Timber-based hybrid structures: why?

Roberto Crocetti
Novana AB

Outline

- Why combine timber with other materials?

- Examples of combinations of timber with other materials

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- Examples of combinations of timber with other materials

Why not?

Reinforced concrete: an excellent hybrid product

The Pantheon, **unreinforced concrete** (Dome structure, diameter: 43 m)

The Sandö bridge, **reinforced concrete**, world's largest span for a concrete bridge when it was constructed in 1943 (span: 264 m)

The Burj Khalifa, world's tallest building (828 m), construction completed in 2010

Composite structures of steel and concrete

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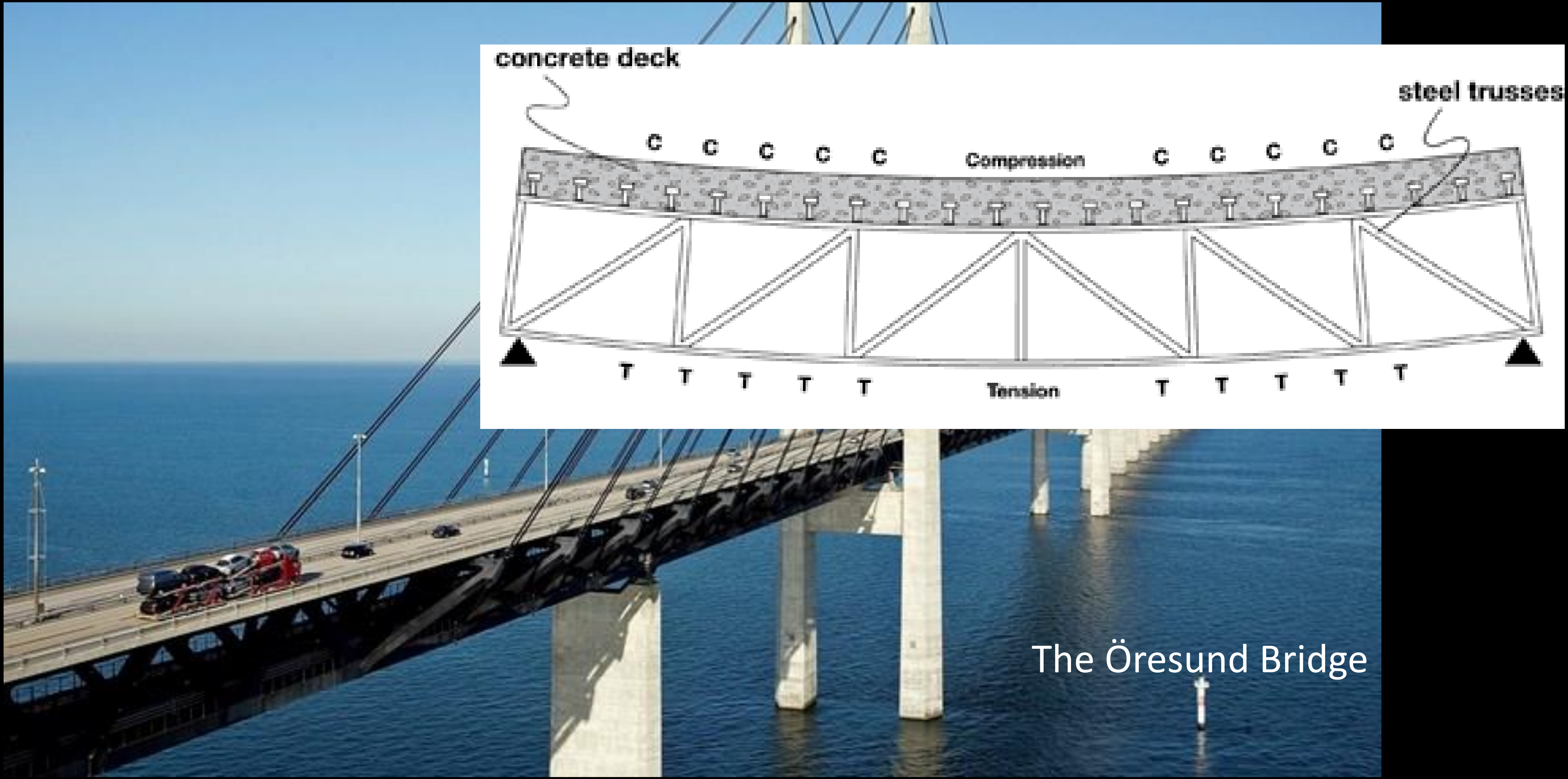
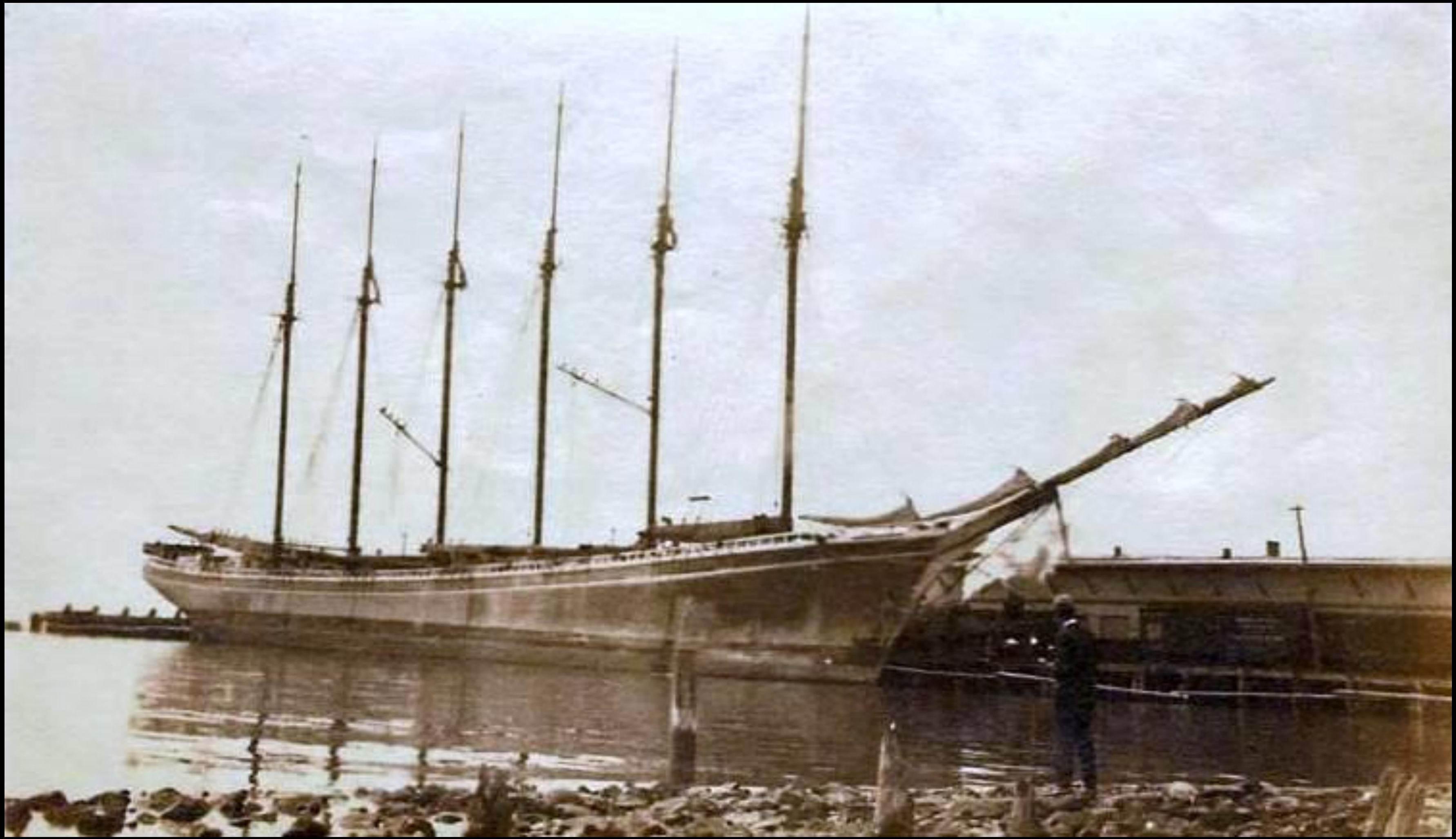


