Timber Structures

- Review of masonry mechanics
- Merits of wood as a structural material
- Possibilities in wood structure
- **Technical concepts:**
  - Modulus of Elasticity (stiffness)
  - Bending moment diagrams

Masonry Structure

- **Must act in compression (no resistance to tension)**
- **Very high compressive strength**
  - **Design is a problem of form**
  - **Stability and not strength limits masonry**
- **Thrust line: line of forces acting within a masonry structure to ensure that compression is maintained**

Construction Process

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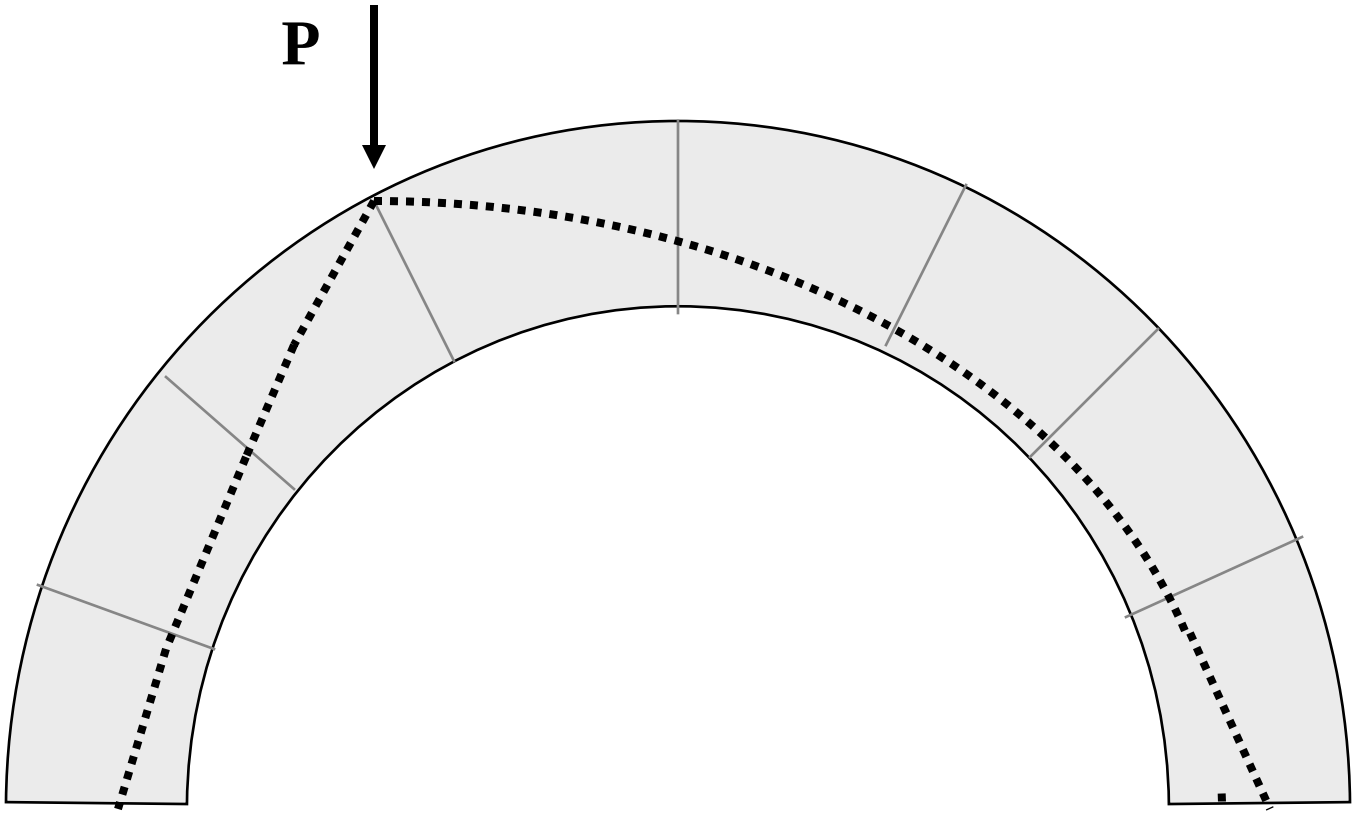
Masonry Design: Line of Thrust must be within the masonry



Eladio Dieste (1917-2000)

- Trained as a civil engineer in Uruguay
- 1947: Completed Casa Berlingieri with his first use of reinforced brick
- 1960: Completed Church of Atlantida
- 1995: Retrospective of his career held in Spain

The Future of Brick Vaulting

- **Reasons for superiority of brick over reinforced concrete for thin shells:**
  - **Less cement**
  - **Formwork is removed much more quickly**
  - **Vaults are more lightweight**
  - **Easier to achieve double curvature with brick**
- **Low stresses in well-designed shells**

The Future of Brick Vaulting

The things that we build must have something that we could call* cosmic economy*, that is to be in accord with the profound order of the world.

