Willkommen
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Materials Science & Technology

Combination of timber, CFRP and GFRP for the design and construction of a bowstring arch bridge

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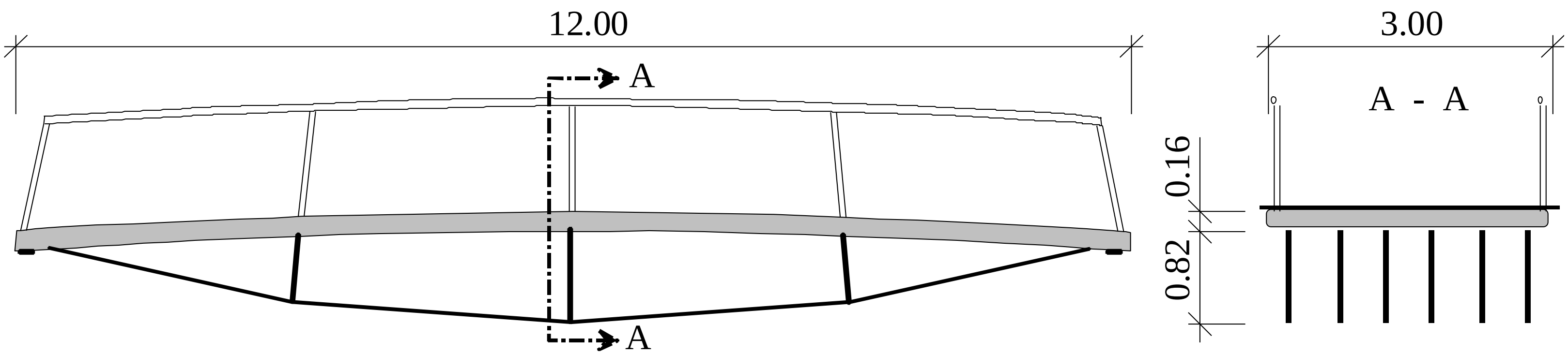
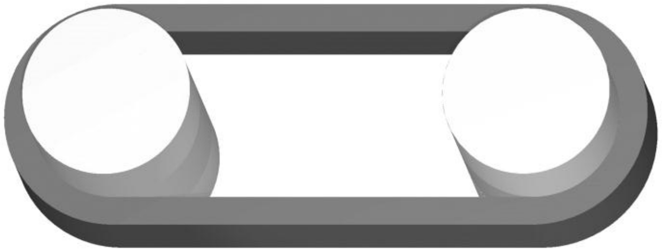
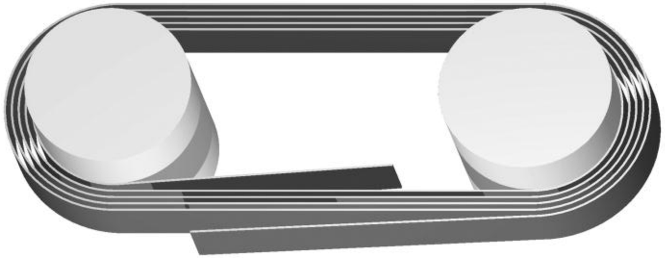
Basic Parameters



Material	E	ρ	Strength
	GPa	kg/m³	MPa
Glulam GL24h (EN 1194)	11.5	455 at u = 12% (measured)	$f_{m,g,k}$ = 24 $f_{c,0,k}$ = 24
CFRP	150	1500	f_t = 2000
GFRP	44.5	2000	f_c = 900