The Öresund Bridge

Of course, we can do extraordinary things using (*nearly*) only timber…


THE DE HAVILLAND "MOSQUITO" LIGHT BOMBER

Wyoming (USA) - the largest wooden ship ever built



Service : 1909–1924

Length: 140 m

Material: yellow pine

Gliwice Radio Tower Poland

Completed: 1935

Height: 118 m

Material: impregnated larch

But…is this the future?

Some unfavourable properties of timber

1. Low mass

2. Low Young’s modulus

3. High variability of mechanical properties

4. Low ductility

5. Durability

Some unfavourable properties of timber

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3. High variability of mechanical properties
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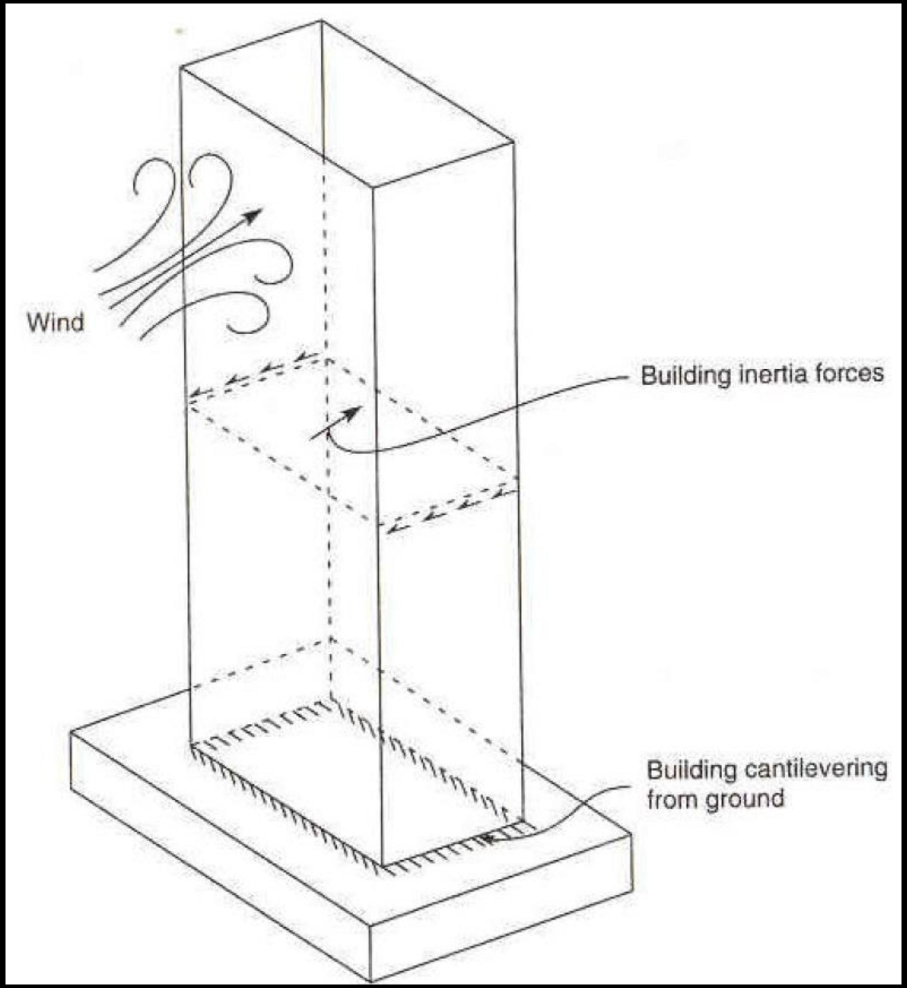
Low mass
Low Young's modulus



- Risk of tilting
- Wind-induced vibration (comfort criteria)

Acoustics and vibrations in floors

Some unfavourable properties of timber

1. Low mass
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3. **High variability of mechanical properties**
4. Low ductility
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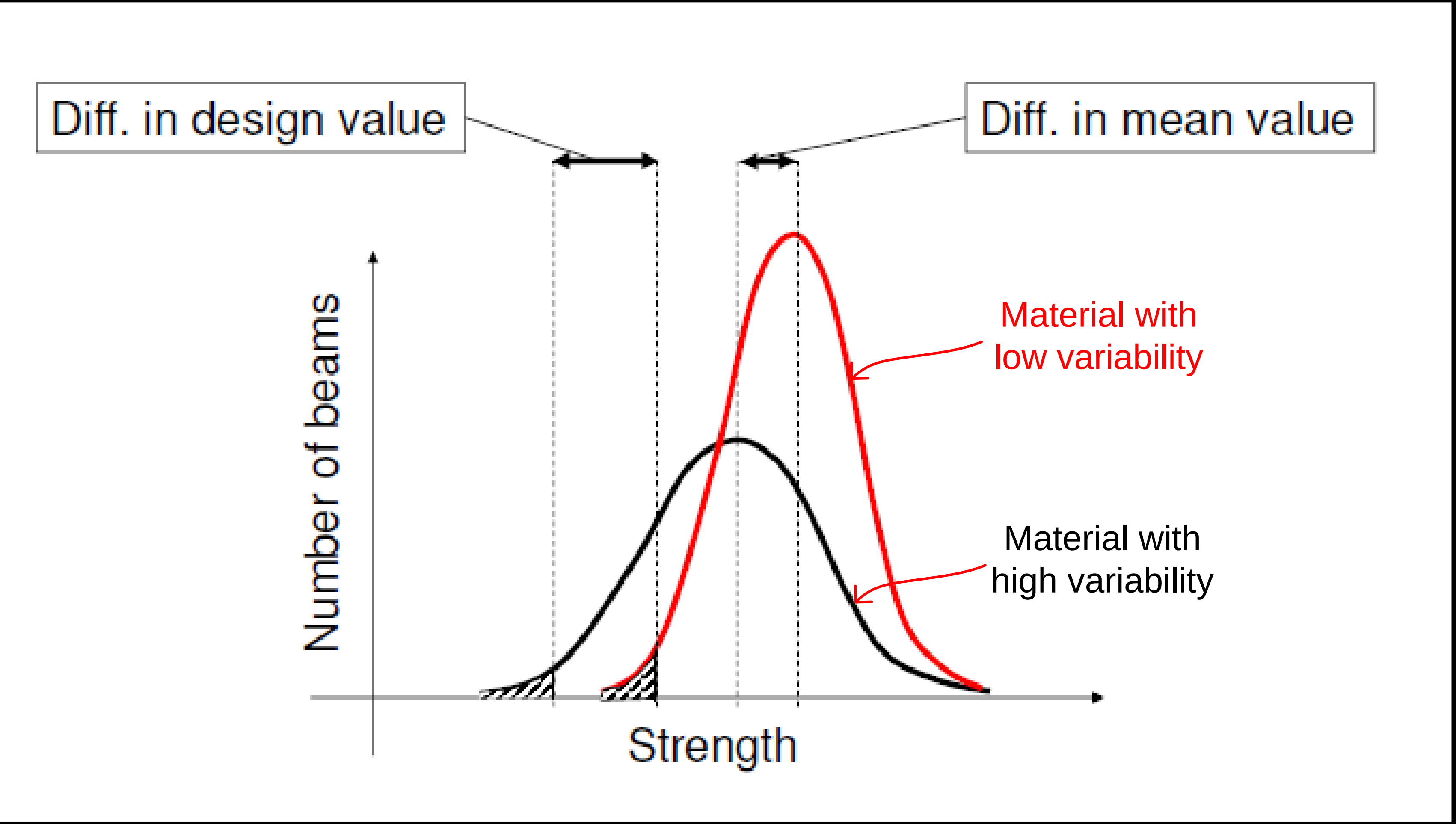
High variability of mechanical properties and