-Eladio Dieste

- **The need for sustainable structures will require us to combine traditional methods of construction with new technologies.**

Only one primary building material comes from a renewable resource, cleans the air and water; utilizes nearly 100% of its resource for products; is the lowest of all in its energy requirements for its manufacturing; creates fewer air and water emissions than any of its alternatives; and is totally reusable, recyclable and 100% biodegradable. And it has been increasing in US net reserves since 1952, with growth exceeding harvest in the US by more than 30%.

American Wood Council

Only one primary building material comes from a renewable resource, cleans the air and water; utilizes nearly 100% of its resource for products; is the lowest of all in its energy requirements for its manufacturing; creates fewer air and water emissions than any of its alternatives; and is totally reusable, recyclable and 100% biodegradable: WOOD. And it has been increasing in US net reserves since 1952, with growth exceeding harvest in the US by more than 30%.

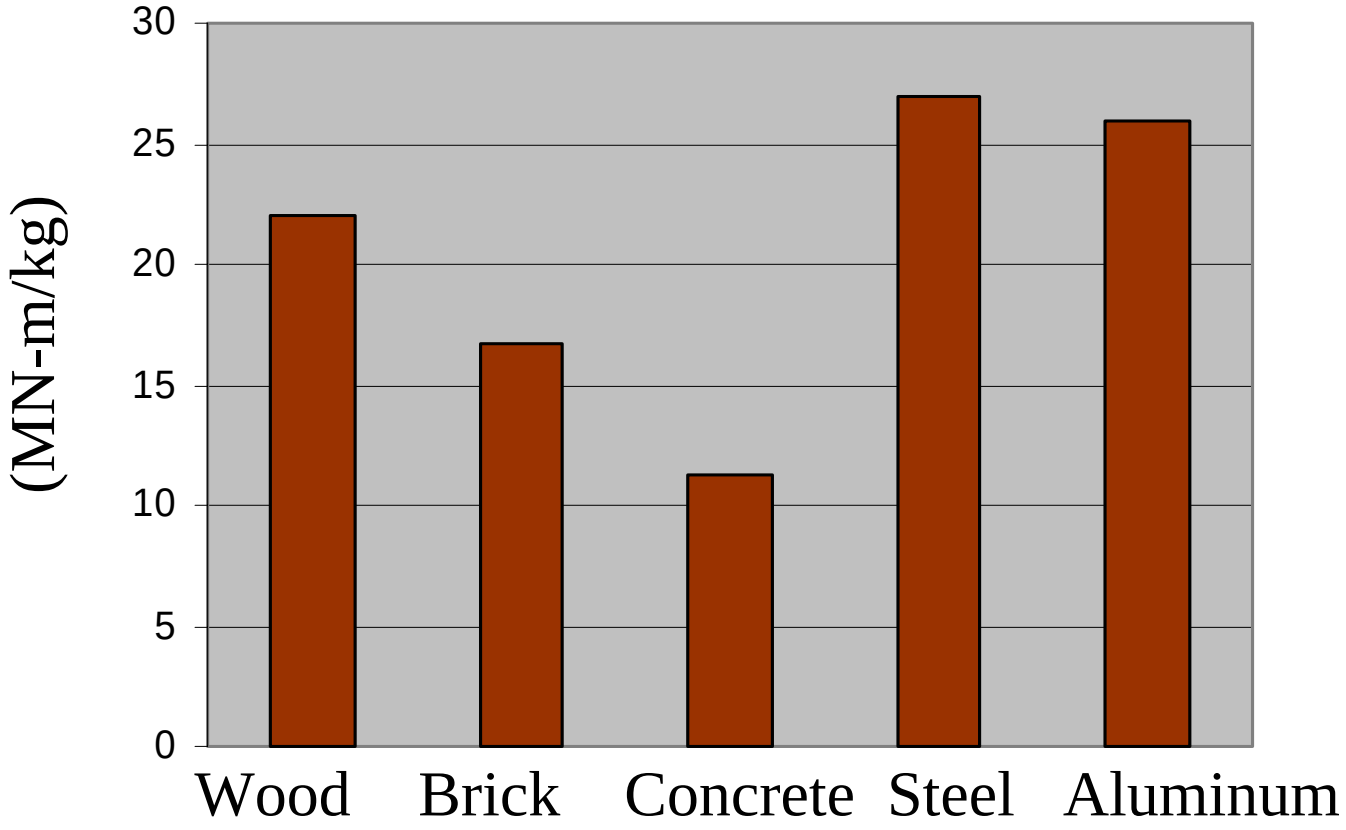
Properties of Timber

- Cellular structure is very efficient
- Handles both compression and tension well
- Different strengths with and against the grain
- Inhomogeneous material with imperfections

