Deconstructable screw-connections for timber concrete composites

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1. Introduction

During the past few decades, timber-concrete composite (TCC) solutions have become popular as they have been recognized to be an effective alternative to traditional concrete floors [1, 2]. TCC floors, are composed out of a, typically relatively thin, concrete slab above a timber component (e.g., glued laminated timber beams, laminated veneer lumber or cross laminated timber plates) that are connected together using shear connectors. Beside beneficial mechanical performance [2, 3, 4], TCC is also characterized by a lower self-weight and a better environmental performance compared to conventional concrete floors [5].

The more common approach to fabricate TCC is the wet-dry system where the wet concrete is poured on the timber component. Alternatively, also a prefabricated concrete slab can be connected to the timber component (i.e., the dry-dry system). For the wet-dry system usually permanent shear connections are used. Examples are adhesive connections [6], connections with metallic fasteners [e.g. 7, 8], and connections with non-metallic connectors [e.g. 9]. Permanent shear connectors are typically characterized by sufficient shear resistance, however, TCC slabs cannot be disassembled, which results in challenges at the end of service life related to recycling/reusing. This has been addressed by several researchers, and accordingly, several deconstructable TCC connectors have been developed [e.g. 10-15], mainly for the application in the dry-dry system. Recently at Aalto University, we developed a more versatile deconstructable connector concept that can be applied in both wet-dry and dry-dry construction systems [16-18]. In the following sections of this document, a short summary of the deconstructable connector is presented, including its application and disassembly processes as well as its mechanical properties both at the connection level and at the slab level.

2. Deconstructable shear connector

The deconstructable connector consists of a structural self-tapping screw which is covered at the upper section using a ~ 0.5-mm-thick protective layer made of heat-shrink tubing (HST) and a reusable lid that could be made of Styrofoam or silicon rubber (Figure 1). The HST layer prevents the screw from direct contact with the fresh concrete, enables mechanical interlocking between the concrete and the threads of the screw, and creates a plug for the lid. The lid is removeable and makes the screw head accessible for disassembly.

The connector can be used for both wet-dry and dry-dry construction systems. In the wet-dry system, the connector is simply inserted into the timber part and the concrete is then cast on top (Figure 2). One advantage is that no additional steel/plastic tubes are needed inside the formwork before concrete casting. In addition, the connector can be inserted at any desired insertion angle.

Figure 1: Deconstructable connector using self-tapping screws: individual components, production process, and final configurations [17].

In the dry-dry system, a formwork is initially prepared to prefabricate the concrete slab. The connector is inserted into the base of the formwork and then the concrete is cast. After the concrete has dried, the screw is removed from the concrete slab. The concrete slab is then placed on the timber part and the screw is inserted through the connector hole.

The composite system made with this connector can be easily disassembled by removing the screw from the connector hole (Figure 2). Afterwards, the timber part and the concrete slab can be taken apart.

3. Push-out shear tests

An experimental study was carried out to investigate the shear properties of the deconstructable connector [17]. The experiments were performed on glulam-concrete composite specimens. Identical specimens were also fabricated using regular self-tapping screws and tested to create a basis for comparison. The shear tests were conducted using the push-out test set-up shown in Figure 3. Several variables were investigated including the insertion angle of the connector, screw diameter, fabrication method, and connector arrangement.

Based on the results, the shear strength and shear stiffness of the deconstructable connector were similar to those of the regular self-tapping screws. It was also proved that, with a certain insertion angle, the connector can be disassembled even if up to 15 mm slip is reached under loading. Satisfactory mechanical interlocking was formed between the concrete and the threads of the screw that were covered by the HST layer. As a result, the failure modes of the two connector types were also similar (Figure 3). This makes it easier to adapt the existing analytical models to estimate the load-slip curves.

