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LOAD DURATION AND MOISTURE EFFECTS IN THE AXIAL WITHDRAWAL CAPACITY OF SCREWS IN CROSS LAMINATED TIMBER

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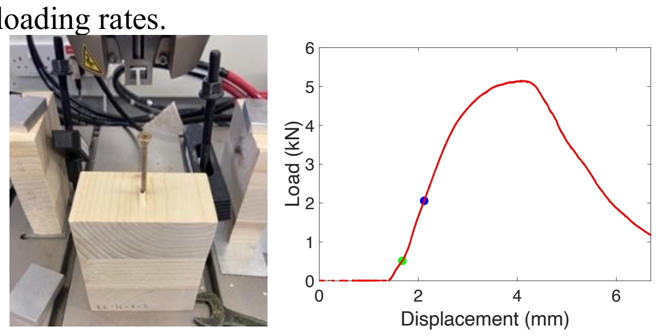
INTRODUCTION

In timber structures, the connection design is critical due to their ductility and energy dissipation properties. Eurocode 5 (EC5) includes design guides for characteristic withdrawal capacity in axially loaded screws. However, there is a lack of guidance on the combined effect of moisture content and loading duration on the effectiveness of screws in CLT. Due to timber's hygroscopic nature and risk of biodegradation, the moisture impact is more critical than in other common building materials. Water damage can also lead to accidental failure, hence connection capacity at high loading rates requires further investigation to prevent disproportionate collapse. Therefore, this research aimed to investigate the combined effect of moisture content and rate of loading on the withdrawal capacity of screws in CLT. Specimens of CLT were prepared by inserting screws and modifying their moisture content to 8, 16, and >20% to represent EC5's three service classes. They were then tested at three loading rates of 6, 6000 and 60000mm/min with the latter representing accidental loading. The results were compared to existing models, and the current EC5 k_{mod} factors.

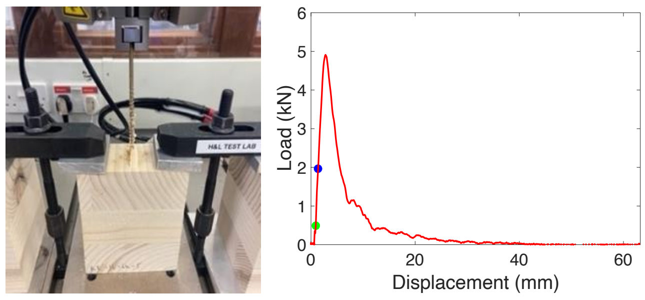
RESULTS

FAILURE TYPES & LOAD DISPLACEMENT

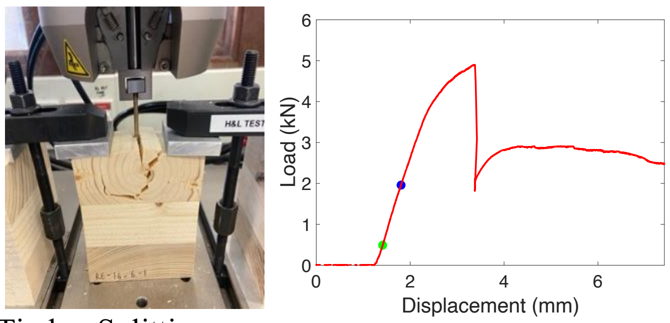
Multiple failure types were observed, with withdrawal failure being most common in samples of high moisture content and high loading rates, whilst timber splitting was seen in low moisture samples at low loading rates.



