Sticking Together when Things Get Hot:

INVESTIGATING THE SHEAR CAPACITY OF LAMINATED TIMBER POST HEATING

Andrej Carpinato and Martyn McLaggan
Email: acarpinato1@sheffield.ac.uk
Department of Civil and Structural Engineering

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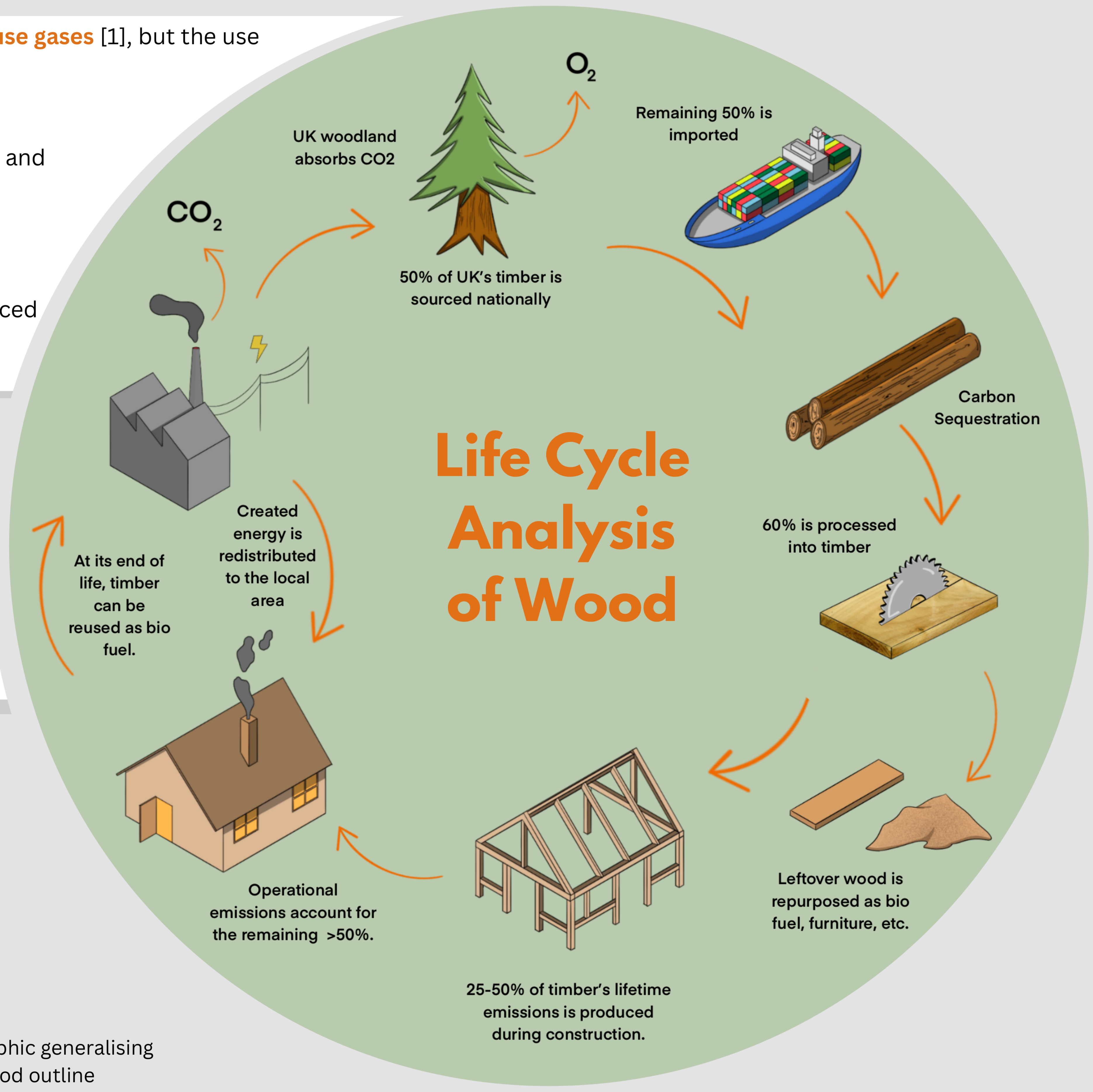
Full Report

The Timber Revolution

Switching to timber based construction can potentially remove up to **9% of global green house gases** [1], but the use of timber is **heavily restricted** due to government regulations regarding combustible materials as well as the lack of readily available knowledge on how wood burns [2].

