FROM TREE TO MODERN CROSS-LAMINATED WOOD HOUSES

Jonas SHARIFI

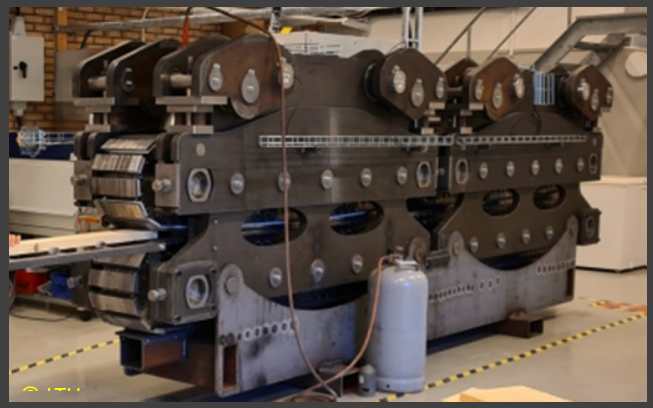
A bit about me…

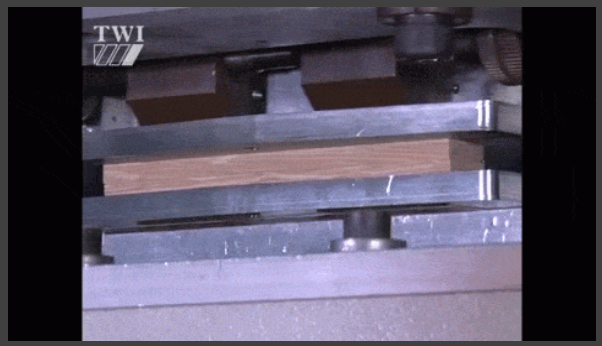
- B.Sc. at Jönköping University
- M.Sc. at Luleå University of Technology
- PhD. at Luleå University of Technology

- Nock Massiva Trähus

LTU

- CT-Scanning
- Wood welding
- Densification of wood





Common Wood Species

No. of species in Sweden:

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- **Norway spruce (*Picea abies*)**
- **Scotsh pine (*Pinus sylvestris*)**
- **Birch (*Betula*)**
- **…**

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- **In Sweden: 45**

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No. of species in the World:

No. of species in Sweden:

- Norway spruce (*Picea abies*)
- Scotsh pine (*Pinus sylvestris*)
- Birch (*Betula*)
- …

- In Sweden: 45

No. of species in the World:

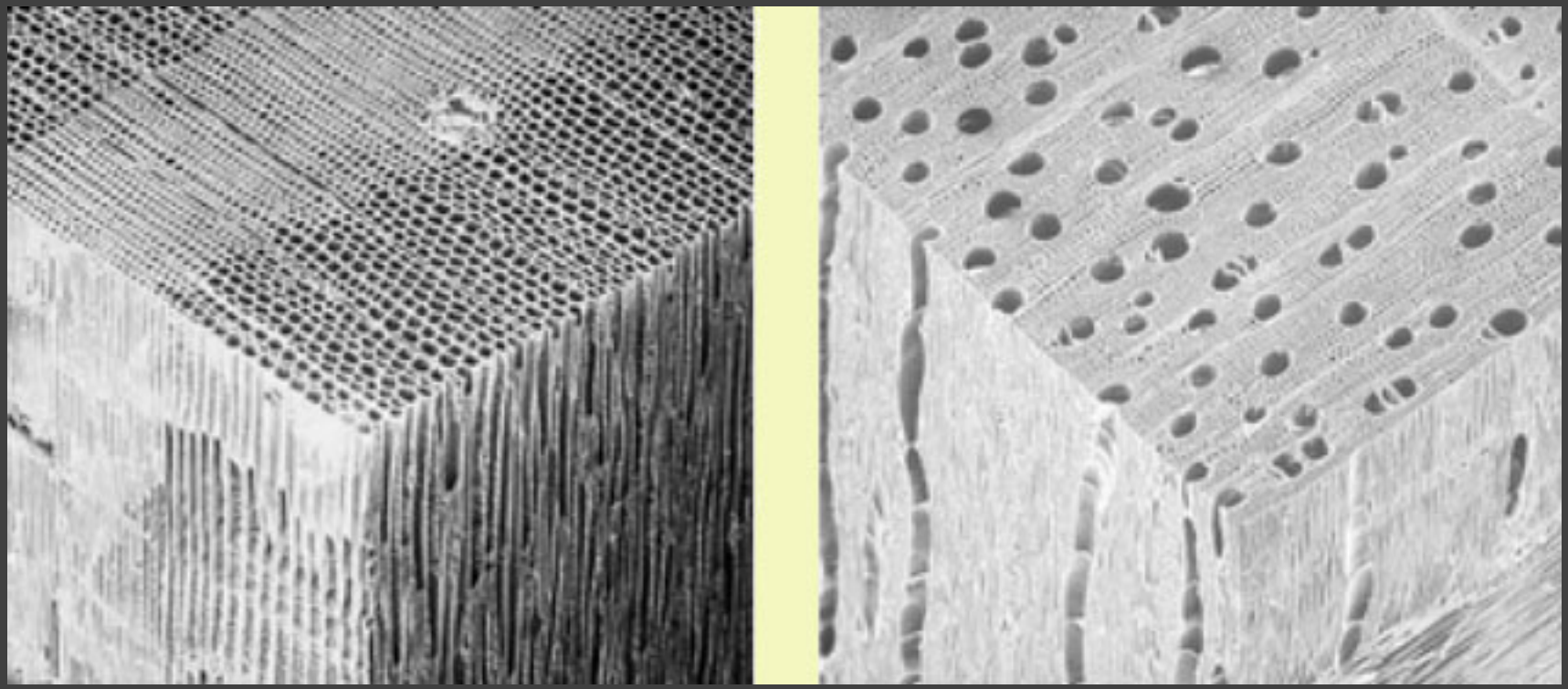
- At least 64 000!!