Large scatter → low characteristic strength

Some unfavourable properties of timber

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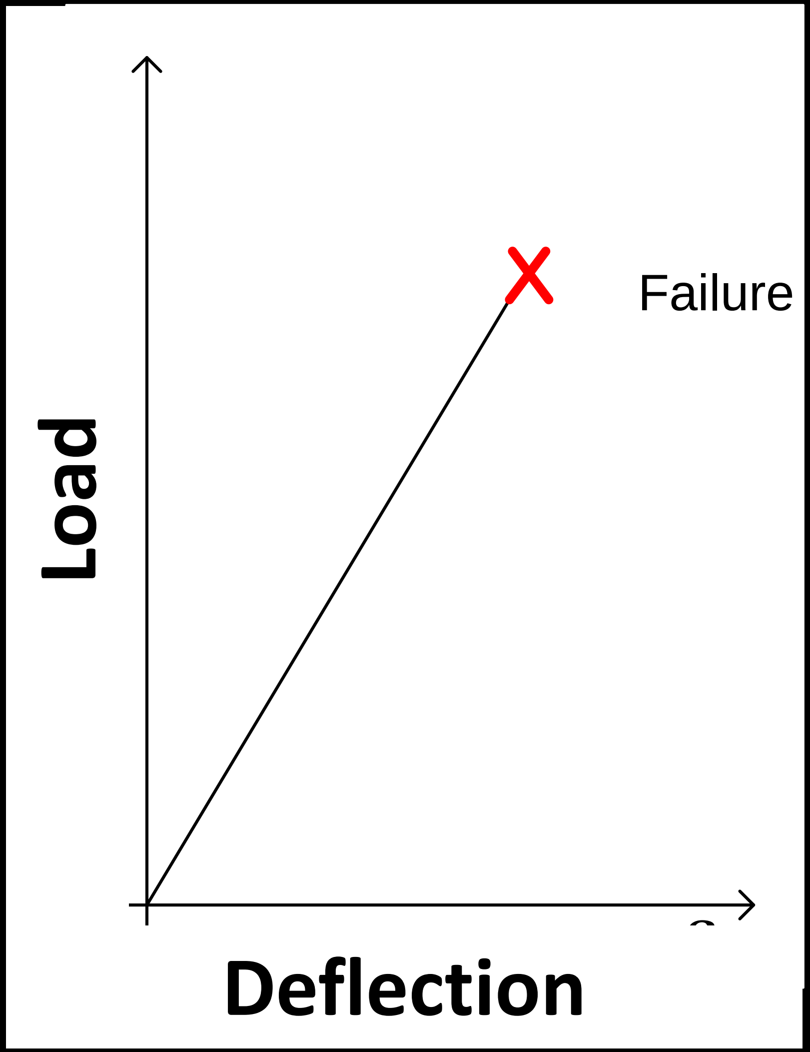
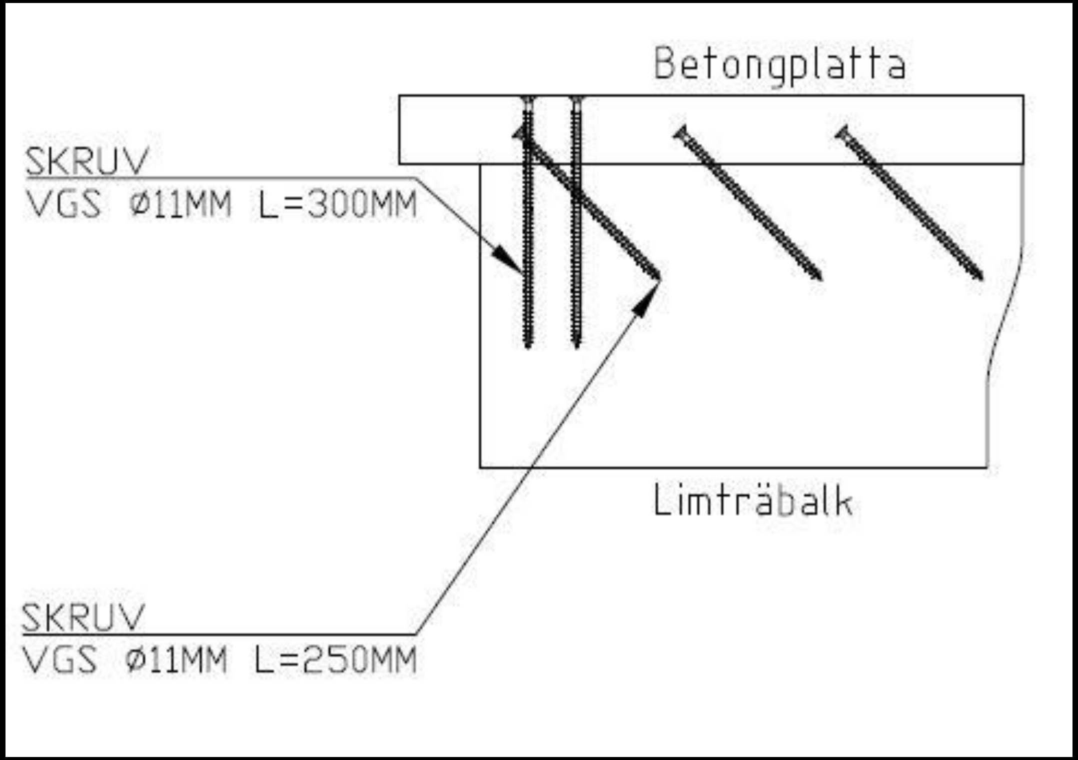
Low ductility



Solution/s?

