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Response of Mechanically Fabricated Dovetail Joints for CLT Folded Structures

S10

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Introduction

CLT folded plate structures have the potential to create efficient, low cost, sustainable and aesthetically pleasing structures for an immensely wide range of geometric forms accommodating for the ambitious architect to the prudent planner. Integral, multiple tab and slot, joints offer motion of only one degree of freedom, whilst accommodating a simple construction and providing a semi-rigid connection. This project undertakes a parametric investigation into the structural response of the dovetail joint in three-layered CLT, by means of solid finite element analysis using Abaqus. The structural behaviour of an entire folded plate structure is also explored in a grasshopper parametric model.

Abaqus

Method

Abaqus models of three-layered CLT panel dovetail joints were built varying the parameters, tab length, angle, spacing, number and panel thickness. The joints were subjected to a 20mm displacement. The configuration of these joints is displayed in Figure 1 and a typical stress plot is displayed in Figure 2. The parameters were varied to a feasible minimum and maximum, and are normalised by the largest value for this poster. The angular stiffness and load bearing capacity were estimated from the results.

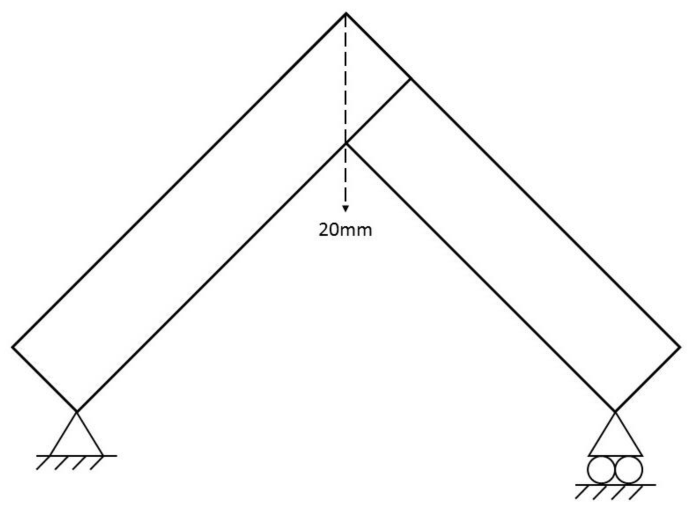

Figure 1: Joint configuration

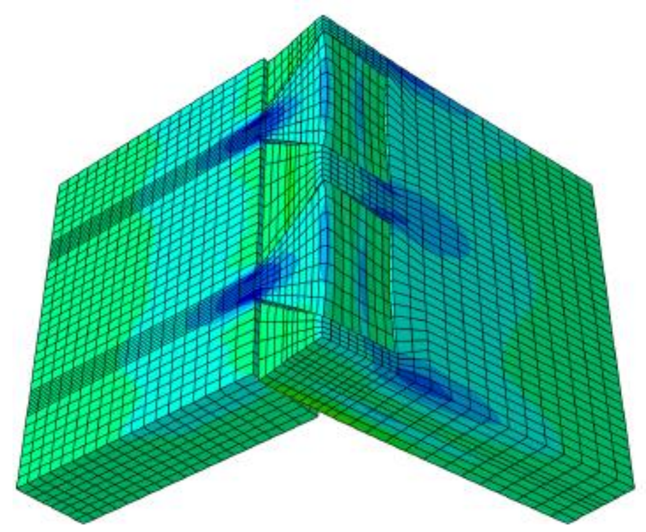

Figure 2: Typical in plane stress plot – S11

Stiffness

The stiffness is affected by the parameters in different ways, as depicted by Figure 3. The panel thickness has the largest effect, in what seems to be an exponential trend. The tab angle follows in a negatively parabolic trend. The tab number understandably increases the stiffness. The tab spacing and length have negative correlations with a relatively small impact across the range.

A typical stiffness for a dovetail joint in three-layered CLT is 0.1 kNm/mrad/m.