Uses of Wood

Microscopic View of Wood Species

Softwood

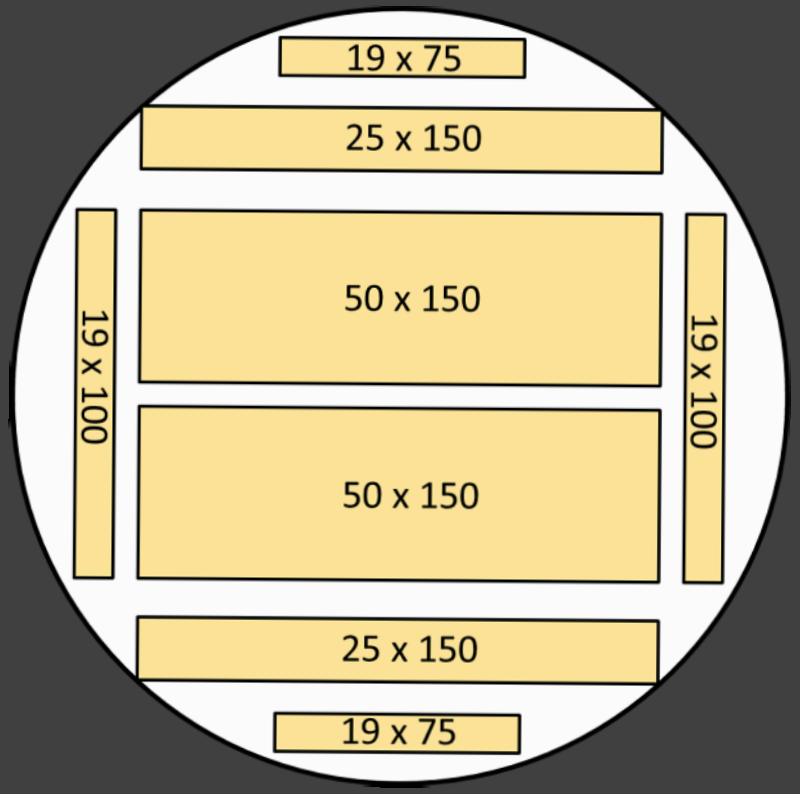
Hardwood

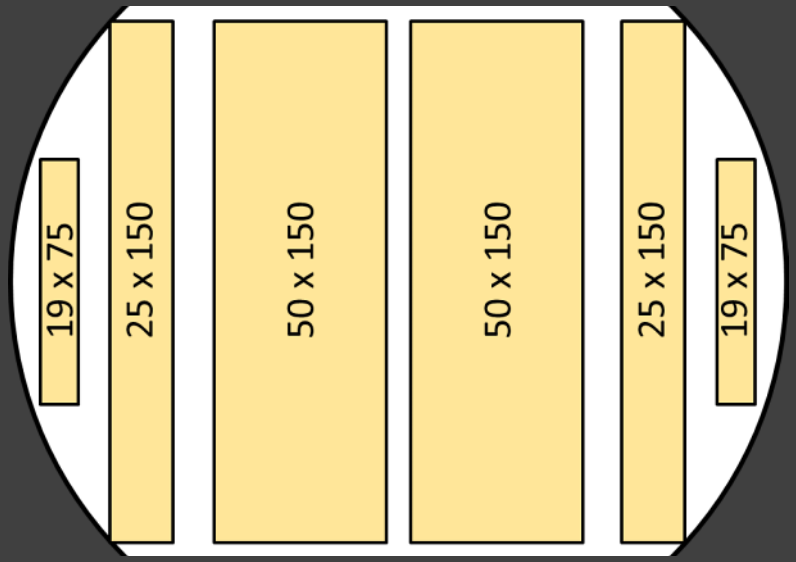


Macroscopic View of wood

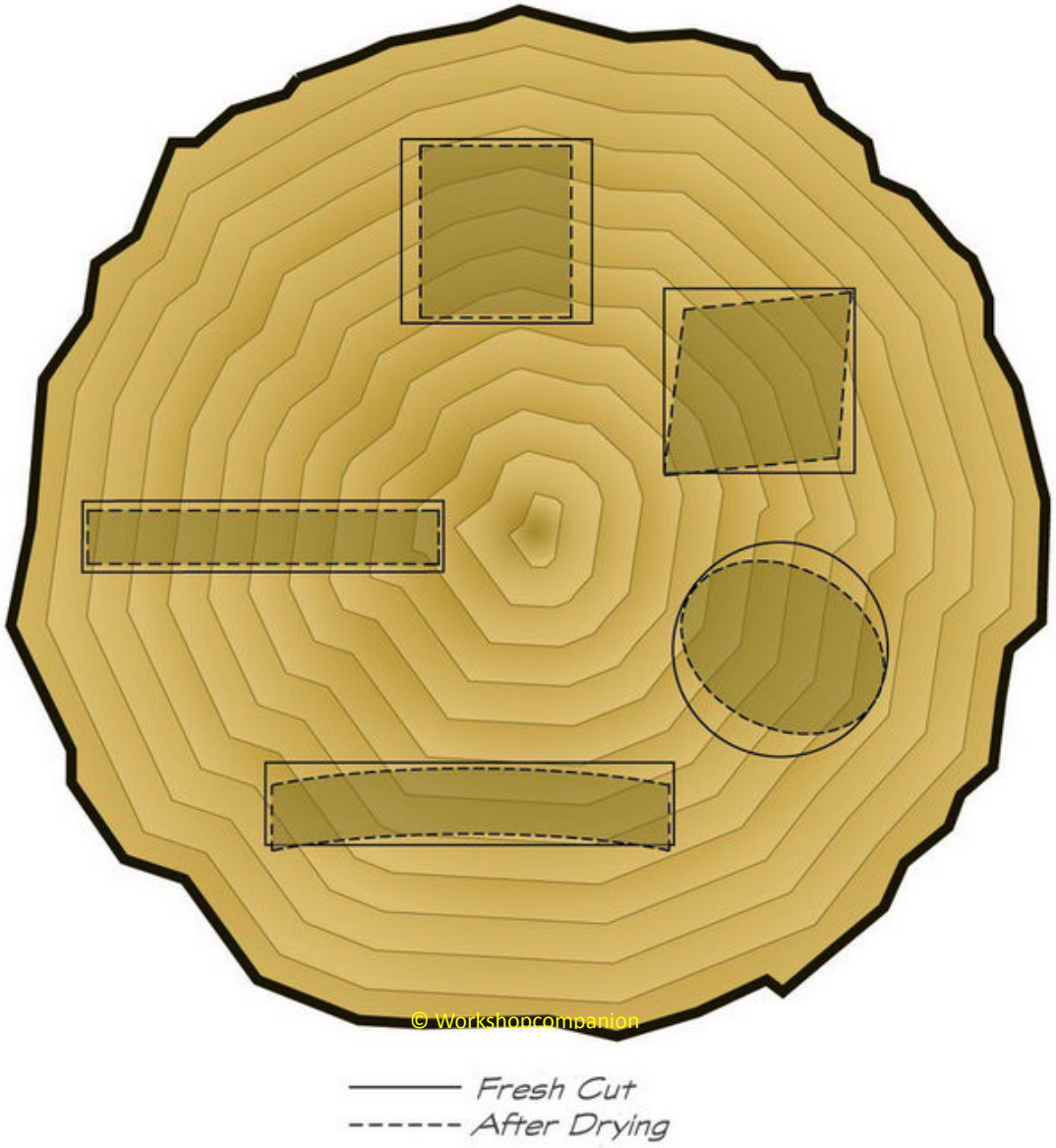
Reaction Wood

How Wood Is Cut





Wood Deformation



Wood Deformation

Green sorting (green timber):

- **Thickness, width, (quality)**

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- Thickness, width, (quality)

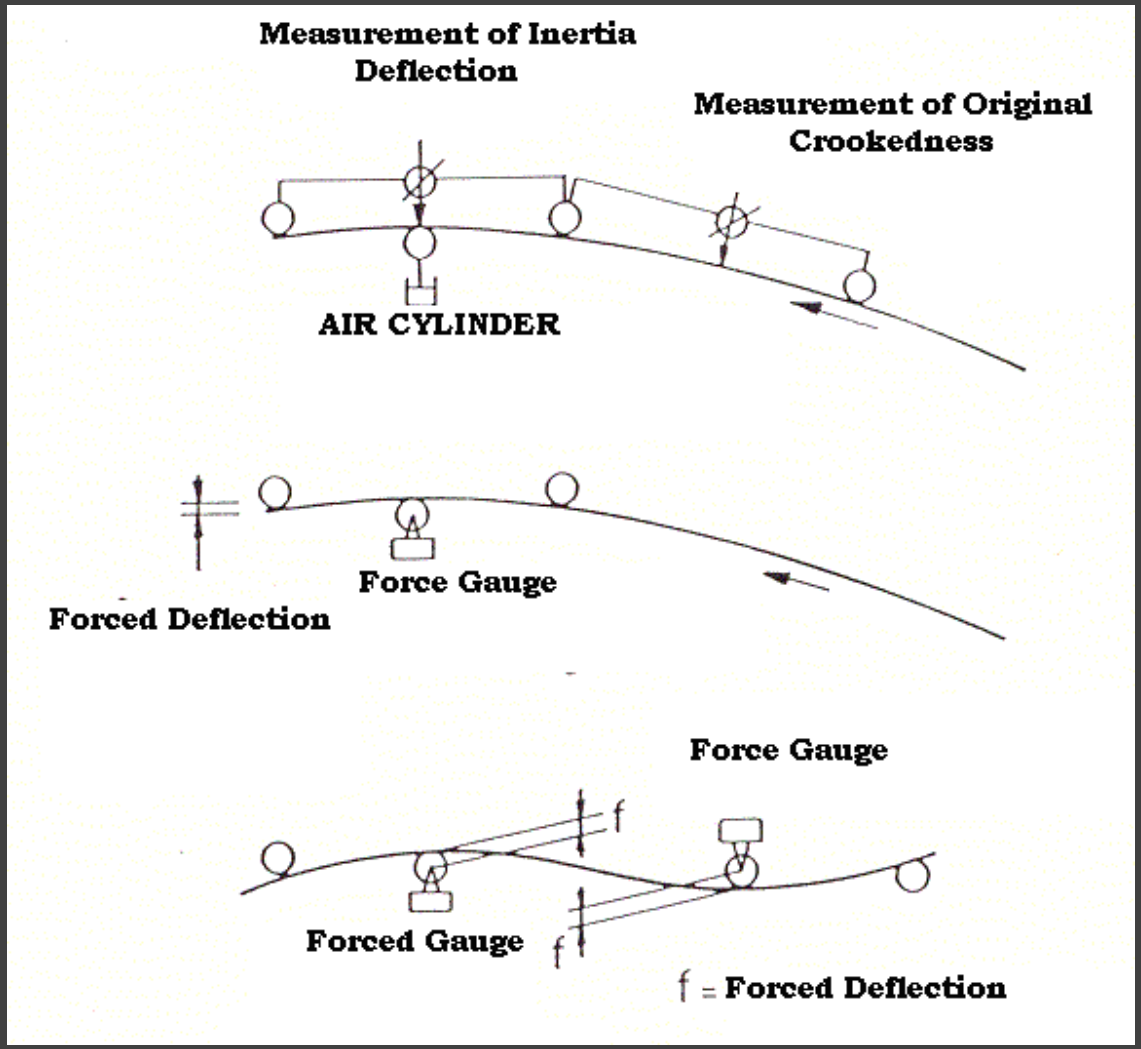
Dry wood sorting:

- Knots (number, size, type, shape, location)
- Fissures (drying checks, ring shakes, splits)
- Wane
- Resin pockets, scars, slope of grain, top rupture, compression wood
- Warp (bow, cup, twist)

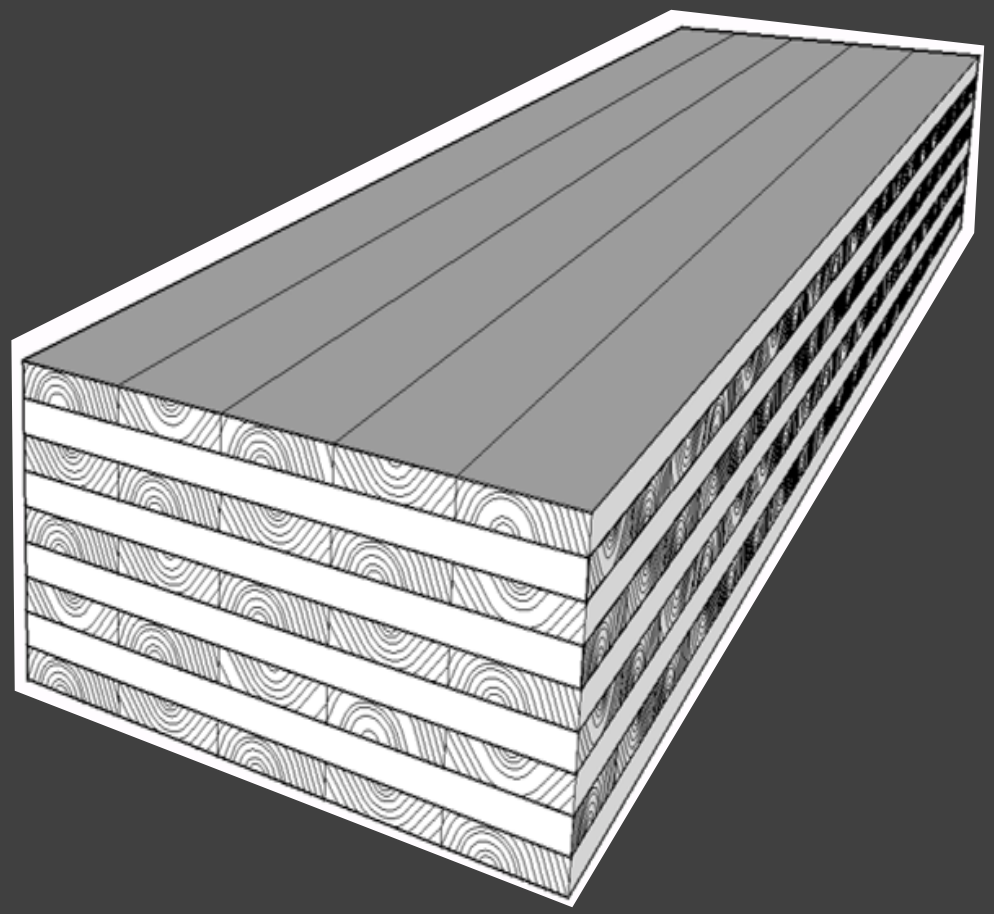
Wood Grading

	C14	C18	C24	C30	C35
Bending parallel	14	18	24	30	35
Tension parallel	7,2	10	14,5	19	22,5
Tension perpendicular	0,4	0,4	0,4	0,4	0,4
Compression parallel	16	18	21	24	25
Compression perpendicular	2,0	2,2	2,5	2,7	2,7
Shear	3,0	3,4	4,0	4,0	4,0
5 percentile MOE parallel bending	4700	6000	7400	8000	8700
Mean MOE parallel bending	7000	9000	11000	12000	13000
Mean MOE perpendicular	230	300	370	400	430
Mean shear modulus	440	560	690	750	810
5 percentile density	290	320	350	380	390
Mean density	350	380	420	460	470

