

Timber-based hybrid structures: why?

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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

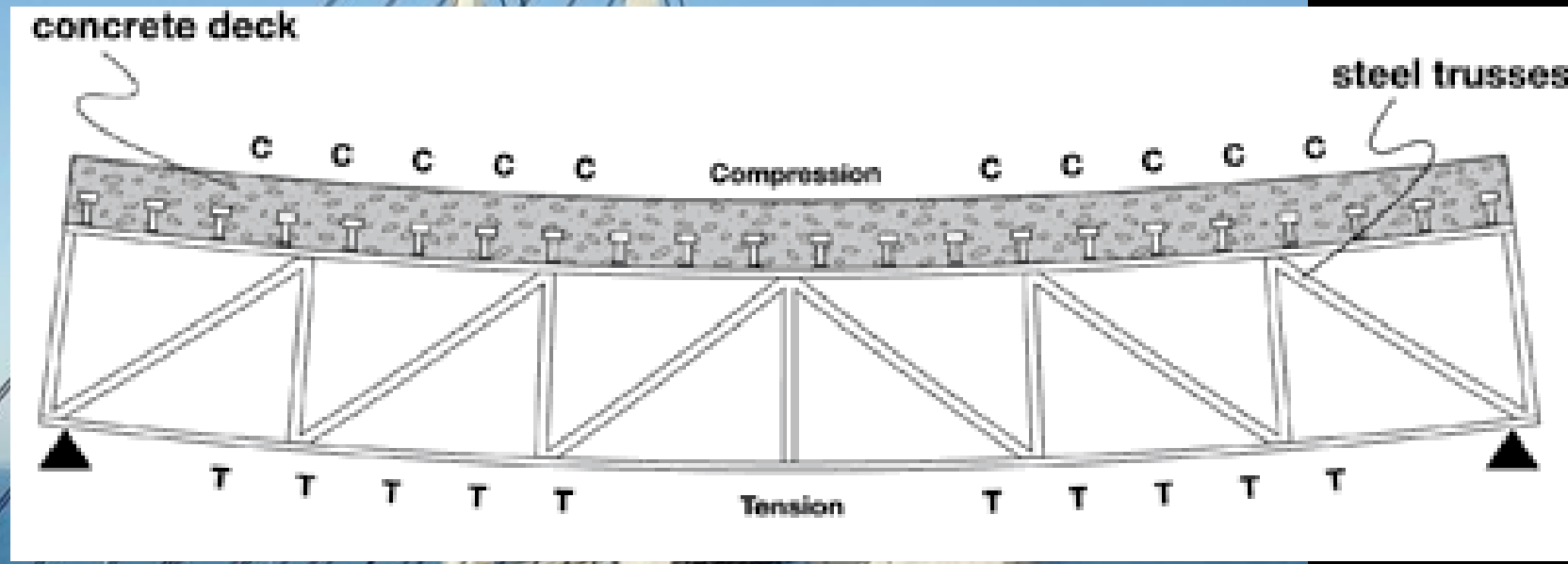
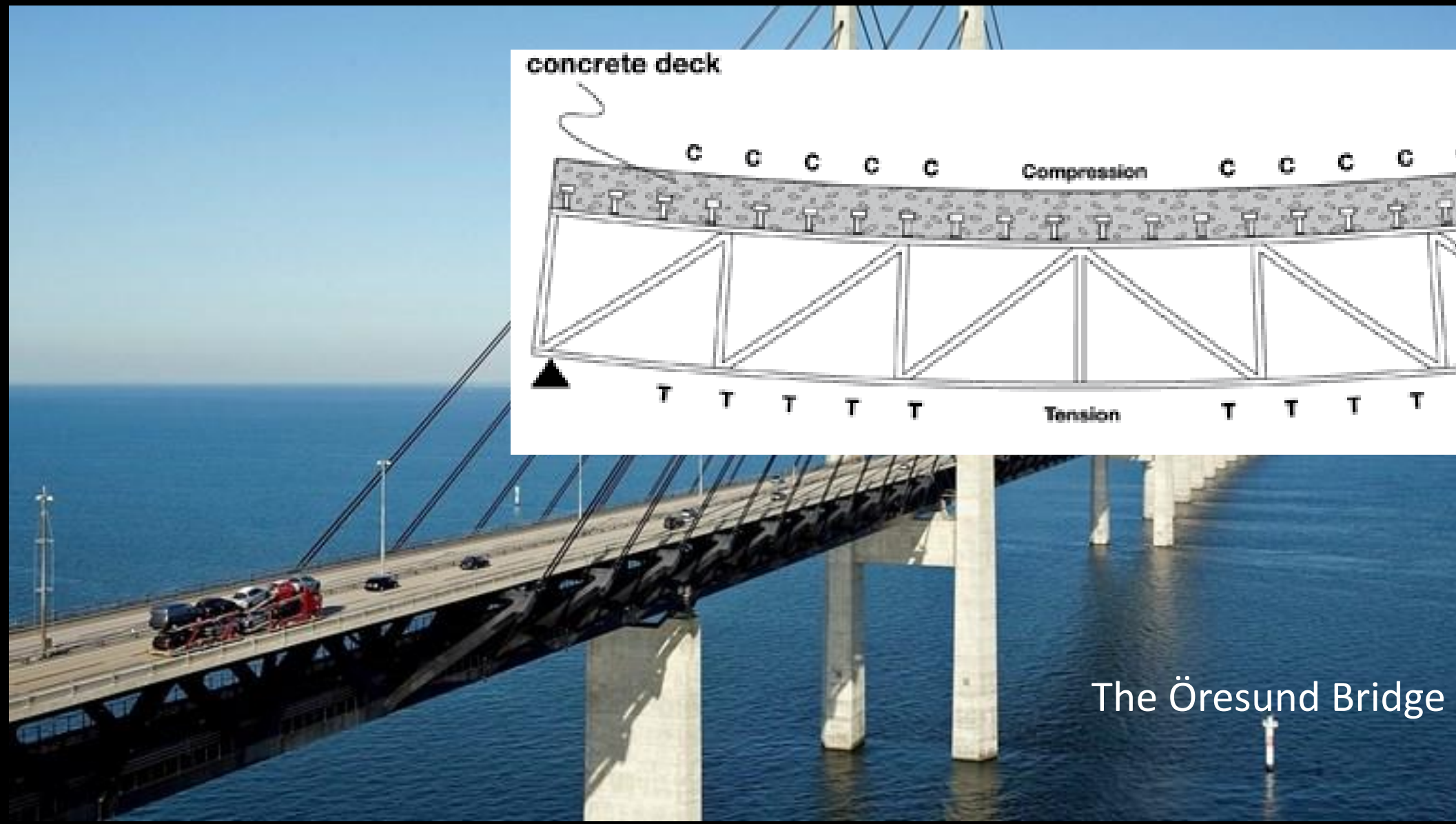


