Identify the factors of creep behavior on small clear wood

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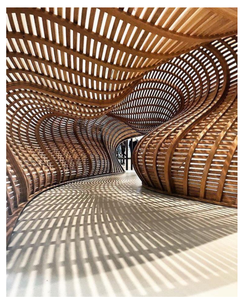
Context and objectives

Alfred-Alexandre Delauney, between 1867 and 1890. The United States Library of Congress's Prints and Photographs division under the digital ID pga.01016.

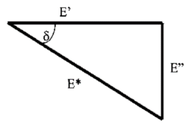


"Drift" Sculpture by Matthias Pliessnig at the Renwick Gallery in WashingtonDC, USA. (ParametricArchitecture, 2018)

Wood has been used in architecture scene to ancient time. As a structure material, its long-term behavior needs to be considered and controlled.

In controlled conditions, wood is a liner viscoelastic material which shows a delay deformation during loading and dynamic mechanical analysis.

Dynamic mechanical analysis



E*: Complex modulus
E′: Storage modulus
E″: Loss modulus

$$E^* = E' + iE"$$

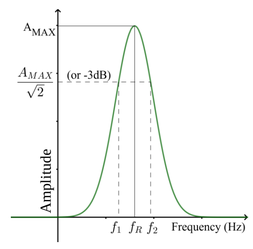
$$\tan\delta = \frac{E"}{E'}$$

Vibration test

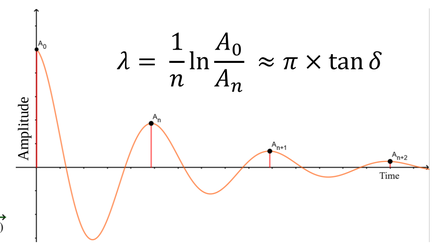
$$E = \frac{48\pi^2\rho l^4 f^2}{m^4 h^2}$$

E: Dynamic MOE
ρ: Density
l: Length of the specimen
h: thickness of the specimen
f: resonance frequency
m = 4.73

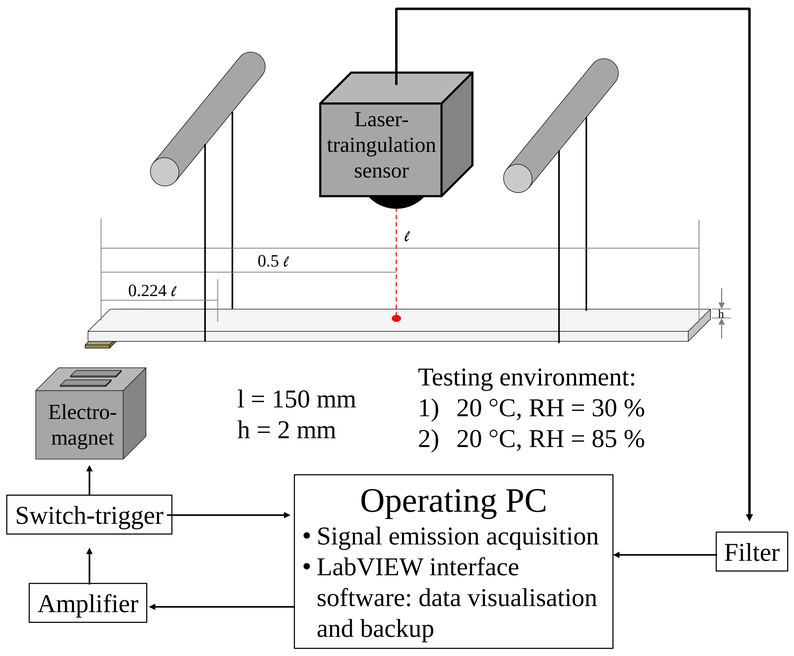
$$Quality\ Factor\ Q^{-1} = \frac{f_1 - f_2}{f_R} = \frac{\Delta f}{f_R} \approx \tan\delta$$



$$\lambda = \frac{1}{n}\ln\frac{A_0}{A_n} \approx \pi \times \tan\delta$$



Vibration tests



A series of vibration signal was given by the electromagnet to the metal piece at the end of the specimen. The signal was collected by the laser-triangulation sensor. The Q^{-1} was calculated by the LabVIEW and the specific modulus was calculated by the resonance frequency and the size, density of the specimen in Microsoft Excel.