Pin-loaded CFRP Straps as tendons

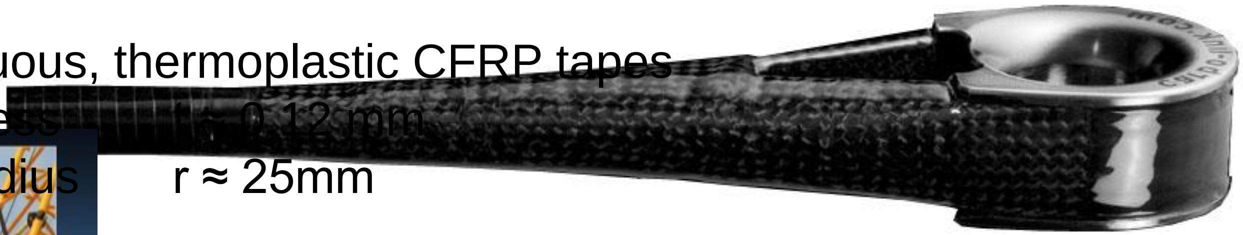




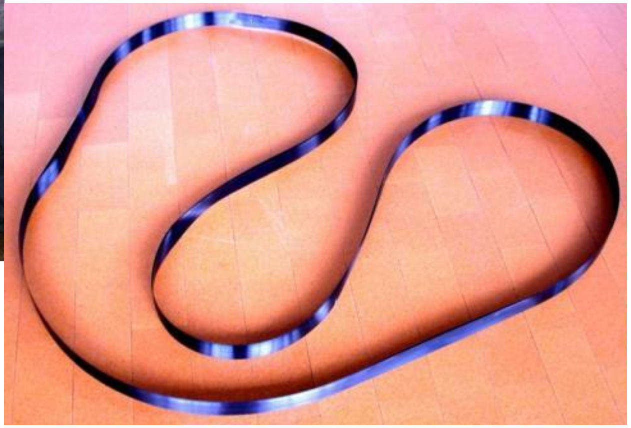
ntinuous, thermoplastic CFRP tapes

ickness t ≈ 0.12 mm

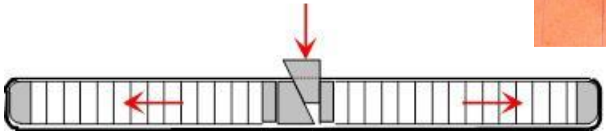
n. radius r ≈ 25mm



