Aalto University
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The Durability of Wood-Concrete Composite Bridges

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Outline:

1. Introduction
2. Behavior and Design of Connectors
3. Long Term Pull-out Tests
4. Long-term Fatigue Tests
5. Current Condition of Two Bridges
6. Conclusions

1. Introduction

Wood-concrete Composite Bridge

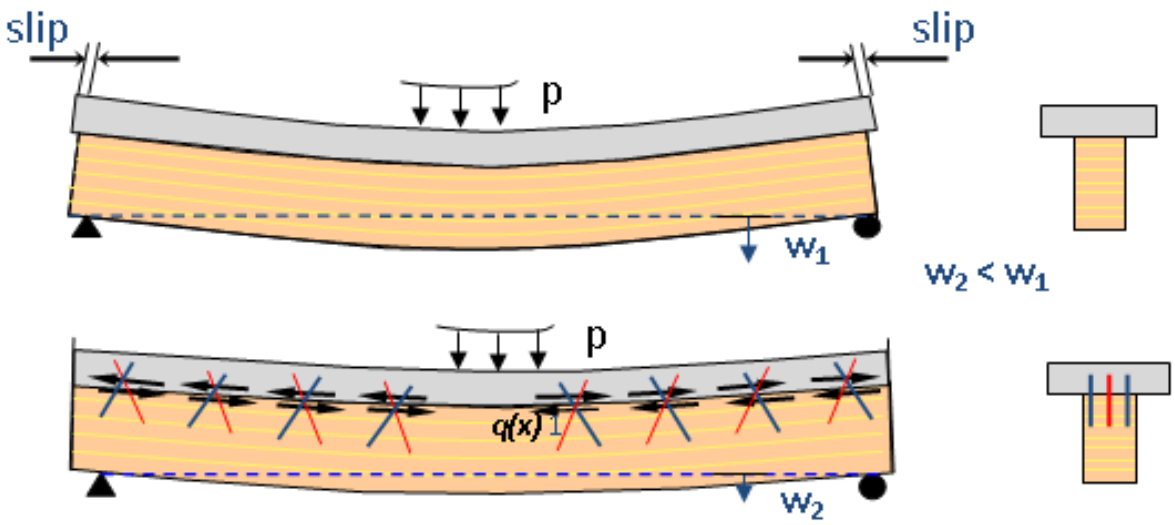
Composite Bridge:

- Concrete deck slab
- Glulam Beams
- Connectors to join the two parts of different materials

2. Behaviour and Design of Connectors

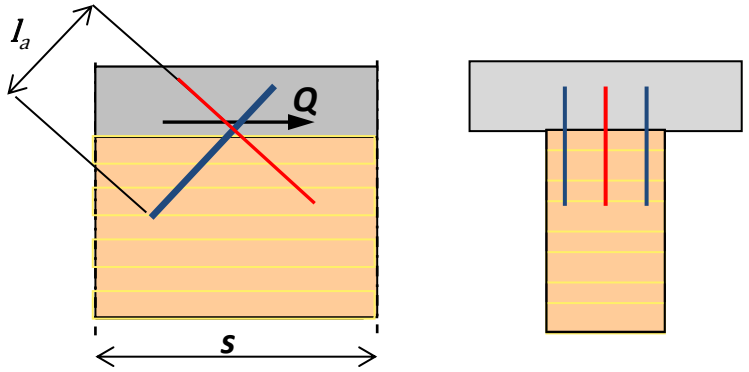
Basic principle:
Two material parts are connected by using connectors

- Without connectors slip occurs between the two materials
- By preventing the slip the beam acts as a composite girder
- As the consequence the stiffness increases
- The connectors are loaded by the horizontal shear flow is q(x)



2. Behaviour and Design of Connectors

Truss Analogy

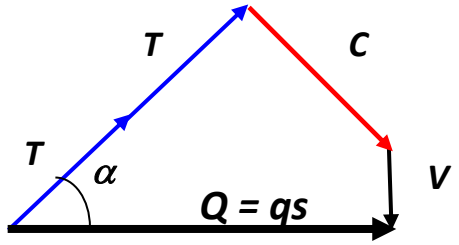


Capacity of a bar in tension

$$T_c = \pi d_a l_a f_{v\alpha k}$$

Anchoring stress capacity (according EC)

$$f_{v\alpha k} = k_\alpha \left(\frac{\rho_k}{\rho_o}\right)^{3/2} \left(\frac{d_o}{d_a}\right)^{1/5} \cdot f_{vo}$$



here

$$k_\alpha = \frac{1}{\sin^2\alpha + \frac{3}{2}\cos^2\alpha}$$

and

d_a = diameter of the embedded bore hole

ρ_k = characteristik density of wood

ρ_o = 500 kg/m³ (constant)

f_{vo} = 8,465 MN/m² (constant)

d_o = 10 mm (constant)

