Interreg North-West Europe
EUROPEAN UNION
Adhesive-Free Timber Buildings
European Regional Development Fund

Technical Note 4
Compressed Wood dowel-laminated EWPs

One of a series of short briefings on timber technology produced by the towards Adhesive-Free Timber Buildings (AFTB) research project. The project is co-funded by Interreg NWE, 2016-2020. This note explains briefly the experimental testing of adhesive-free engineered wood products.

DLT Panels

Fig. 1 shows AFCLT panels produced, which are ready to be used in Liverpool Demonstrator. It is a five-layer panel (3 longitudinal and 2 transverse) connected by 10 mm compressed wood dowels. Fig. 2 displays a DLT panel is subjected to 4-point bending to provide load-deflection relationship.

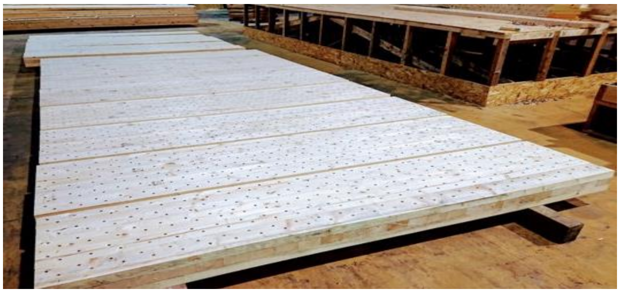

Fig. 1. Dowelled laminated timber (DLT) panels

The load-central deflection curves obtained from structural tests are shown in Fig. 3. The results from the corresponding cross laminated timber panels using adhesive are also shown in the same figure to give necessary comparison. As it can be seen, the initial stiffness of DLT panel is much smaller than its adhesive panel counterpart, due to relative slippage between laminates during bending. However, the performance of DLT panels is more ductile. There is a need to improve the initial stiffness by enhancing shear resistance between laminates, which may be done by surface profile of laminates to provide necessary interlocker.

Fig. 2. A DLT panel under four-point bending load (U. Liverpool)

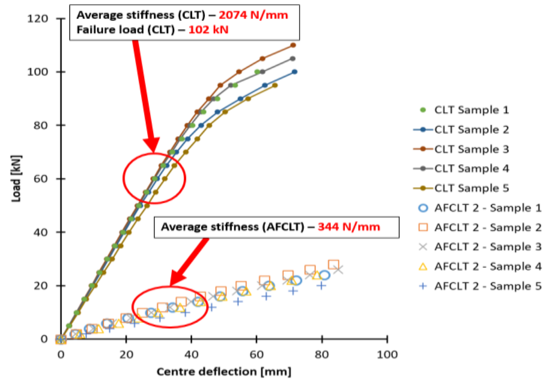

Fig. 3. Load-deflection curves of AFCLT panels and CLT panels (U. Liverpool)

Stacked-board shear walls

Large wall elements were tested in two different ways to determine the ultimate load and stiffness. Every wall element consists of two identical parts, each part was made of 23 individual boards including 2 edge boards (2370x180x40 mm) and 21 filling boards (2370x180x24 mm), connected by 20x594 mm wooden dowels, total dimension of the part was 2370x180x584 mm (Fig. 4).

Finally, two parts were connected by an adhesive joint, due to limited width of 60 cm of the wall elements provided by the industrial partner. The wooden boards were made from softwood at C24 strength level, while beech and densified beech (50%) were used for dowels. Two types of dowel arrangement were also used, namely one row design and two row design.

Table 1. Evaluation of vertical load tests for wall samples

Element	Compressive load Force [kN]
Two rows beech dowels	3283
Two rows comp. Beech dowels	4263