Composite structures of steel and concrete



The Öresund Bridge

Composite structures of steel and concrete



The Öresund Bridge

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



THE DE HAVILLAND "MOSQUITO" LIGHT BOMBER

Now in its fourth month in operational service in the world, and the Royal Air Force's "lightning" low-level daylight bomber in vital Area and tactical, night or intruder, roles, the Mosquito is credited for its multi-mission versatility. Its high speed, which develops 1,000 m.p.h., which gives a top speed of approximately 600 m.p.h., and its exceptional range of speed over most German fighters and, consequently, its superiority in vertical maneuverability to enable the Mosquito to be based heavily and covered for great distances, as demonstrated by the raids on Berlin.

The Mosquito is also used as a long range day tactical and night intruder with a very formidable complement of four machine and four machine gun concentrated in the nose. Other variants are used for photographic reconnaissance and precision attack of targets in the low level. The Mosquito is a twin-engine aircraft with a span of 104 ft. 6 in. and a length of 60 ft. 6 in.

- | | | |
|----------|------------------|--------------|
| 1. Wing | 11. Landing gear | 21. Bomb bay |
| 2. Wing | 12. Landing gear | 22. Bomb bay |
| 3. Wing | 13. Landing gear | 23. Bomb bay |
| 4. Wing | 14. Landing gear | 24. Bomb bay |
| 5. Wing | 15. Landing gear | 25. Bomb bay |
| 6. Wing | 16. Landing gear | 26. Bomb bay |
| 7. Wing | 17. Landing gear | 27. Bomb bay |
| 8. Wing | 18. Landing gear | 28. Bomb bay |
| 9. Wing | 19. Landing gear | 29. Bomb bay |
| 10. Wing | 20. Landing gear | 30. Bomb bay |

De Havilland

© De Havilland



**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

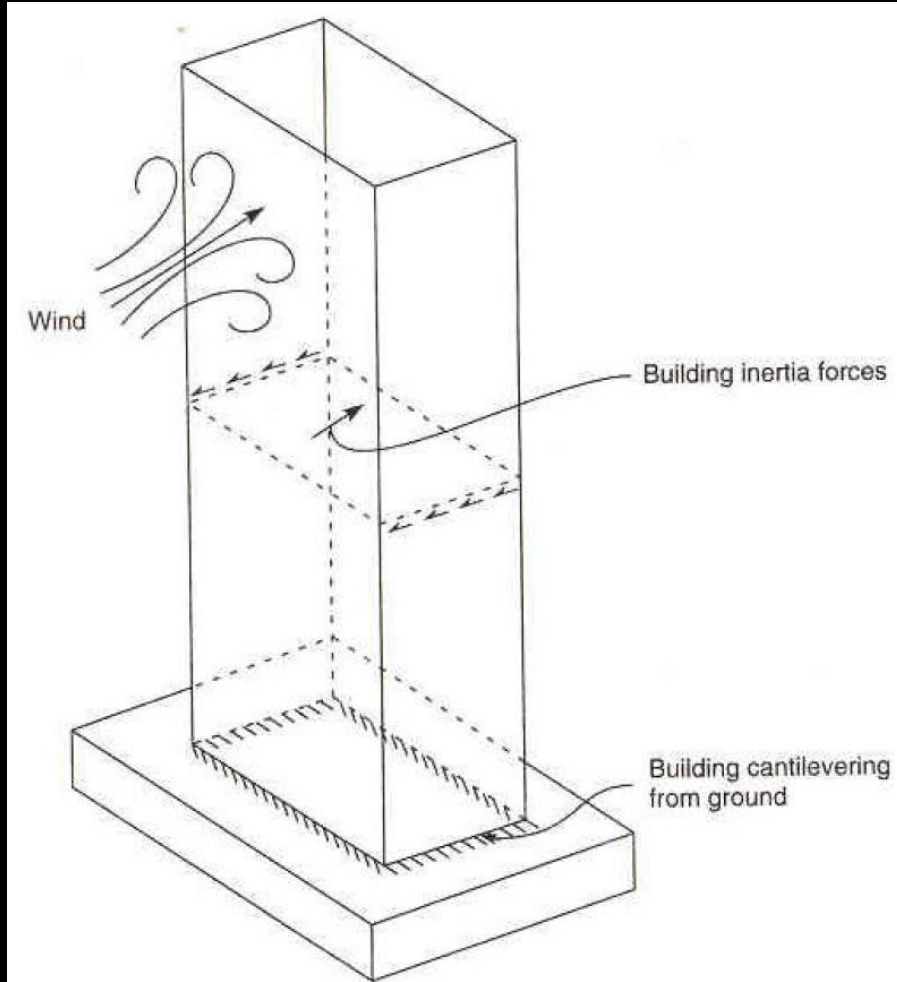
1. Low mass
2. Low Young's modulus
3. High variability of mechanical properties
4. Low ductility
5. Durability

Some unfavourable properties of timber

1. **Low mass**
2. **Low Young's modulus**
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5. Durability