3. Long-term Pull-out Tests

Testing procedure to find out the effect of ageing to strength

Pull-out strength tests:

- 11,7 mm threaded bars
- anchoring length 130 mm
- 45° angle to grains

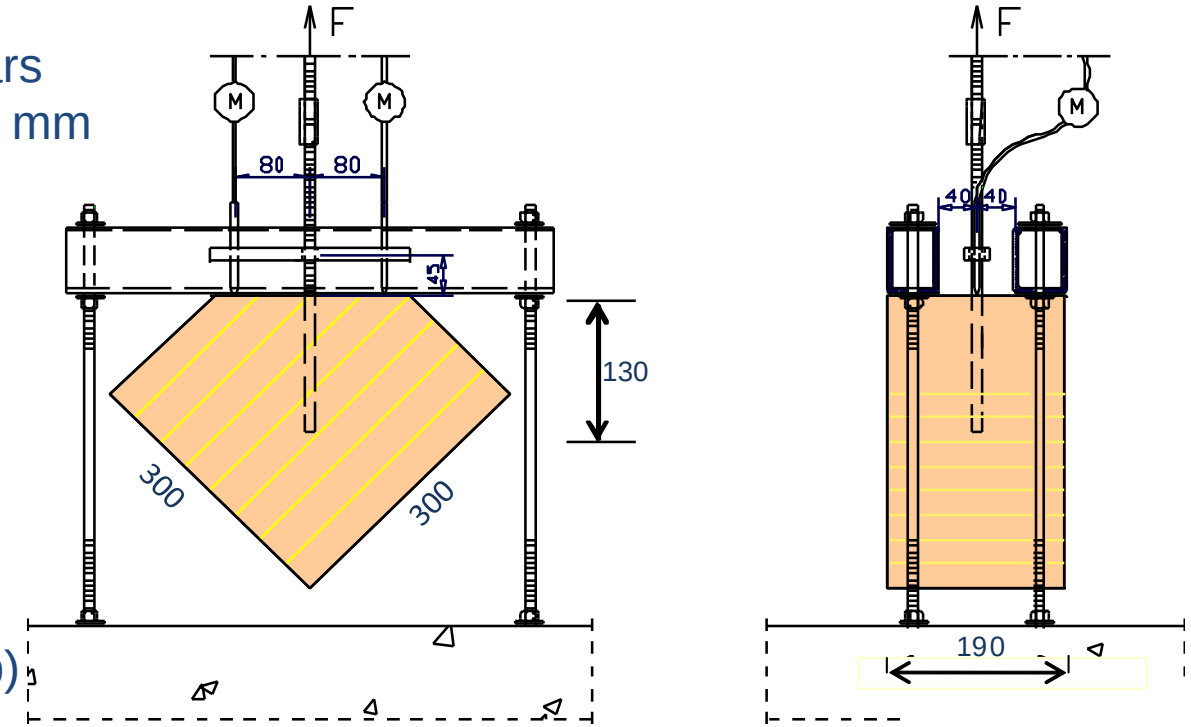
Adhesives groups:

- 12 Epoxy glued bars
- 12 PU -glued bars

Testing age:

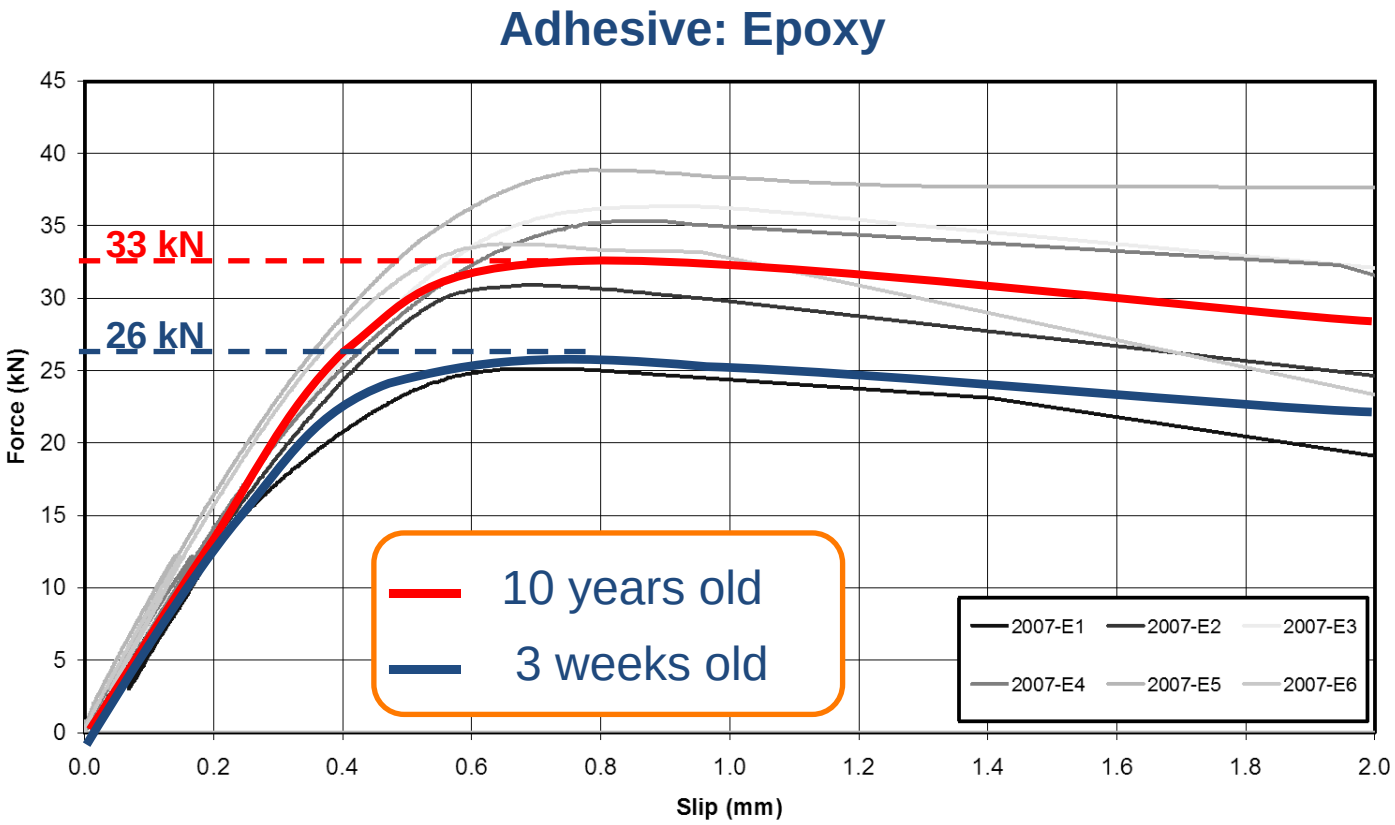
- 3 weeks
- 10 years

(6 pieces of each group)



3. Long-term Pull-out Tests

The influence of ageing to strength and load-displacement curves

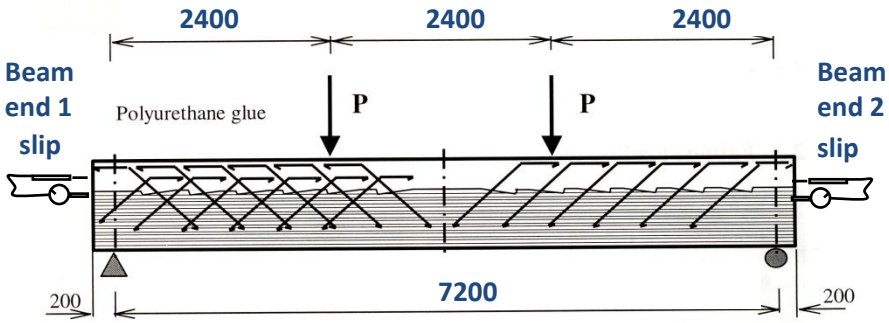


4. Long-term Fatigue Tests

Effect of ageing to fatigue behaviour of a composite girder

Structure of the test beam:

- tension and compression bars on one half of the beam
- tension bars only on the other half
- wedge shaped notches on surface