Hybrid structures 1: prefab floor timber + concrete



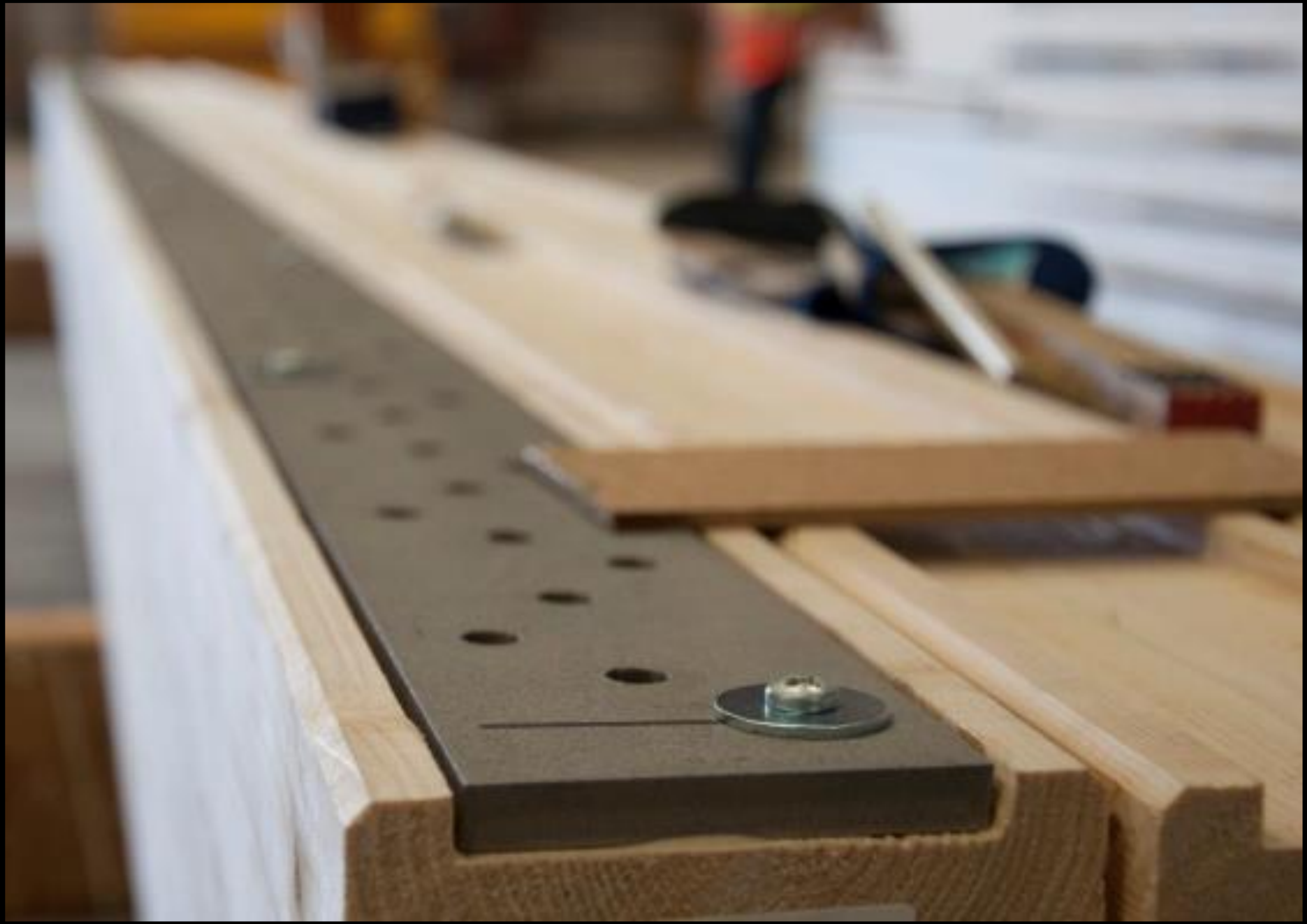
- Significant increase of stiffness → reduce problem with vibration

- Increase of mass → better stability against overturning/tilting, and better acoustic performance

- Reduced depth of floor → better economy

Bachelor's thesis by E. Lindstén and K. J. Öberg, LTH

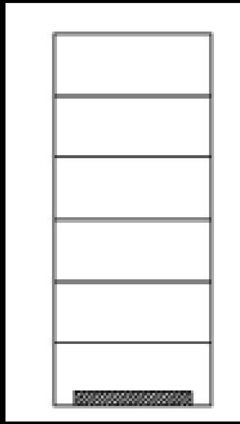
Hybrid structures 2: timber + steel or FRP



- Glulam beams 115x270, L=6m, both unreinforced and reinforced with glued steel plate 10x80 mm^2.
- Increase of both strength and stiffness by approx. 80%
- Ductile behaviour if steel plate is located at tension side of the beam
- Significant reducing in scatter
- *Bachelor's thesis, by M. Kjellkvist and F. Lindahl, LTH*