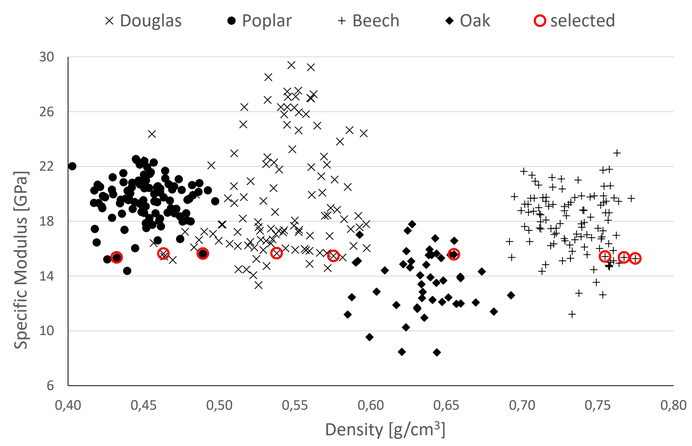
✓ **Data collected: Density, specific modulus, Q^{-1} → Sampling**

Sampling

The vibration test results and the information of the specimens were considered in the sampling. In this study, 9 specimens were selected to have the most wiled density diversity and the closest specific modulus for the creep test. There were 3 **Douglas fir**, 2 **Poplar**, 3 **European Beech**, and 1 **European Oak**.

The matching calculation was done by Microsoft Excel. The criteria value (C) was definded as the variation of the target factor minus all the variation of the control factors. The group with the highest C value was selected for the experiment.

$$C = Variation\ target - \sum Variation\ controls$$



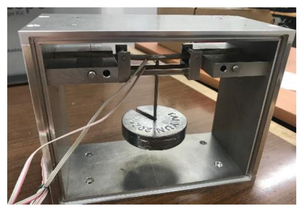
Wood creep behavior

The specimens were placed in the environment 20 °C and RH = 85% testing when they were stable. A 4-point bending test was done in the same condition. The distance of the support was 110 mm and the distance of the loading was 60 mm. 2 gauges collected the deformation at the same time.

$$\varepsilon_c = \frac{\varepsilon^- - \varepsilon^+}{2}$$

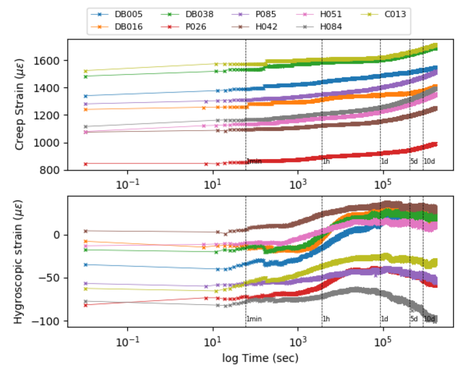
$$\varepsilon_h = \frac{\varepsilon^- + \varepsilon^+}{2}$$

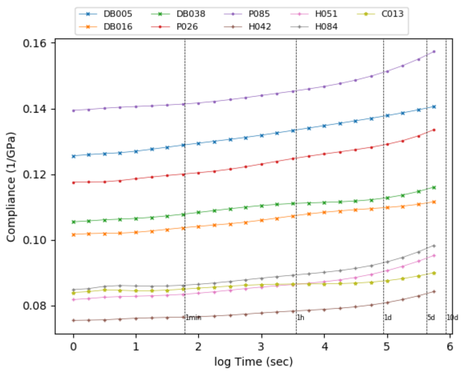
ε_c: Creep strain
ε_h: Hygroscopic strain
ε^+: ε compression side
ε^-: ε tensile side



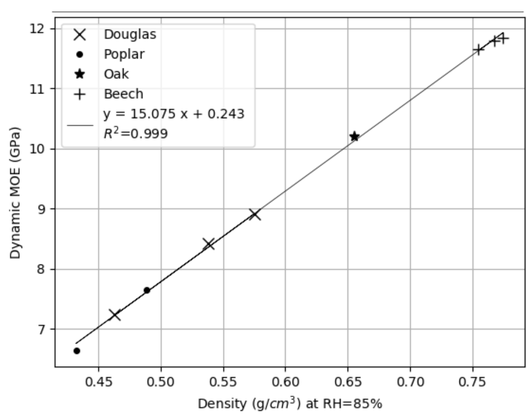
$$J(t) = \frac{\varepsilon(t)}{\sigma}$$