Laminated timber is a popular structural composite formed from alternating layers of timber and adhesive glue. Despite being a robust and strong material, laminated timber can behave unpredictably when exposed to high temperatures especially if **delamination** occurs, caused by failure of the bonding between layers[3].

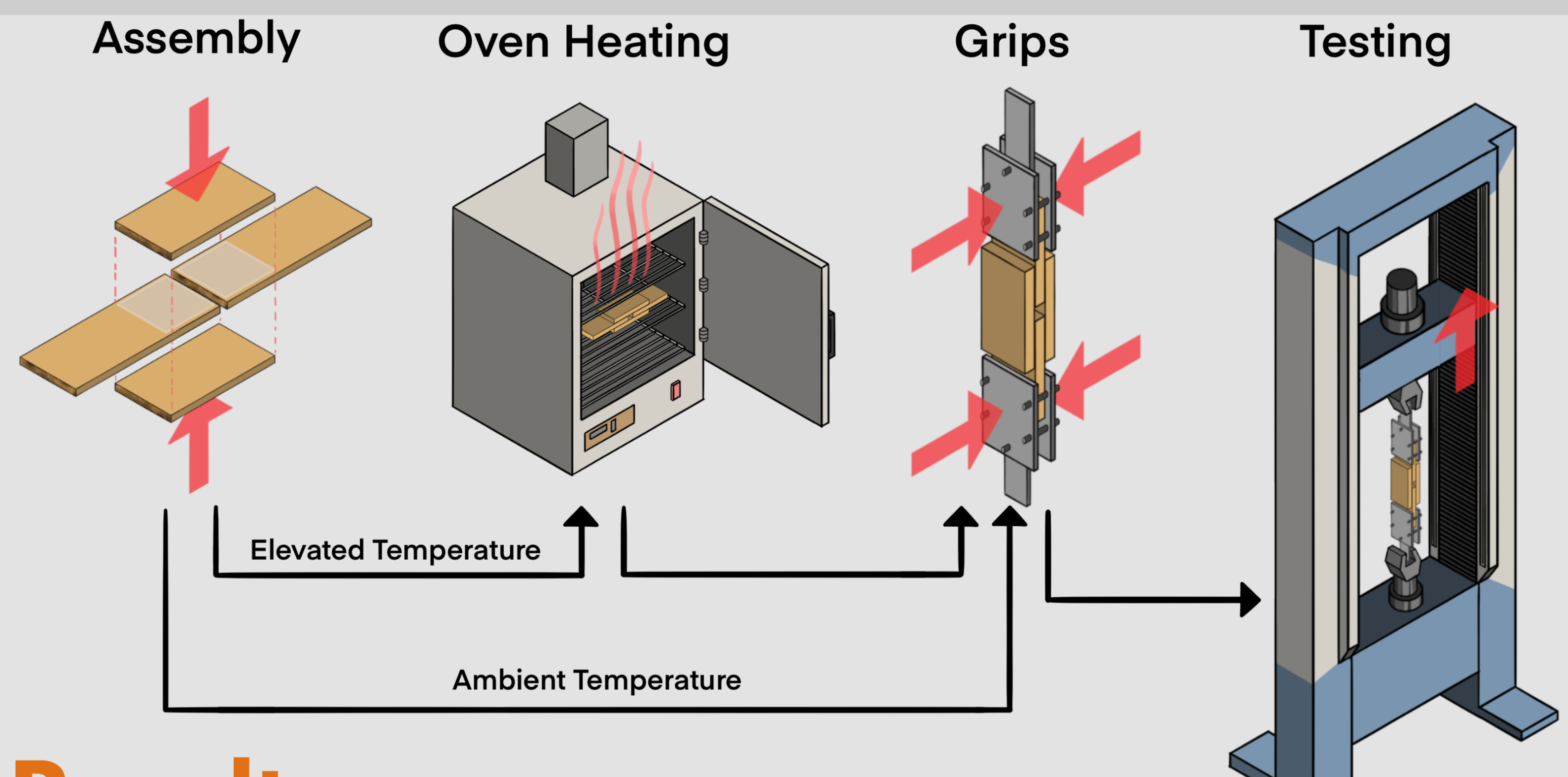
The aim of this study is to determine how the fire performance of laminated timber is influenced by the properties of the adhesives and the methods used in its manufacture. The construction industry can stand to gain a lot from research into this field.



Let's Cook!