Increase of stiffness

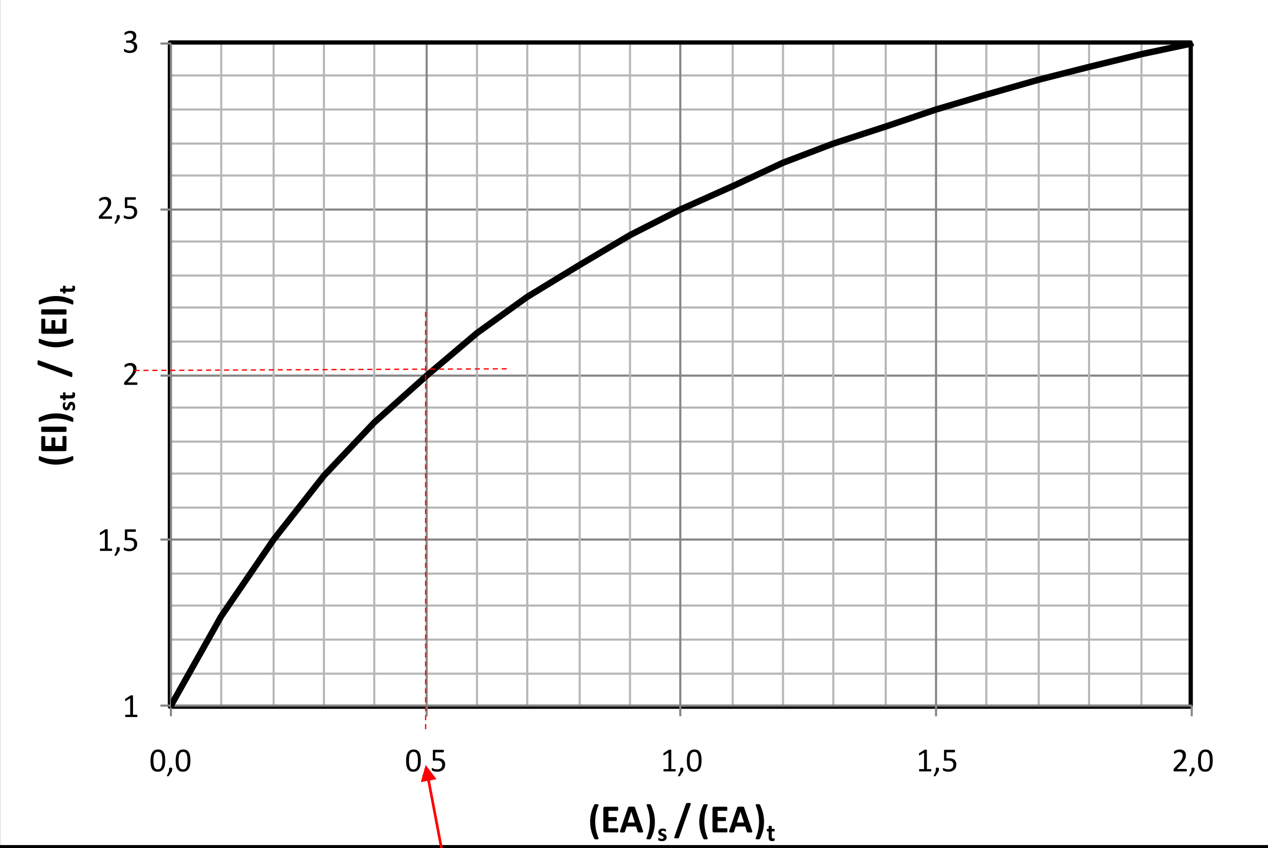
if the reinforcement ratio is 2,6% ($n\rho_s$~0,5), the stiffness doubles and consequently the elastic deflection decrease by half.



$$\frac{(EI)_{st}}{(EI)_t} = \frac{\left(1+4\frac{(EA)_s}{(EA)_t}\right)}{\left(1+\frac{(EA)_s}{(EA)_t}\right)} = \frac{(1+4n\rho_s)}{(1+n\rho_s)}$$

"st": reinforced beam

"t": unreinforced beam



Corresponds to a steel reinforcement ratio of 2,6%

It is typically argued that gluing 4-5 laminations to a glulam beam is simpler and cheaper than gluing a steel of CFRP strip

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…which is basically true…

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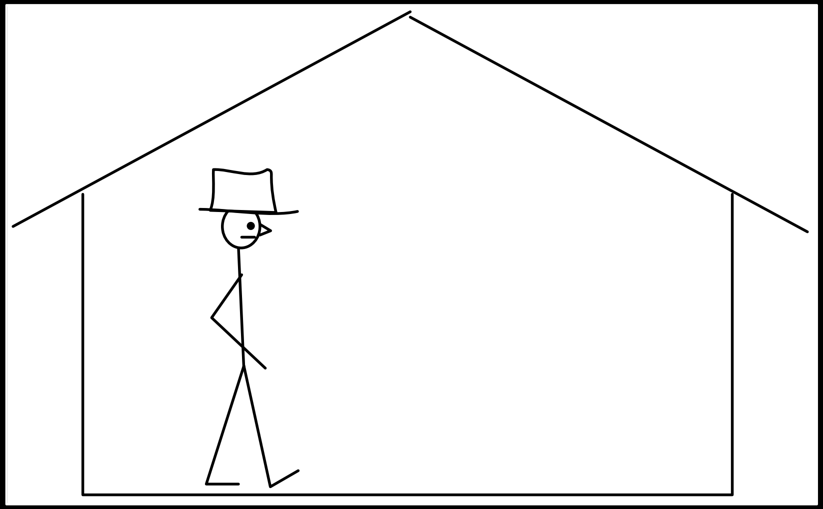
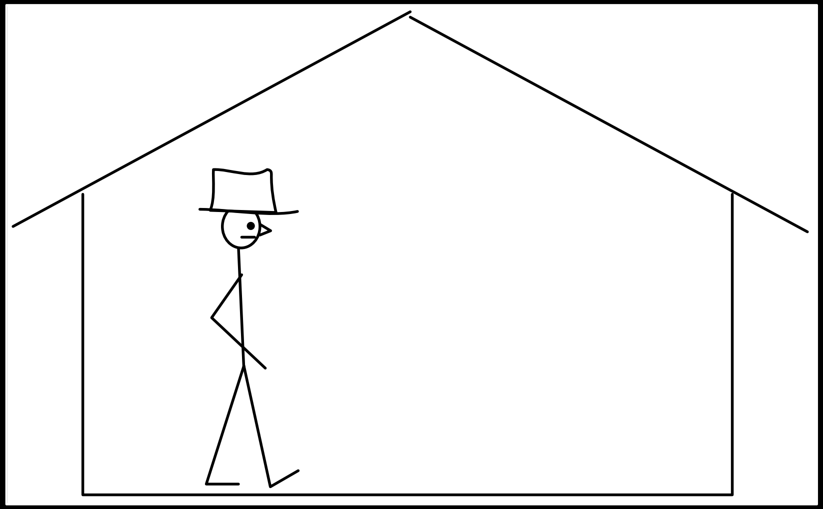
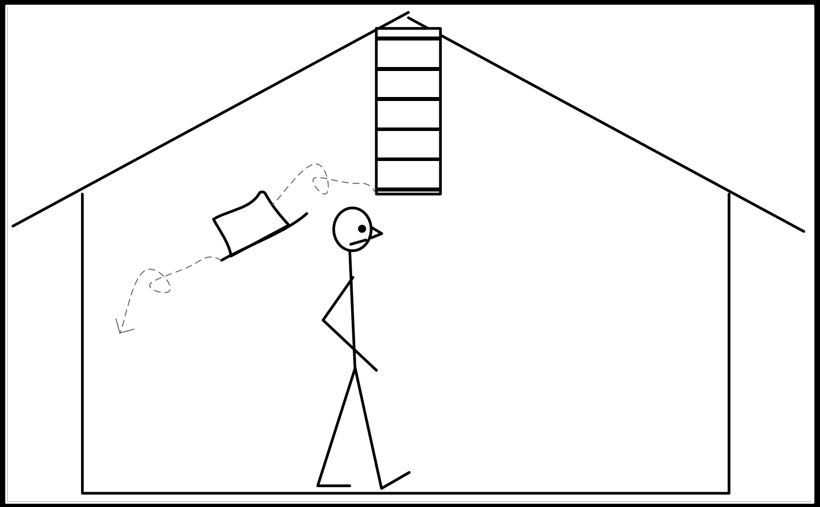
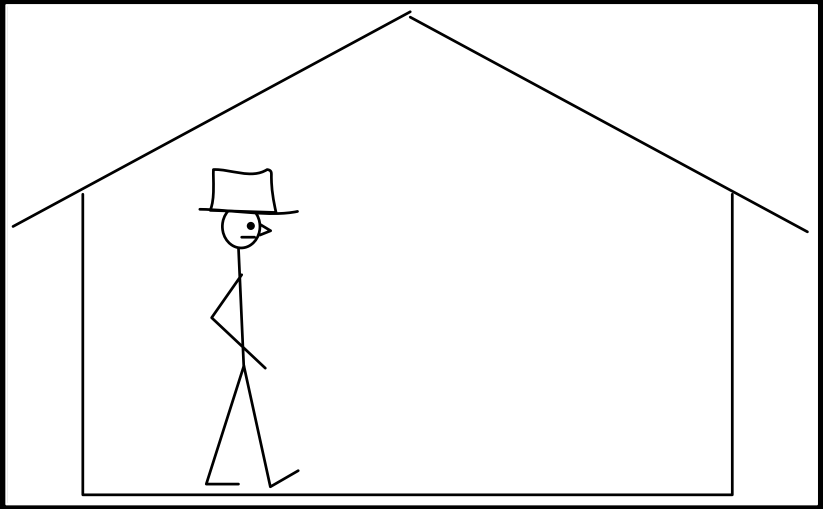
…which is basically true…