Progress Ideology of Metal

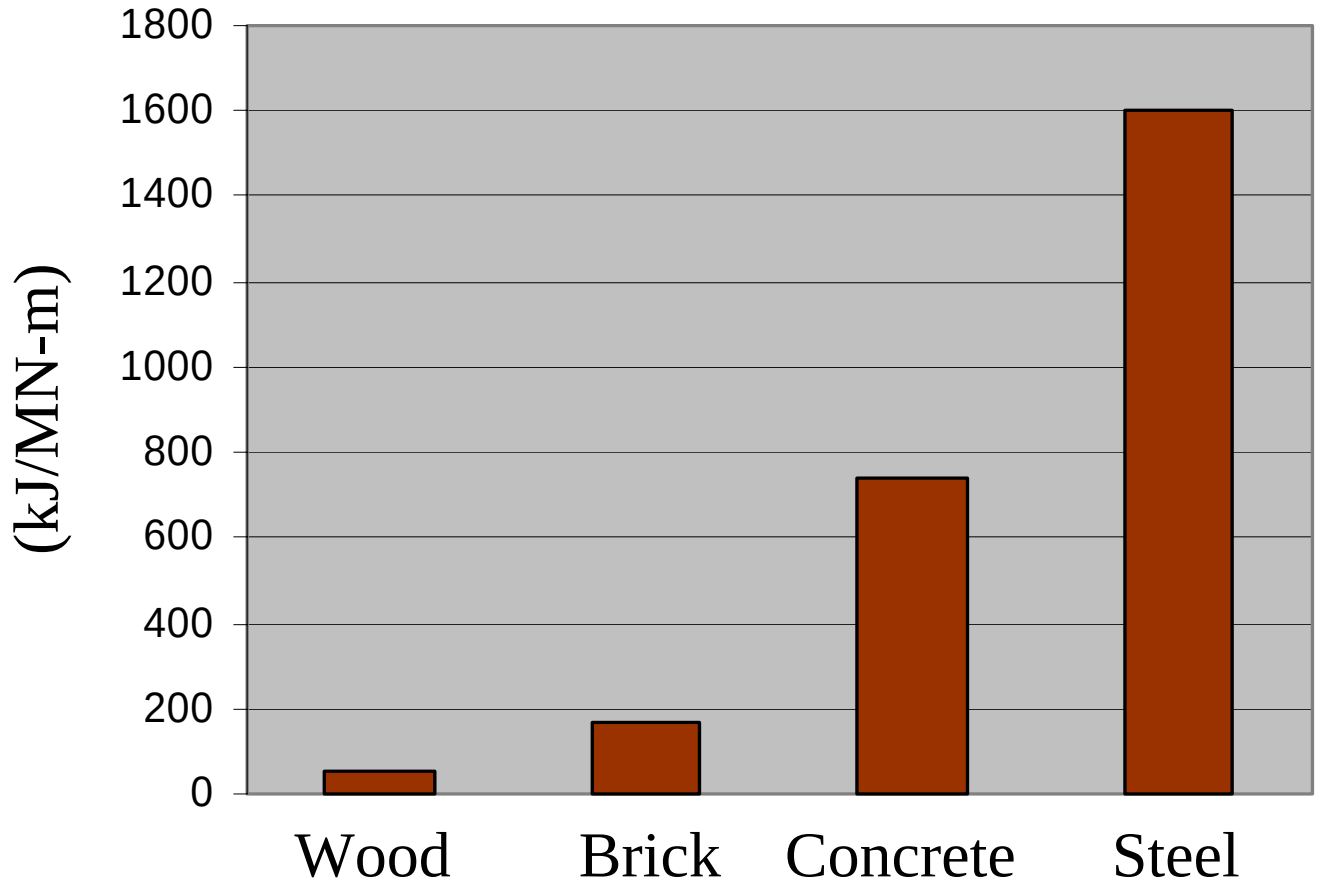
- **Airplane designers from 1920-1940 neglected wood, though it was superior to metal in many design considerations.**
- **Engineers linked metal with technical progress: “wood was anathema to the ideals of precision and power”.**
- **Article by Schatzberg, Technology & Culture, January, 1994.**