Lateral Prestressing



Principle



Tensioning of the bow

Tensioning of the bow

Tensioning of the bow

Tensioning of the bow

Load Tests

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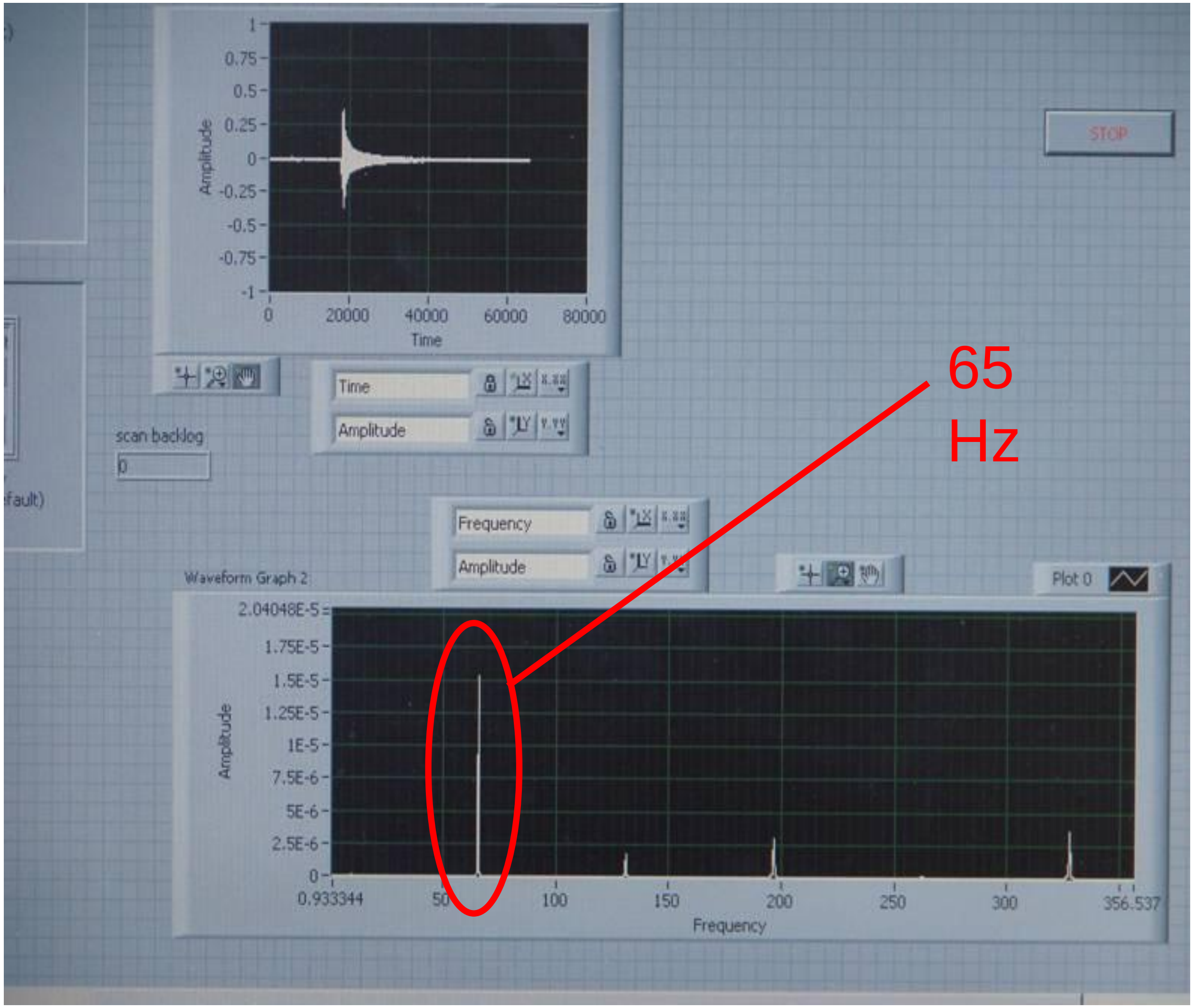
Load Tests