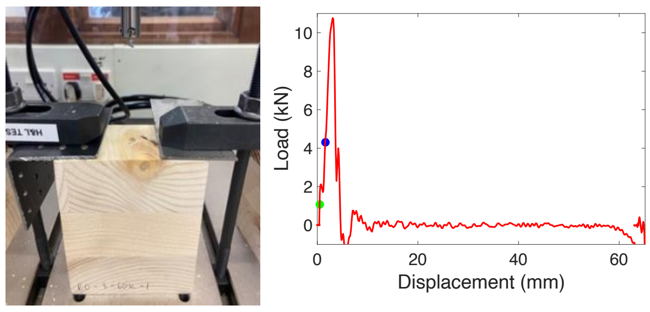
Withdrawal Failure 6mm/min



Withdrawal Failure 60000mm/min



Timber Splitting

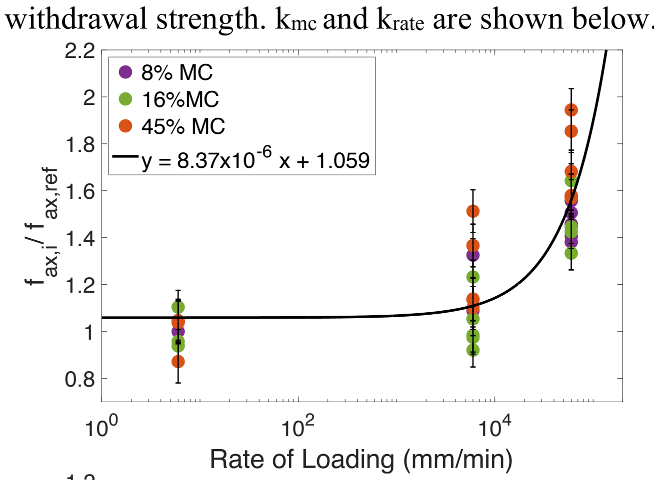


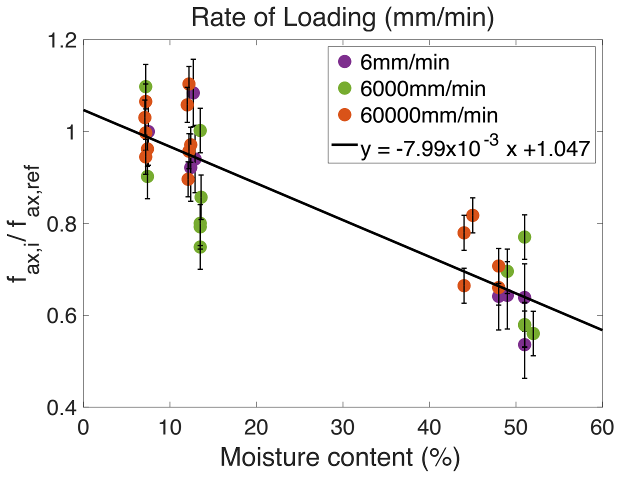
Screw Tensile Failure

k FACTORS

REDUCTION COEFFICIENTS

The reduction coefficients, k_{mc} and k_{rate}, were found from the gradient of the linear regression of a plot of the independent variable against the normalised withdrawal strength. k_{mc} and k_{rate} are shown below.

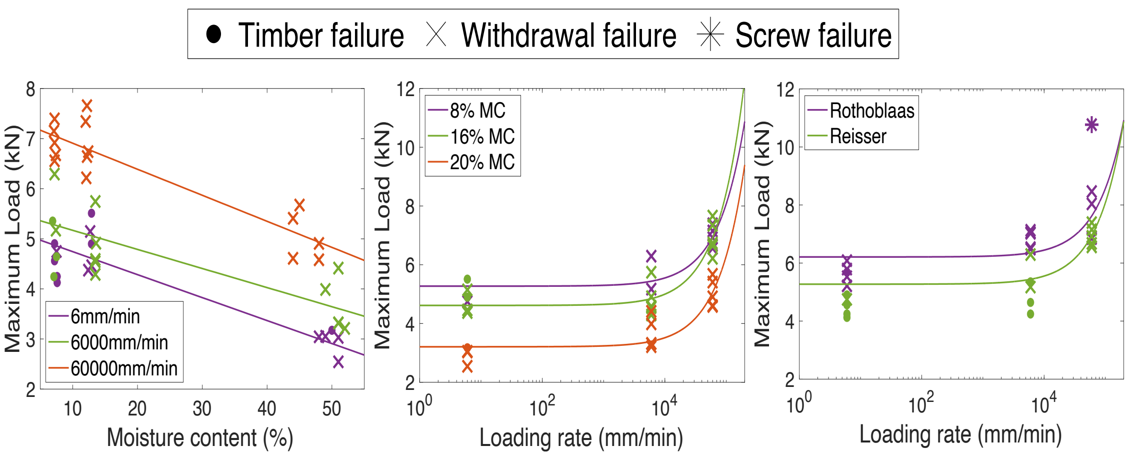




k_{mc}	k_{rate}
-7.99×10^{-3}	8.37×10^{-6}

F_{max} TRENDS

The graphs show that withdrawal capacity has a negative correlation with moisture content at all loading rates and a positive correlation with loading rate at all moisture contents and for both screw types.