Stiffness (E) per unit weight



Source: Biggs (1991)

Embodied Energy per Stiffness



Source: Biggs (1991)

Embodied Energy per Stiffness

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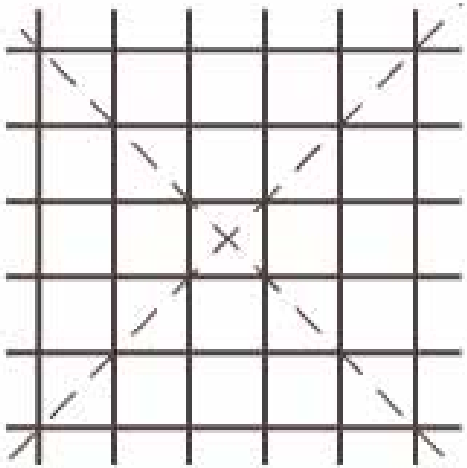
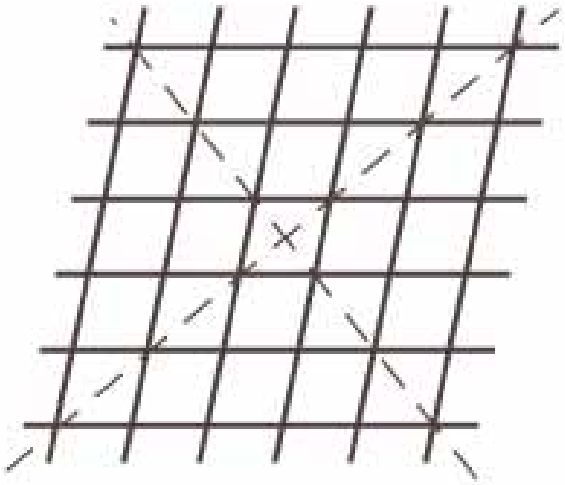
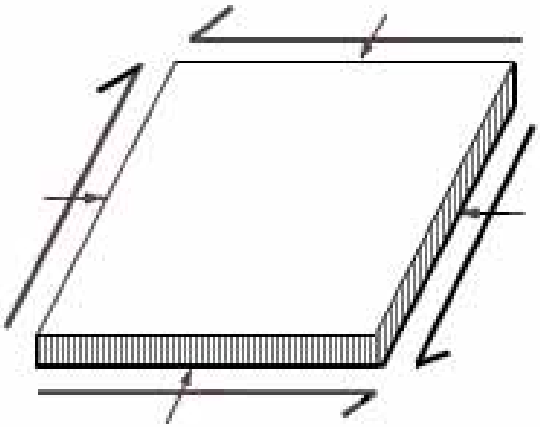
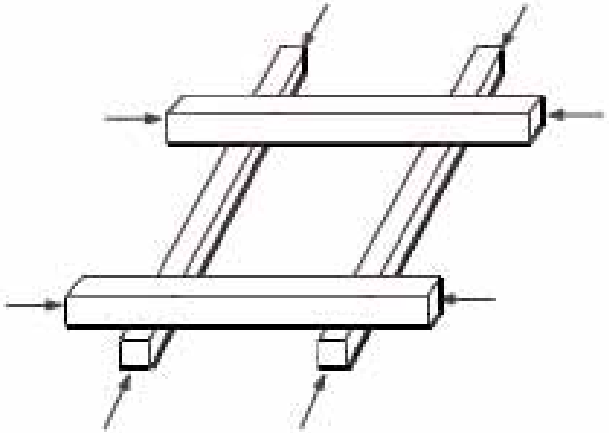
Timber Grid Shells