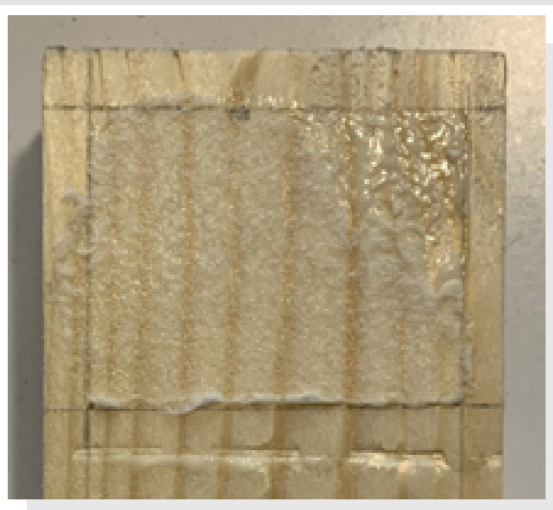
To achieve these goals, spruce planks was assembled into double lap joints and bonded using two different polyurethane adhesives. Using a tensile testing machine, the maximum shear capacity of the specimen's joints was initially assessed at ambient conditions before heating the remaining specimens at elevated temperatures of 50 and 150°C.

The method outlined above was amongst the first to evaluate the post fire performance of laminated timber under load.



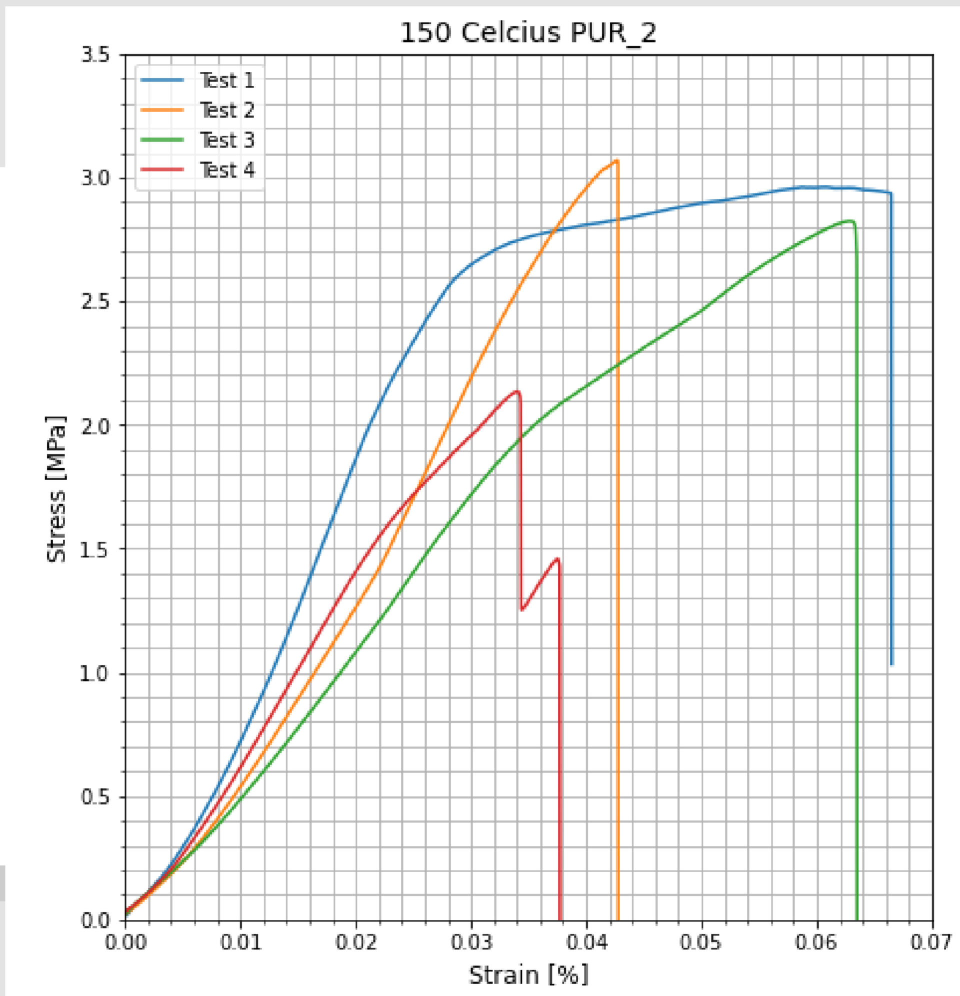
Left: Graphic generalising the method outline

