INFRASTAR

Innovation and Networking for Fatigue and Reliability Analysis of Structures – Training for Assessment of Risk

Structural and action models : The benefit of monitoring

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ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

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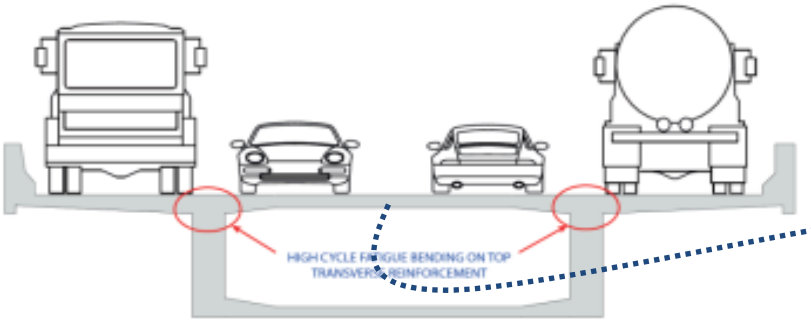
Motivation

- High loss of revenue and productivity due to **inefficient infrastructure**
  - *bridges and WT structures are the critical link*
- Resistance models are significantly advanced [illegible] there is still much uncertainty associated with the **loading** [illegible] safety problem
- While satisfactory for new [illegible] are often **overly conservative** for ex[illegible]
- Low cos[illegible] **sensor technology** allow action effects to be mon[illegible]sly
- New structural engineering techniques required for safety verification based on **monitored data**

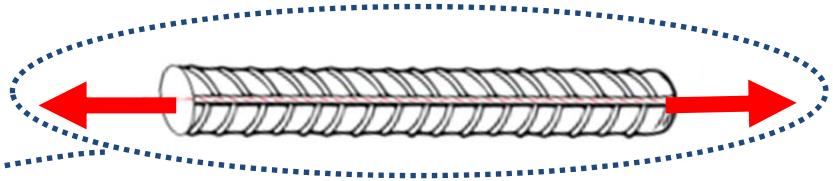
Our task is to show that there is no fatigue problem !

Why monitoring of traffic action effect on structural members ?

Traditional approach for action effect determination:



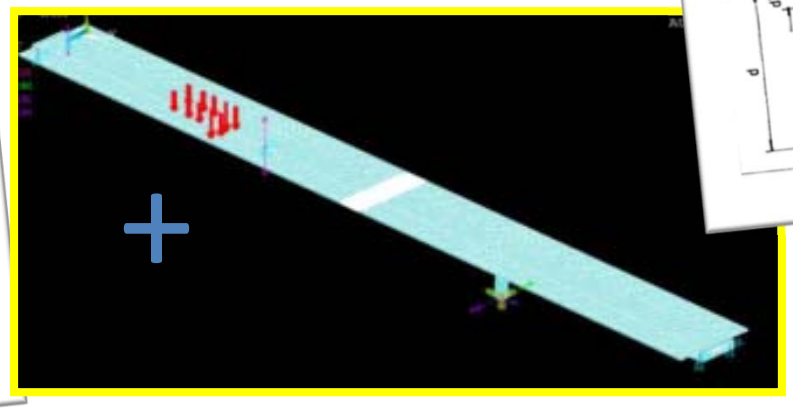
Δσ=?



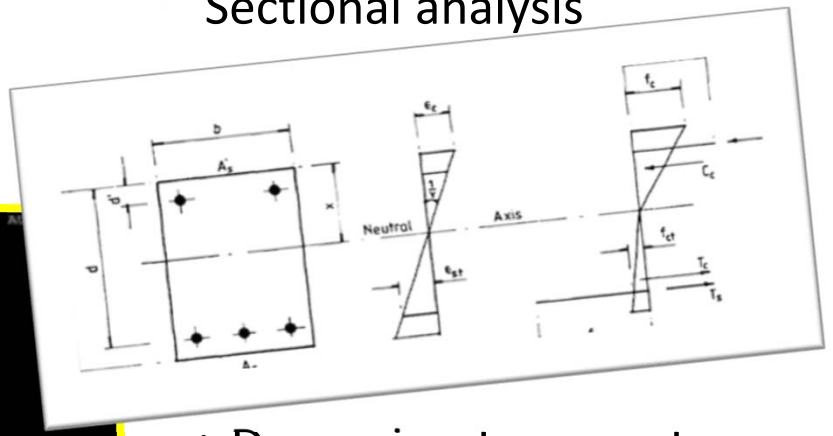
What is the strain experienced in the bar ?

\+

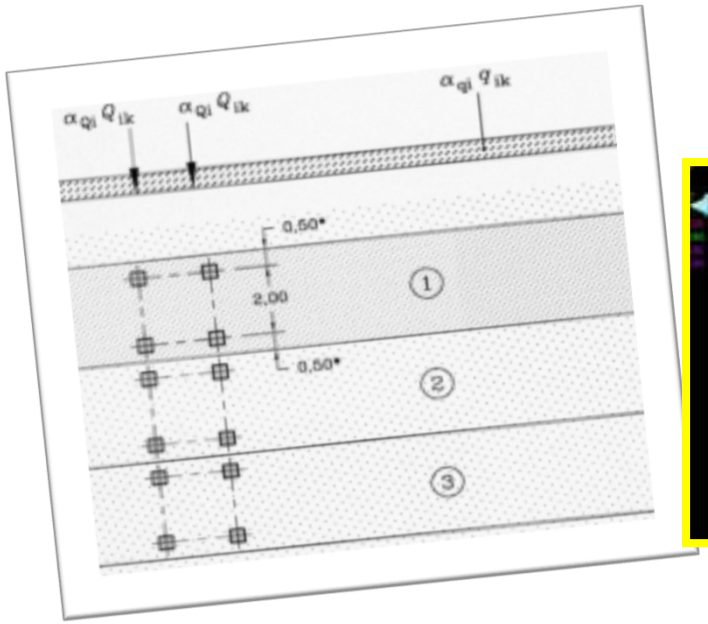
Structural analysis
(many assumptions)



Sectional analysis



\+ Dynamics, temperature effects, secondary elements +…..

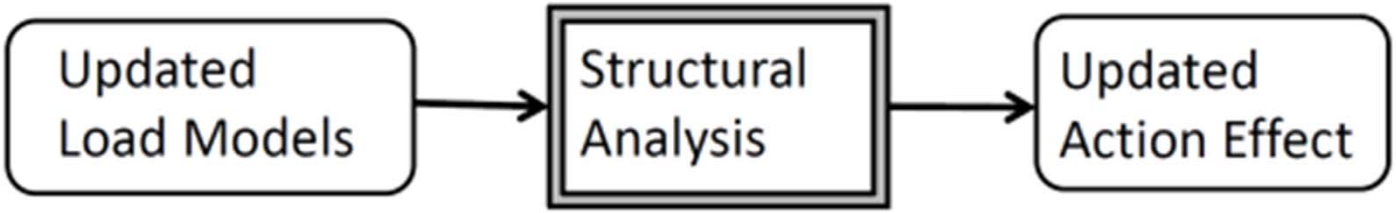


Updated load models

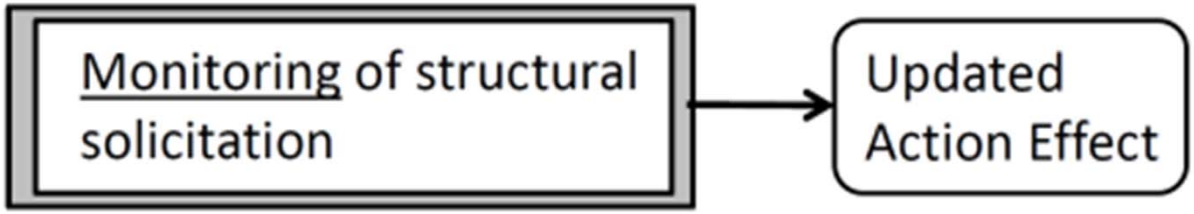
These effects are inherent in the monitoring result!

Determination of updated action effect following a stepwise procedure : *The role of structural models*

Level 1 :

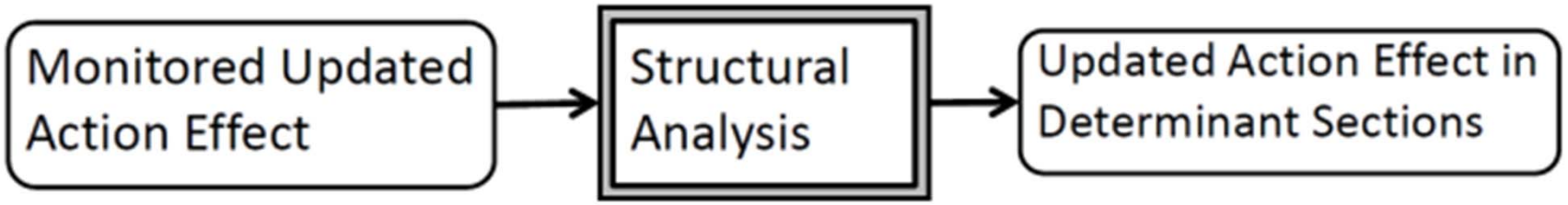


Level 2 :