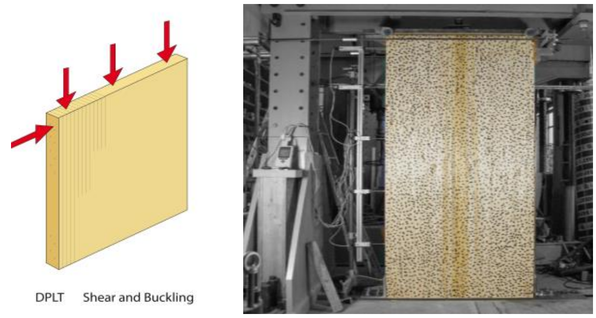

Fig. 4. Horizontal loading test set-up

For each variation in dowel material and arrangement, three specimens were prepared, thus a total number of 4 variations (one row no densified/densified, two rows no densified/densified) and 12 wall elements are tested. For ultimate loading tests, load was applied by upward movement of the lower frame with a speed of 5kN/s. load was increased to maximum level at approx. 4000kN. Table 1 shows summary of the result of the vertical loading test for wall elements with two rows dowels. After examining the load-bearing behavior on the basis of the analysis of the component tests, a calculation model was developed that can map the load-bearing behavior with a very good approximation.

Then the last four specimens were used for stiffness (horizontal loading) test. Each specimen was placed on a large steel frame, anchoring of the bottom corners was to avoid uplifting movement, horizontal load was introduced at the top by a hydraulic cylinder. Inductive displacement transducers were distributed evenly through the wall height; photogrammetric measurement was also used to capture strain in different directions. Photogrammetric results showed displacement in three principle directions. In x direction = in the direction in the plane along the boards, the results were similar in all elements with around -84mm to -95mm at the top area (Fig. 5).

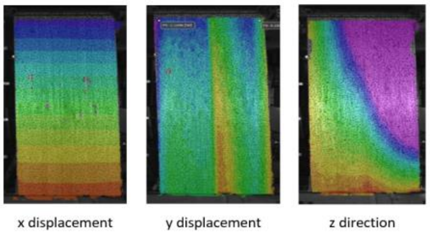

Fig. 5. Photogrammetric pictures for wall specimens for displacement in three principle directions

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Floor Slab

The fabrication of the adhesive-free laminated timber (AFLT) panels was carried out with the compressed wood dowels of an average density of 1200 kg/m3. The AFLT panels fabricated was left for two to three weeks before it was tested to ensure a tight fit between the compressed wood dowels and the timber laminae as a result of the moisture dependent swelling and spring back of the compressed wood dowels. Four-point bending tests were carried out on the AFLT slab.
The large-scale tests were carried out on 12 test specimens with differently designed configuration with the dimension of 3000x600x120 mm. For this reason, strain measurements were carried out with the help of LVDT sensors at particular interest points. The four-point bending test records the applied loads and central deflection of the panels, from which the initial stiffness and failure load can be determined.

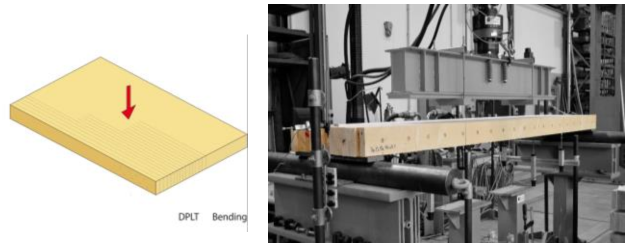

Fig. 6. 4-point bending tests of adhesive-free laminated timber

Each slab in Fig. 6 consists of 18 individual boards which connected by dowels with 20 mm diameter and approx. 600mm length. The boards were made from spruce at strength class C24, the dowels were divided into two types: beech and compressed beech (50%).

Table 2. Results of the 4-point bending tests

Element	Ultimate load [kN]	Deflection [mm]
Beech dowels	100	53,9
Comp. Beech dowels	110	49,4

Table 2 shows the ultimate load and maximum deflection of the slab with one row dowels. The load bearing capacity of the different combinations (uncompressed/compressed dowels) achieves approximately high values of 100 [kN]. The results show that the use of compressed dowels for the connection of slabs as ceiling elements is feasible. It has been concluded that the use of board stacking elements makes better use of timber of lesser quality. Furthermore, it could be observed that, even in the case of failure of individual boards, a redirection of the forces took place and the load bearing capacity increased further. This aspect is particularly relevant to safety since the elements presented very ductile behaviour.