Amplitude
Time
20000
40000
60000
80000
STOP
scan backlog
Frequency
Waveform Graph 2
2.04048E-5
0.933344
356.537
Plot 0
65 Hz

Fundamental Frequency of a vibrating string

$$f = \frac{1}{2 \cdot \ell} \cdot \sqrt{\frac{F}{\rho \cdot A}}$$

$$F = 4 \cdot \ell^2 \cdot f^2 \cdot \rho \cdot A$$

$$F = 4 \cdot 3.00^2 \cdot 65^2 \cdot 1500 \cdot (0.03 \cdot 0.004) = 27.4\,\text{kN}$$

Step	Load	Mean deflection	Mean tension force ***F***	Accumulated tension force	Tension from static calculation	Deflection from static calculation
	kN	mm	kN	kN	kN	mm
0	0	0	21.0	126	149	0
1	8.5	6.54	23.8	143		
2	17.2	14.1	26.6	160		
3	25.6	20.8	29.4	176	208	18.7
Design load	$4/m^2$				405	83.1

Side-Topic: Monitoring while passing by….

Monitoring with iphone or….

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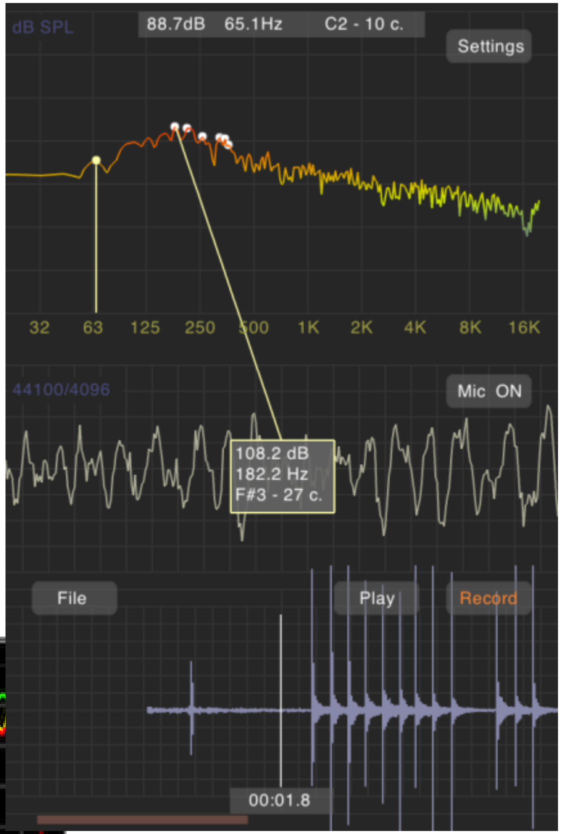
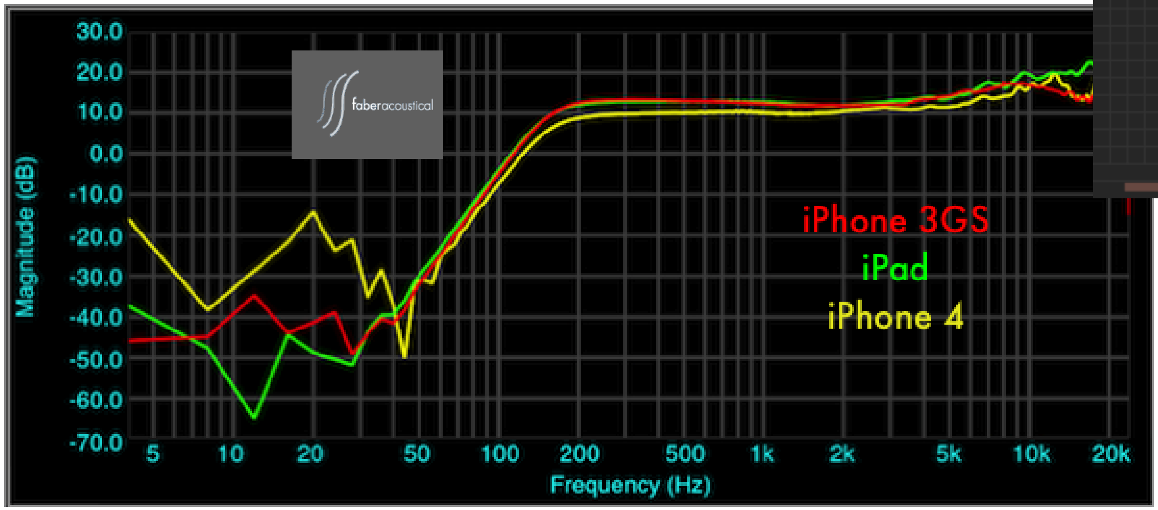
- iAnalyzer or similar App
- Indicates peaks in spectrum
- Has to be corrected for mic-response