η_{rate} and η_{mc}

MODIFICATION FACTORS

The reduction coefficients are used in the following equations to produce two modification factors for the effect of moisture content and rate of loading. The modification factors are then applied to Uibel and Blaß's model[1] to predict the axial withdrawal capacity of screws in CLT with respect to moisture content and loading rate.

Moisture content modification factor:

$$\eta_{MC} = \frac{f_{ax,i}}{f_{ax,8\%,ref}} = 1 - k_{mc}(8 - MC)$$

Rate of loading modification factor:

$$\eta_{rate} = \frac{f_{ax,i}}{f_{ax,ref,6mm/min}} = 1 - k_{rate}(6 - ROL)$$

Predicted axial withdrawal capacity of fastener:

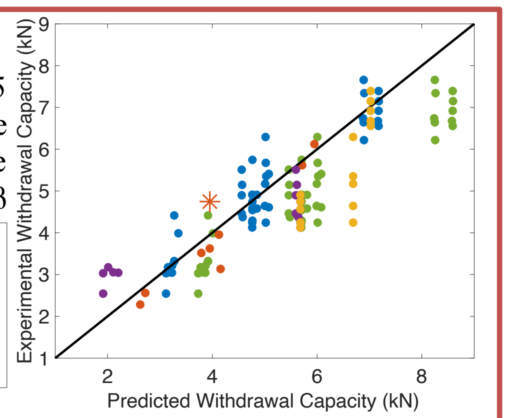
$$F_{ax,pred} = 0.44\, d^{0.8}\, l_{ef}^{\;0.9} \rho^{0.75}\, \eta_{rate}\, \eta_{MC}$$

CONCLUSIONS

- Samples were more likely to fail by withdrawal at high moisture contents and high rate of loading. Whereas, at low loading rates and low moisture contents, timber failure was more common.
- Modification factors η_{mc} and η_{rate} are suggested as additions to the current EC5 equation for axial screw withdrawal, due to their significant correlation between prediction and experimental results. A more conservative combined factor is also suggested to replace the current k_{mod} factor for connection design.

COMPARISONS OF MODELS

The prediction model that best fits the experimental data is from EC5 after modification by the new factors suggested in this paper. The correlation value is high enough to suggest these factors could be considered as an addition to EC5. The r value using the Uibel and Blaß model is less significant since the model is for screws with diameters greater than 6mm.



COMPARISON TO k_{mod}

Model	η_{mc}			η_{rate}			k_{mod} (instantaneous)		
	8% MC	16% MC	45% MC	6mm/min	6000mm/min	60000mm/min	SC1	SC2	SC3
Silva et al.[2]	1.000	0.932	0.439						
Ringhofer and Schickhofer[3]				1.000	1.177	1.236			
Eurocode 5 (Glue laminated Timber)							1.100	1.100	0.900
Gawne	1.000	0.936	0.704	1.000	1.050	1.500	0.966	0.899	0.690

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[1]Uibel, T. and Blaß, H.J. (2007). Edge Joints with Dowel Type Fasteners in Cross Laminated Timber. In: *CIB - W18 Meeting forty*. CIB-W18
[2] Silva, C., Branco, J.M., Ringhofer, A., Lourenço, P.B. and Schickhofer, G. (2016). The influences of moisture content variation, number and width of gaps on the withdrawal resistance of self tapping screws inserted in cross laminated timber. *Construction and Building Materials*, 125, pp.1205–1215.
[3]Ringhofer, A. and Schickhofer, G. (2014). Influencing Parameters of the Experimental Determination of the Withdrawal Capacity of Self-Tapping Screws. In: *WCTE 2014 Conference Proceedings*. World Conference on Timber Engineering. pp.1–10.