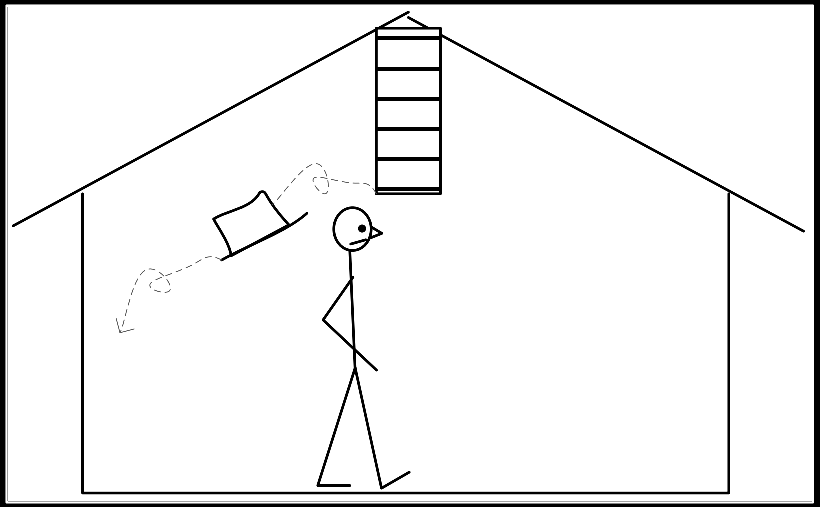
…however, there a number of examples where reinforcement by means of steel or CFRP could be significantly advantageous