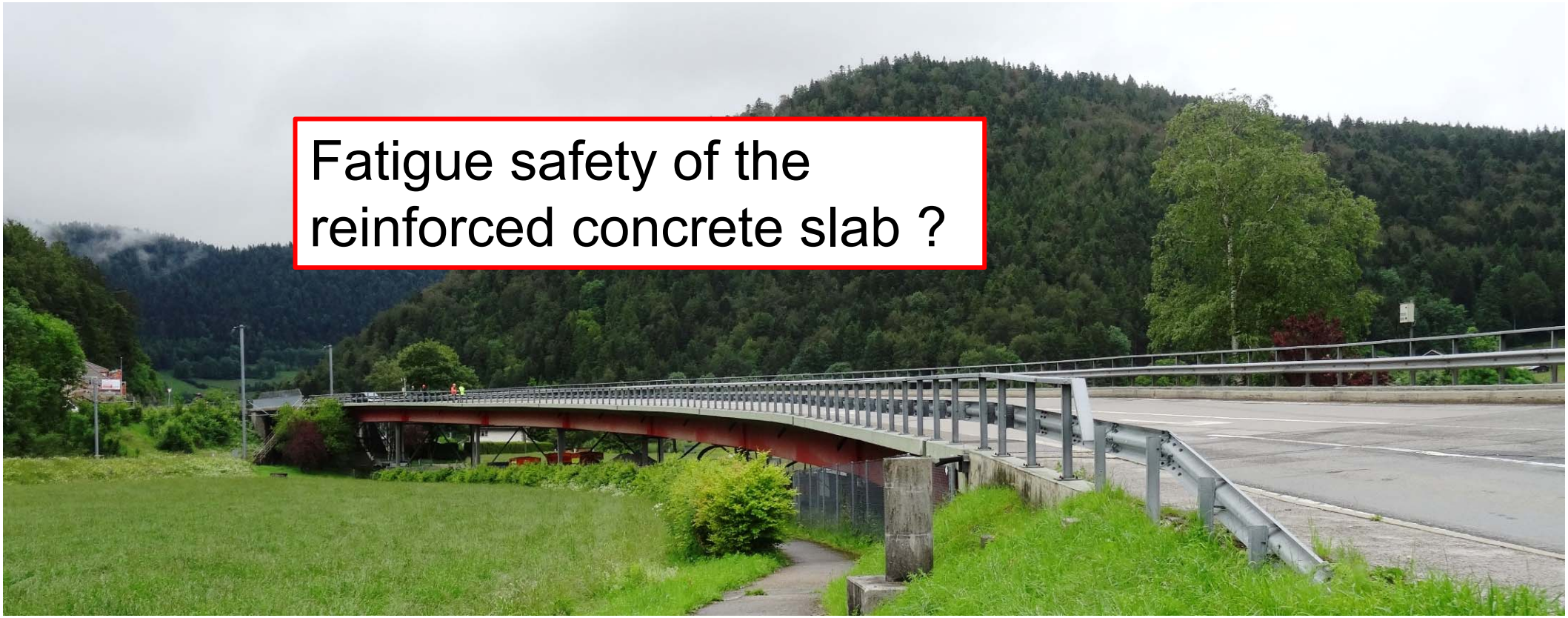
Monitoring reduces uncertainties.

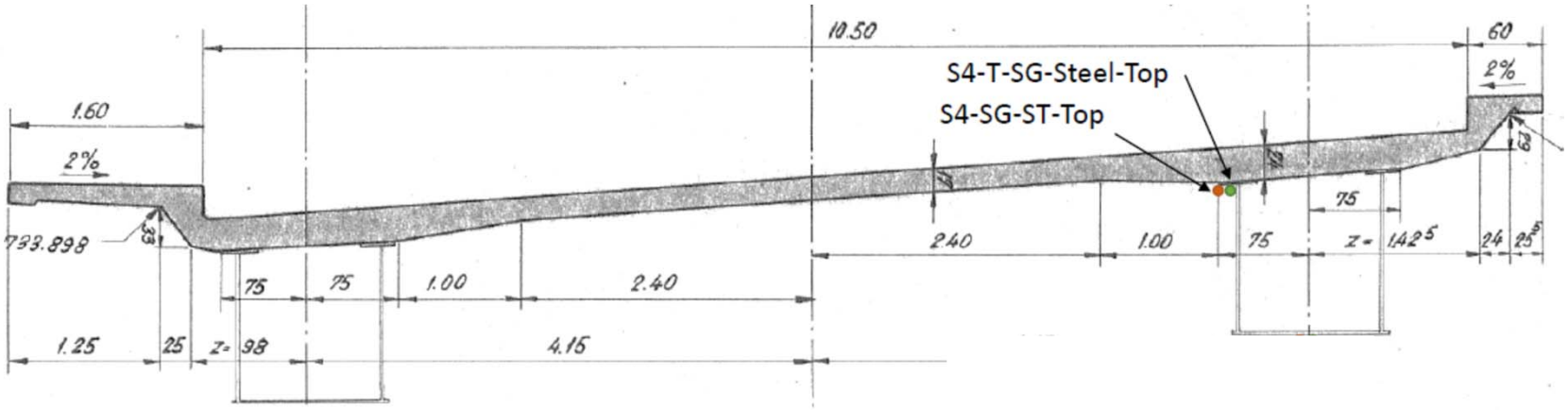
Effect of permanent actions can not be monitored.



«Crêt de l'Anneau» Viaduct, 1958

Composite steel – concrete structure



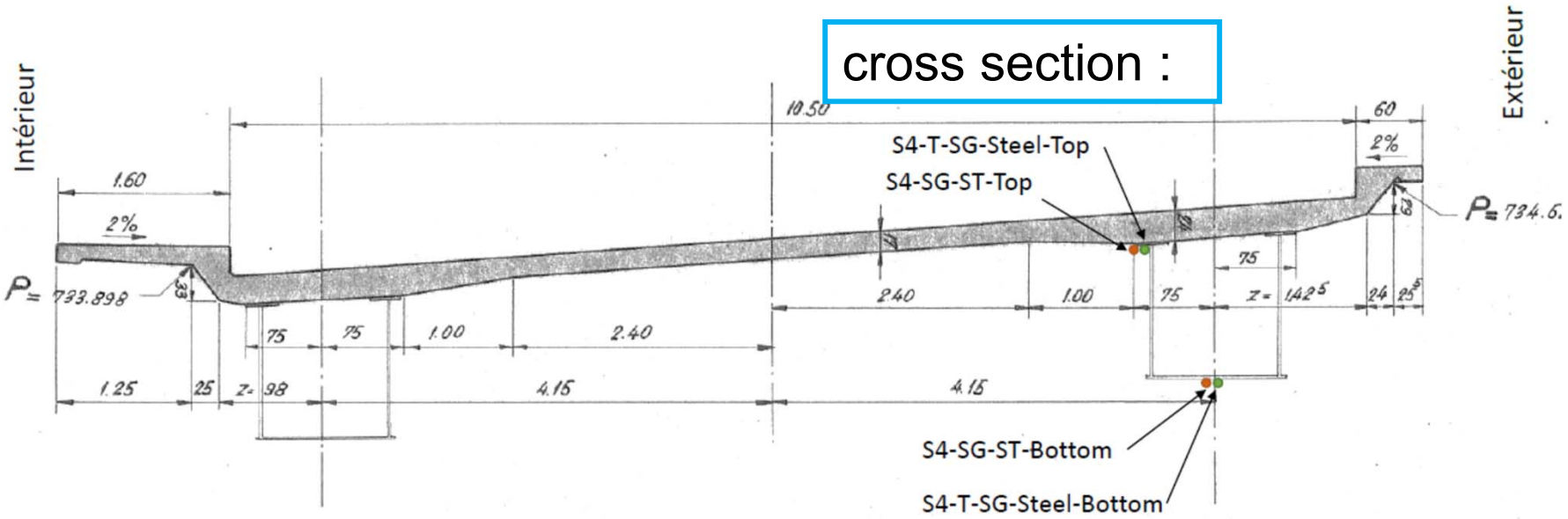


Monitoring: sensor deployment

Jauge en ¼ de pont – 4 fils

Thermocouple

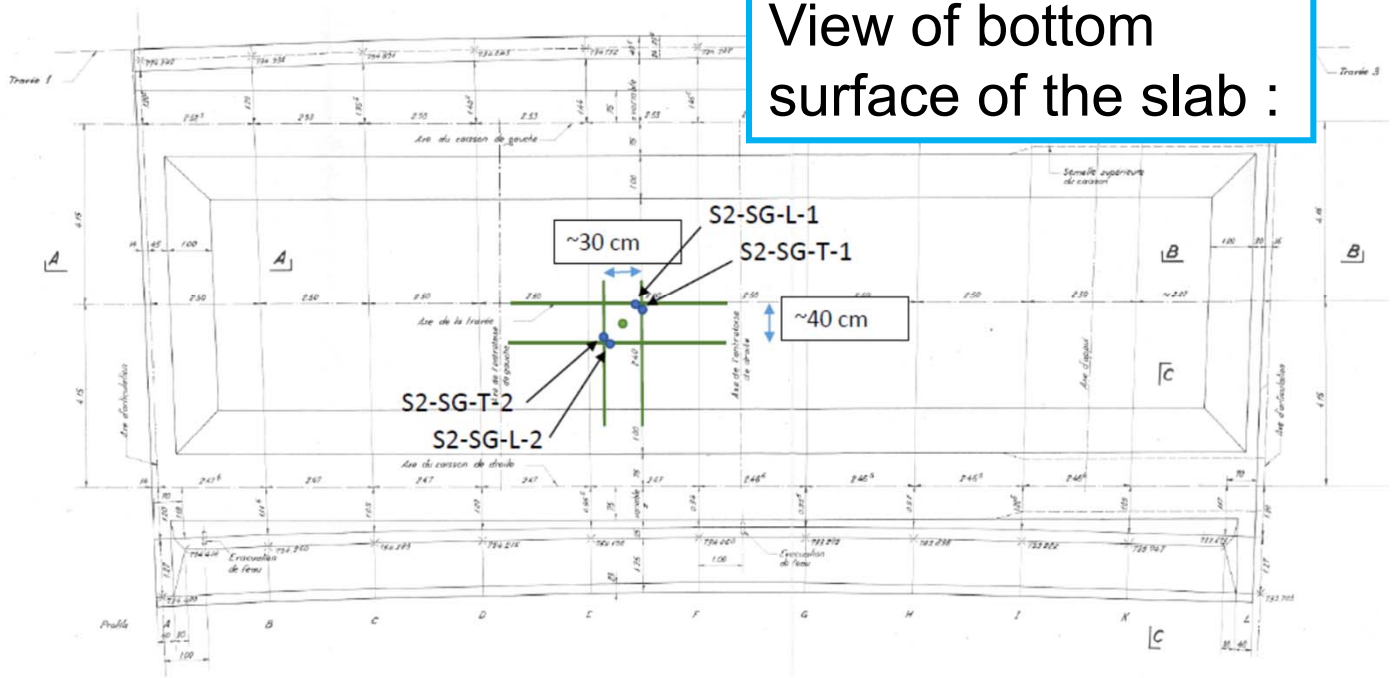
cross section :