Wood Grading

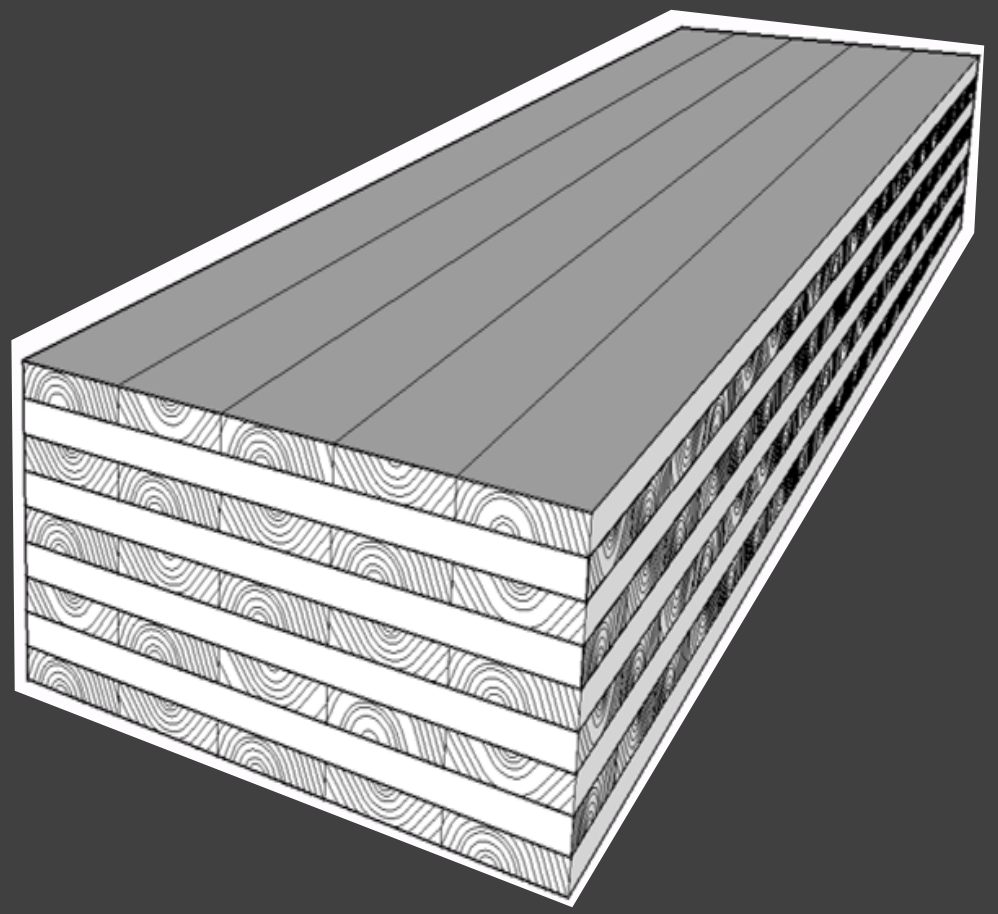


Cross-Laminated Timber (CLT)



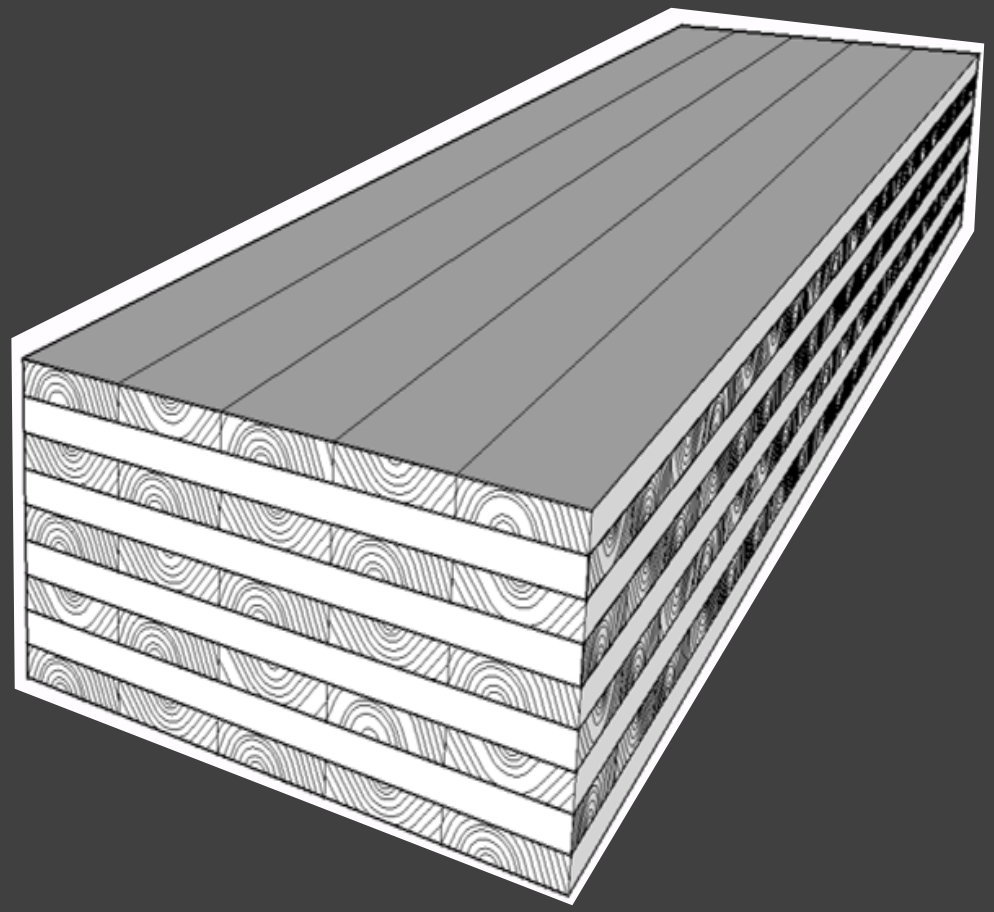
Cross-Laminated Timber (CLT)

- Crosswise layers of boards



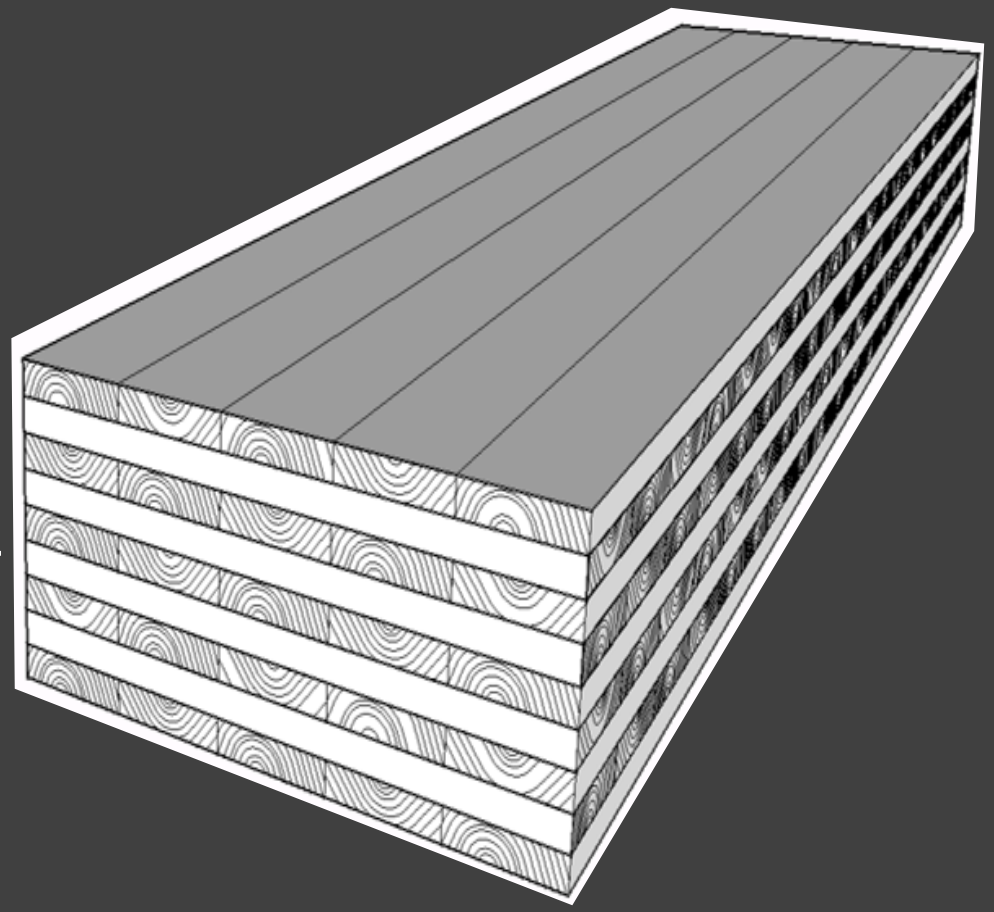
Cross-Laminated Timber (CLT)

