Super-Tall Timber

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Background

Humans have built using timber for thousands of years, but ever since the industrial revolution in the 19th century, it has gradually been replaced by stronger materials like steel and concrete. However, due to the development of "Engineered Timber" products like Glulam beams and CLT panels, shown in Figure 1. These are made by cutting up timber into planks, removing the ones with flaws like knots, and gluing them back together. The resulting beams, columns and panels are stronger, more reliable and can be larger than plain wood. This enables timber to compete with steel and concrete.

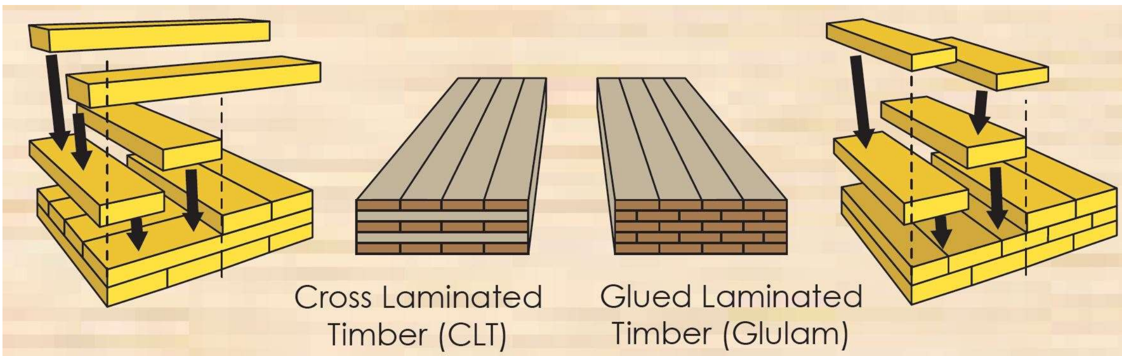

Figure 1: CLT vs glulam, two engineered timber products.

There are a lot of benefits to using timber, but the two main ones are sustainability and fast, easy construction. Now, building with timber obviously requires cutting down quite a lot of trees, but most forests in the EU are very well managed, and have been increasing in size for decades, because previous governments very sensibly started planting lots of trees. Now, you can think of most forests as 'tree farms', where the crop is only harvested every 30 years – thinking about it like this, you can see that using timber might actually *increase* the number of trees in the world – how many cows would there be in the world if we didn't eat them? Timber is a lot faster to construct than other buildings, for example the 10-storey timber tower shown in Figure 2 was built in 27 days by only 4 workers. This is possible since all of the parts are created in factories to the exact shape and size required, and then on-site they are simply lifted into place and fixed using nailed steel brackets.

Figure 2: Murray Grove

My Project

"CLT Platforms" are a type of timber building, where all the walls and floors are made of CLT panels and is very popular form of construction for residential buildings, for example Murray Grove.

Currently it is limited in height to around 10 storeys, due to the floor panels being squashed by the walls carrying a lot of compressive force, at the connections shown in Figure 3.