- e.g. here for 65.1Hz:
  88.7dB + 25dB ≈ 114dB

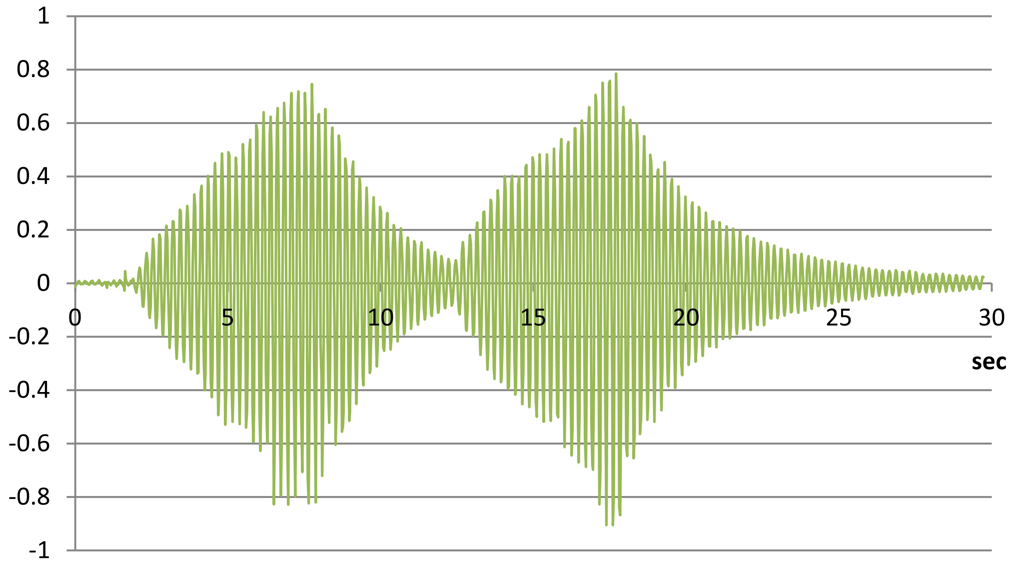


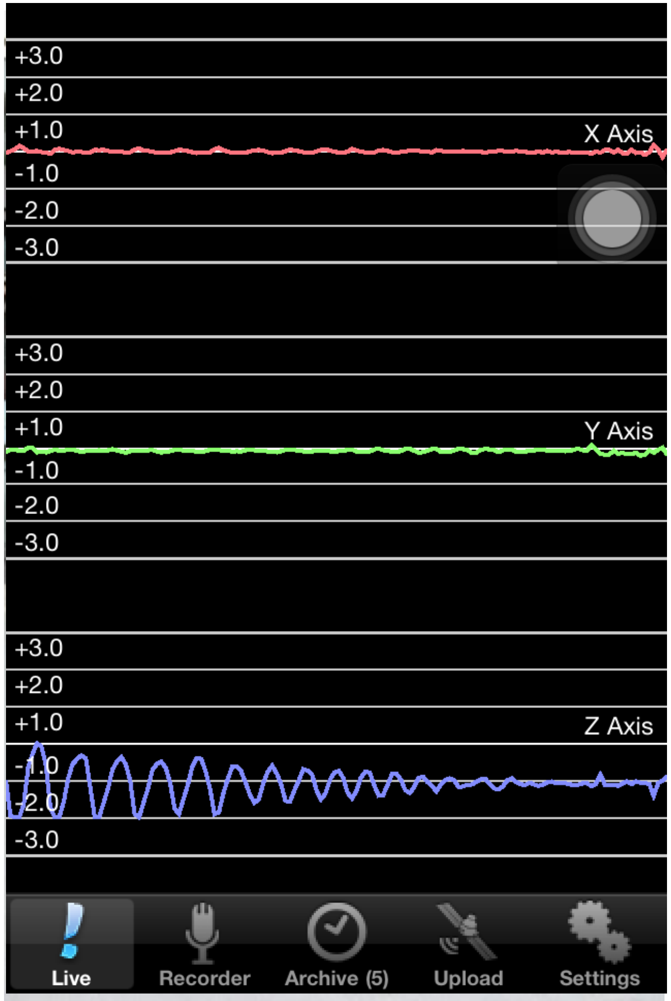


Monitoring with iphone or….(continued)

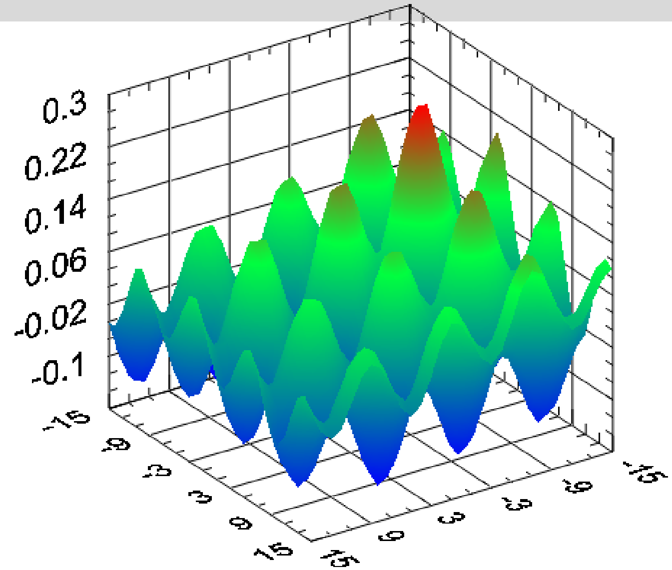
- Context Log, AccelPro or similar App
- Indicates and records x,y,z accelerations
- Data can be exported to a PC
- Analysis e.g. with MS-Excel