- Crosswise layers of boards
- Main laminate direction



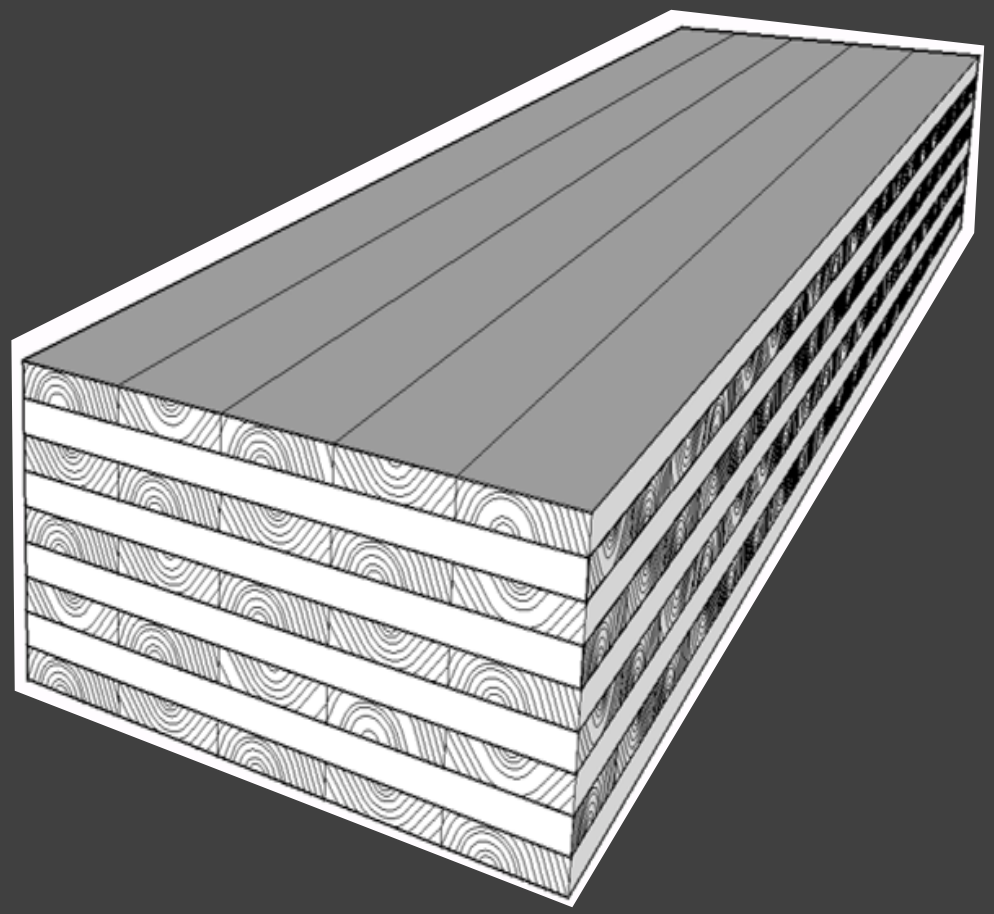
Cross-Laminated Timber (CLT)

- Crosswise layers of boards
- Main laminate direction
- Odd/even-numbered layer



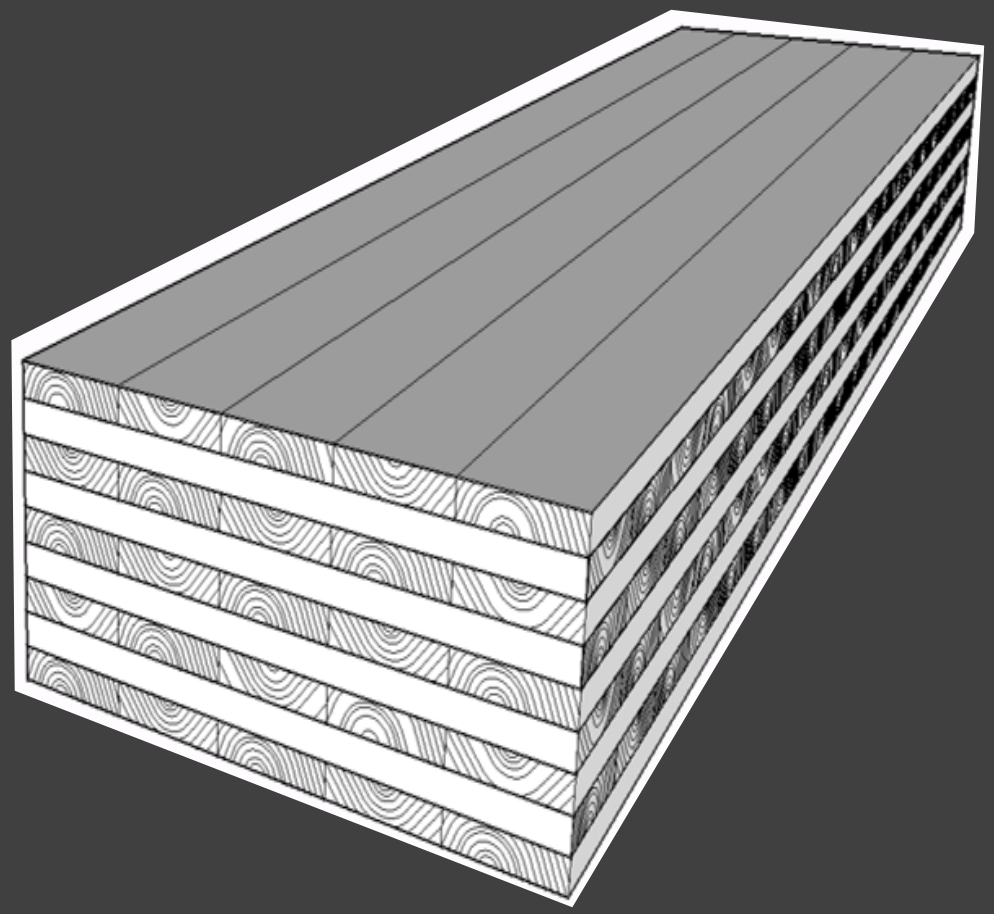
Cross-Laminated Timber (CLT)

- Crosswise layers of boards
- Main laminate direction
- Odd/even-numbered layer
- Glued/non-glued side edges



Cross-Laminated Timber (CLT)

- Crosswise layers of boards
- Main laminate direction
- Odd/even-numbered layer
- Glued/non-glued side edges
- <u>Different materials</u>



Main species in the market:

- Softwood
  - Spruce
  - Larch
  - Fir
  - Douglas fir
  - Pine

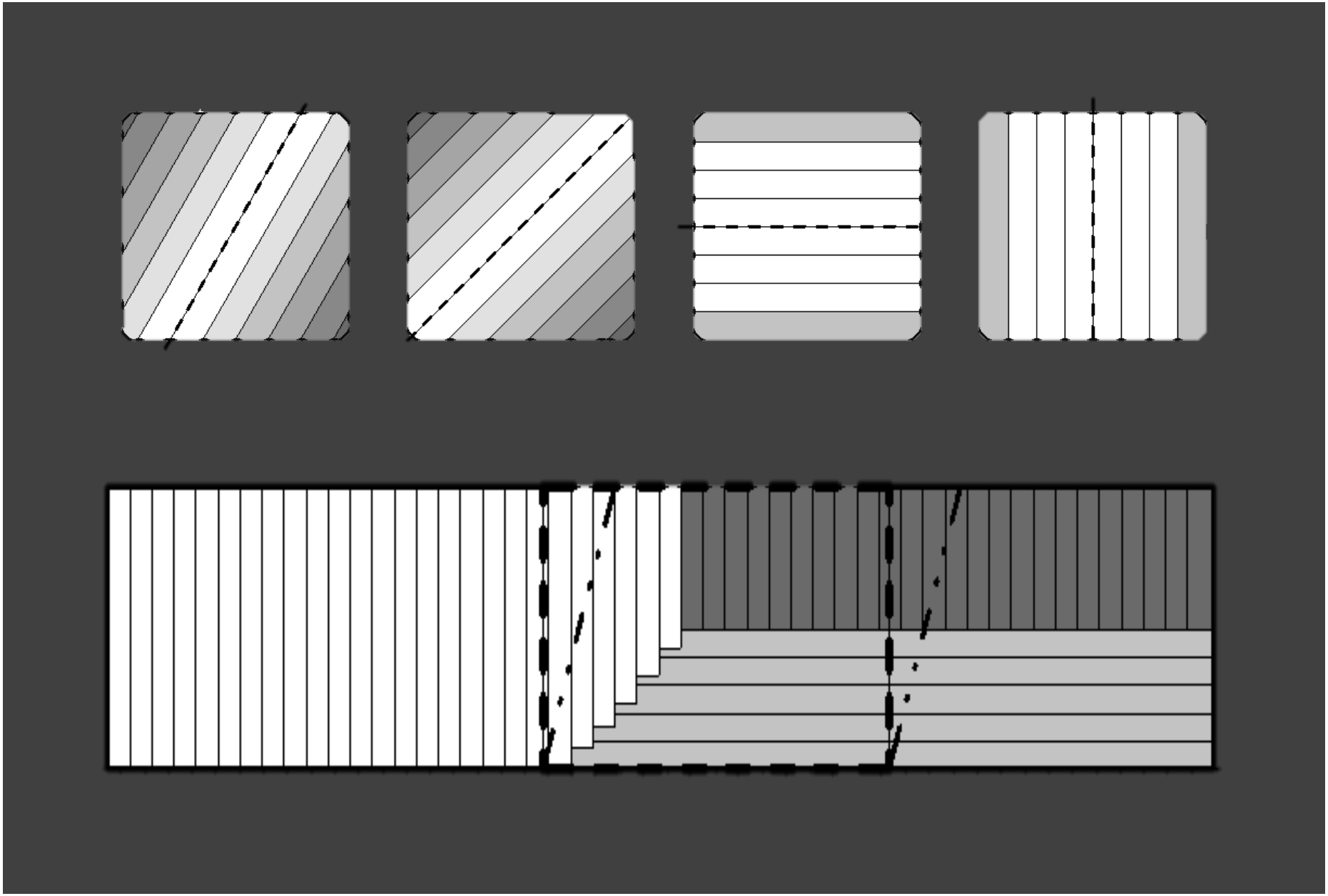
- Hardwood
  - Birch
  - Less common due to machining difficulties
  - More expensive