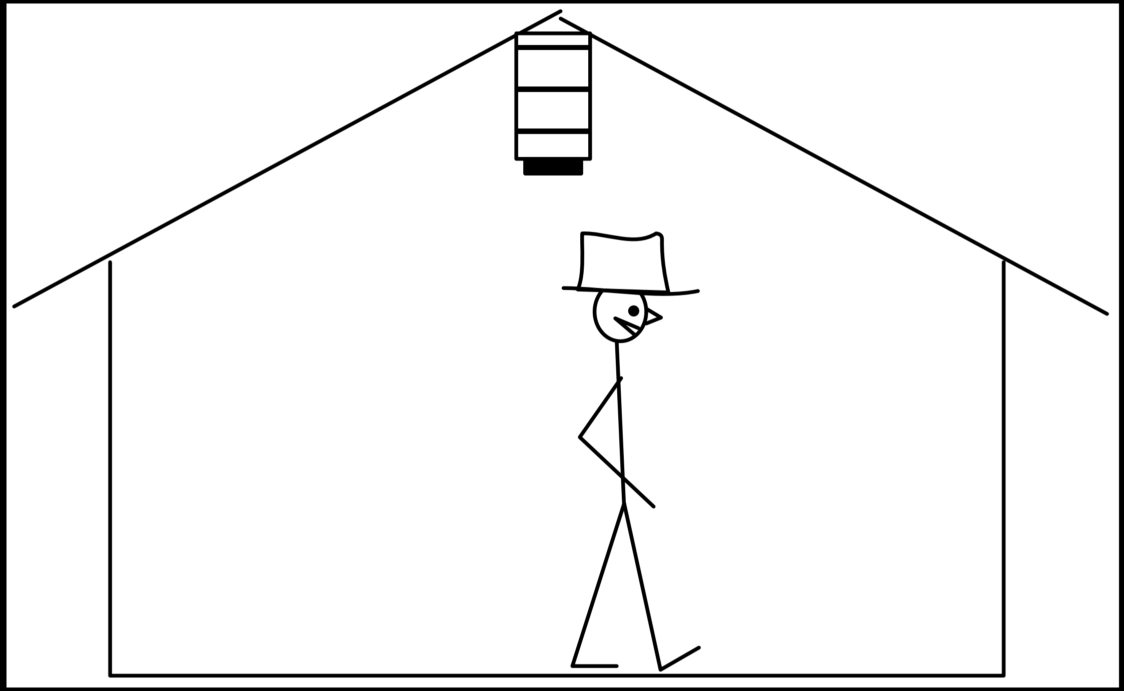






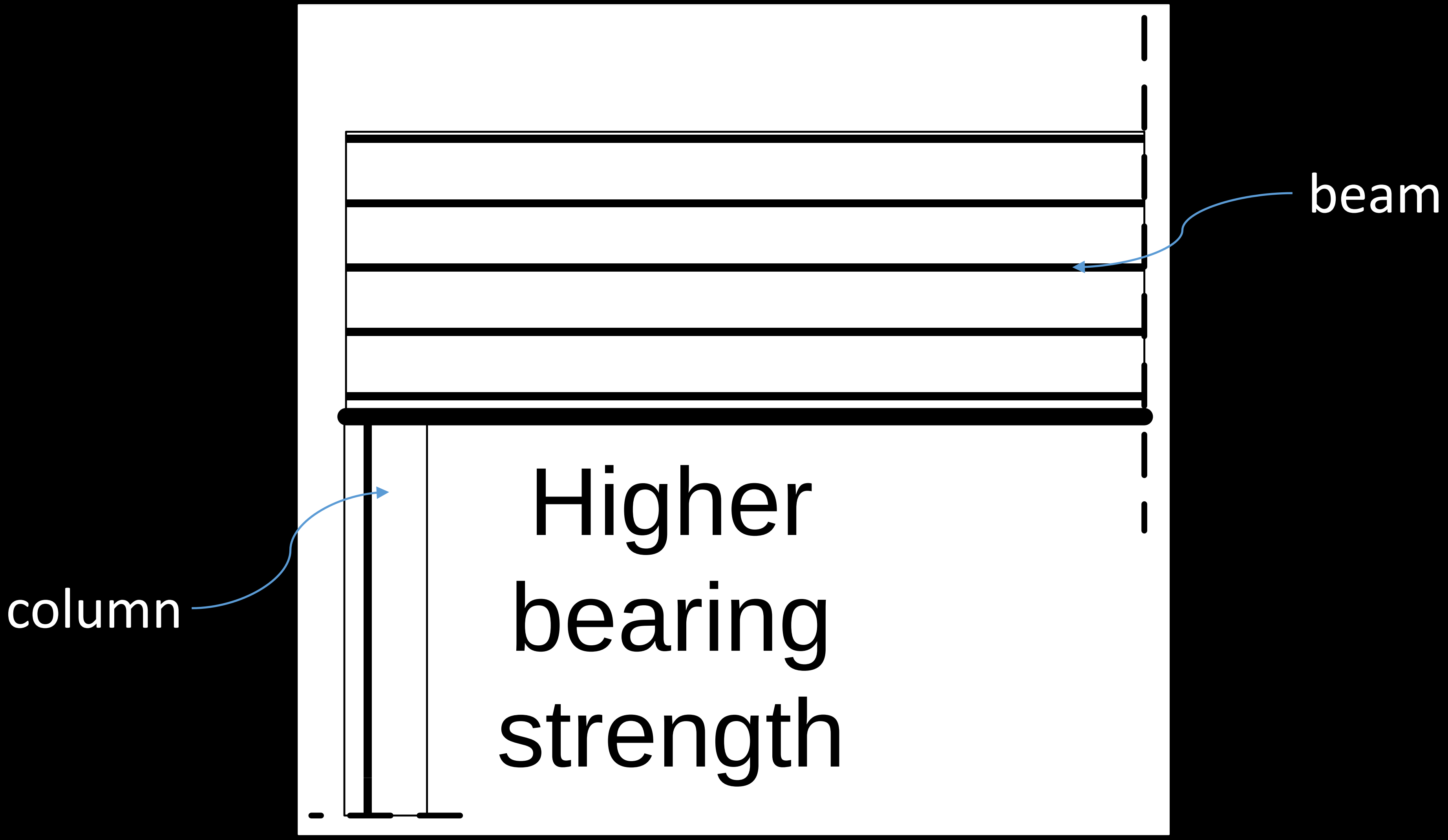




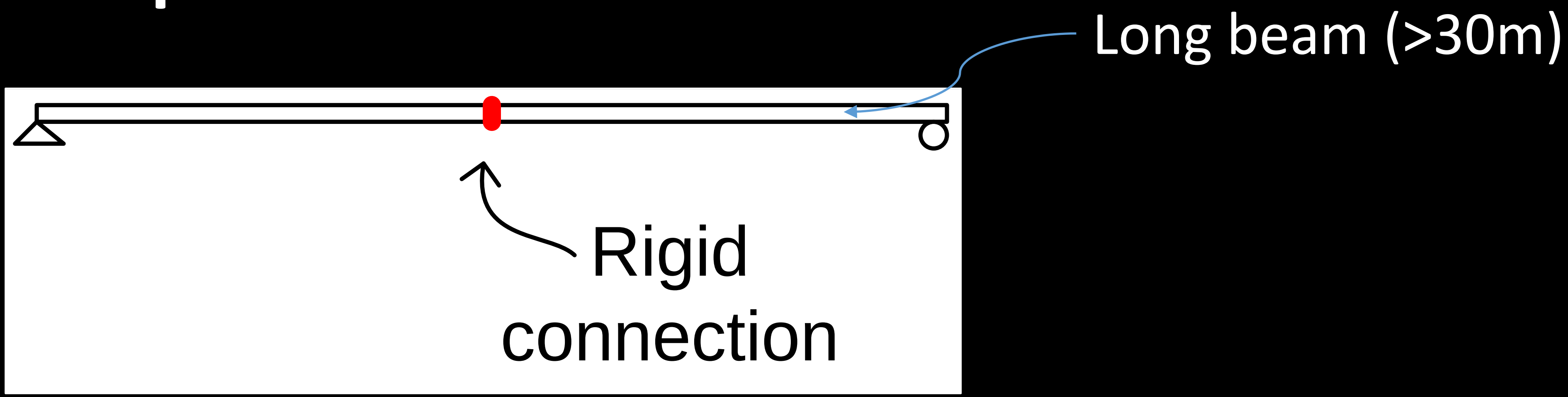


Using reinforced beams can also have other advantages…

Example 1

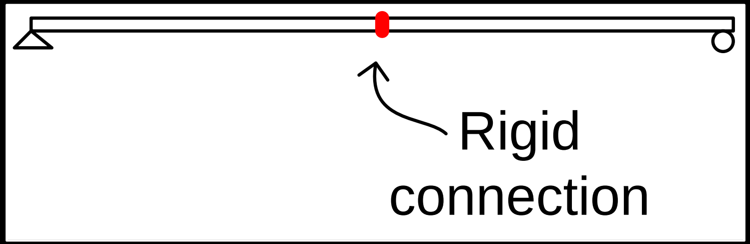


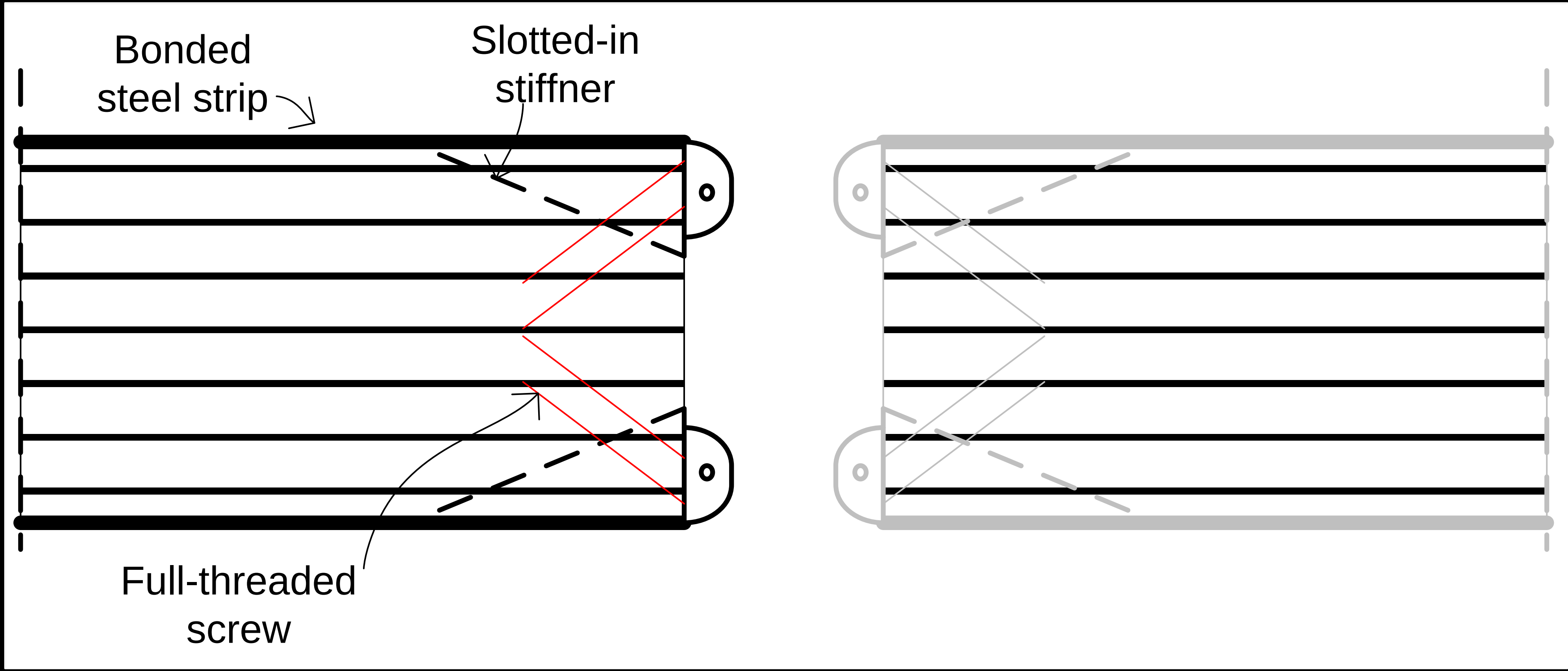
Example 2



To achieve a sufficiently stiff and strong connection is not very easy

Example 2


Rigid
connection


Bonded
steel strip
Slotted-in
stiffner
Full-threaded
screw

Some unfavourable properties of timber

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5. **Durability**

Durability: Modified timber

- Acetylated Swedish Scots Pine
- "Local" wood
- Environmentally friendly
- *Test on dowel connection*
  Master's thesis by Sandra Anderberg, LTH -2016

It is typically argued that acetylated wood is very expansive…

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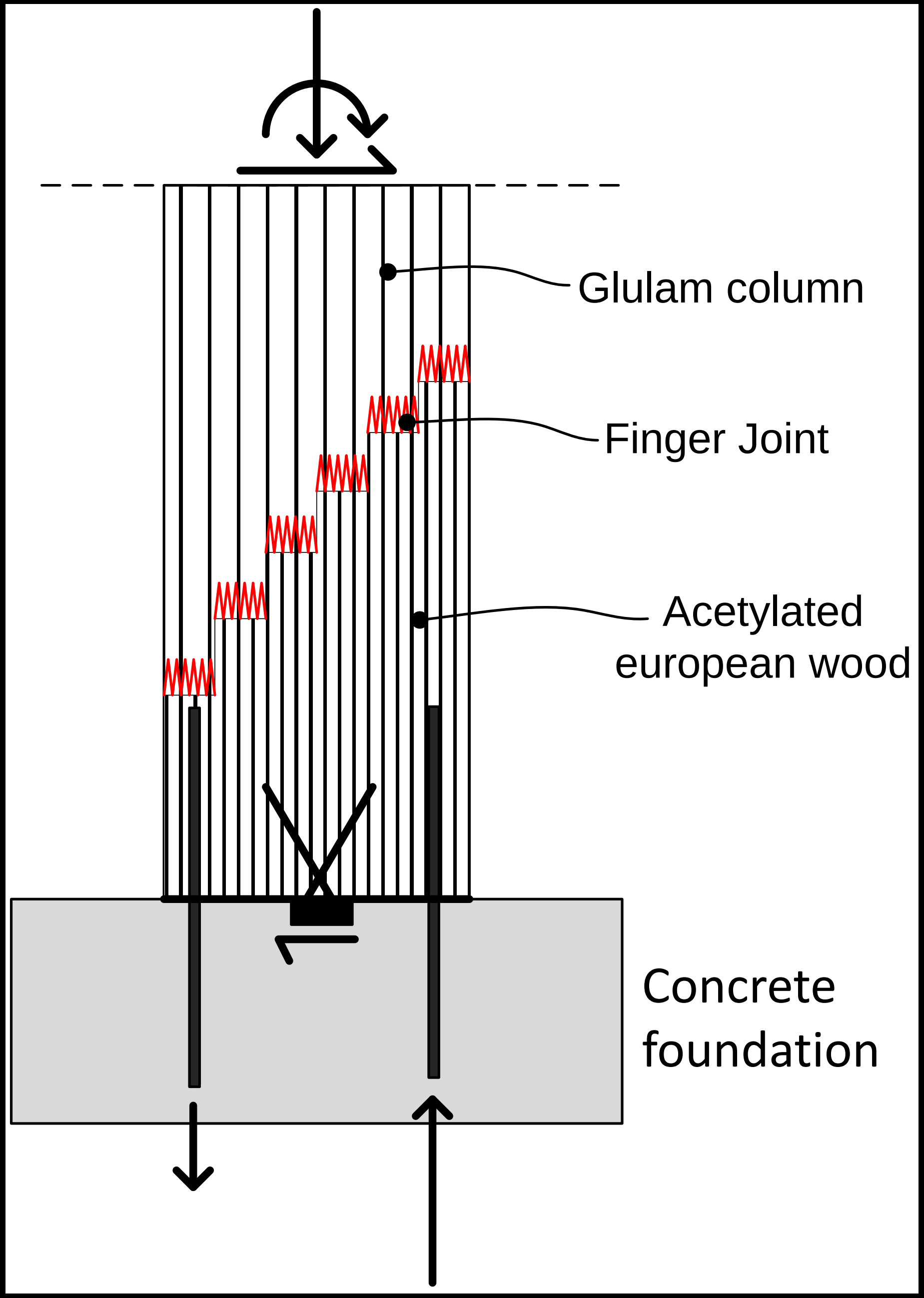
…however, most often we need material with high durability only at some specific (very limited!) parts of the structure

Hybrid member: untreated wood and acetylated wood



a few examples of (real) timber-based hybrid structures