Low mass

Low Young's modulus



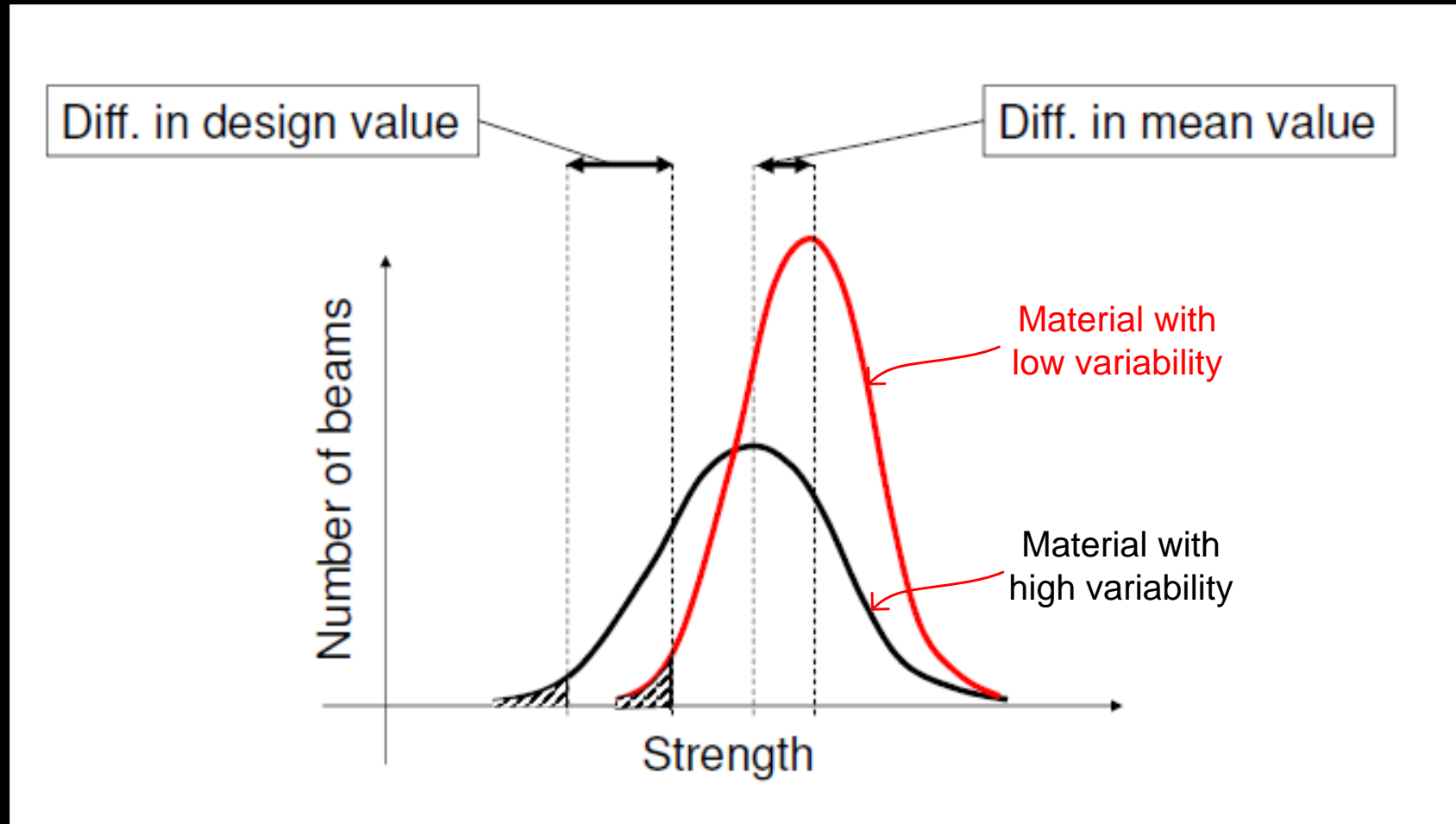
Acoustics and vibrations in floors

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

Some unfavourable properties of timber

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- 3. High variability of mechanical properties**
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High variability of mechanical properties and