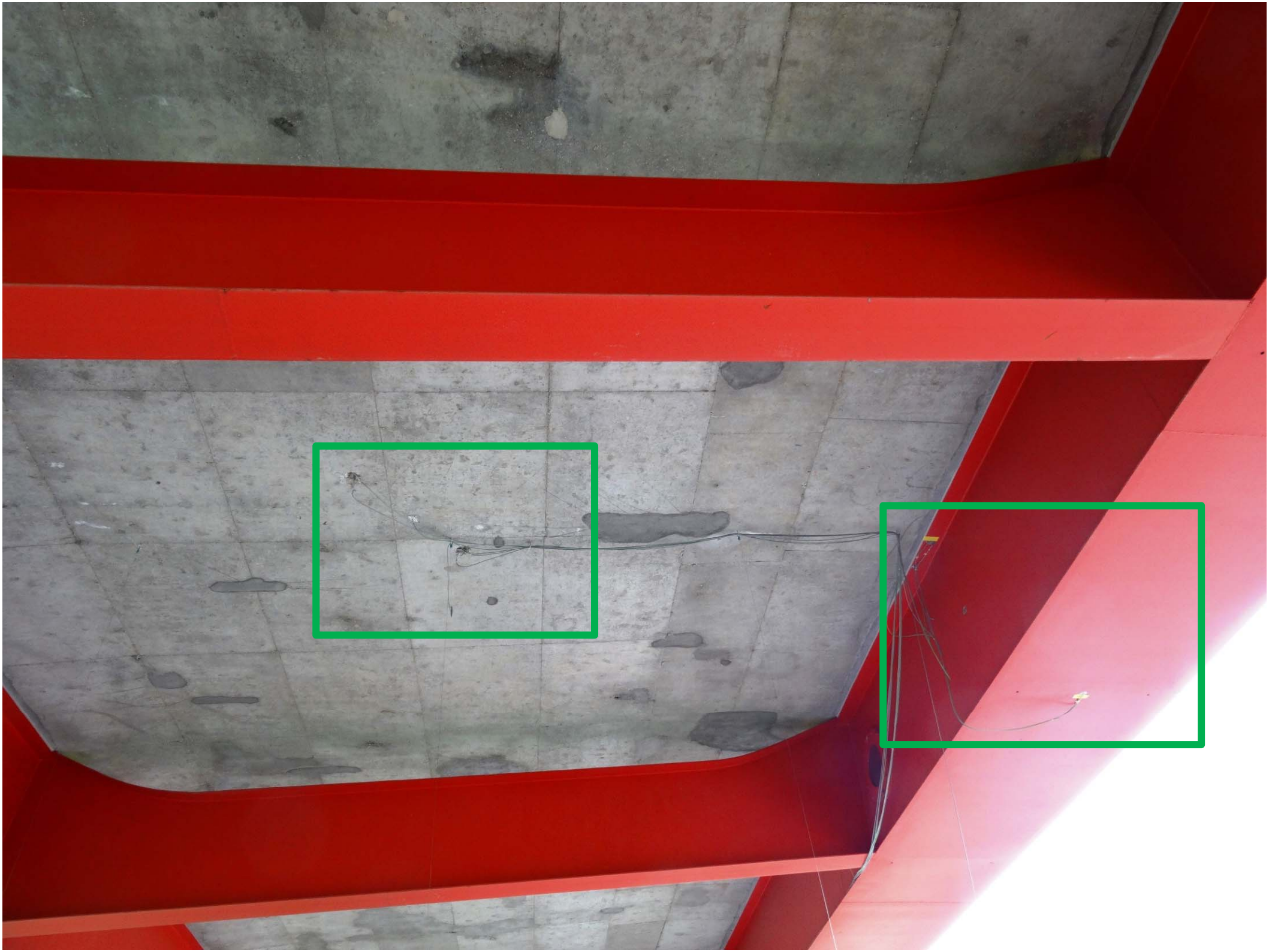


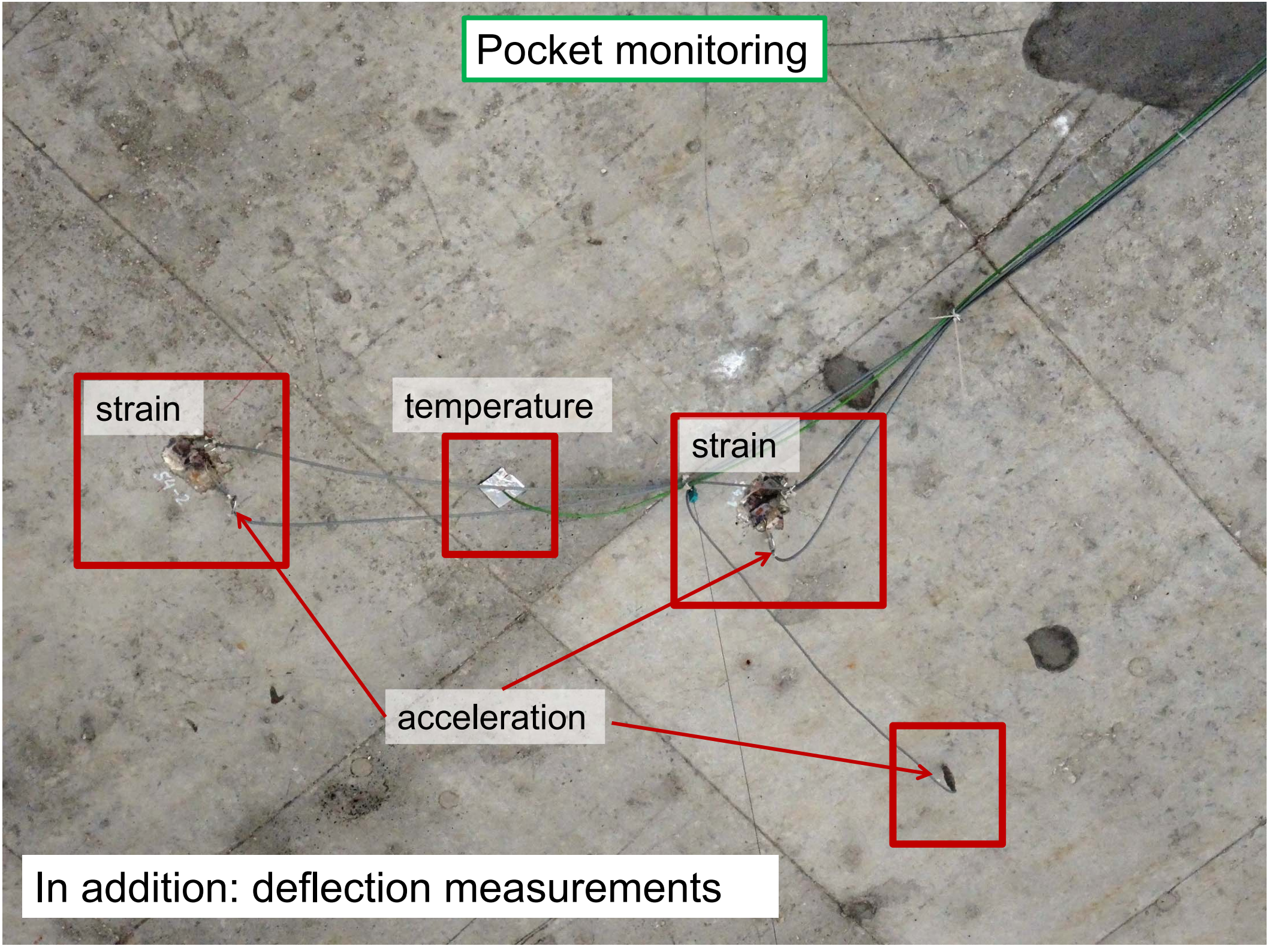
Jauge en ½ de pont – 5 fils

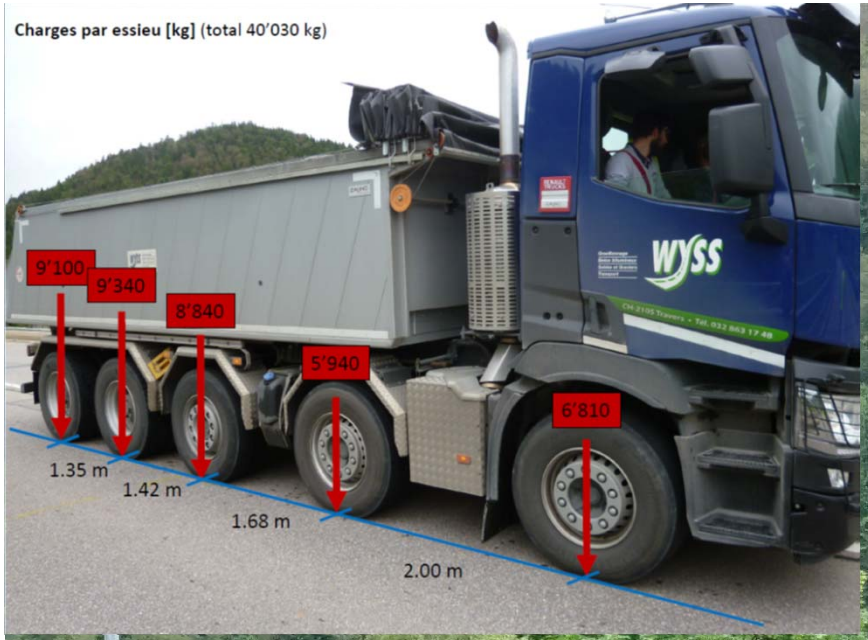
Thermocouple

View of bottom surface of the slab :