- (Bamboo)

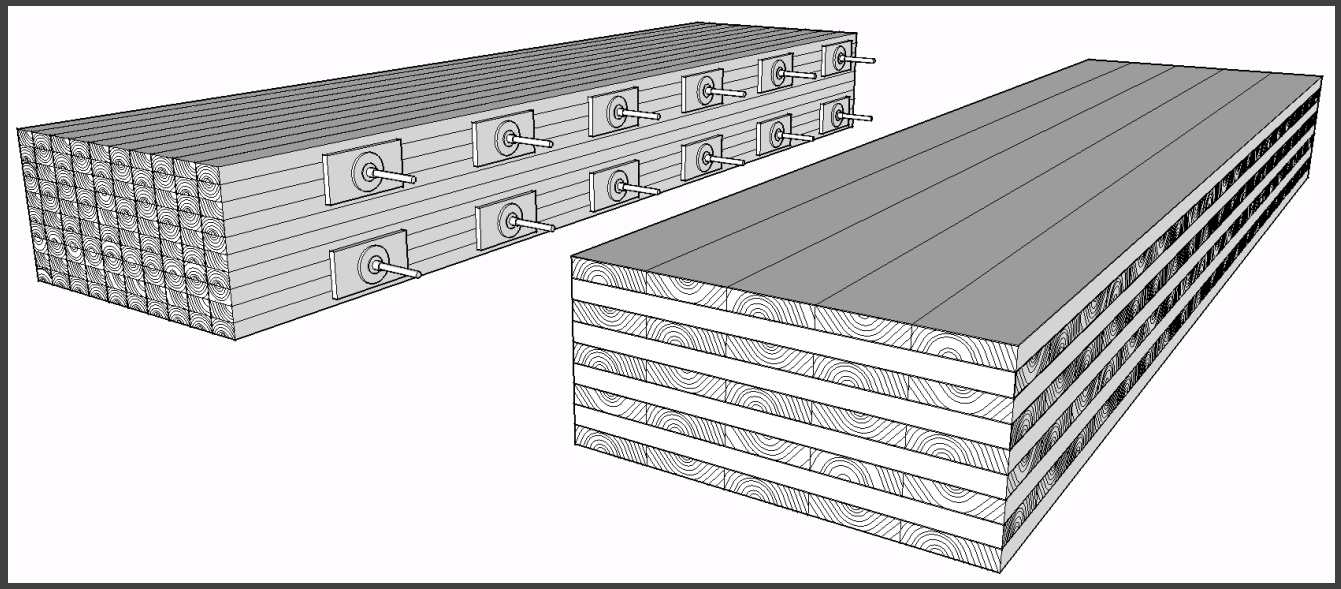
Grading of boards used for CLT

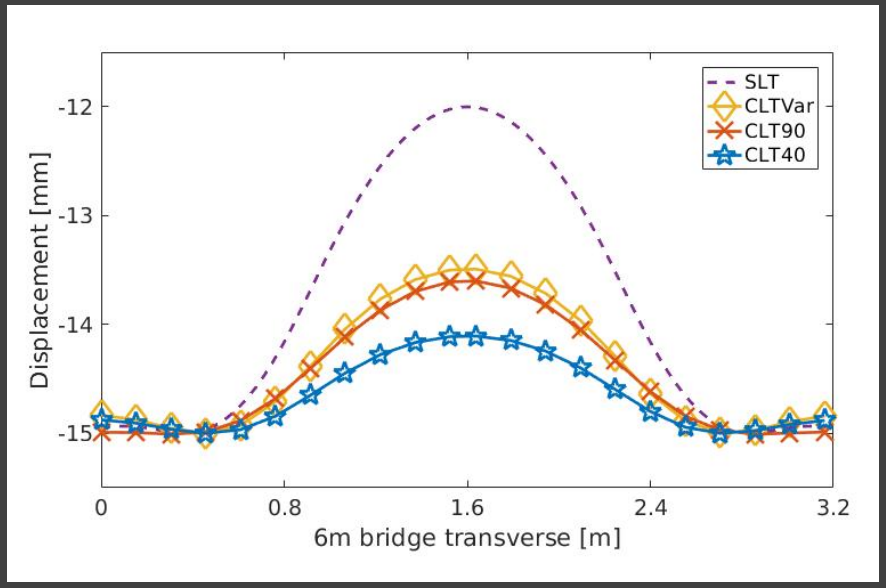
- C24 - grade boards
- Increasing use of lower graded boards (C14)

Construction of CLT



Properties of CLT





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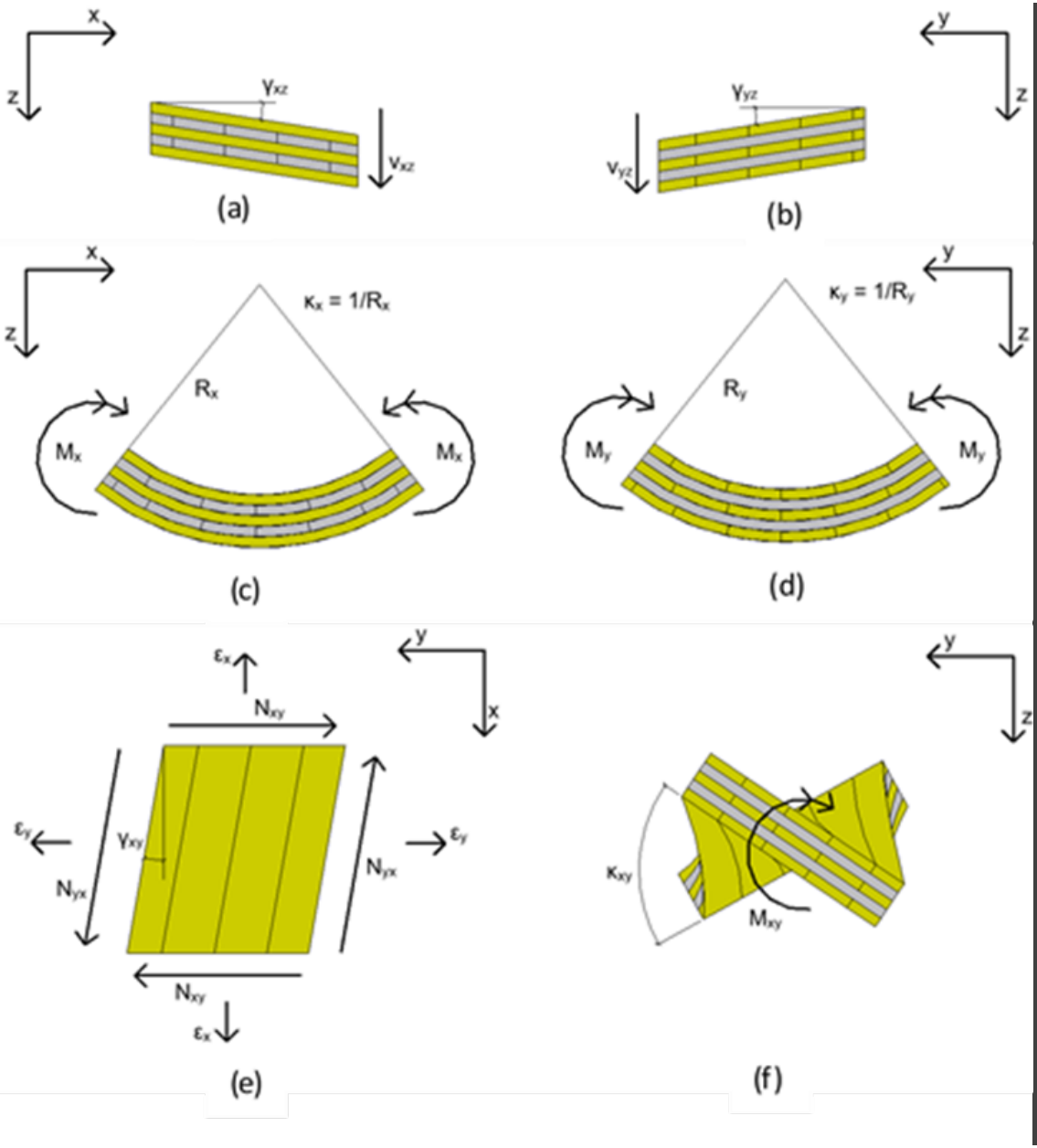
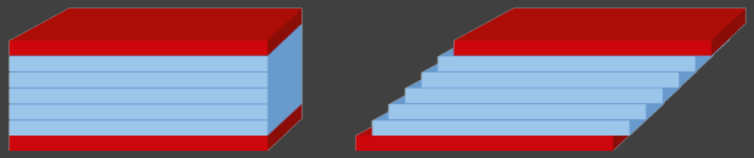


