Universität Stuttgart
Fakultät für Bau- und Umweltingenieurwissenschaften

Adnan Ali Imran

Material Modeling and Simulation of Wood for Anchoring Applications

Motivation

Wood is one of the oldest materials that still has not lost its importance in the construction industry. The objective of this study is to understand the behavior of timber as a construction material. And the influence of different parameters on its mechanical properties. Further, to simulate it under different loading scenarios with the help of commercially available software LS-Dyna. Which has a build-in, dedicated material model (MatWood-143) for wood. And finally, to validate the responses with available literature and testing data.

MatWood-143

Transversely isotropic:
Simplify the mechaical behaviour of wood to 2 directions, parallel to grains and perpendicular to grains. Only 5 independent elastic parameters are required.

E_L, $E_T = E_R$, $G_{LT} = G_{LR}$, G_{TR} and ν_{LT}

Pre- and Post-peak hardening:
Wood shows considerable amount of hardening under compressive loads. That has been formulated through pre- and post-peak hardening parameters.

$N_\parallel$, $N_\perp$, $c_\parallel$, $c_\perp$, G_{hard}

Post-peak softening:
Wood illustrates softening response under tensile and shearing loads. Which has been formulated through damage variables and fracture energies.

D, $d_{max\parallel}$, $G_{fI,\parallel}$, $G_{fII,\parallel}$, B, $d_{max\perp}$, $G_{fI,\perp}$, $G_{fII,\perp}$

Failure

- Parallel mode $\quad f_\parallel \geq 0$

$$f_\parallel = \frac{\sigma_L^2}{X^2} + \frac{(\sigma_{LT}^2 + \sigma_{LR}^2)}{S_\parallel^2} - 1 \quad \text{and} \quad X = \begin{cases} X_T & \text{for} \quad \sigma_L > 0 \\ X_C & \text{for} \quad \sigma_L < 0 \end{cases}$$

- Perpendicular mode $\quad f_\perp \geq 0$

$$f_\perp = \frac{(\sigma_T + \sigma_R)^2}{Y^2} + \frac{(\sigma_{TR}^2 - \sigma_T \sigma_R)}{S_\perp^2} - 1 \quad \text{and} \quad Y = \begin{cases} Y_T & \text{for} \quad \sigma_T + \sigma_R > 0 \\ Y_C & \text{for} \quad \sigma_T + \sigma_R < 0 \end{cases}$$

Conclusion

- Material model working but has some limitations.
- With single element tests, all failure modes are observed.
- For large scale problem, like 4-PBT the failure mode has been captured with adjustment of hourglass energy, damping energy, loading time and mass scaling.
- For 3-PBT, no distinct perpendicular failure mode has been observed.
- More investigations are required before applying for anchoring applications.

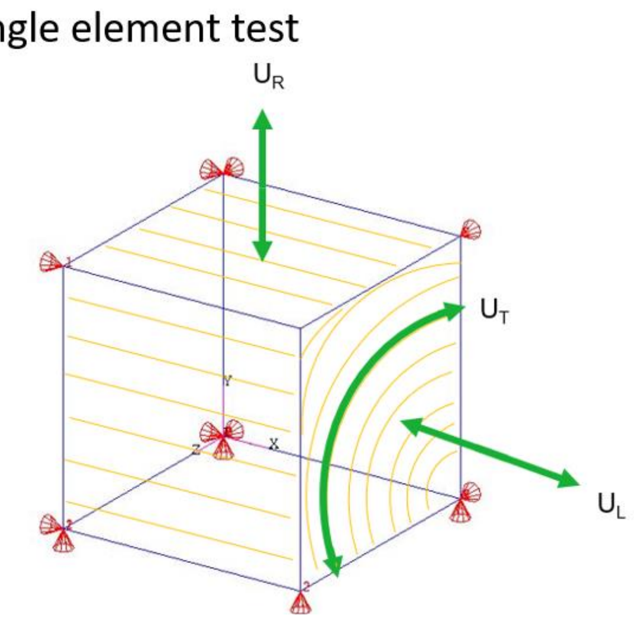
Supervision

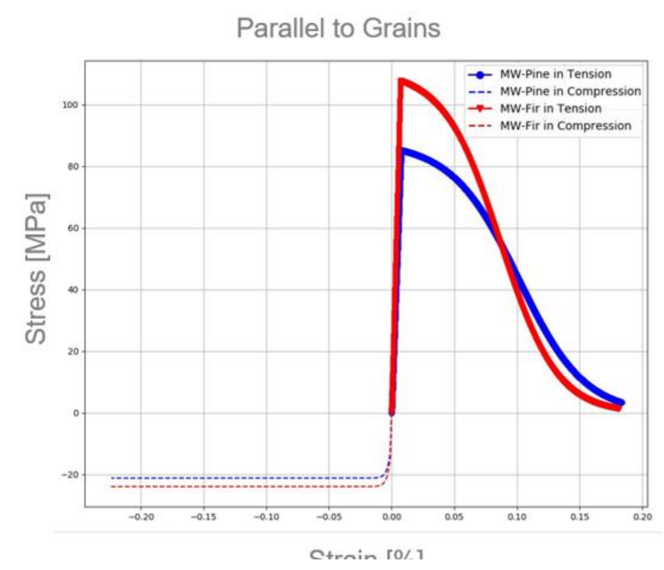
De Groof, Vincent, Dr.-Ing.
https://www.hilti.com