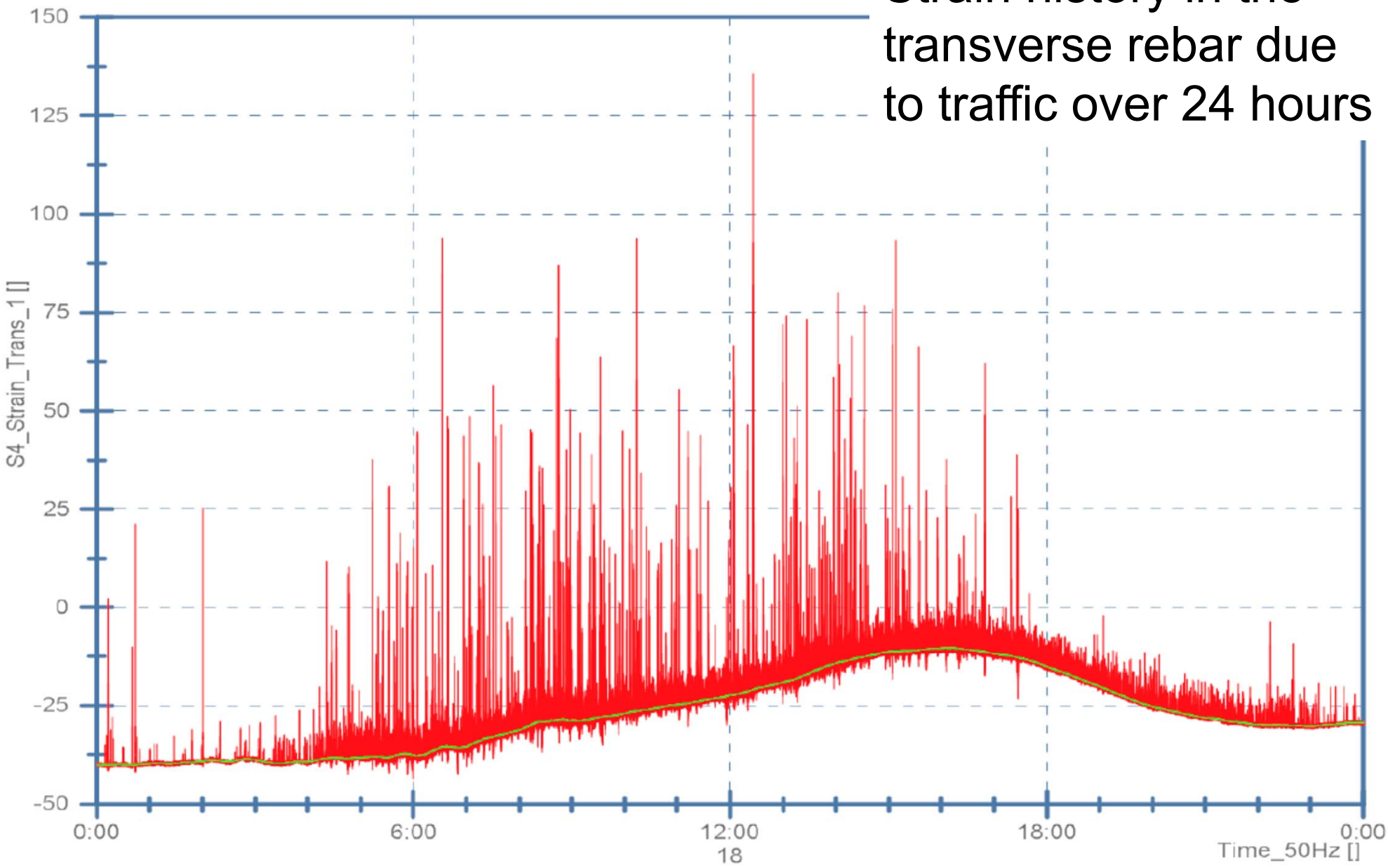



Pocket monitoring
strain
temperature
strain
acceleration
In addition: deflection measurements

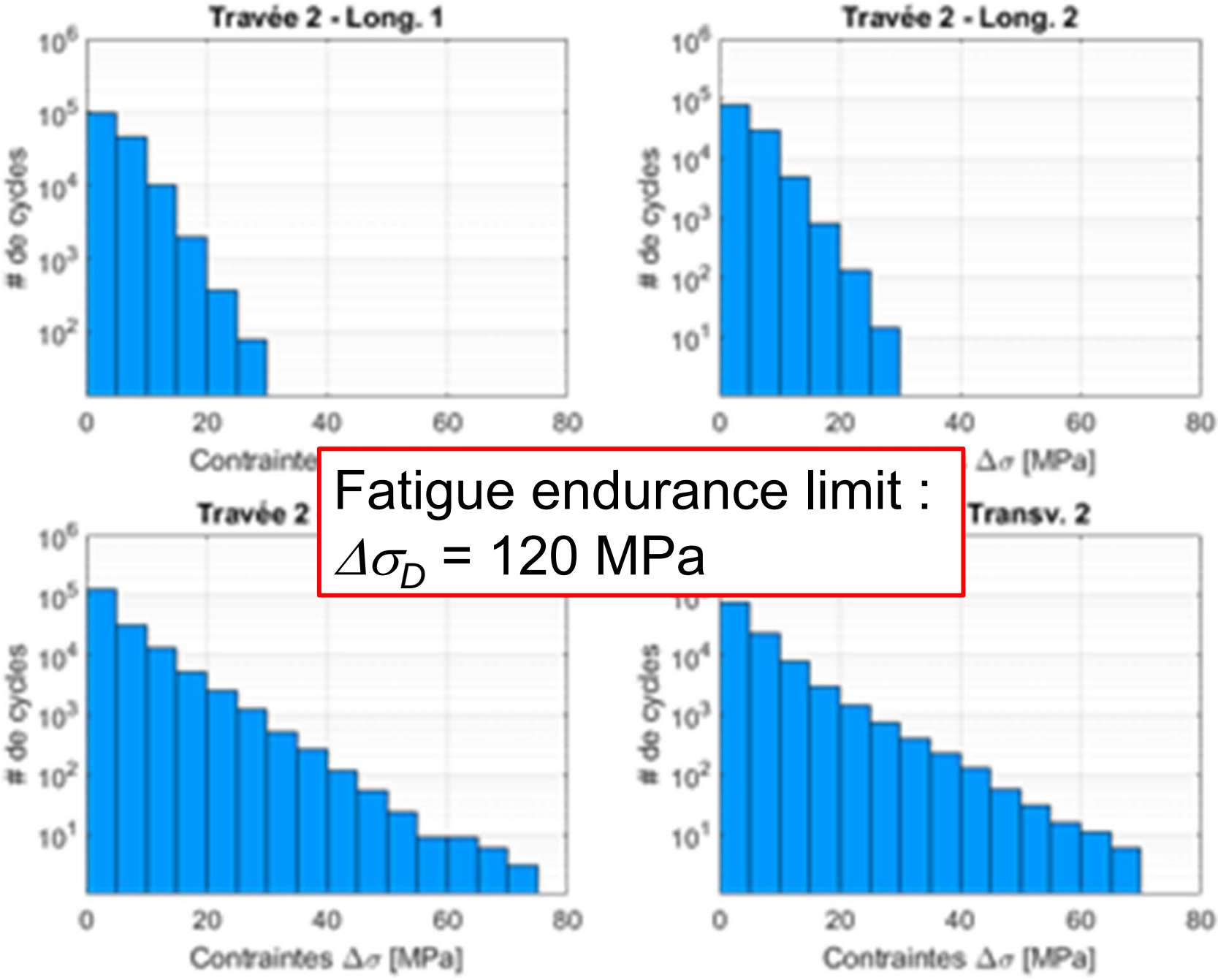


Testing with a truck of known weight

Strain history in the transverse rebar due to traffic over 24 hours



Annual histograms of tensile stress amplitudes for the four in-strumented rebars at one slab zone