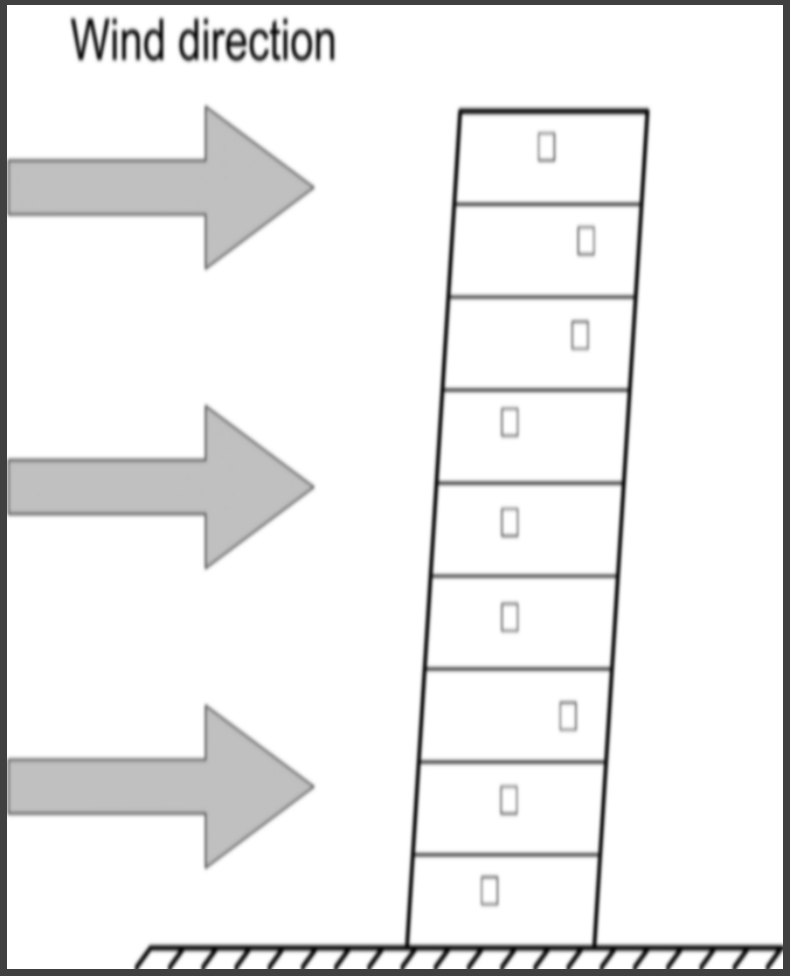
- Mindlin–Reissner plate theory

$$\begin{Bmatrix} M_x \\ M_y \\ M_{xy} \\ V_{xz} \\ V_{yz} \\ N_x \\ N_y \\ N_{xy} \end{Bmatrix} = \begin{bmatrix} D_{11} & D_{12} & 0 & 0 & 0 & 0 & 0 & 0 \\ & D_{22} & 0 & 0 & 0 & 0 & 0 & 0 \\ & & k_{33}D_{33} & 0 & 0 & 0 & 0 & 0 \\ & & & k_{44}D_{44} & 0 & 0 & 0 & 0 \\ & & & & k_{55}D_{55} & 0 & 0 & 0 \\ & & Sym. & & & D_{66} & D_{67} & 0 \\ & & & & & & D_{77} & 0 \\ & & & & & & & k_{88}D_{88} \end{bmatrix} \begin{Bmatrix} \kappa_x \\ \kappa_y \\ \kappa_{xy} \\ \gamma_{xz} \\ \gamma_{yz} \\ \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{Bmatrix}$$

Properties of CLT

Construction of CLT





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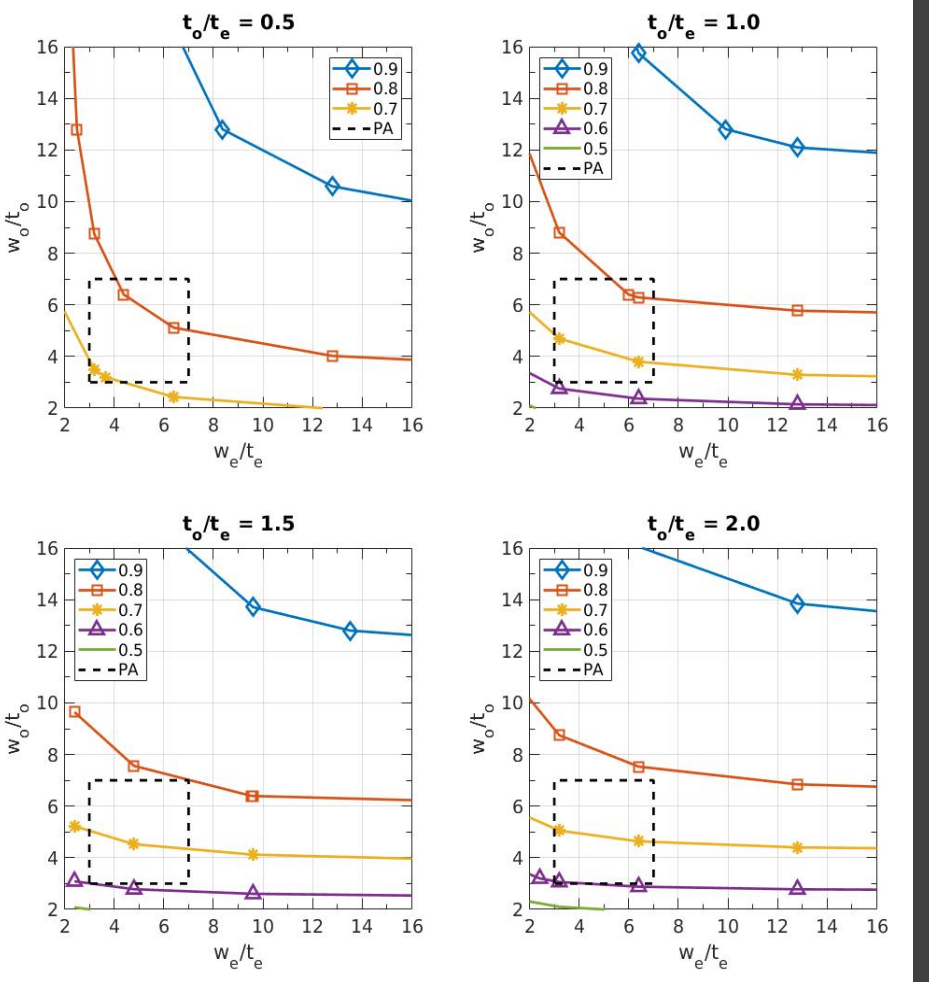

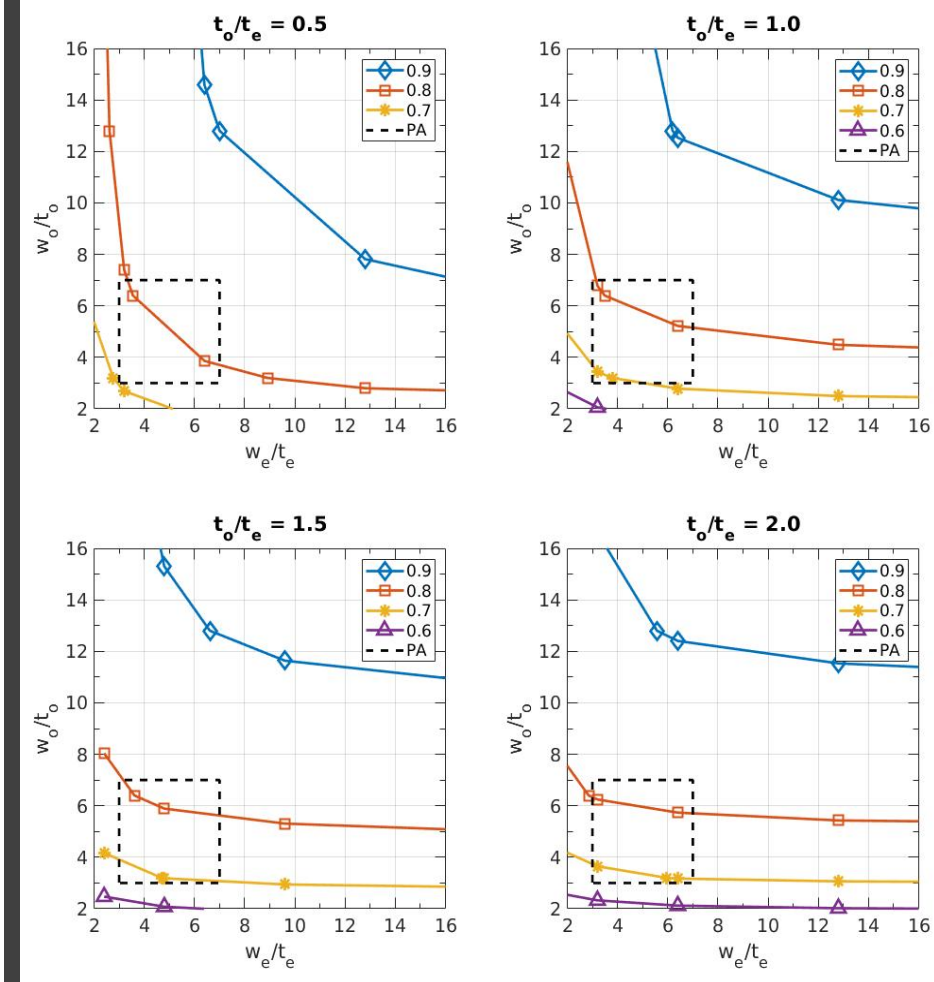

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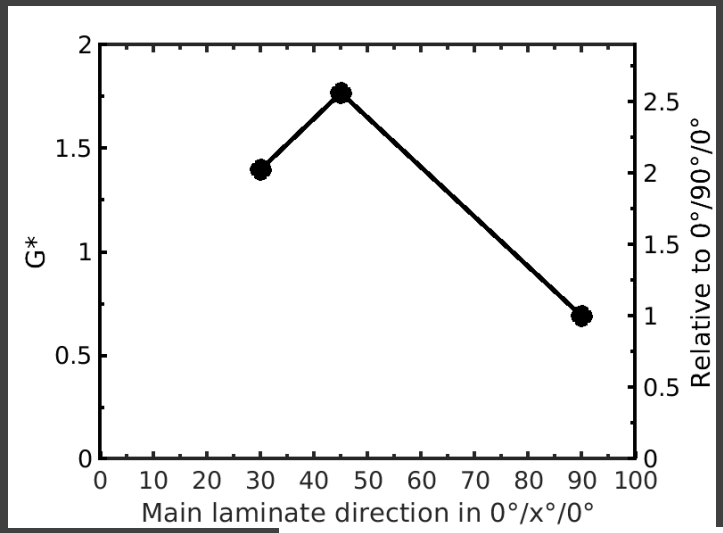