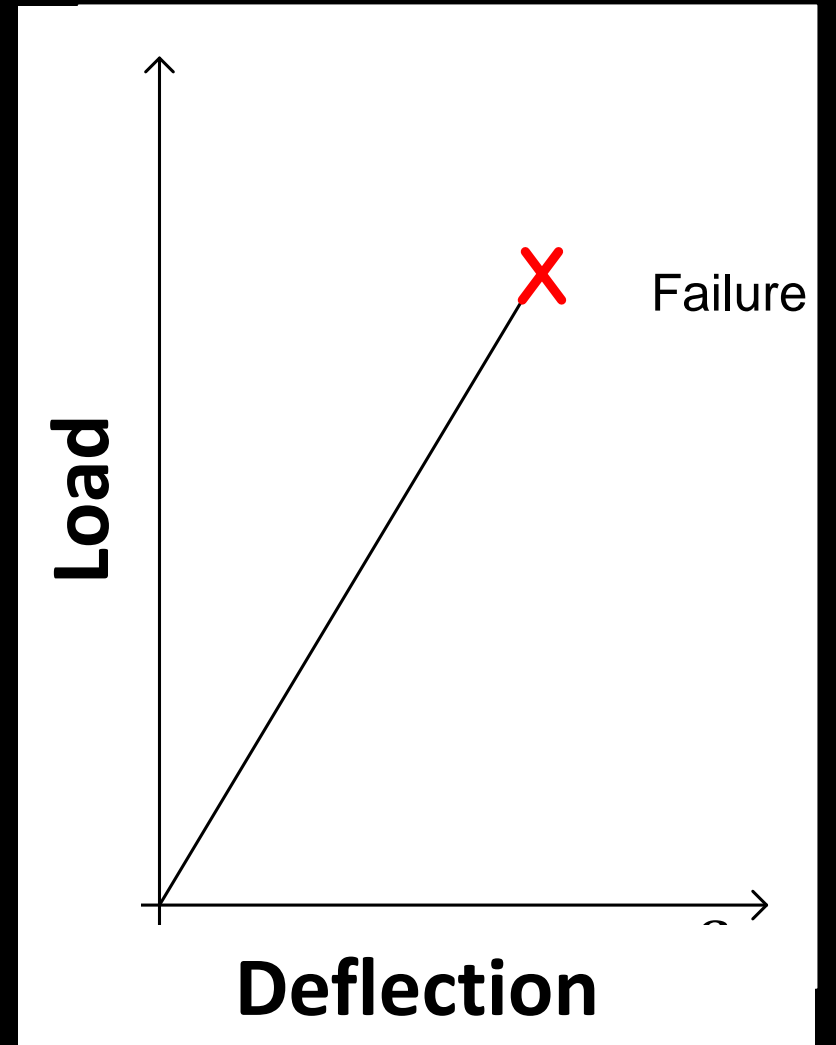


Large scatter → low characteristic strength

Some unfavourable properties of timber

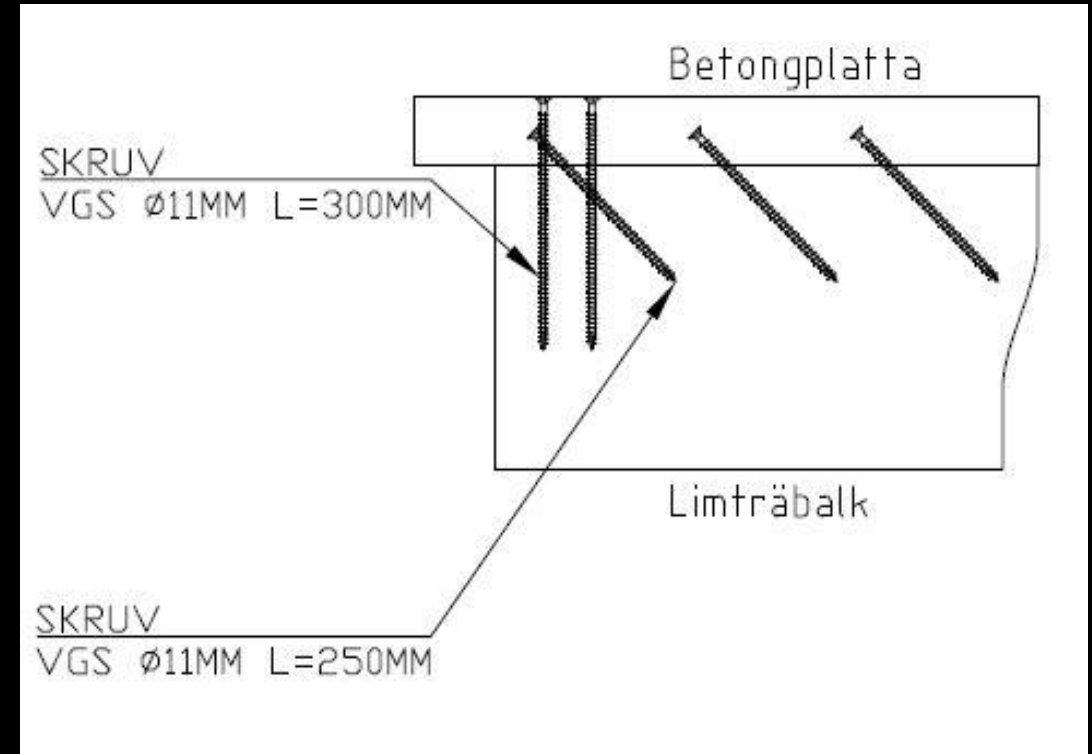
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- 4. Low ductility**
5. Durability

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

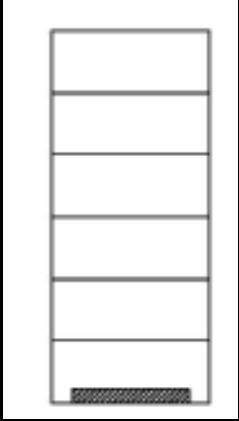
Hybrid structures 2: timber + steel or FRP



- Glulam beams 115x270, L=6m, both unreinforced and reinforced with glued steel plate 10x80 mm².
- 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

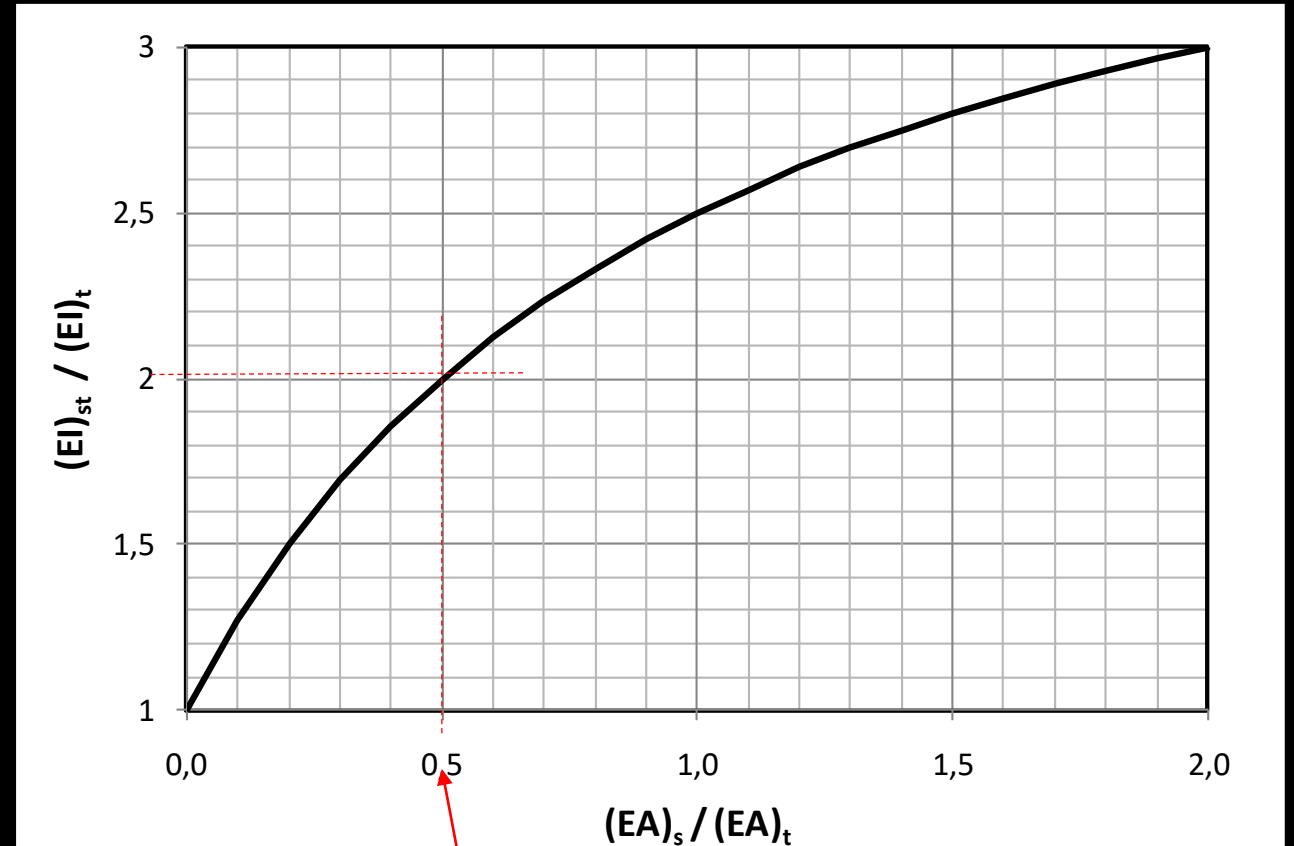
if the reinforcement ratio is 2,6% ($n\rho_s \sim 0,5$), the stiffness doubles and consequently the elastic deflection decrease by half.