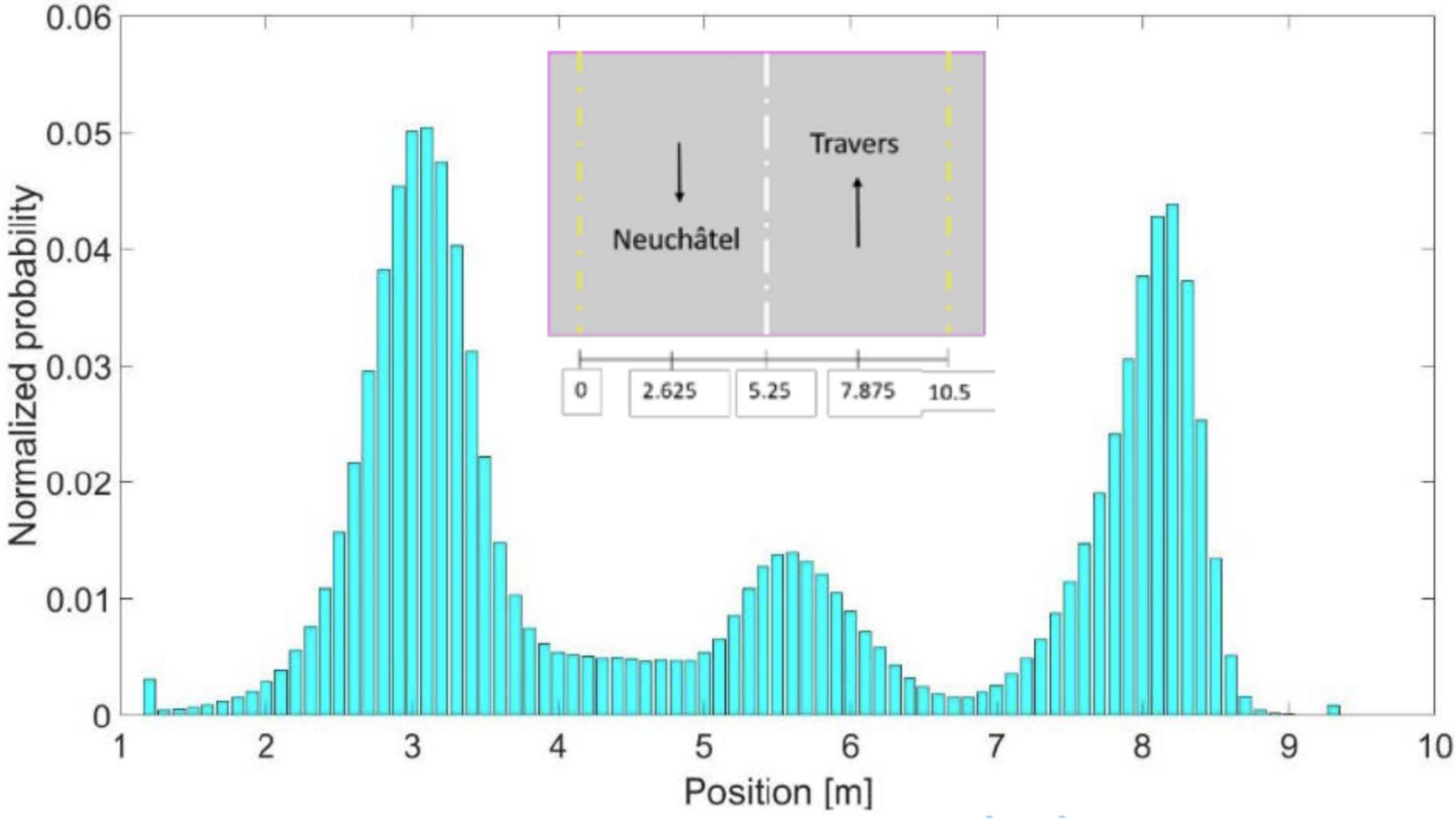


Quantification of road traffic and temperature effects on fatigue of a RC bridge deck based on data from monitoring

Authors: Imane Bayane [(1)], Amol Mankar [(2)], Eugen Brühwiler [(1)], John Dalsgaard Sørensen [(2)]

1. EPFL ENAC IIC MCS, Ecole Polytechnique Fédérale de Lausanne
2. Aalborg University, Thomas Manns Vej, 23, 9220 Aalborg.

normalized annual distribution of vehicle positions



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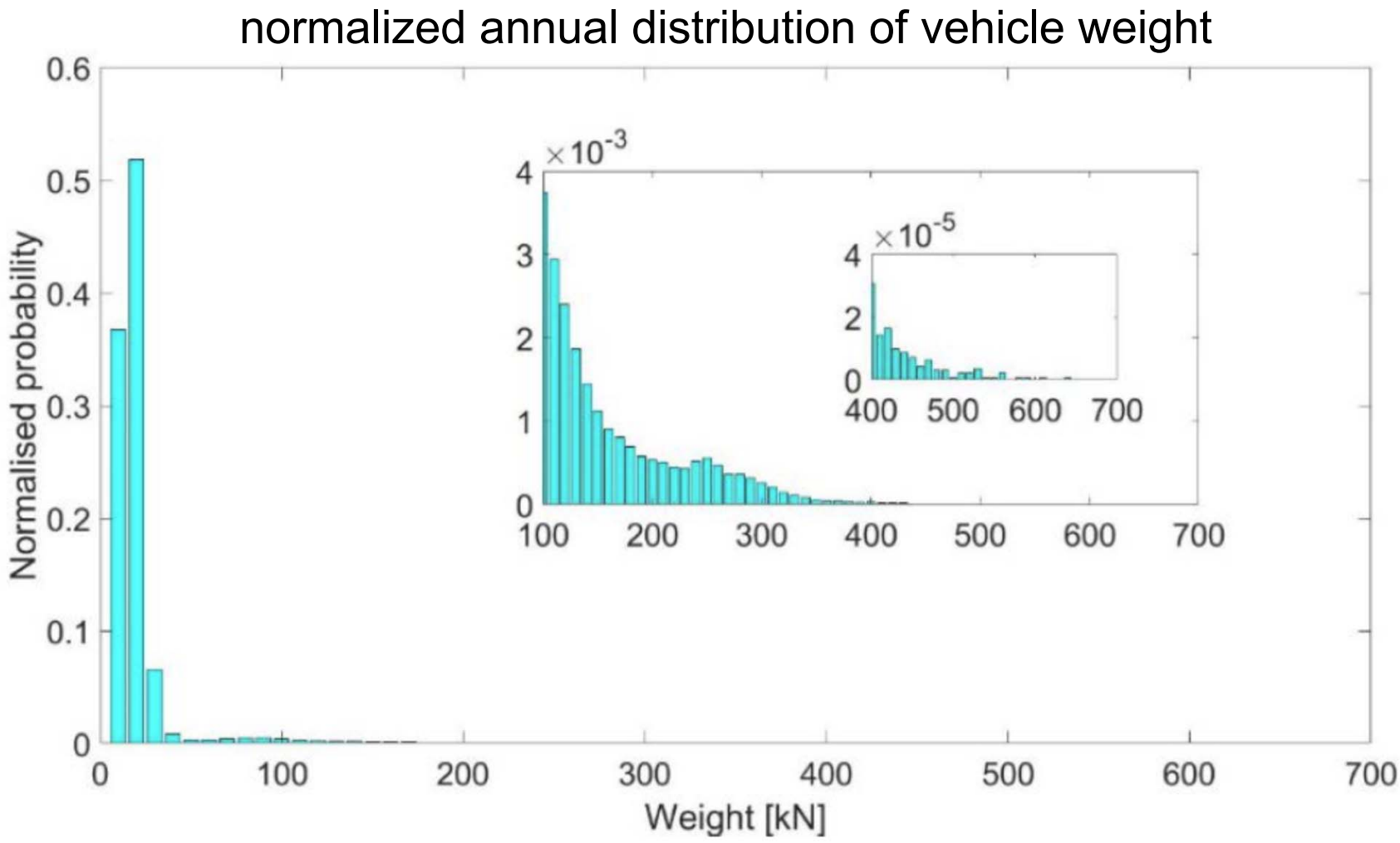

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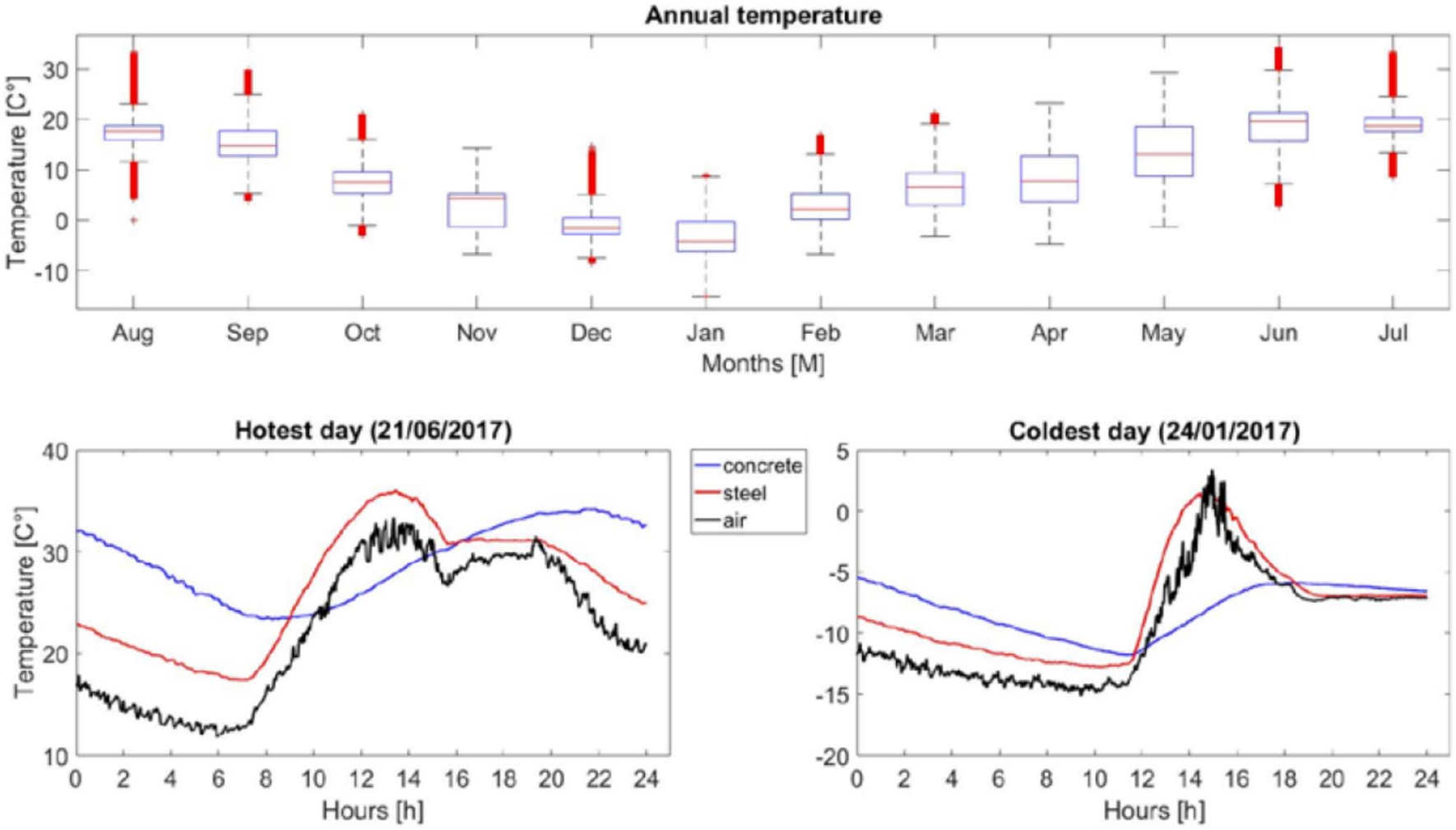
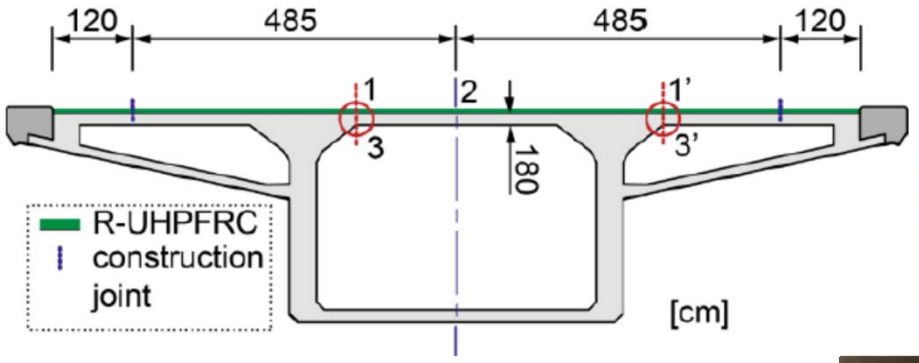