Bridge over Nynäs railway, Haninge

Structure type: Three hinged arch

Span: 35 m

Erection: march 2017

Structural Engineer: Roberto Crocetti

Courtesy: Moelven Töreboda AB

Bridge over motorway, Hägernäs, 2007

Bridge over motorway, Hägernäs, 2007

Three-hinged arch

Span: 34 m, length 42 m

Structural Eng: Roberto Crocetti

Courtesy: Moelven Töreboda AB

Steibridge, Norway

Completed: 2016

Type: Network arch

Span : 80 m

Material: impregnated pine

(steel diagonals and hangers,

concrete deck)

Courtesy: Moelven Limtre

Traversina bridge, Switzerland

- Parabola-shaped beams
- Structural Eng. Jürg Concett

The Bullit Center, Seattle, USA

Courtesy: Solaripedia

Multy storey residential building in UBC Vancouver, Canada, 2017

- Student accomodations
- **2 storey/week**
- Load bearing system: Glulam+ CLT + Concrete (lateral bracing)
- 18 storeys

Courtesy: UBC Brock Commons

Multy storey residential building in Skövde, 2017

Kv. Vallen

Courtesy: Moelven Töreboda AB

Now, are you still not convinced that *hybrid* is good?

A successful hybrid

This a "***hybrid***" made of 2 dried grapes:

- Corvina (45–95%)
- Rondinella (5–30%)