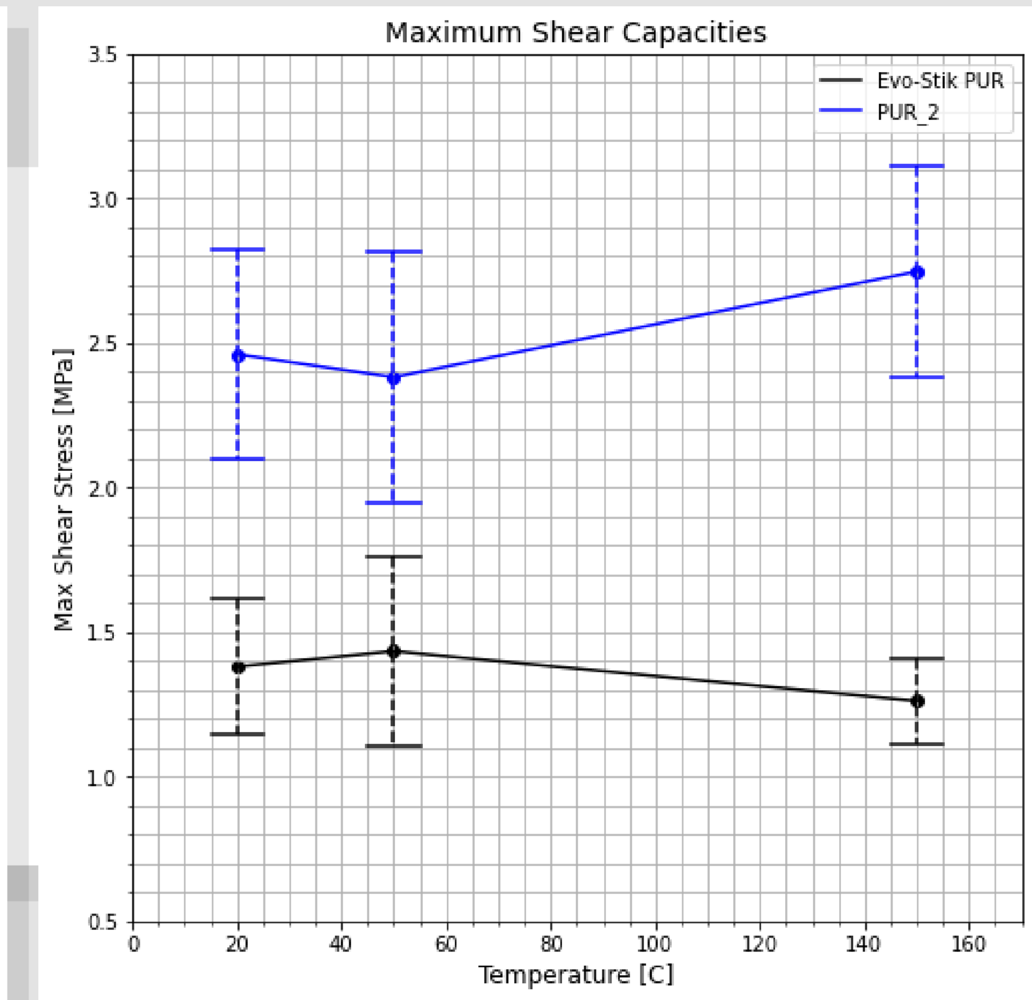
Results



Above are photographs of the modes of failure seen during testing. Failure ranged from delamination (glue failure) to fracture in the wood (timber failure)

Two adhesives were tested including a commercial brand Evo-Stik and a industrial grade adhesive PUR_2. Stress and strain graphs were produced for both adhesives at ambient, 50 and 150°C