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

“st”: reinforced beam

“t”: unreinforced beam



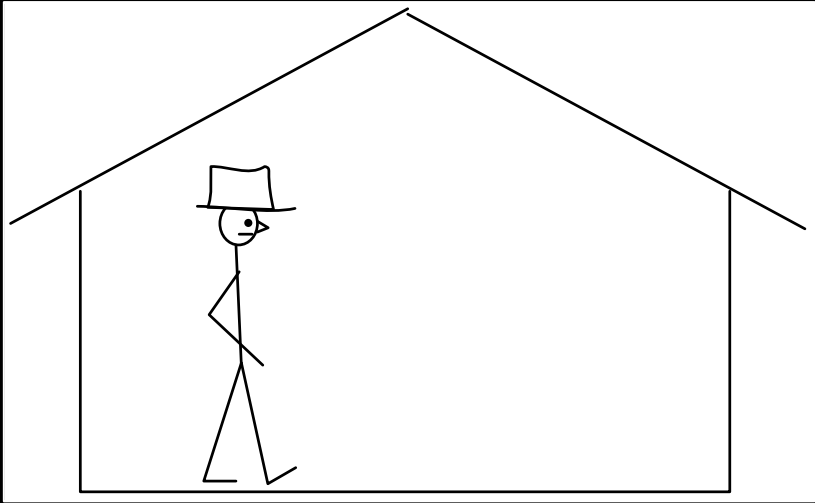
Corresponds to a steel reinforcement ratio of 2,6%

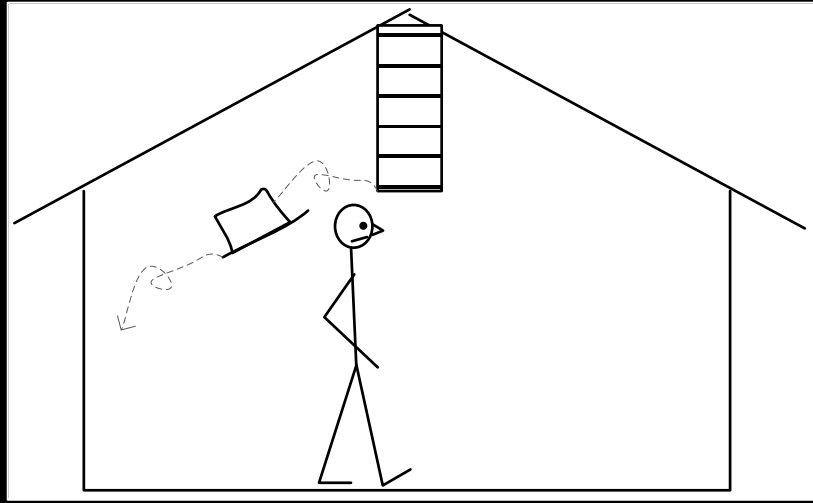
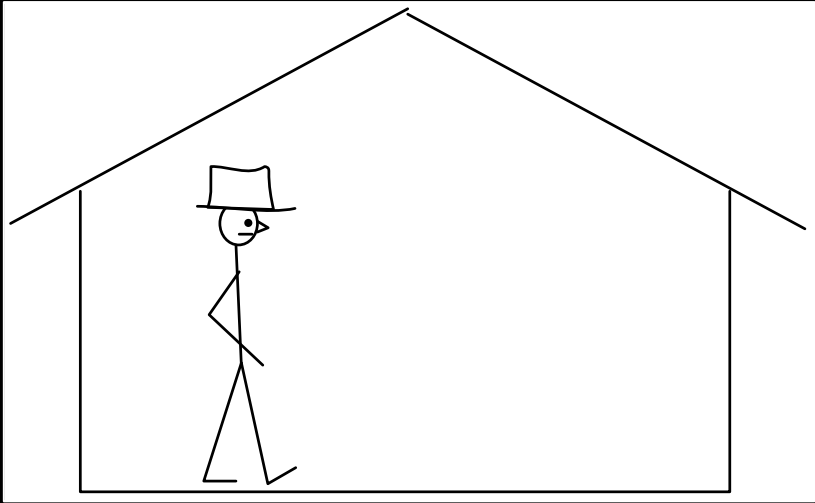
It is typically argued that gluing 4-5 laminations to a glulam beam is simpler and cheaper than gluing a steel or CFRP strip