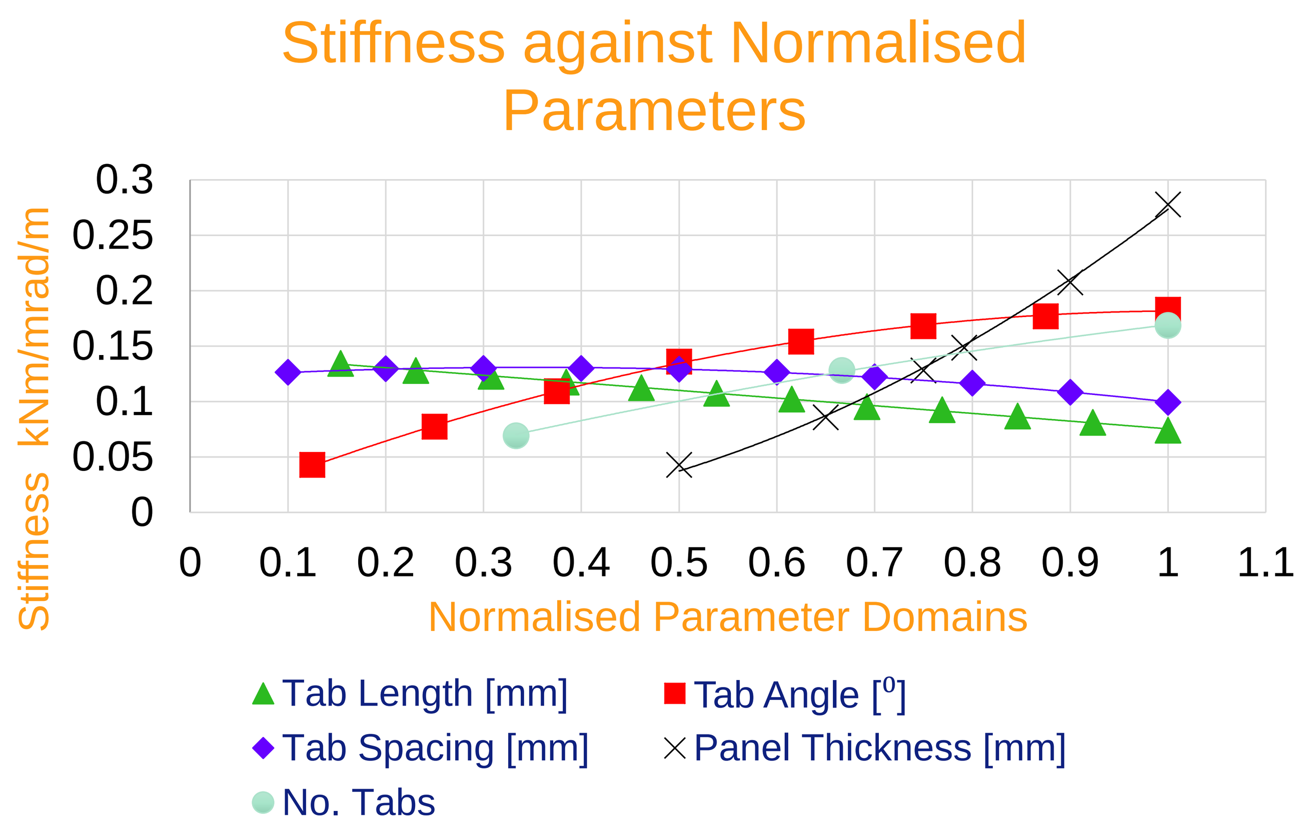

Figure 3: Angular stiffness against normalised parameters

Load Bearing Capacity

The load bearing capacity is indicated to by quantifying the amount of elements that have exceeded the yield stress within a standardised region for each layer of each panel, at 10^0 rotation, a typical rotation for failure.

The study explored the way in which the parameters affected the load bearing capacity, and as can be seen the trends are similar as to above, as depicted in Figure 4.