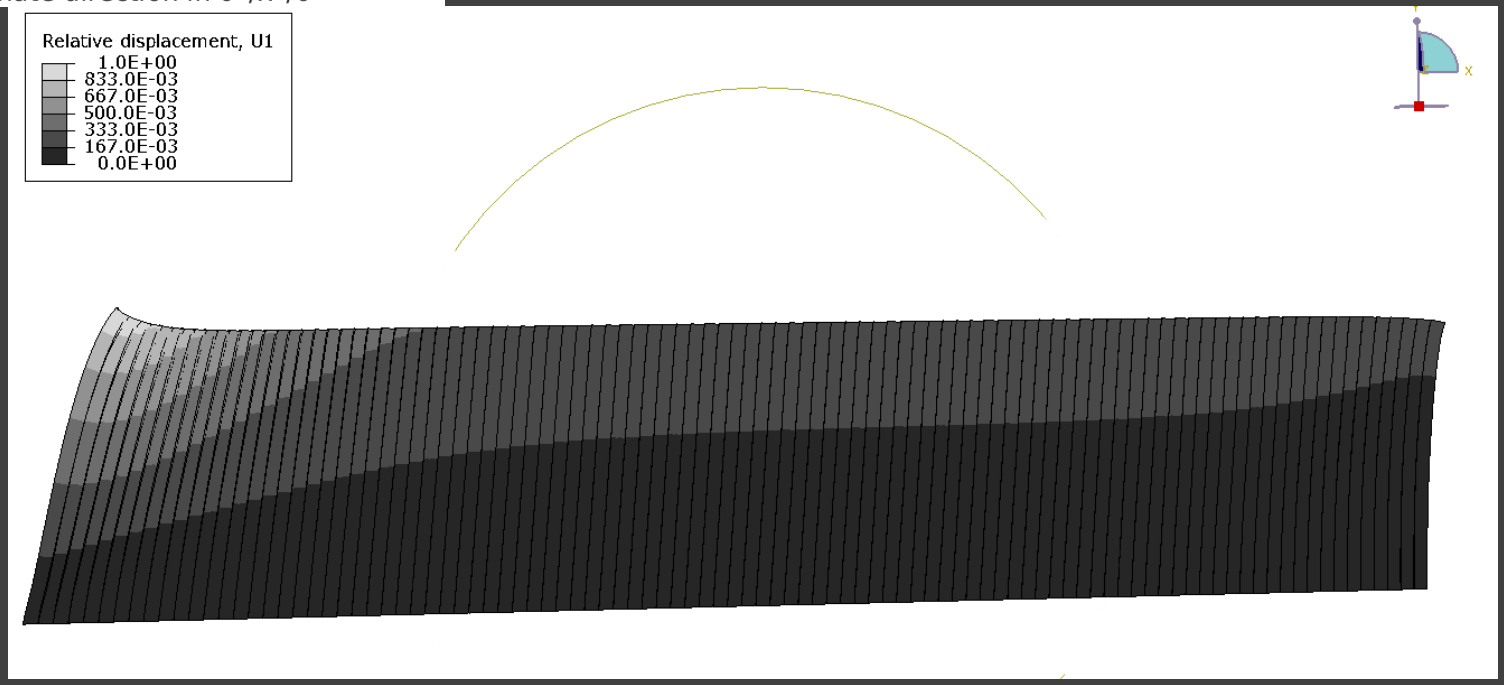

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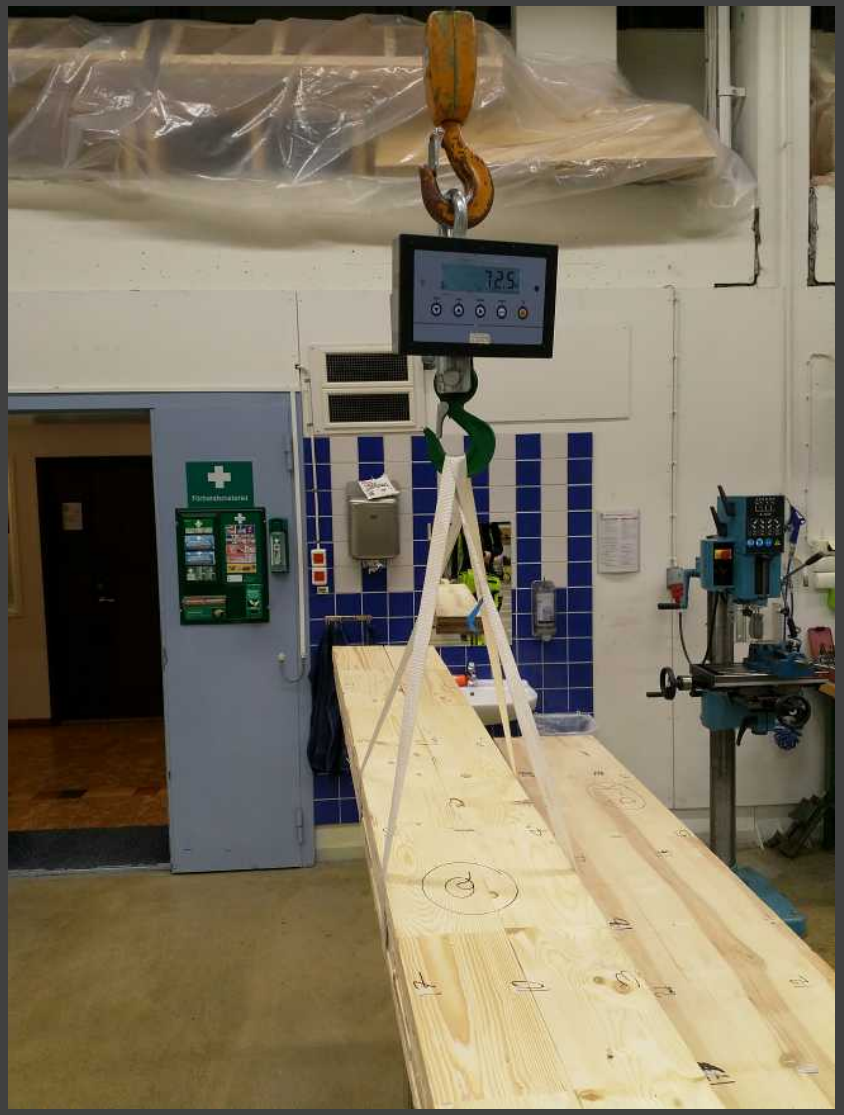


History of wooden buildings:

- 1874
- (1888)
- 1994

- 1355 - 1356

History of CLT:

- 1994 Founded
- 2000s Wider usage in Europe
- 2003 Martinsons in Bygdsiljum
- 2019 Stora Enso and Södra
- 2020 Setra
- 2022 Common method of construction in Sweden, Norway, Germany, Austria, Switzerland, UK and North America.

Advantages of CLT:

- Sustainable
- Easier on site (pre-fabricated)
- Faster installation
- Cleaner construction site
- Lighter weight, cheaper foundation
- Thermal properties, good insulator
- Fire resistant

Disadvantages of CLT:

- More expensive than steel and concrete
- (building code restrictions)
- Increasing the cost of electrical, plumbing etc. (lack of cavety)
- Less flexibility during renovations

Some disadvantages may disappear due to an increased market of CLT.

Fire and CLT:

- **Industrial flame retardant treatment**
- **Add protection on the wood**

- **Charring rate = 0,6 - 0,7 mm/min**
- **A layer of char protects and maintains the strength of the wood inside**

Sustainability of CLT:

- **Eco-friendly**
- **Renewable wood**
- **Can reduce carbon emissions up to 80% (compared to concrete)**

CLT producers in Sweden:

- **Holmen (earlier Martinsons) 22 000 m^3**
- **Setra 100 000 m^3**
- **Stora Enso (largest in Europe) 100 000 m^3 (270 000 m^3 in Europe)**
- **Södra 14 000 m^3 (140 000 m^3)**

T2, Skellefteå, 2018

- 9 m
- 2 storeys
- Concrete, glulam and CLT

The Tree, Bergen, 2015

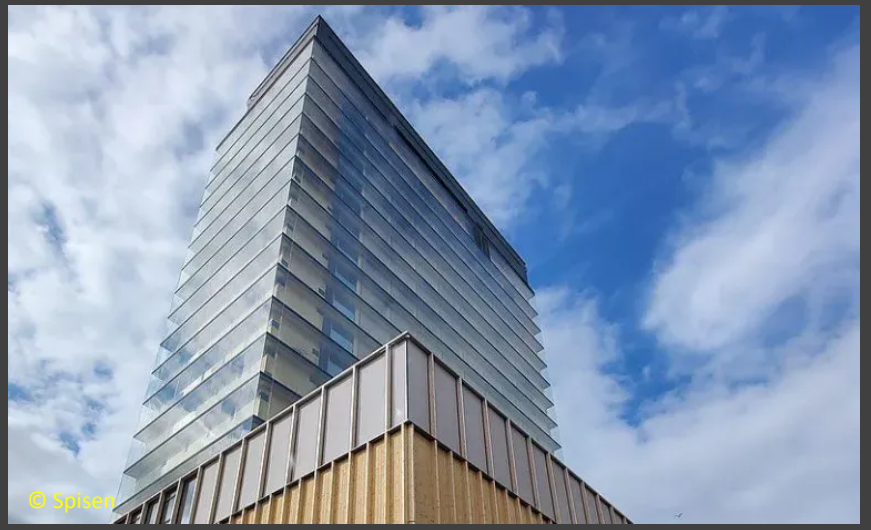
- 49 m
- 14 storeys
- Glulam truss work + concrete on top floor

The University of British Columbia, 2017 (Brock Commons)

- 53 m
- 18 storeys
- 70 days to complete the structure
- Steel, concrete and wood