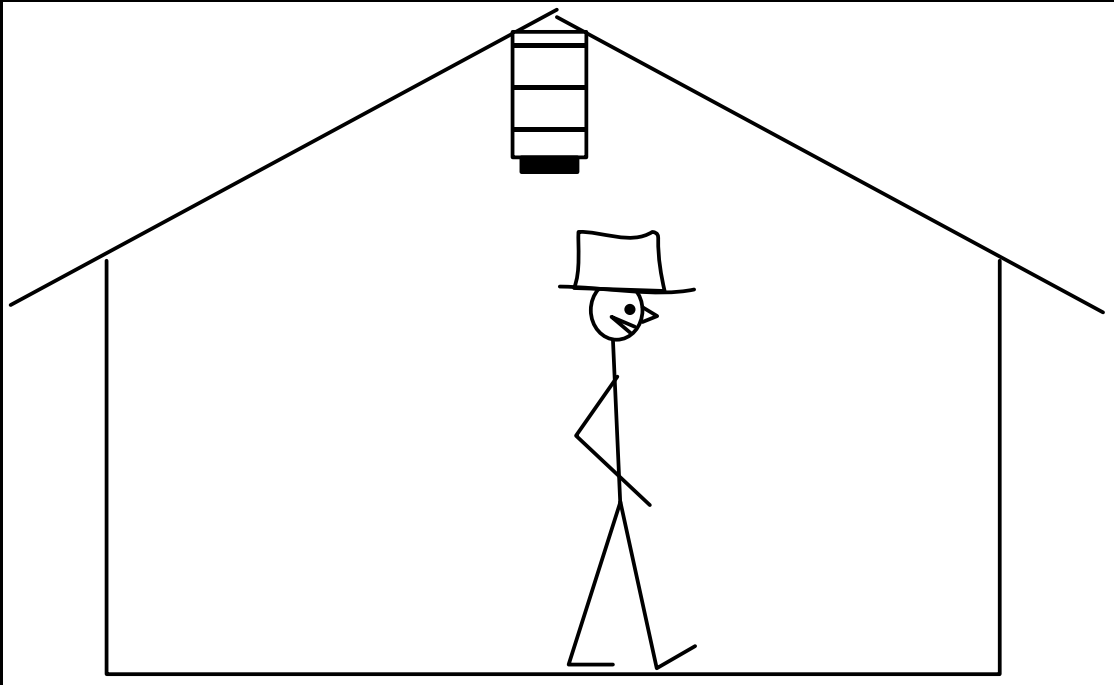
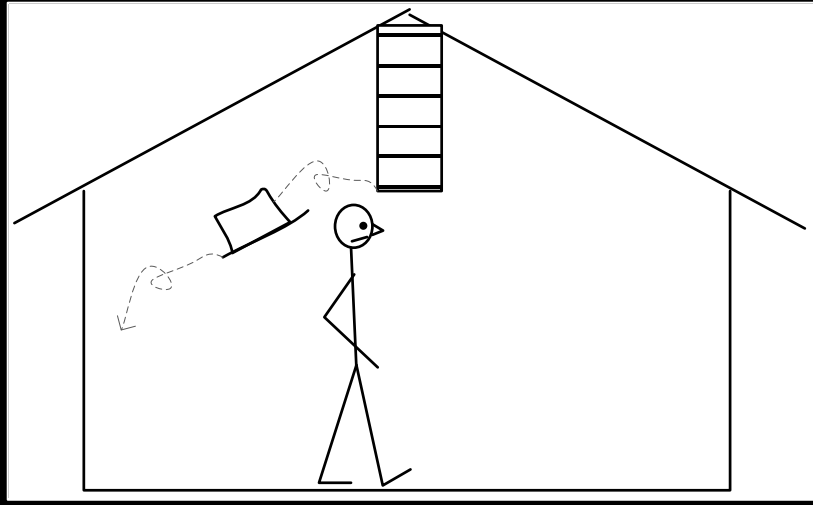
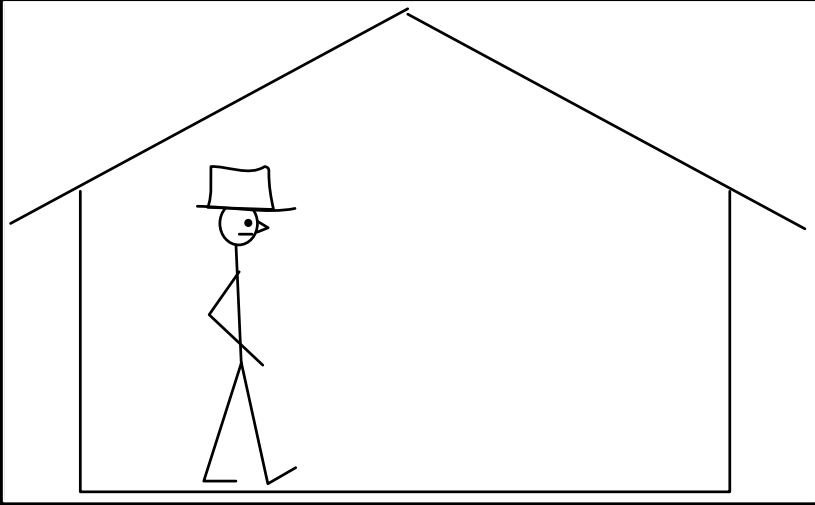
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...which is basically true...**

It is typically argued that gluing 4-5 laminations to a glulam beam is simpler and cheaper than gluing a steel or CFRP strip ...which is basically true...