Japanese Pavilion, Hanover, 2000

Image courtesy Nicolas Janberg, http://www.structurae.de/en/photos/img418.php

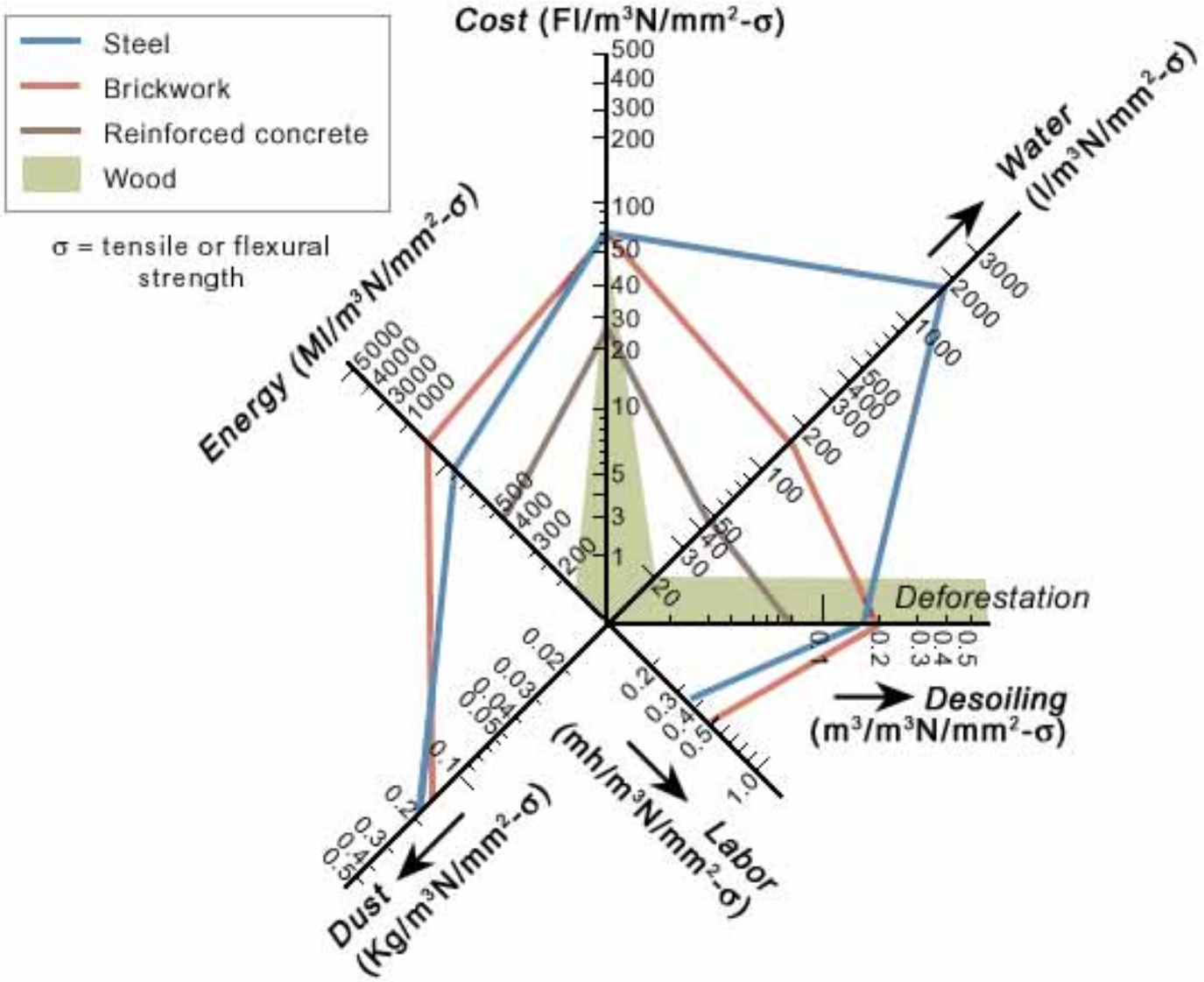
Expo Pavilion, Hanover, 2000

Image courtesy Nicolas Janberg, http://www.structurae.de/en/photos/img696.php

Conclusions

- **Wood is a highly engineered, sustainable material**
  - **Underused: many possibilities for wood as a structural material**
- **Stiffness (modulus of elasticity) measures the deformation in relation to an applied load**
- **Bending moments for simply-supported beams can be derived from the hanging cable for the given loading**

Ecological Profile of Materials



Ecological profile of various material properties expressed per unit strength.

The Institution of Structural Engineering

Material Properties

	Stiffness MN/m2	Density kg/m3	Energy kJ/kg	Energy/stiffness	
Wood	11000	500	1170	53	22
Brick	30000	1800	2800	168	17
Concrete	27000	2400	8300	738	11
Steel	210000	7800	43000	1597	27
Al	70000	2700	238000	9180	26

Material Properties

	Stiffness ksi	Density lb/ft3
Wood	11000	30
Brick	3100	130
Concrete	3000	150
Steel	29000	490
Al	10000	170