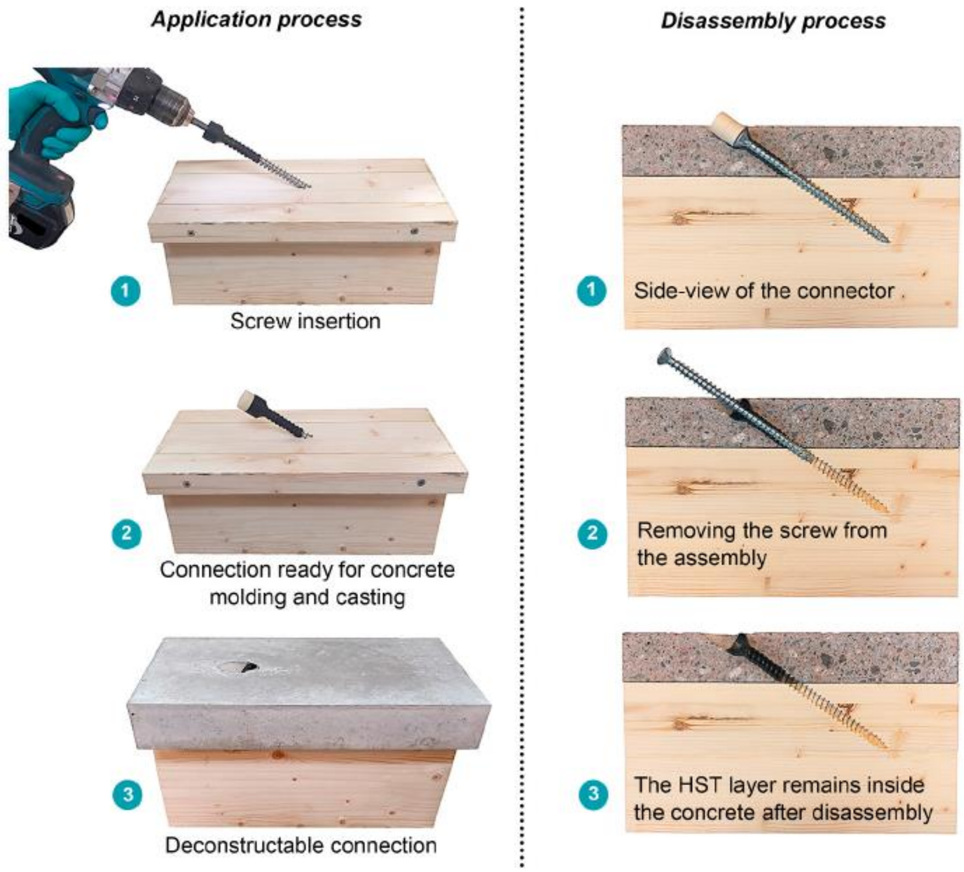

Figure 2: Application steps and disassembly of the deconstructable connector in the wet-dry system [17].

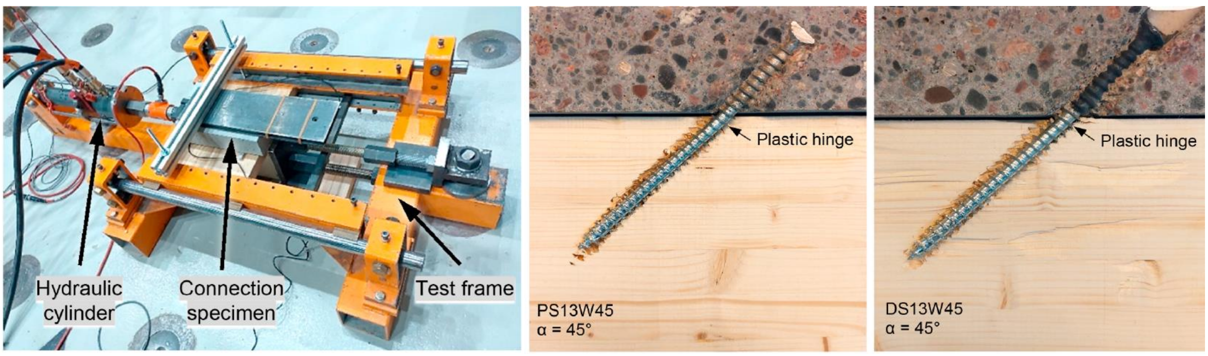

Figure 3: (left) The push-out load set-up: test frame, (middle) example failure mode of a regular screw connector (right) example failure mode of a deconstructable connection [17].

4. Vibration and bending tests

In a subsequent study, the effectiveness of the deconstructable connector in fabricating deconstructable CLT-concrete composite floors was investigated [18]. For this purpose, several CLT-concrete composite elements with the span of 4 m were fabricated using the deconstructable connector. For comparison also elements using regular self-tapping screws with similar geometrical characteristics were fabricated. The experiments were conducted on a simply supported, four-point bending test set-up shown in Figure 4. The first eigenfrequency, damping ratio, bending properties, and failure modes of the composite elements were experimentally investigated.

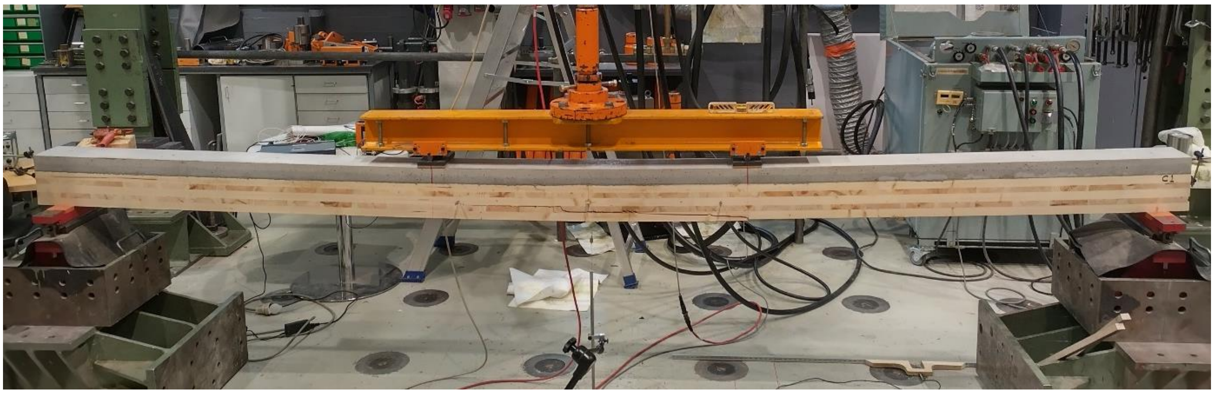

Figure 4: Four-point bending test of a deconstructable CLT-concrete composite element.

It was demonstrated that the deconstructable CLT-concrete composite elements can provide similar vibration performance and bending properties compared to the identical composite elements made with the regular self-tapping screws. No important difference was observed in the failure modes of the two types of composite elements. Furthermore, after the destructive bending tests, the deconstructable composite elements were easily disassembled using a cordless screwdriver, even though they had been exposed to large deformation during the bending test.

5. Summary

The deconstructable TCC connector developed and investigated within this project can facilitate recycling or reusing of timber elements, concrete slabs, and the fasteners at the end of service life. It is easy to use for both prefabrication and cast-in-situ approaches; it can provide sufficient shear properties compared to a regular self-tapping screw; and it can be easily disassembled.

Development of such competitive deconstructable solutions will encourage the sustainable and responsible use of natural resources in the built environment. This will also indirectly contribute to improving the health and wellbeing of people by reducing the environmental impacts of building construction which is currently one of the main sectors that significantly contributes to the CO_2 emission globally.

6. References

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