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

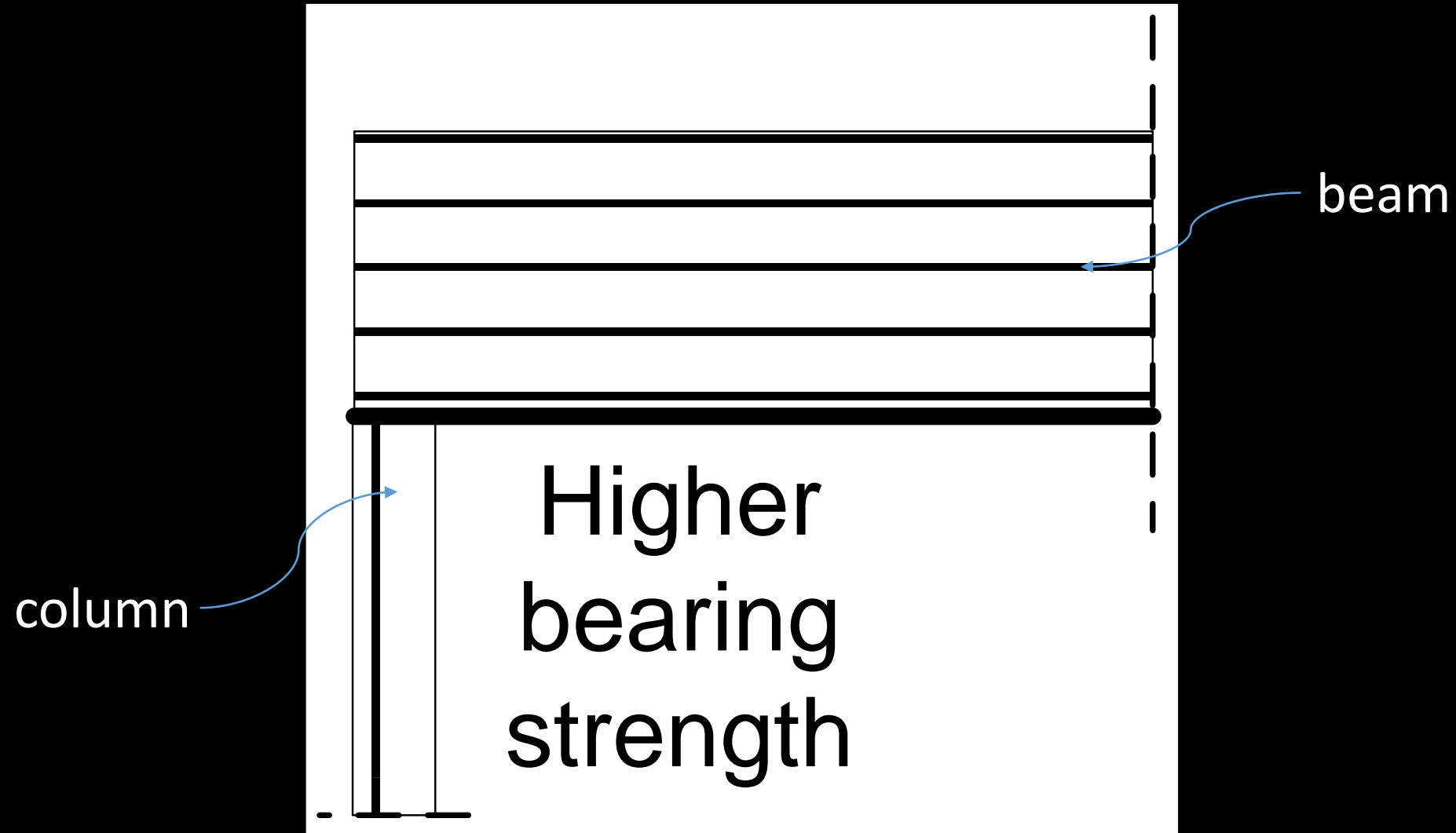




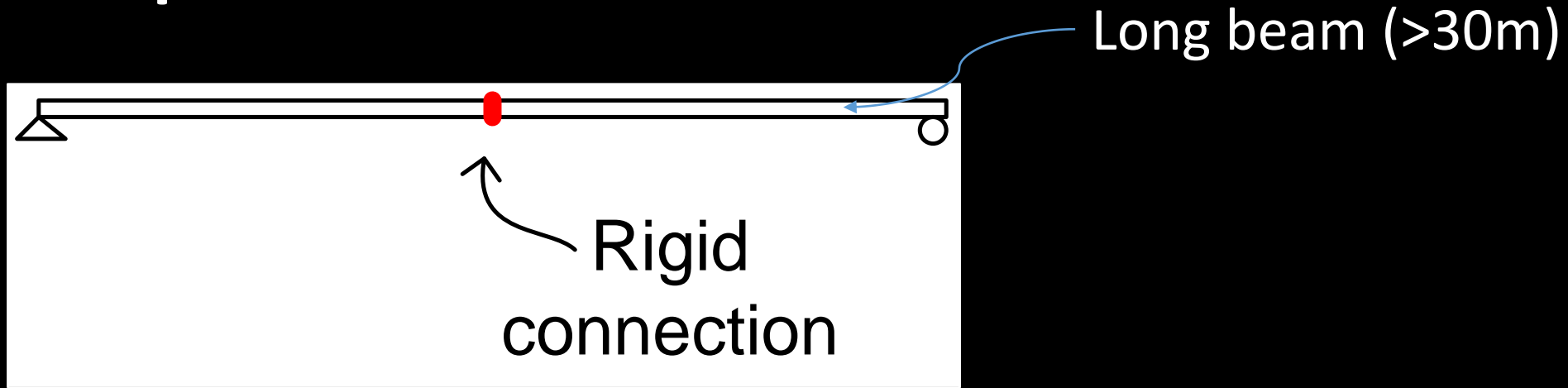


Using reinforced beams can also have other advantages...