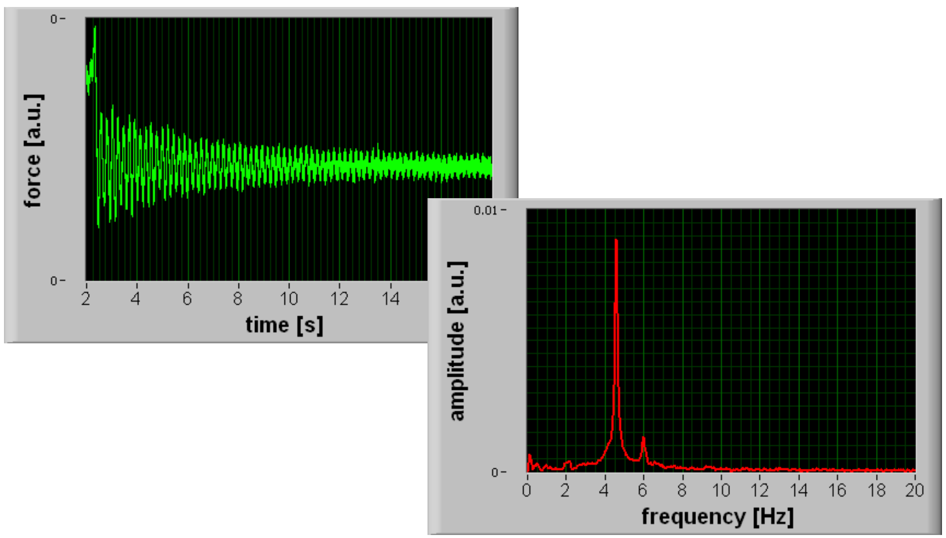
- e.g. here: $f_0 \approx 4.5$Hz, $\zeta \approx 1.2\%$