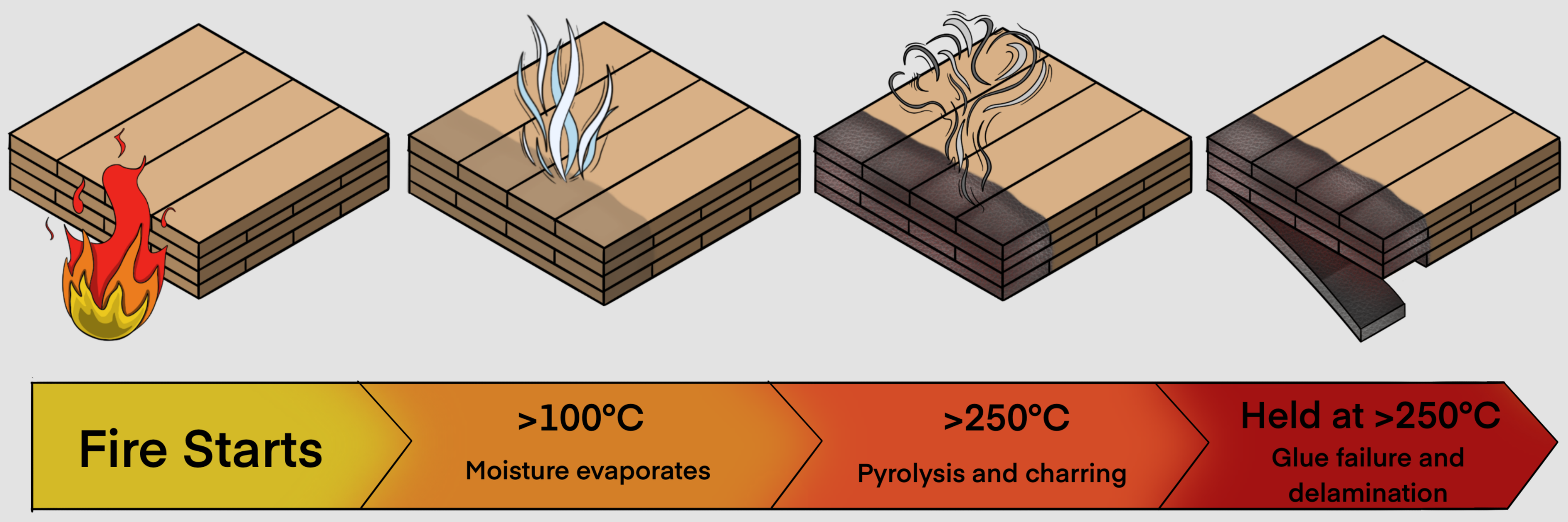


Important Factors

Viscosity, the Evo-Stik PUR was inconsistent in the quality of its bonding which is likely due to the glue being a more viscous adhesive and hardening very quickly. The PUR_2 adhesive was a comparably runnier substance with a longer setting time. The delayed setting and reduced viscosity allows the adhesive to be absorbed deeper within the timber, forming more interlocking mechanisms and increasing its overall strength and consistency.

Surface Preparation, the strongest specimens seen in the majority of the tests, were found to have planed or smoother surfaces. By treating the surface, the porosity of the timber will dramatically increase through the act of slicing the wood cells [4], encouraging the timber to soak up more adhesive and allow for a stronger bond.

Strength Recovery, The 150°C tests suggested that the samples had cured faster in the oven. Cooling the heated samples before testing had shown that they had regained and grown in strength. This can alleviate the ambiguity surrounding fire damaged buildings. In some cases, it is not necessarily obvious what the structural capacity of an element is, especially when the material has not been charred or visibly damaged [5].



Above: Timeline of the behaviour of laminated timber when exposed to fire.

What Happens Next?

It was interesting to note that the difference between the behaviour of the different adhesives was not tied solely to their strength. The PUR_2 adhesive would appear to bolster the properties of the composite when exposed to higher temperatures and allowed to cool. These results suggest that fire damaged timber doesn't necessarily have to be discarded, saving investors' money and time.

The tests also emphasised the importance of material preparation before the application of the timber adhesive to ensure a stronger bond. Taking into account the quality of the timber's surface in future tests, the shear capacity of the composites can undoubtedly be expected to exceed current figures.

Although the results and analysis attest to the important role the adhesive assumes in the durability of timber laminated structures to heat, more tests need to be run as timber is a natural material with anisotropic properties, therefore it can be difficult to determine results with so few repeats.

Acknowledgements: I would like to extend my thanks to Dr M. McLaggan and Professor Davison Buick for their guidance and getting me glued into the topic! Additionally, this project would have been impossible without the assistance of Sam Gibson in the lab.

References: [1] Climate Change Committee. (2018). Biomass in a low-carbon economy. [2] Xia, B., O'Neill, T., Zuo, J., Skitmore, M. and Chen, Q. (2014). Perceived obstacles to multi-storey timber-frame construction: an Australian study. [3] Antonela Colic, Luke A. Bisby, Felix Wiesner, Juan Patricio Hidalgo. (2021) Delamination and char fall-off in fire exposed cross-laminated timber loaded in shear. [4] Sogutlu, C. (2017). Determination of the effect of surface roughness on the bonding strength of wooden materials. [5] Ziehl, P.H. and Caicedo, J. (2012). Inspection, testing, and monitoring of buildings and Bridges.