J_0: the first point of compliance
J_{10}: Compliance at 10th day



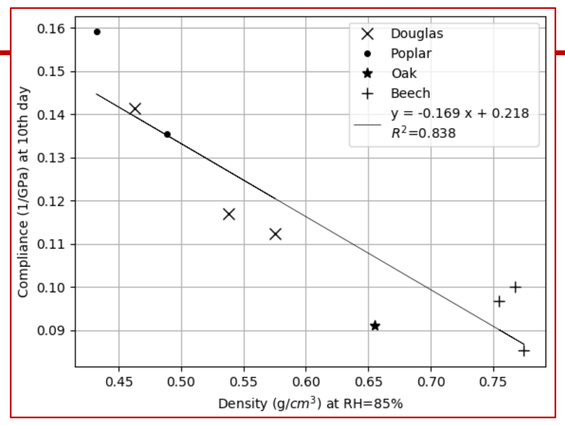


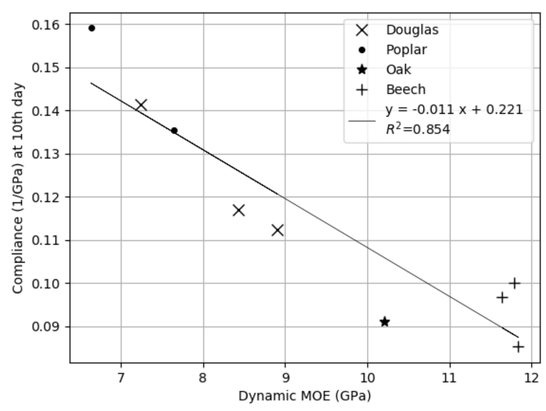
Results and Discussion



The same specific modulus
→ similar cell wall structure:
✓ microfibril angle
✓ Grain angle

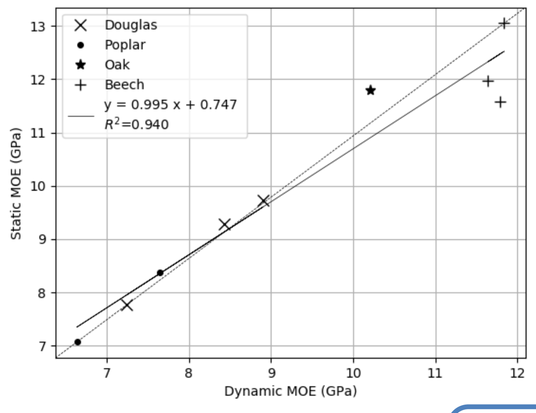
Density ⟷ Porosity
Porosity ⟷ MOE





Specific modulus = constant
→ dynamic MOE can also be a predictor of long-term creep test.

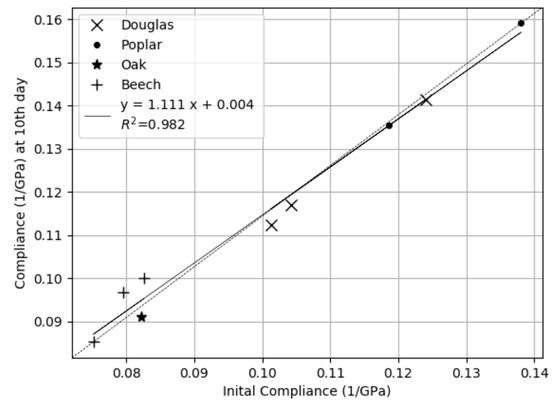
Density → **Dynamic MOE** → **J_{10}**



Comparing the dynamic MOE value from vibration test and the static MOE, it had also a good correlation with a 10% increment.

A linear relationship between J_0 and J_{10}.

The static MOE can well-predict the creep behavior.



Static MOE ⟵ $Static\ MOE = \frac{1}{J_0}$ ⟵ **J_0**

Conclusion

In this study, we can find a linear relationship between dynamic and static MOE. It means that vibration tests can well measure the characteristics of wood, and we can also observe the rheological behavior. Under stable environment, when the specific modulus of the specimens was controlled, we can assume that all the wood specimens have similar cell wall structure. In this case, density was a strong predictor of creep behavior.

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Acknowledgments

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