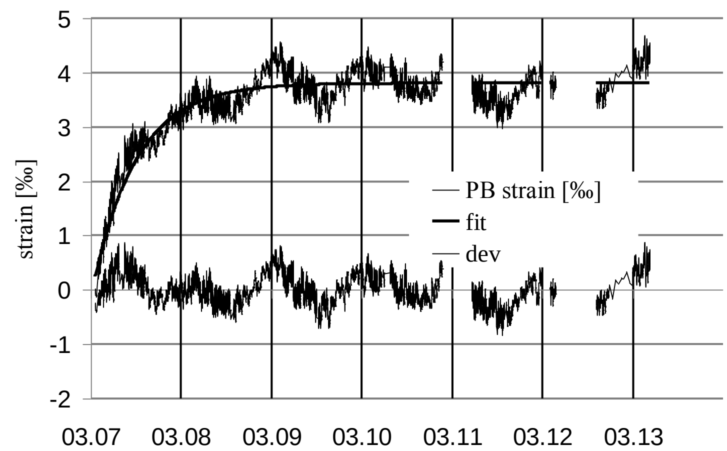




More Monitoring

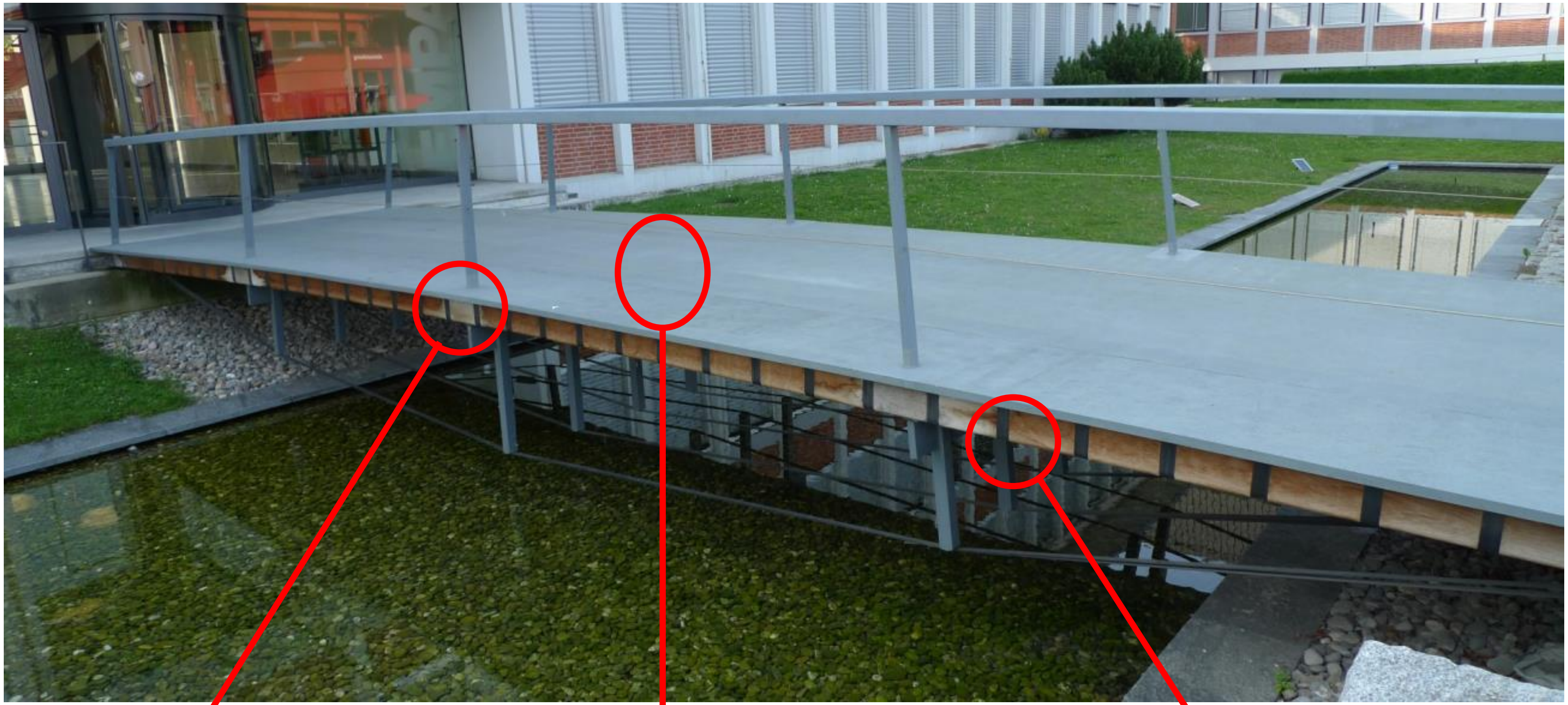






For detais: see e.g. Brönnimann et al: ICTB 2010 publication

Weak points / Potential for improvements



Anchorage of railing posts
Not tight
Lokaly and temporarily increased MC of timber

Decking
Slippery when wet and/or frozen
Sanding not sufficient

Timber bridge deck
Cup deformations due to MC gradient
T > 80°C under decking in summer

Conclusions

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- Pedestrian bridge made exclusively of glulam structural timber, CFRP and GFRP at the Empa site in Duebendorf, Switzerland.
- Lateral and longitudinal prestressing of the bridge with CFRP loop straps
- Load tests confirmed a superior stiffness of the system.
- Bridge in place since 2007 and since then continuously monitored
- From the advantages of the construction like lightweight structure, high stiffness, prevention of corrosion problems, easy installation, good value and an expected long service life, a good market potential for such structures can be expected.

Thank you

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- Urs Meier, Empa
- Rolf Brönnimann, Empa
- Philip Irniger, Dr. Deuring + Oehninger AG
- Andreas Winistoerfer, Carbo-Link AG

- Bafa

- **and YOU for your attention**