Example 1

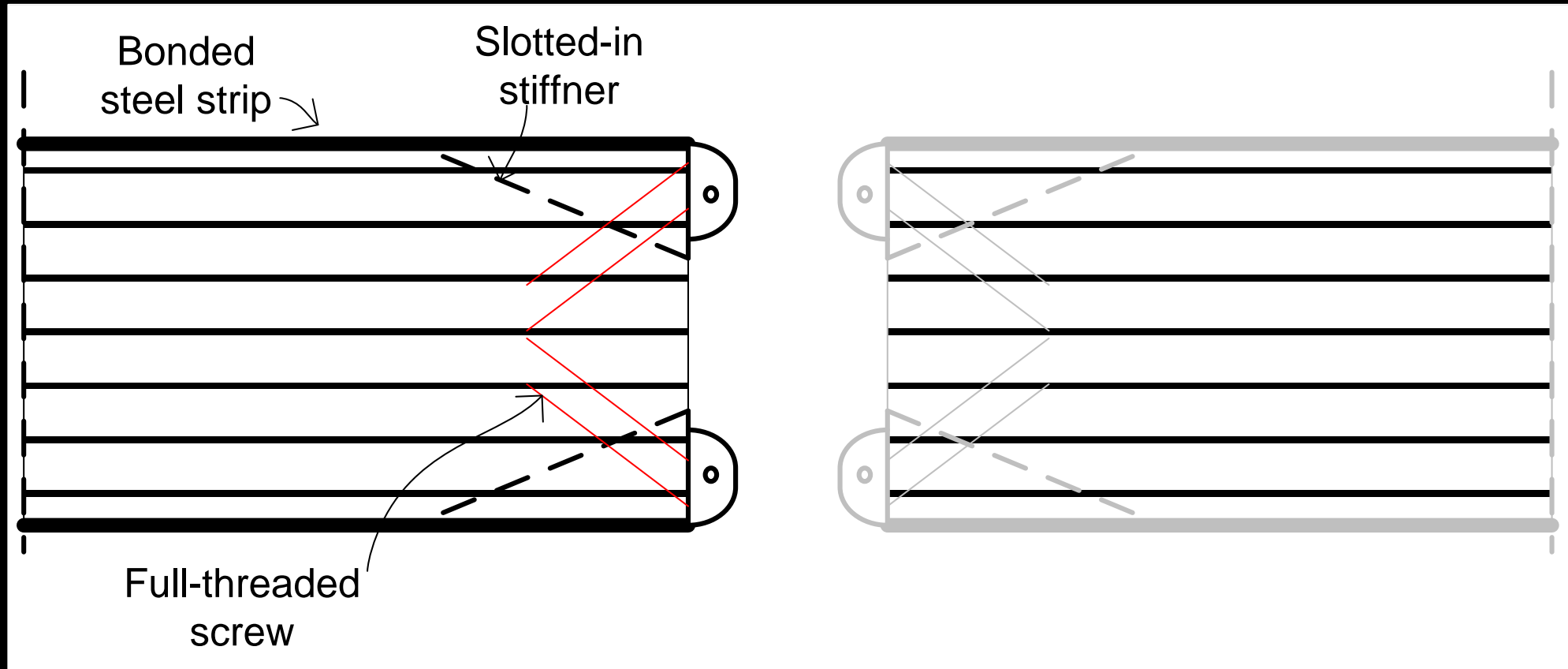
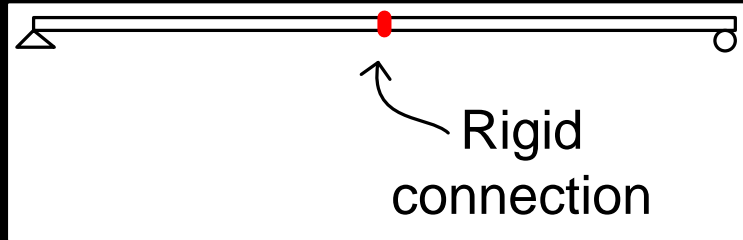


Example 2



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

Example 2



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 expensive...

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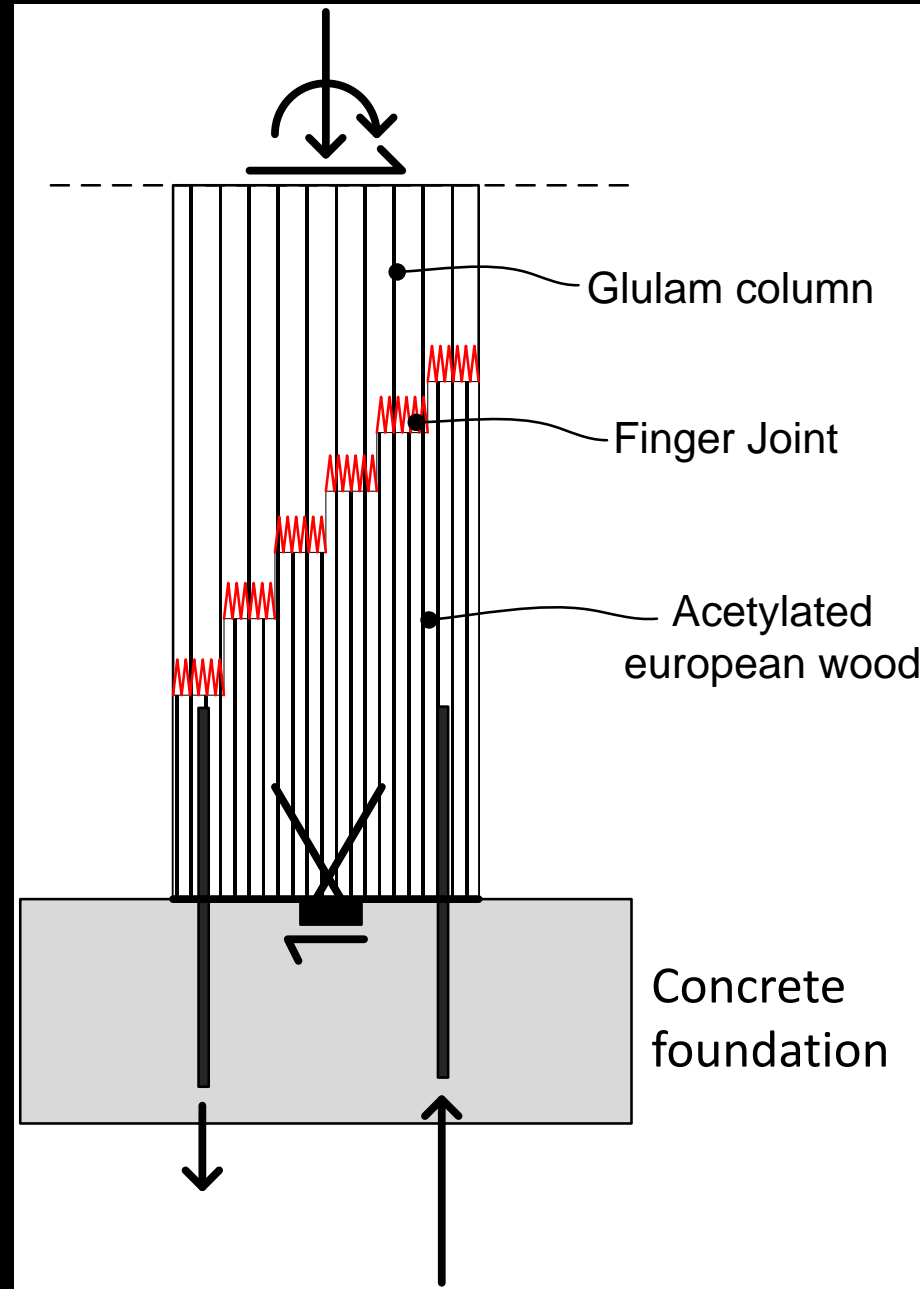
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It is typically argued that acetylated wood is very expensive...

...which is basically true...

...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%)