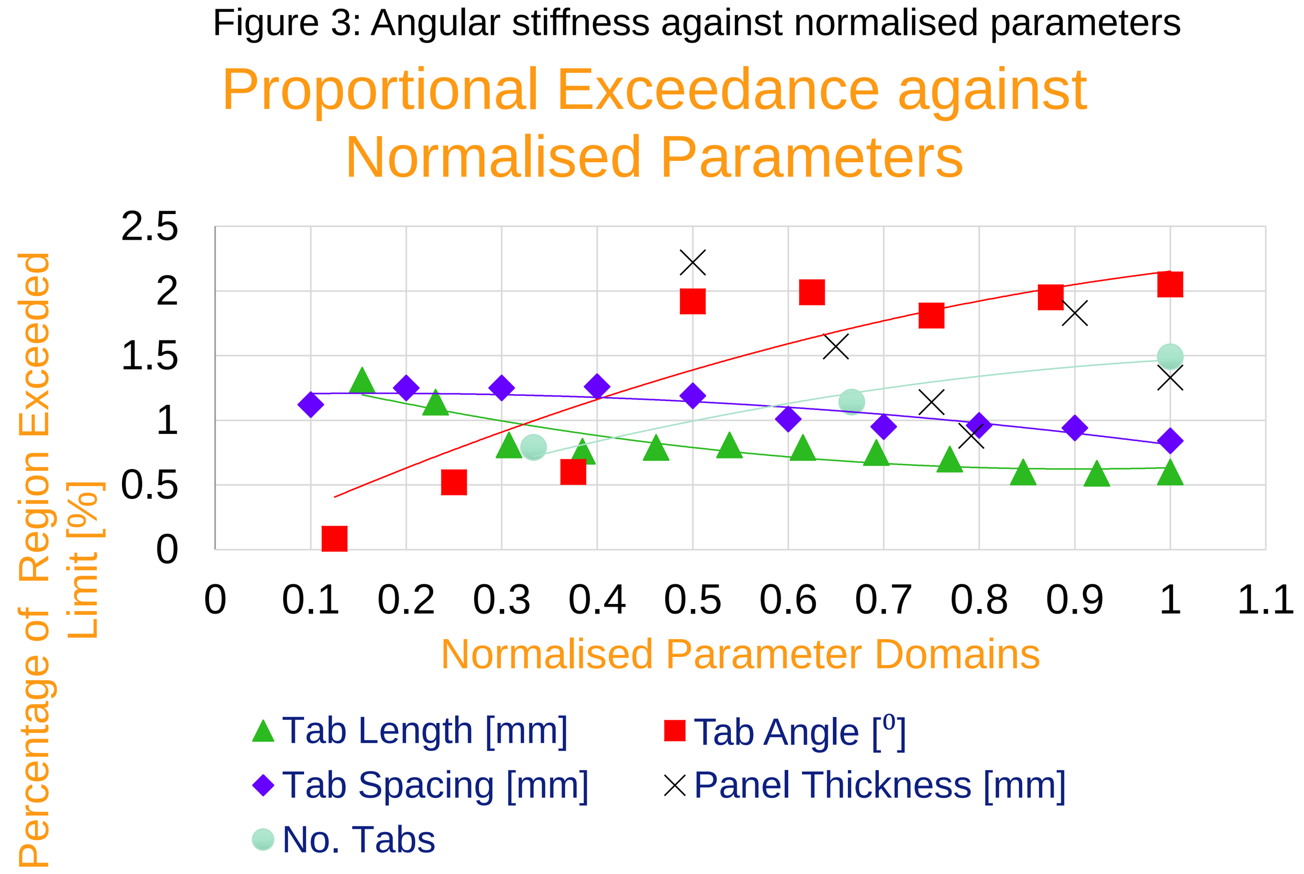

Figure 4: Proportional exceedance against normalised parameters - 10^0

Grasshopper

Method

The geometry of the folded plate structure is comprised of surfaces representing each panel, which are bounded by vertices which lie on one of two lofted surfaces. A simple arch like shell structure with a four metre wide opening is modelled, with each surface meshed to a 20x20 grid with TRIC shell elements, which have 6DOF and uniform stress (Argyris et al., 2000). A few panel configurations were assessed with a 4.5kN/m^2 gravity load case and a 1.5 kN/m^2 horizontal wind load case, considered separately. Figure 5 displays the surface geometry of a configuration and Figure 6 displays a stress plot produced using Grasshopper finite element analysis plug-in Karamba.