Chillon Viaduct: Monitoring of the deck slab strengthened using R-UHPFRC



Measurement of :

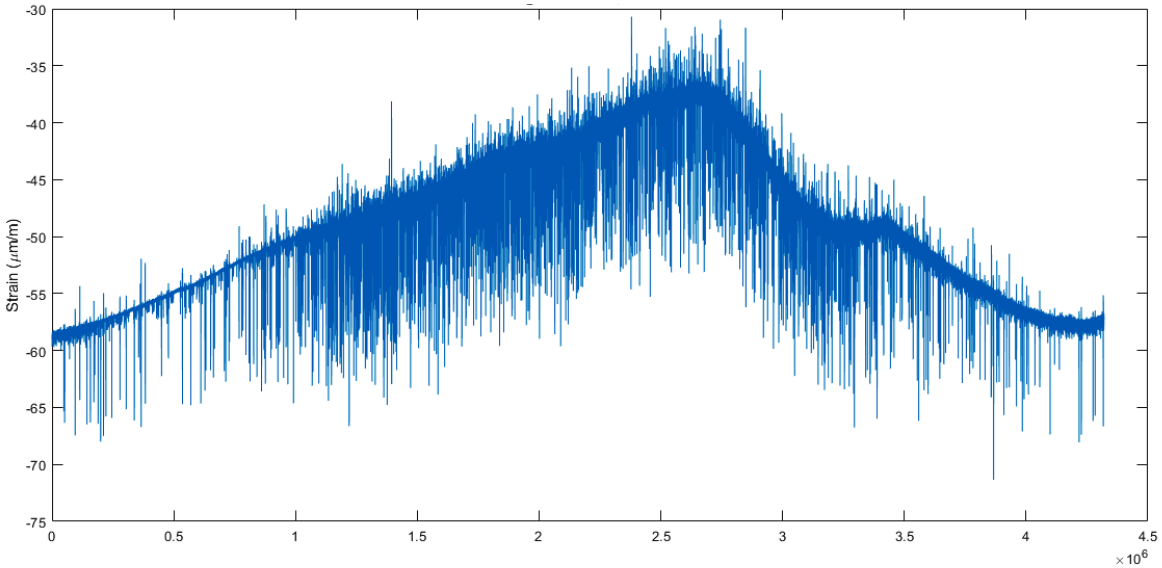
- rebar strain
- temperature
- accelerations (ETH Zurich) for system identification

Interview with Swiss Radio about Monitoring of Civil Structures, 25 Sept. 2018

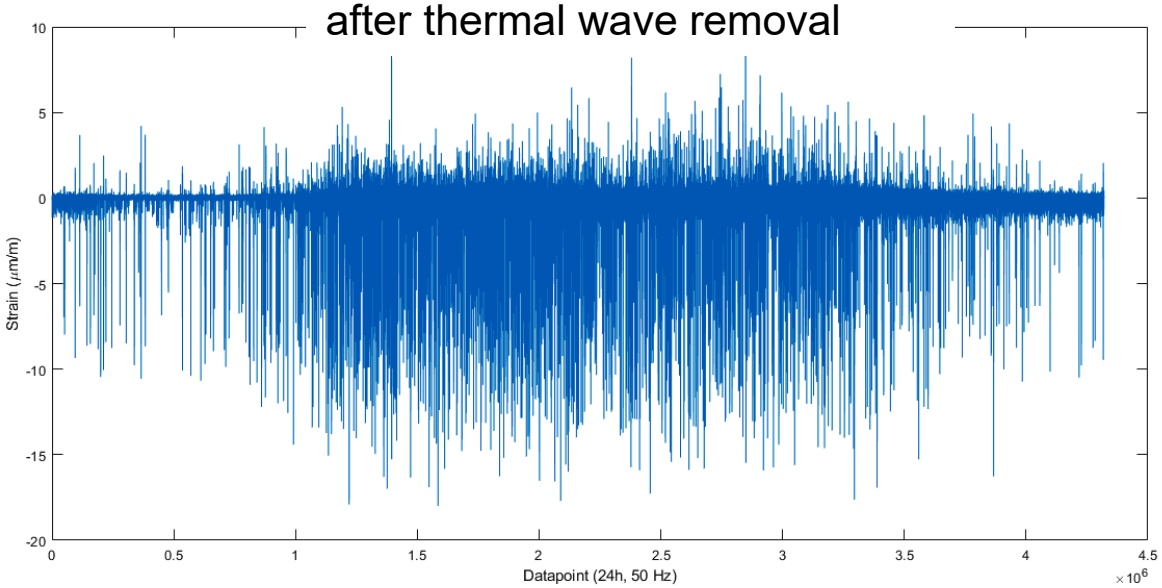
Chillon Viaduct: Monitoring of the deck slab strengthened using R-UHPFRC