Dowelled timber beams

Fig. 7 shows adhesive free laminated timber beams to be used in Liverpool Demonstrator, with a zigzag pattern of compressed wood dowels. Its depth is 360 mm. These beams were structurally tested under four-point bending to obtain structural behaviour. The load-displacement curves of AFLT beams with different dowel spacing and the related glulam beams are exhibited in Fig. 8. It can be seen that although the initial stiffness of AFLT beams is much lower than their glulam counterparts there is a significant enhancement when the dowel spacing is decreased from 100 mm to 50 mm. Again, the initial stiffness can be further enhanced by introducing laminate surface profile to produce an interlock compatible to adhesive.

Fig. 7. Dowelled timber beams for the Liverpool demonstrator

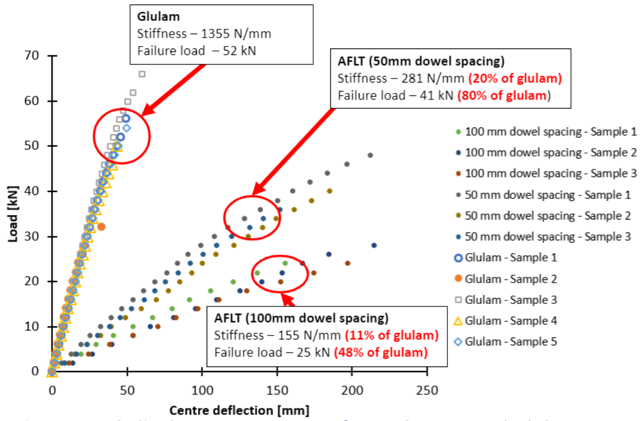

Fig. 8. Load-displacement curves of AFLT beams and glulam beams

Conclusions

- It is practicable to use thermally compressed timber to replace the hardwood dowelling traditionally used in all-timber EWPs.
- For most products tested there was little improvement in the as-new stiffness and strength of the EWPs compared to hardwood dowelled products. An improved performance was observed in two situations. Firstly, where the dowels had a load-bearing, rather than a purely connective function, for example in the slab-floor structure. Secondly where the laminate material was of relatively low embedment deformation, e.g. oak, rather than softwood.
- Laboratory-scale tests indicate that there is a need for testing a long-term performance for EWPs using compressed wood dowels. It is expected that they will continue to provide an exceptionally tight-fit throughout service-life as a result of the shape-memory induced spring-back effect. This has yet to be proven at scale.
- Dowelled EWPs remain significantly less stiff than their glued equivalents, future research will address whether this issue can be resolved by profiling the laminate-laminate interfaces with enhanced interlocking behaviour. The dowel material does not appear to be the determining factor.

Stakeholders Welcome

A key aim of the project is to engage with businesses, regulators and other interested parties. Adhesive-free timber building technology could be of interest to your business. Please get in touch via the e-mail addresses below:

Interreg North-West Europe

Adhesive-Free Timber Buildings

European Regional Development Fund

For more information please visit the Adhesive Free Timber Buildings (AFTB) project website http://www.nweurope.eu/AFTB or use the contacts.

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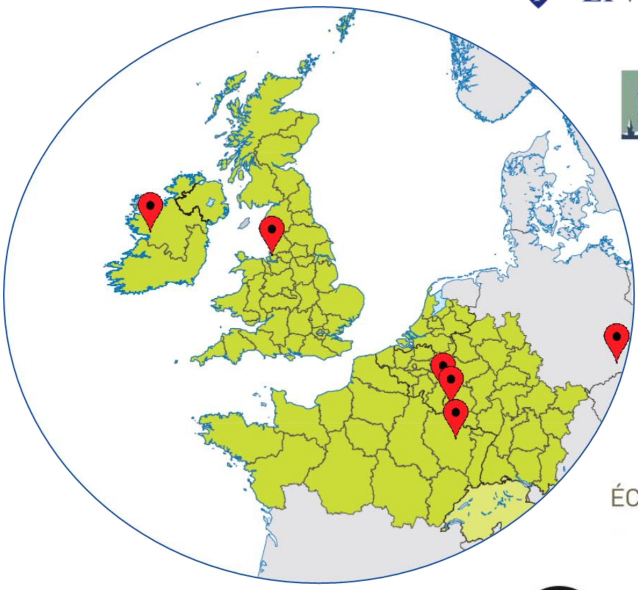

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