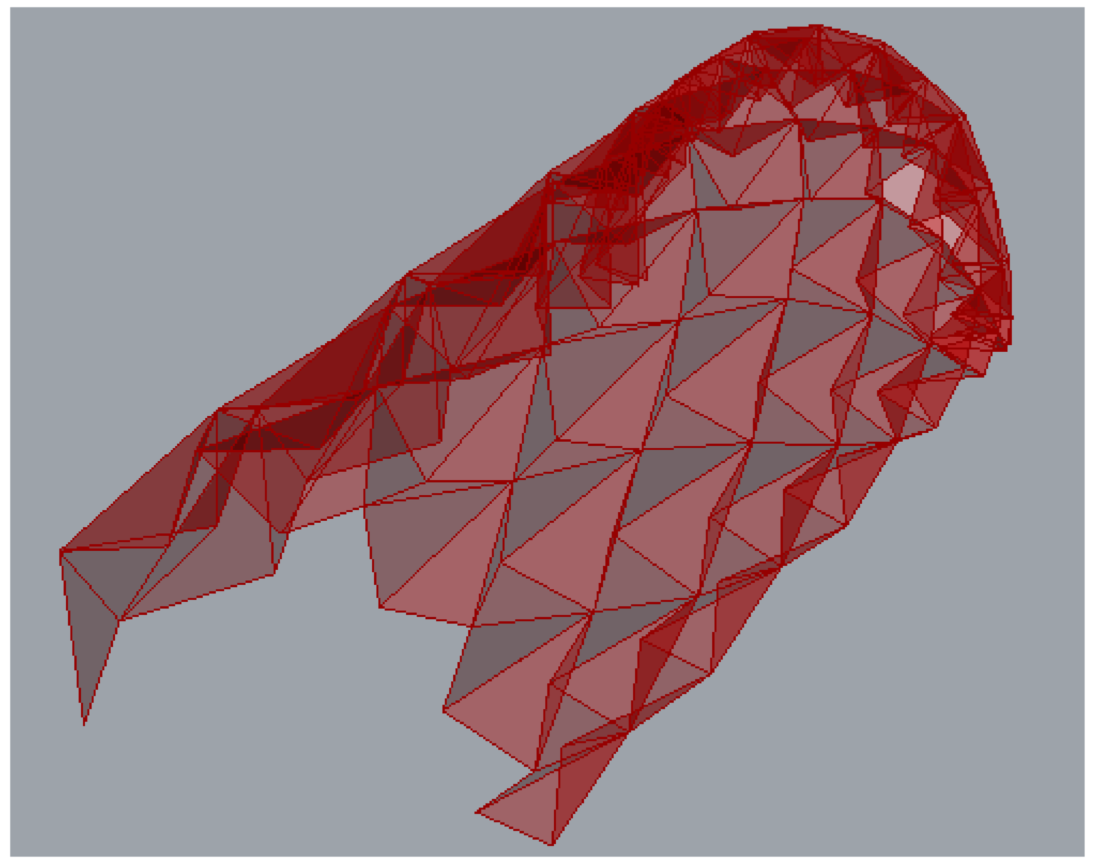

Figure 5: Grasshopper surfaces of structure

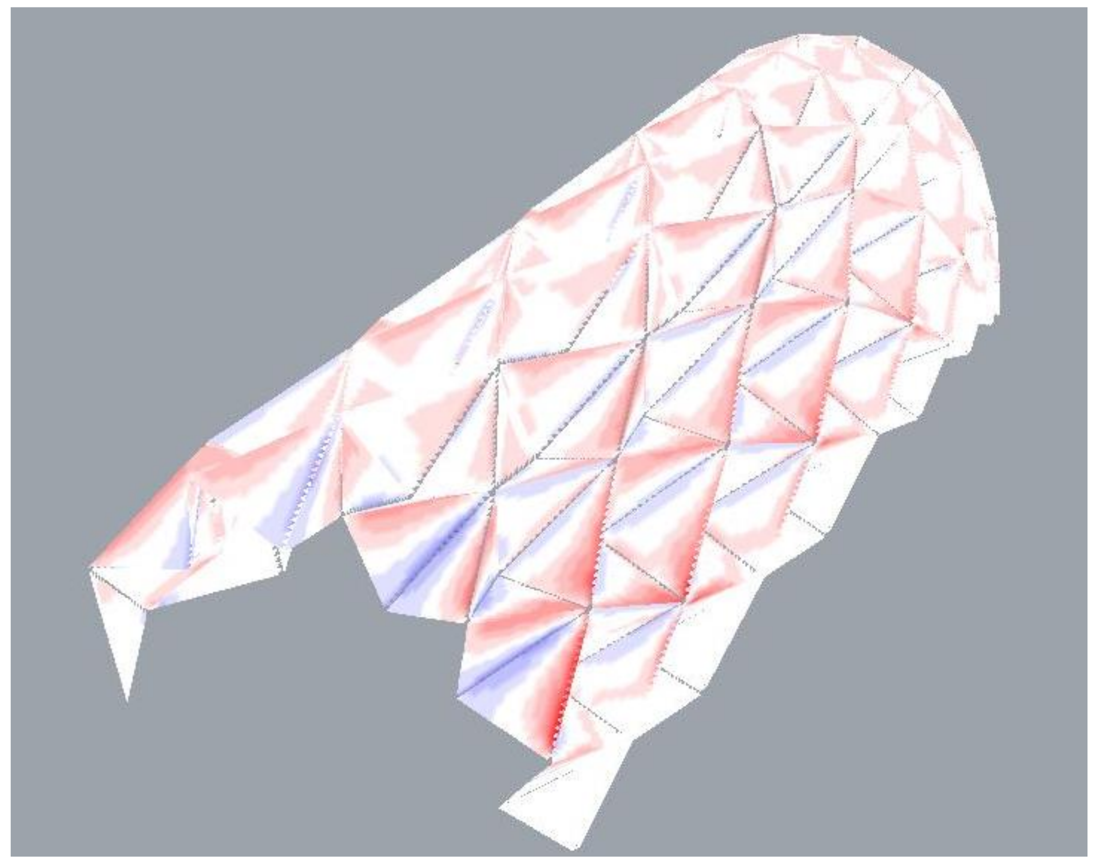

Figure 6: Global principal stress 1 distribution of structure

Results

The model firstly validated the Abaqus loading conditions. The maximum deflection was found to be 4mm, which when considering the joints are modelled as rigid, shows that the Abaqus loading is comprehensive and covers a sufficient range.

Other behaviour observed are loads can be non-uniformly distributed along joints, there can be large stress concentrations at corners and such structures are very sensitive to global instability. These all would have a critical impact of the design of the joints.

Conclusion

The parameters having the largest impact on stiffness and load bearing capacity of the joints are panel thickness and tab angle respectively. The tab spacing and length have the least relative effect, with the tab number being in between. Weaker joints were those that had narrow regions of material, thereby creating large stress concentrations, a benchmark minimum narrowness to ensure satisfactory performance would be 40mm. The tab panel was found to be more critical to failure across all studies. Finally, the grasshopper model confirmed that complex stress patterns need to be accounted for.

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References

Argyris, JH, Papadrakakis, M, Apostolopoulou, C, & Koutsourelakis, S. 2000. The tric shell element: theoretical and numerical investigation. *Computer methods in applied mechanics and engineering*,**182**(1), 217–245.