Analysis of measurements by Bartek Sawicki and Morteza Ahmadivala : joint paper

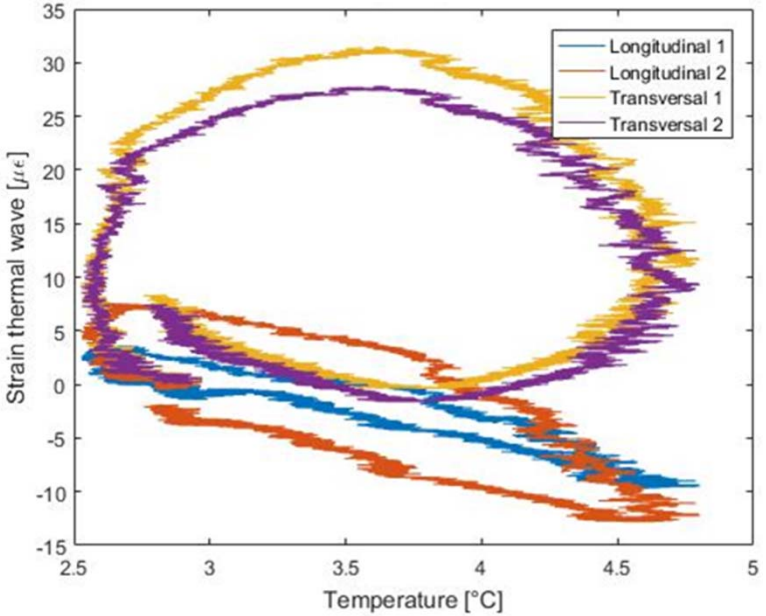
31 Aug 2016: longitudinal rebar



31 Aug 2016: longitudinal rebar after thermal wave removal

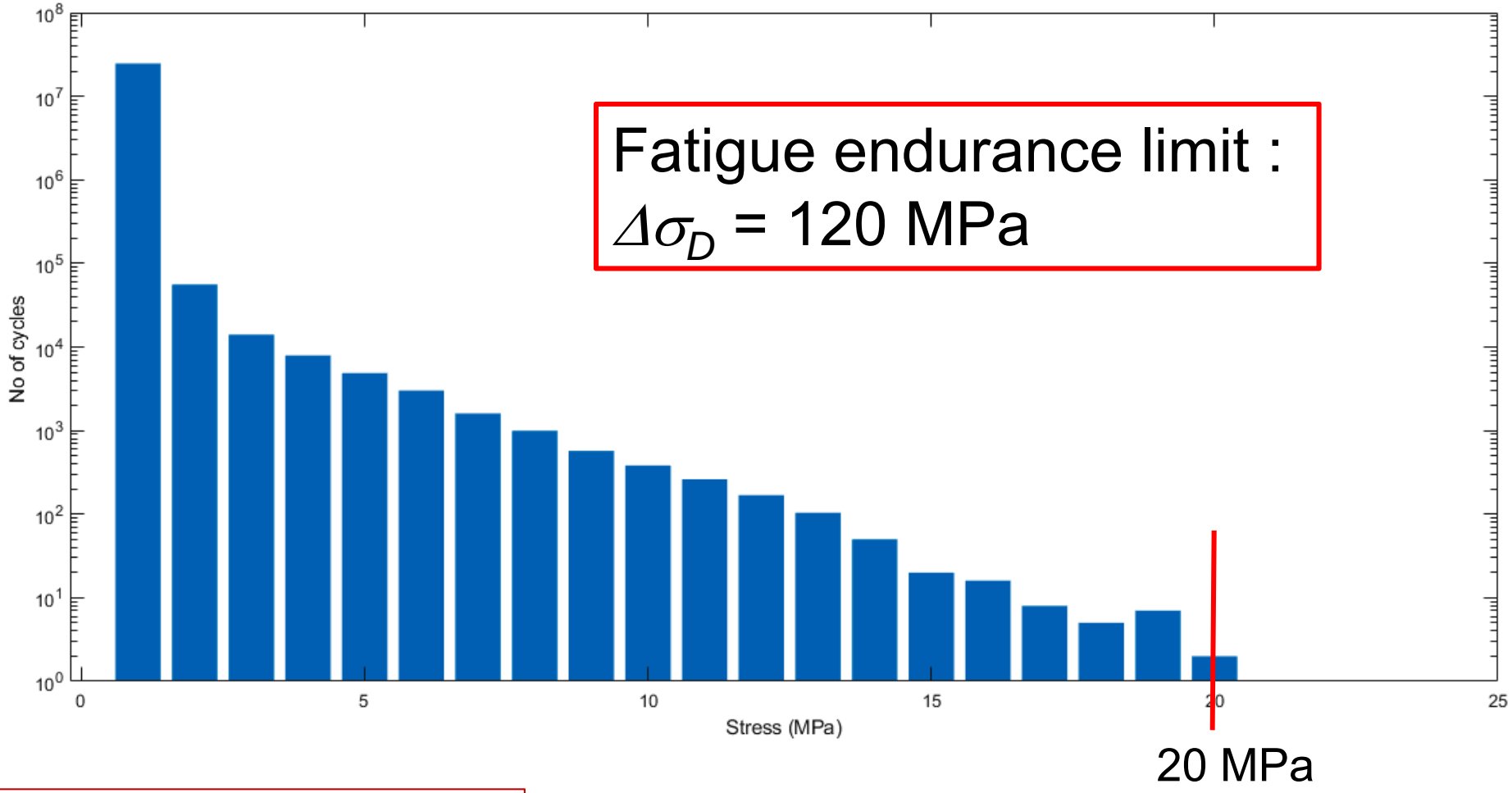


15 Nov 2017: «thermal wave»



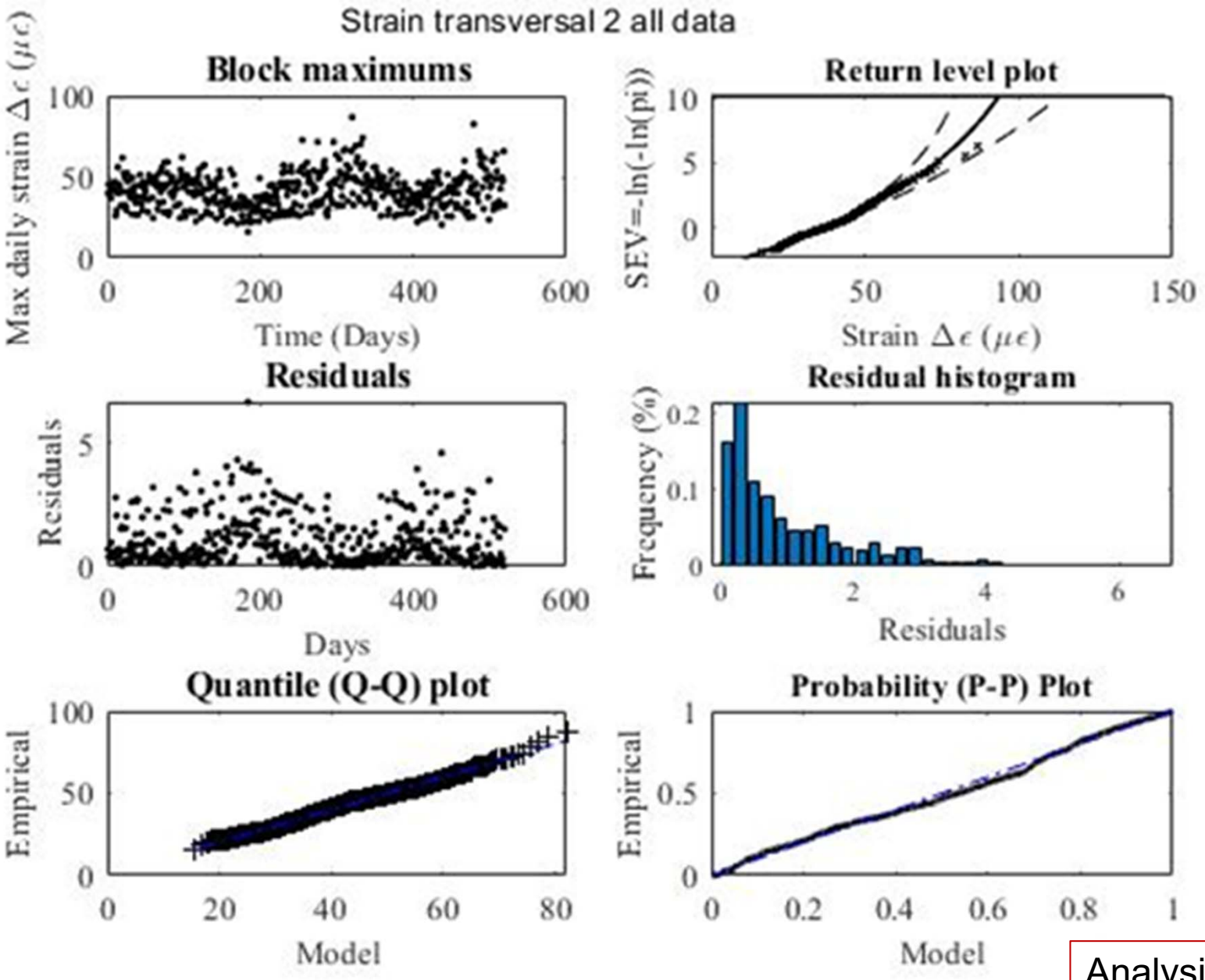
Chillon Viaduct: Monitoring of the deck slab strengthened using R-UHPFRC

Histogram of tensile stress amplitudes in the transverse rebar (August 2016, 31 days)



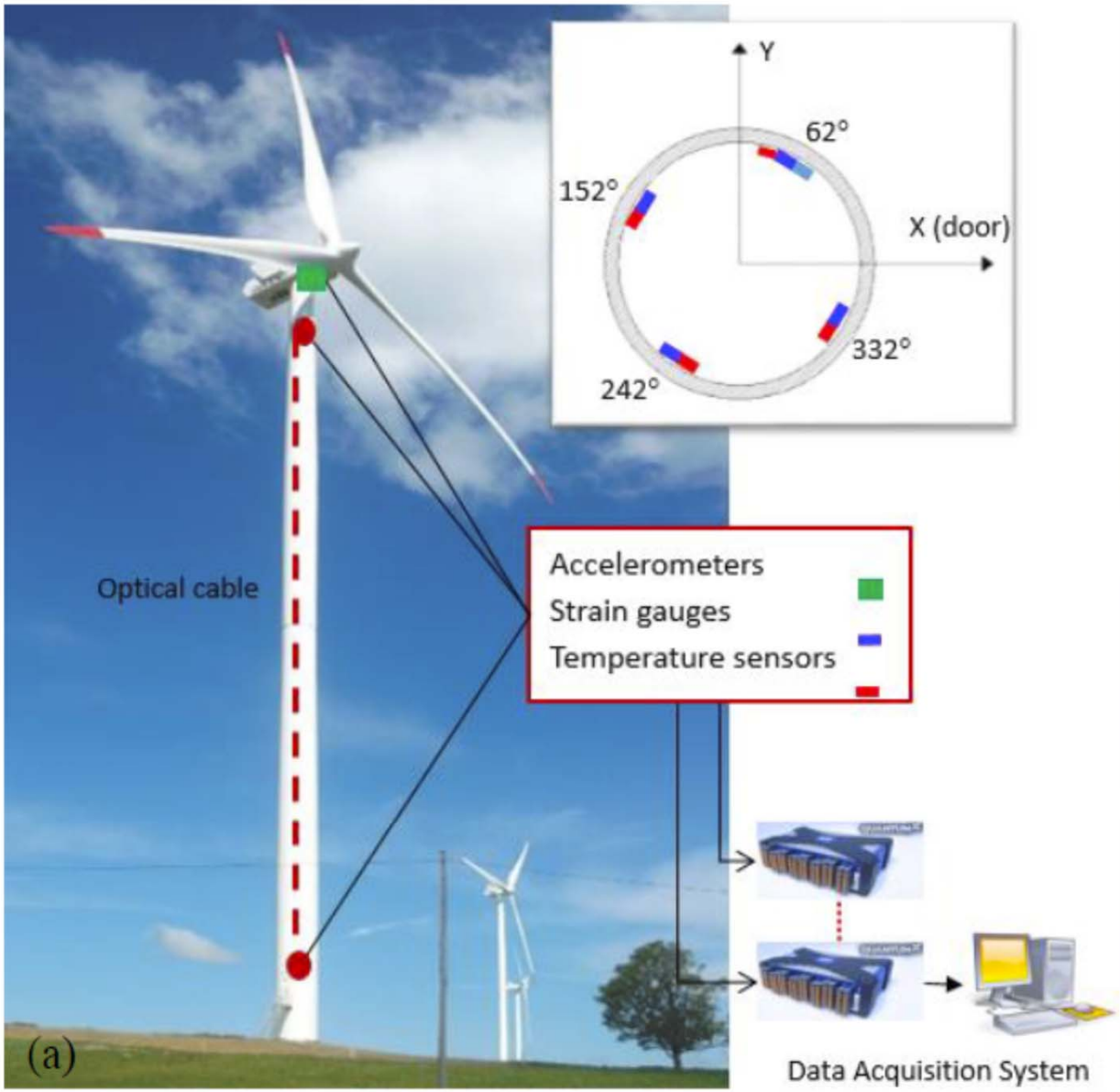
Analysis of measurements by Bartek Sawicki and Morteza Ahmadivala : joint paper

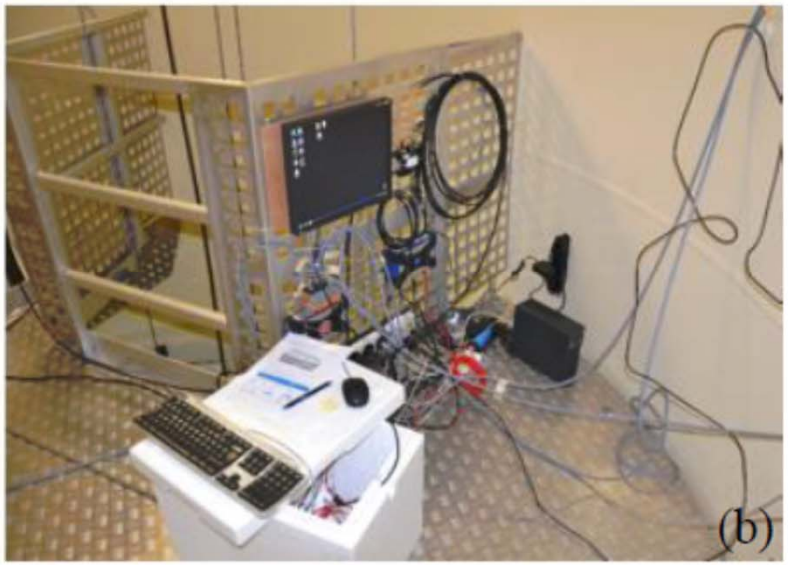
Chillon Viaduct: Monitoring of the deck slab strengthened using R-UHPFRC



