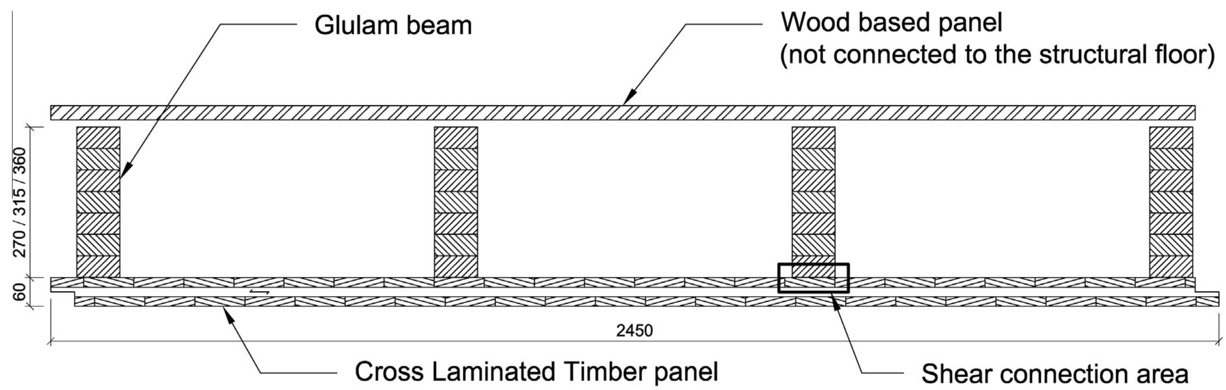

Fig. 1. Example of a glulam–CLT cassette floor element with CLT panel located at the bottom (dimensions in mm).

of these different fastener types improves the overall joint strength and stiffness and was suggested to make a robust design of the composite member. A more detailed background about the motivation for combining inclined screws and double-sided nail plates is presented in the background section and in [2]. The combination of double-sided nail plates and screws is also evaluated in this article which presents the results of three different series of bending tests performed on glulam–CLT beam elements connected with either:

– double-sided punched metal plate fasteners;
– inclined self-tapping screws;
– double-sided punched metal plate fasteners combined with inclined self-tapping screws.

In addition, a single test on a glulam–CLT beam specimen assembled with screw-gluing is also presented for comparison reasons, as the corresponding floor configuration with assumed full composite action between the glulam beams and CLT panel.

The aim of the study is to evaluate the performance (strength, stiffness, behaviour) of composite beam elements with double-sided nail plates used as shear connectors and to evaluate the influence of inclined screws added to this type of shear connection on the overall beam performance. The study intends to evaluate the technical feasibility according to the Finnish building regulations of a particular design of a glulam–CLT composite floor element of 6.4 m span made with such shear connectors.

2. Background

Vibration in the serviceability limit state is one of the requirements which often governs the design of timber floors [3,4], especially in modern multi-storey buildings where spans of 6 m or more can be seen. The Eurocode 5 [5] recommends to carry out special investigations with respect to vibrations for residential timber floors having a fundamental frequency below 8 Hz. In Finland, the country where the floor element presented in this study is intended to be used, the National Annex [6] sets this limit at 9 Hz. These requirements therefore means that the floor structure needs to have a bending stiffness to mass ratio as high as necessary to achieve an acceptable vibration performance [4].

Long spans CLT floors can be considered as material intensive structures. The CLT Handbook [7] shows examples of CLT floor designs with respect to vibration with a recommended thickness of 240 mm for a floor span of 6.1 m. In order to increase the bending stiffness and reduce the self-weight of CLT-based floor structures, CLT can be combined with other linear engineered wood products. In this study, a so-called “ribbed floor” element, or cassette floor element, made with glulam beams connected to a CLT panel is investigated.

Ribbed floor elements present some advantages such as a reduced self-weight and the possibility to use the voids between beams for technical installation and airborne sound insulation. In the configuration shown in Fig. 1, the CLT contributes to the fire resistance between apartments and may be left visible for aesthetic reasons. This floor element is completed with an acoustically separated wood based panel serving as a support for the complementing layers (e.g. a non-structural cement-based layer and floor finishes).

The bending stiffness of the built-up floor element is to a large extent governed by the performance of the shear connection between the timber members. The slip modulus and the load-carrying capacity of the shear connection determine the level of composite action of the composite beam as well as the stress distribution in the different timber members. Screwing, gluing, or screw-gluing (the screws being used to apply the required pressure on the glue joint) [8], are some of the solutions which can be used for ribbed floors or hollow-box floor structures, as described in more details in the parallel shear tests study [2]. Press-gluing techniques are very effective from a structural point of view but can be considered as demanding in terms of equipment, preparation and quality controls [8]. Alternatively, the screw-gluing technique is also demanding in terms of quality control, amount of screws and manual work needed. The shear connection can also be made of self-tapping screws only as shown in [9] or for refurbishment of old timber structures [10]. When used in inclined position, screws can provide high stiffness and load-carrying capacity [11,12]. However, for long span composite floors, the amount of screws needed to reach a high level of composite action can become large and alternative connection systems or combinations of different connectors can be interesting in order to minimise the amount of fasteners needed and installation time in an industrialised production process.

The new shear connection system with double-sided punched metal plate fasteners evaluated in this study needs to be installed with dedicated pressing equipment and can therefore be used for prefabricated structures only, but the assembly time of glulam–CLT elements may be reduced compared with a gluing technique as there is no need for curing. In addition, the production controls might also be less demanding than for a glued connection. This type of fasteners is therefore particularly suited for production lines of floor elements where there is a need for rapid assembly.

The uncertainty about the use of double-sided nail plate fasteners used as the sole shear connection for the glulam–CLT floors is due to their low capacity to resist the possible separation forces which may occur (e.g. during handling and erection, and also because of possible hanging loads). The double-sided nail plates