Sara Kulturhus, Skellefteå, 2021

- 75 m
- 20 storeys
- Sweden´s tallest wooden building
- 13 500 flights Stockholm – New York
- Concrete, glulam and CLT

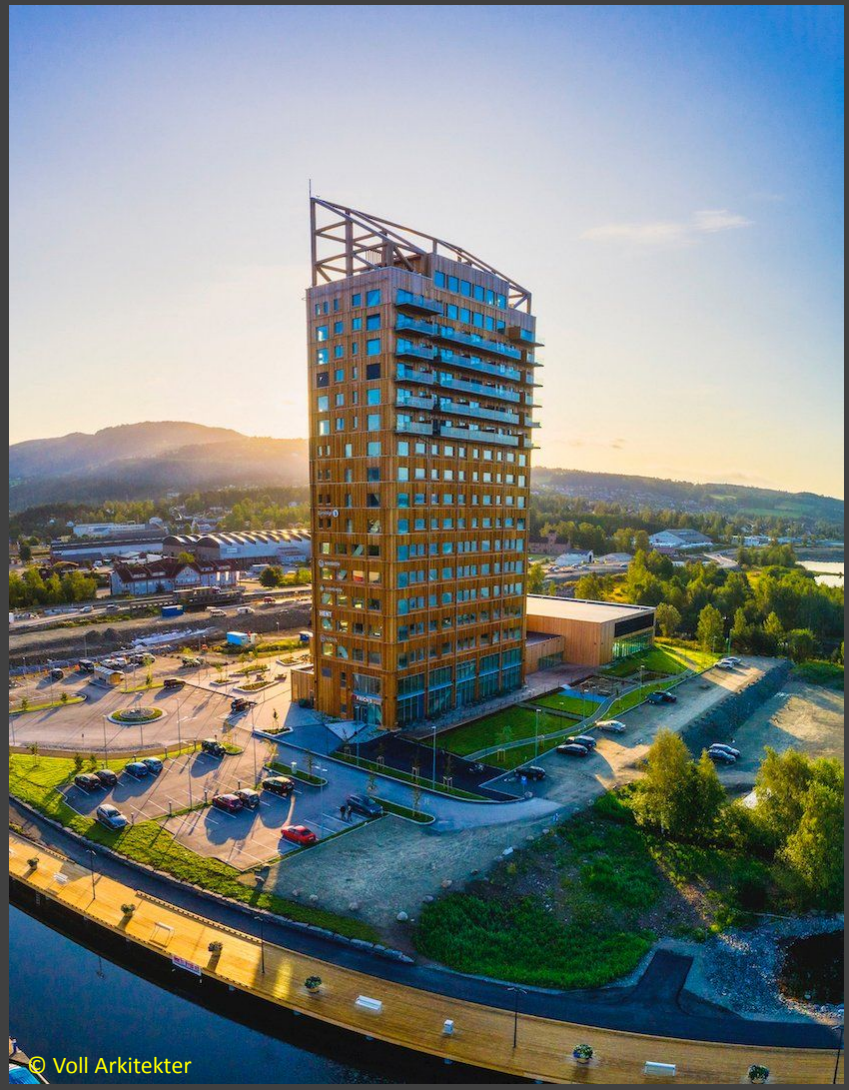


HoHo, Vienna, 2019

- 84 m
- 24 storeys
- 75% wood

Mjøstårne, Brumunddal, 2019

- 85,4 m
- 18 storeys
- World tallest wooden building
- Gluelam structure, CLT for stiffening



The Rocket&Tigerli Tower, Winterthur (Zurich)

- 100 m
- Will be completed in 2026
- ≈25 storeys

W350 Tower, Tokyo, 2041

- 350 m
- 2026 planned to start
- 70 storeys

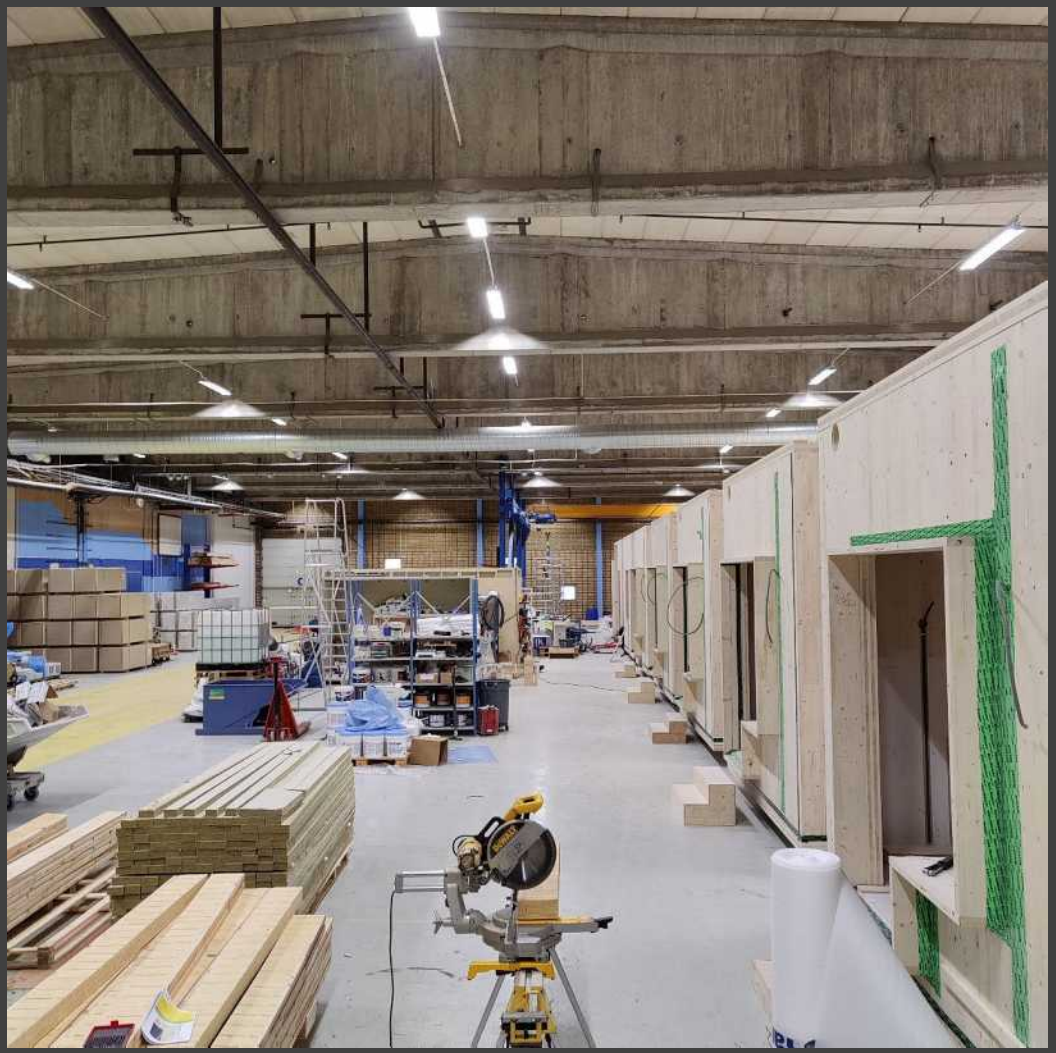
Future of CLT:

- Is promising
- It is called ”the concrete of the future”
- Durable and possible to compare with reinforced concrete
  - Lightweight
  - As durable as concrete
  - Good insulator (compared to concrete and steel)

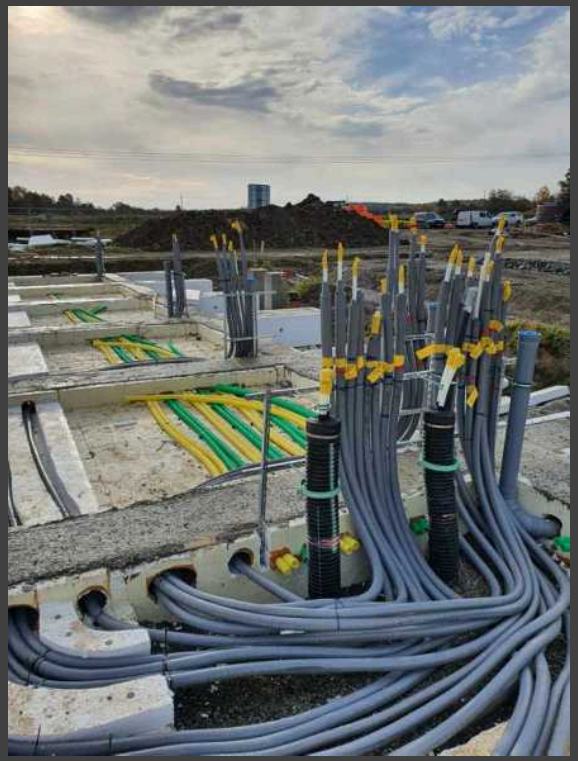
Nock Massiva Trähus:

- Fast-growing wooden house manufacturer
- One of few industrilised apartment buildings producers in CLT
- High prefabrication degree

Nock Factory, Älvängen



On Site



Mounting of Modules

Godisfabriken, Gävle

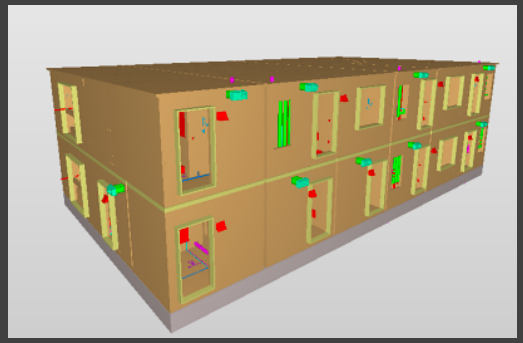
- 8 storeys
- 67 apartments

Fiolen, Norrköping

- 4 storeys
- 40 apartments

Näsbyholm, Härad

- 16 buildings
- 2 storeys
- 144 apartments



Biljetten, Malmö

- 12 Terraced houses (Radhus)
- 4 storeys






Thanks for your time!