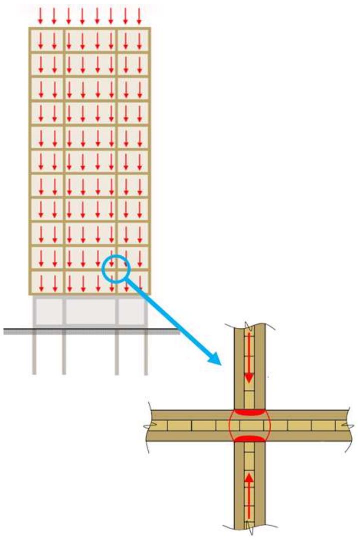

Figure 3: Height limit of CLT Platform Construction

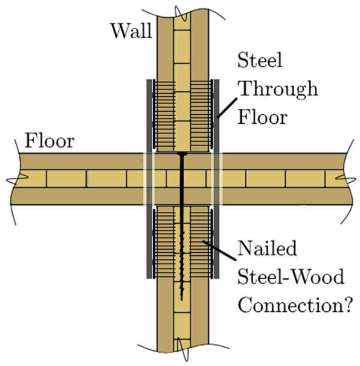

Figure 4: Connection design

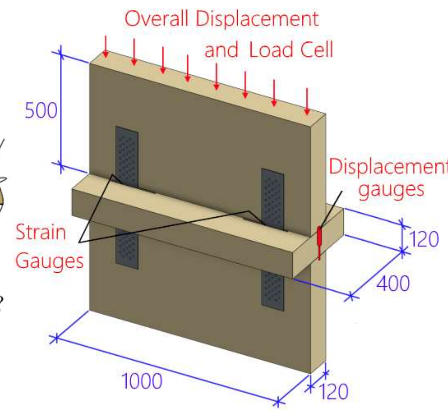

Figure 5: Test Layout

The aim of my project was to design a new connection for this situation, which would prevent the floor panel from being crushed. The design I came up with was to have steel elements which pass through holes cut into the floor and fixed to each wall panel using nails, as shown in Figure 4. This connection will reinforce the floor panel in compression and tension (since sometimes the wind causes one corner of the building to pull up) and is as easy to construct as current methods (the slots will be cut in the factory).

Some tests on my design were required, to find out whether the steel and wood will share the vertical load, or whether the steel would suck up all the load by itself, which it could do since it's a lot *stiffer* than the wood.

The test layout (shown in figure 5) is a model of a metre-long section of this wall-floor-wall connection. The strain gauges on the steel plates are used to measure the force each one was carrying, so that I could investigate how the overall load is shared between each plate, and between the plates and the wood. The displacement gauges at each end of the floor panel measured how much the floor was being squashed, and the squashing machine also provided the overall load applied, and overall change in height, or 'displacement'.

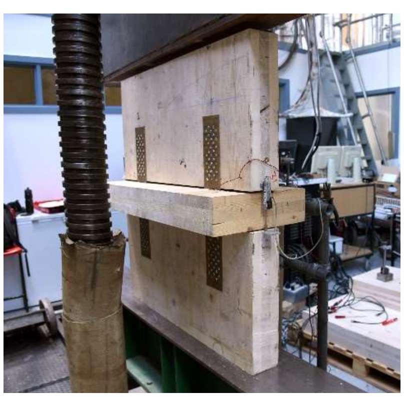

Figure 6: Test A3 in the squashing machine.

Ref.	Description	Steel Plates	Strain Gauges	Packed Slots	Gap
A1	Buckling Allowed	✓	×	×	×
A2	Control	×	N/A	×	×
A3	Shrinkage	✓	✓	✓	✓
A4	Buckling Limited	✓	✓	✓	×

The table on the previous page shows the characteristics of the 4 tests performed. Test A2 was the control, which means it is there to compare the results with – it's timber alone, with no steel reinforcement. Test A3 (shown in Figure 6) has a gap in between the wall and the floor. This is to simulate shrinkage, since timber shrinks when the moisture content of the air changes. The difference between tests A1 and A4 is that test A4 has wooden blocks in the slots, bracing the steel plates and preventing buckling in the slot, while test A1 does not.

