Project Report: Carbon Fibre Connections for Super Tall Timber Buildings

Daniel Blower

My project was run by the Cambridge University Centre for Natural Material Innovation and worked with industry partners, structural engineers Atelier One and architects Rogers Stirk Harbour + Partners, who have designed a concept for a timber skyscraper.

Their concept is for a 160 m tall, 40 storey building. It is made out of engineered timber, which is much stronger than sawn timber straight from trees, because weaknesses like knots and holes have been removed. Specifically it is made from a product called laminated veneer lumber made from beech trees. This is made by rotary cutting trees (a bit like sharpening a huge pencil) into sheets called lamellas, which are around 3 mm thick. The sections with weaknesses are removed, and the remaining lamellas are glued back together to create beams.

Figure 1: Skyscraper concept

Figure 2: Hardwood beech LVL

The building's weight is supported by columns inside the building and an external diagrid, which also resists lateral forces (like wind and perhaps earthquakes). The diagrid transmits all forces to the foundations. Instead of using common steel bolted connections, carbon fibre reinforced polymer (CFRP) plate connections have been designed for the diagrid node connections where two beams cross. My project looked at how these CFRP plate connections behave, to decide whether they could actually be used in a real-life timber

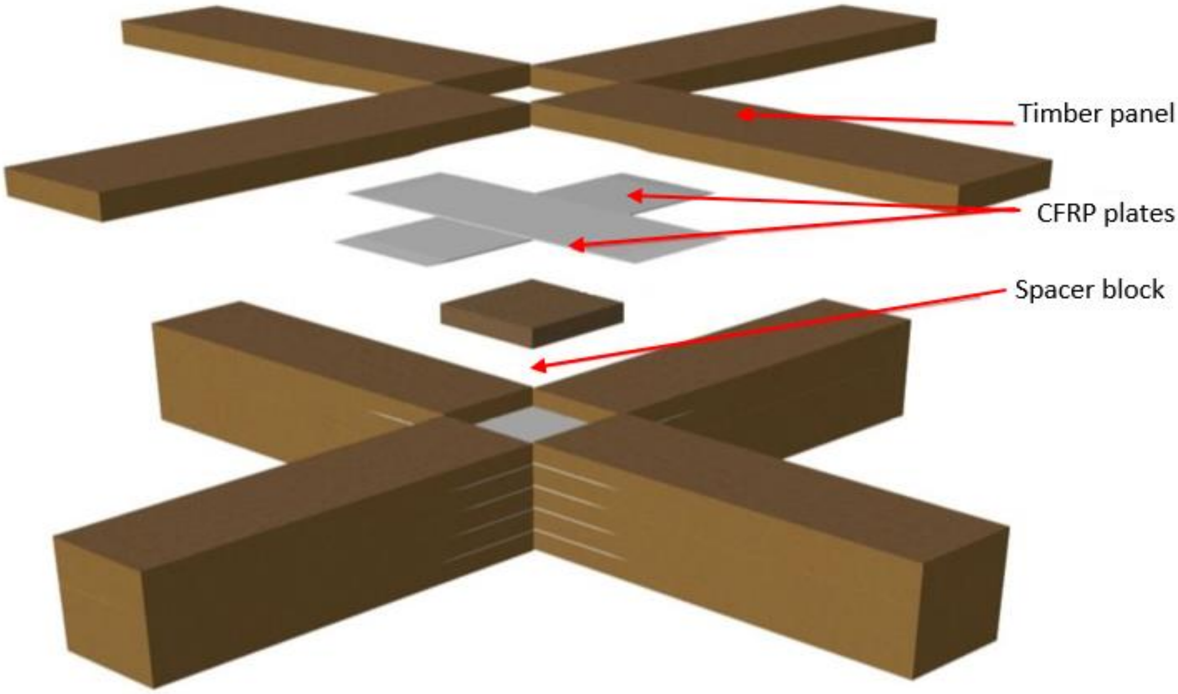

Figure 3: Idea for the diagrid connection with multiple CFRP plates

skyscraper.

Not much research has been done on CFRP plate connections in timber, so I wanted to investigate the more simple behaviour of single CFRP plates embedded in timber. This would then allow research in the future to test more complicated connections, based on the results of my research.

I designed, built and tested twelve timber specimens like the one in Figure 4. I explored two key variables. The first was the orientation of the CFRP plates relative to the lamellas in the LVL. I tested parallel and perpendicular orientations (Figure 5). The second was the embedment length of the CFRP plates in the timber to find if there is a relationship between this and the connection strength.

All twelve timber specimens exhibited a timber shear failure mechanism. This type of failure is sudden and brittle, which is undesirable in buildings because it's impossible to predict when it will happen, meaning it can be very dangerous!

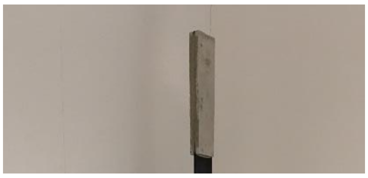

Figure 4: Typical test specimen

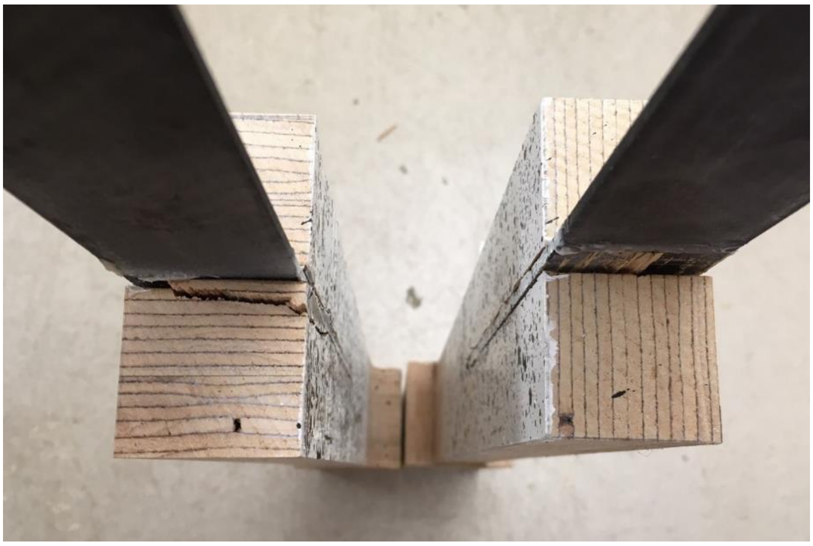

Figure 5: Image showing parallel (left) and perpendicular (right) orientation

The specimens with a CFRP plate perpendicular to the LVL lamellas were slightly stronger because they were glued to 12 lamellas on either side of the slot. Therefore, if one of these lamellas was a bit weaker than the others, it will have a smaller influence on the overall connection strength.

There was a rough linear correlation between the connection strength and embedment length but the experimental pull-out strengths were significantly lower than my predictions. This was because the actual failure mechanism was different to the one I predicted.

My main conclusion is that connections with single CFRP plates aren't efficient because they fail in shear, which is a weak failure mechanism, in contrast to a stronger tensile failure. This would mean that the entire timber cross section would break instead of just the timber that surrounds the plate. Therefore, future research should look at connections that have several plates in them to try to achieve a stronger connection.