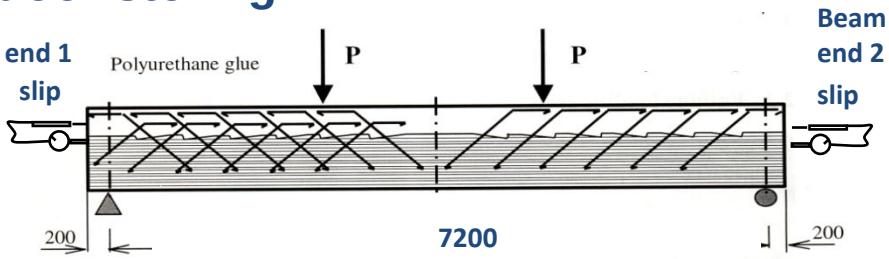
4. Long-term Fatigue Tests

Third fatigue test after 10-years outdoor storing

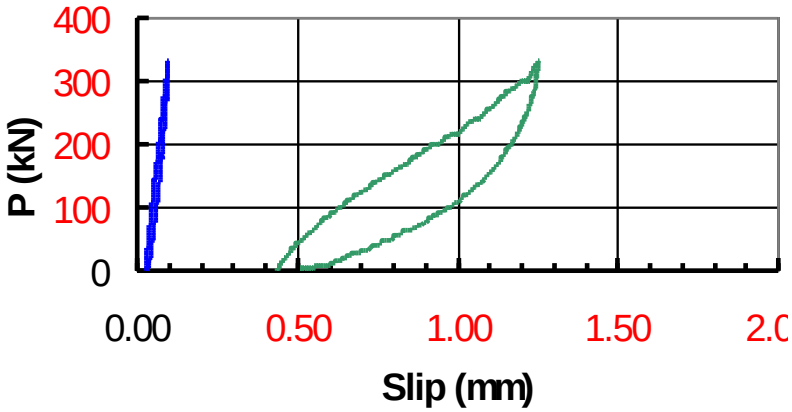
Measured slips at beam ends

N = 1,8 Million load cycles and

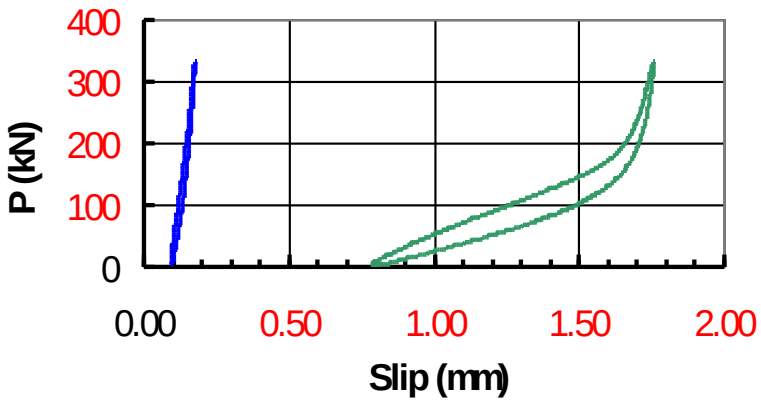
N = 2,5 Million load cycles



N = 1 800 000



N = 2 500 000



— tension + compression bars (beam end 1)

— tension bars only (beam end 2)

5. Current Condition of Two Bridges

Kruununmylly Bridge, after inauguration

The first wood-concrete composite bridge after completion twenty years ago in 1993.

5. Current Condition of Two Bridges

Kruununmylly Bridge, inspection of outlook today

Refurbish is needed in:

- clearance of vegetation
- surfacing the edge beams
- renewing the wooden railings

5. Current Condition of Two Bridges

Kruununmylly Bridge, Inspection of timber beams

Beams are perfect under concrete deck after 20 years service life

- No cracks or other damages were found
- Moisture content was measured to be between 14 – 18 %

5. Current Condition of Two Bridges

Vihantasalmi Bridge, inspection of the outlook after 14 years service

Refurbish is needed to improve the outlook

- Zinc coating of railing poles has caused runs on the surface of the edge beam.

The outer surface of the utmost beam at the end of the bridge is similarly blotchy at railing pole positions

5. Current Condition of Two Bridges

Vihantasalmi Bridge, inspection of outlook and details

Refurbish is needed in:

- clearance of vegetation
- renewing the wooden hand guide
- many other details

5. Current Condition of Two Bridges

Vihantasalmi Bridge, Inspection of wooden members

Problems found:

- Under protective cover **at the ends of inclined members**:

  1. Water pockets
  2. Cracks

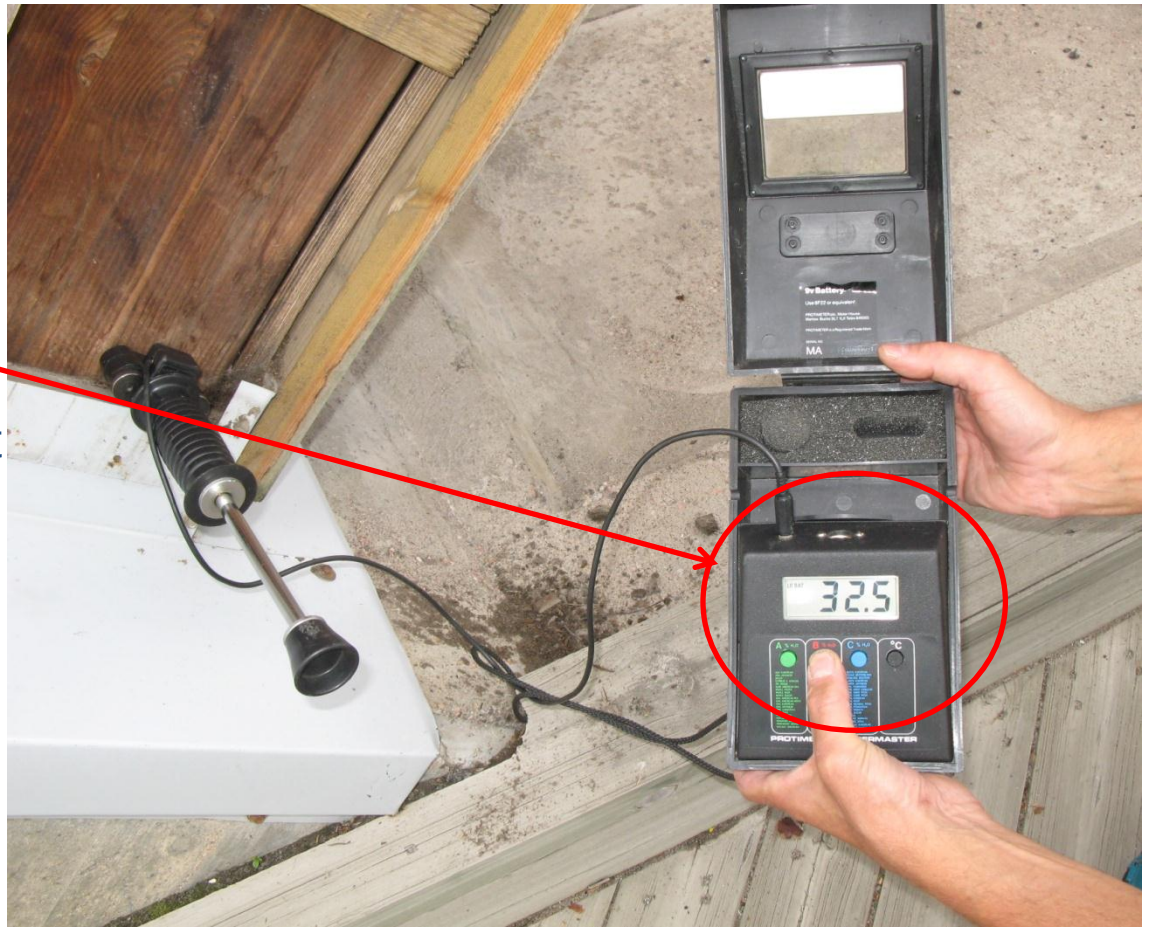
- Designed ventilation for timber members is not able to keep the ends of wooden parts dry

5. Current Condition of Two Bridges

Vihantasalmi Bridge, Inspection of wooden members

Problems found:

- **Some ends of the wooden members are practically in saturated condition**
- High moisture content was before measured at ends of glulam beams of the wood-concrete deck



5. Current Condition of Two Bridges

Vihantasalmi Bridge, Inspection of wooden members

Reasons of high moisture content in the joint:

- The ends of the inclined wooden members are overall confined by steel casing
- And then, cast in concrete
- The water cannot evaporate any-where

5. Current Condition of Two Bridges

Vihantasalmi Bridge, Inspection of wooden members

- The steel “shoe” together with the ends of wooden members above the deck are cast inside a concrete footing block

- In winter dirty snow is piling at the root of the inclined members

Repair actions are needed !

6. Conclusions

- Glued-in reinforcing bars are simple, ductile and stable connectors
- In pull-out tests a little higher strength values obtained for aged specimens compared to newly fabricated ones.
- The fatigue test showed that compression bars are essential to guarantee the long-term strength and stiffness under repetitive loading
- Wood-concrete composite decks are most suitable to be used in small road bridges
- This was confirmed in the inspection of the beams of the oldest bridge of this type, which were in perfect condition

Durable timber bridges must be designed and maintained so that wooden parts can be kept clean and dry during ist whole service life

Questions ?