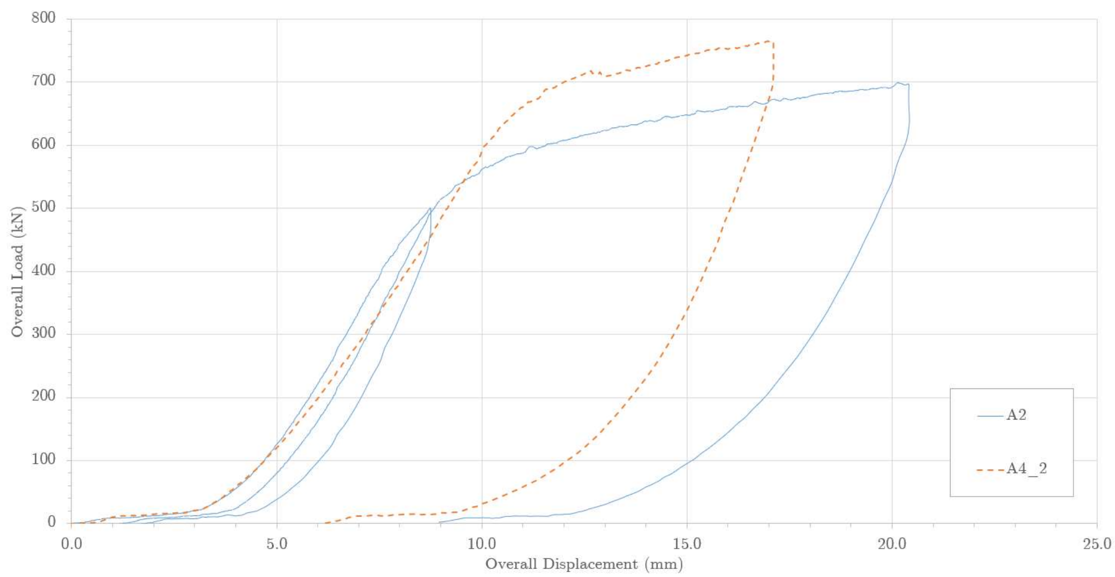

Figure 7: Overall load-displacement results for test A2 and test A4

The overall load-displacement graph for tests A2 (unreinforced) and A4 (reinforced) is shown in figure 7 above. A4 is labelled A4_2 because it was the second time it was loaded. You can see from this graph that the reinforced test reached a load around 70 kN greater than the unreinforced test (that is more than the weight of an elephant!) and had also not squashed as much (had a lower displacement) when it reached this maximum load.

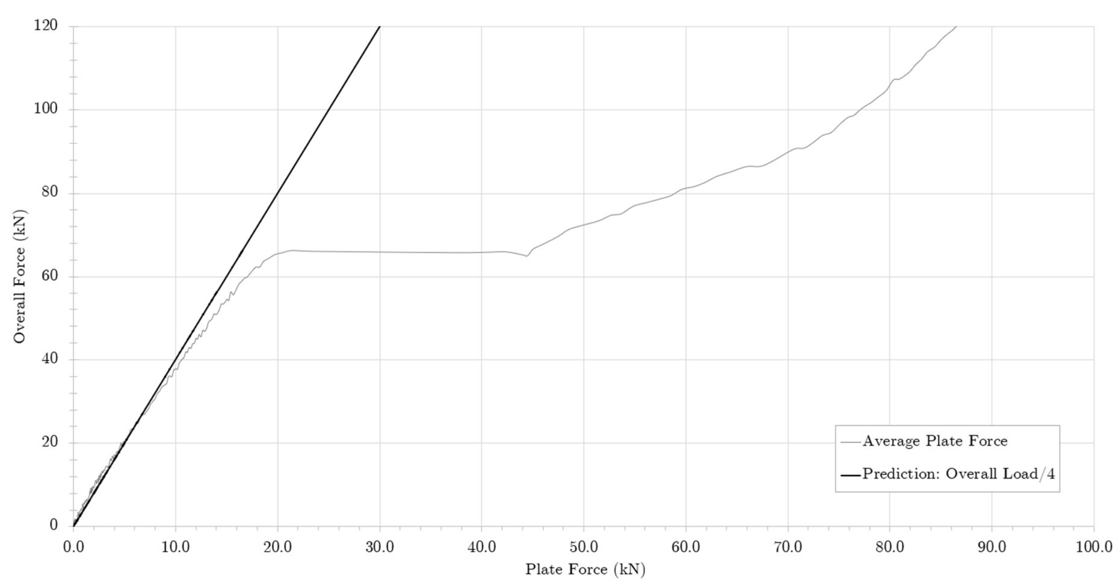

Figure 8: Average of the force in each of the four plates versus overall force for test A4

Figure 8 shows a plot of the average plate force for test A4. The black line is the prediction for if all the load went into the plates only (and not into the floor panel), and the graph shows that the plates do indeed carry all the load until around 65 kN (which is when the first plate buckled).

These results show that the connection design was a good one, but more work is needed before it could be used in a building. The plates buckled too early, so stiffer plates are a god idea, but they only need to be stiff up to the working (expected) load. We know from these tests that even if the plates have buckled at the maximum load, an improvement is still provided.

Hopefully this project has helped to increase our capability in building with timber and paved the way to a more sustainable construction industry.

Dyson Bursary

This project would not have been possible without support from the James Dyson Foundation Bursary. A pneumatic nail gun, thousands of construction nails and strain gauges were amongst the supplies purchased using the funds.