Forster, David, M.Sc.
https://www.ibb.uni-stuttgart.de

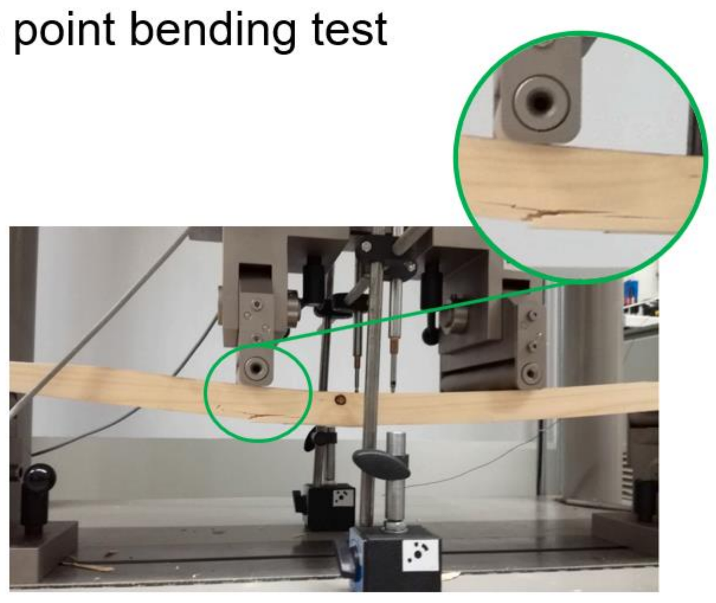
Numerical examples

Single element test

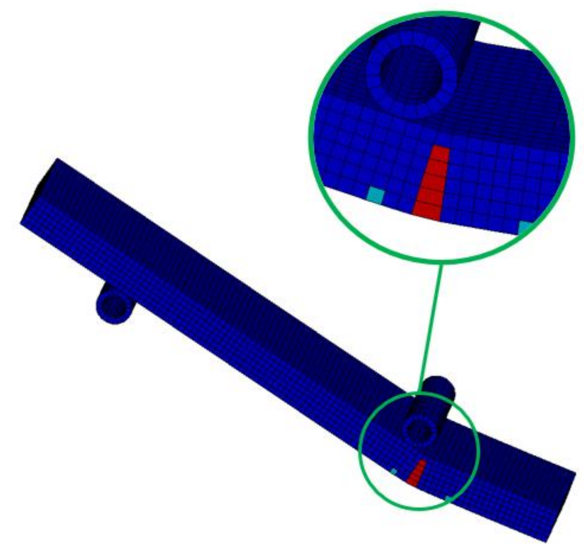




4 point bending test

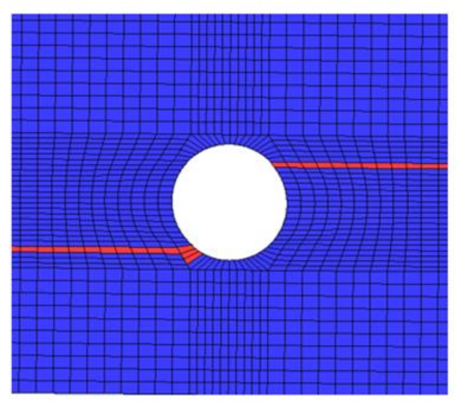


Actual Failure [1]



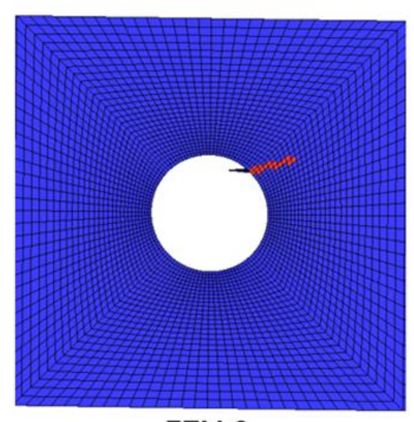
Simulation

3 point bending test (timber beam with a hole inside)



FEM-1

Actual crack [3]



FEM-2

Literatur

1. Eslami, H.; Jayasinghe, L.B.; Waldmann, D.: Nonlinear three-dimensional anisotropic material model for failure analysis of timber. In: Engineering Failure Analysis 130 (2021), p. 333–342
2. Murray, Y.D.: Manual for LS-Dyna Wood Material Model 143. U.S. Department of Transportation. Federal Highway Administration., 2007
3. Fleischmann, M.; Krenn, H.; Eberhardsteiner, J.; Schickhofer, G.: Numerische Berechnung von Holzkonstruktionen unter Verwendung eines orthotropen elasto-plastischen Werkstoffmodells. In: Holz Roh Werkst 65 (2007), p. 301–313

Baustatik und Baudynamik