Analysis of measurements by Bartek Sawicki and Morteza Ahmadivala : joint paper

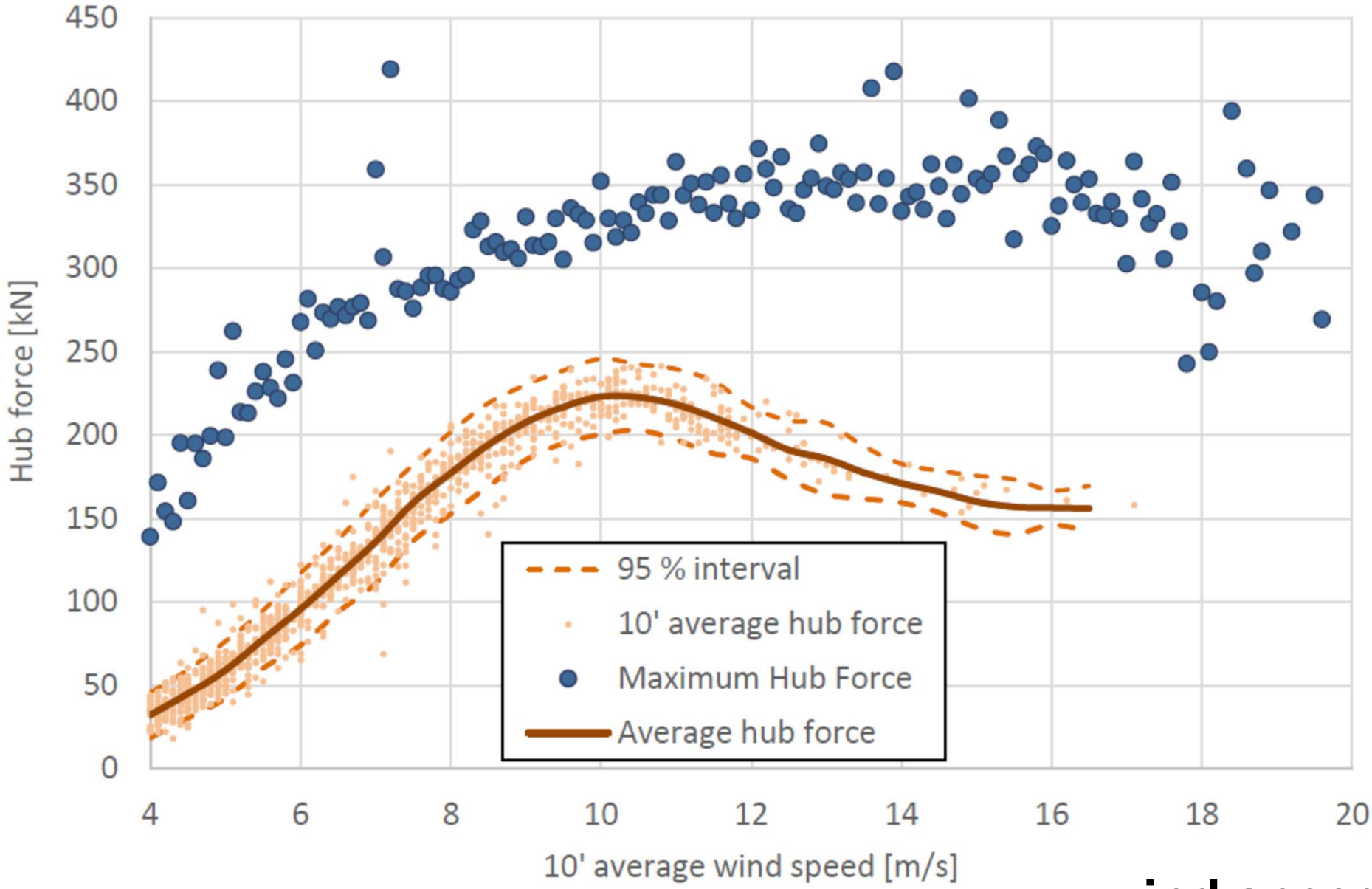
Fatigue action effect on wind turbine tower : *Data from monitoring*





[Loraux, Brühwiler, 2016]

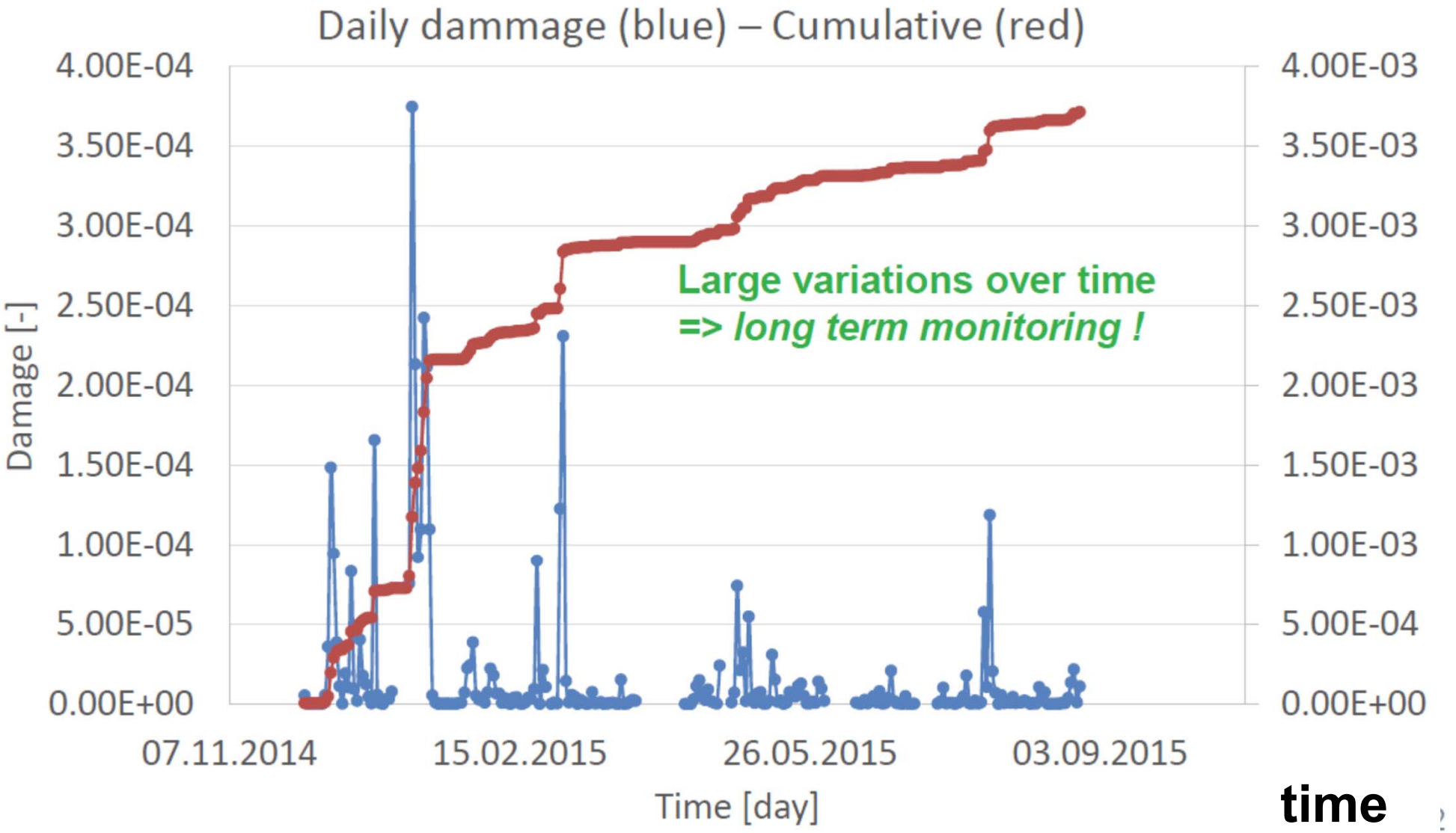
hub force



wind speed

[Loraux, Brühwiler, 2016]

Fatigue damage : welded joint in the transverse direction



➔ *fatigue duration of the welded joint is more than an order of magnitude longer than the 20 years indicated by the fabricator*

[Loraux, Brühwiler, 2016]

Case Study

Generalized Pareto Distribution for reliability of bridges exposed to fatigue

M. Nesterova
Université Paris-Est, SDOA, MAST, IFSTTAR, Marne-la-Vallée, France
F. Schmidt
Université Paris-Est, SDOA, MAST, IFSTTAR, Marne-la-Vallée, France
E. Brühwiler
MCS, EPFL, Lausanne, Switzerland
C. Soize
Université Paris-Est, MSME UMR 8208, Marne-la-Vallée, France

Millau viaduct, France

orthotropic deck

WIM data

Cret de l'Anneau, Switzerland

RC slab + steel gurders

strains monitoring

Fatigue safety verification of the BLS Railway Bridge over the Kander River near Wimmis, 1897

Fatigue safety verification of a steel railway bridge using short term monitoring data

B. Sawicki & E. Brühwiler
Laboratory of Maintenance and Safety of Structures (MCS), École Polytechnique Fédérale de Lausanne (EPFL), 1015, Lausanne, Switzerland

M. Nesterova
Laboratoire Sécurité et Durabilité des Ouvrages d'Art (SDOA), The French institute of science and technology for transport, spatial planning, development and networks (Ifsttar), 77420, Champs-sur-Marne, France

Photo: 15 April 2017

Monitoring of a railway bridge in Zurich

Conclusions

Novel methodology for (fatigue) safety verification is presented :

- ✓ explicit consideration of data from long term monitoring for accurate determination of (fatigue) relevant stresses in structural elements
- ✓ **There is "basically" no fatigue damage** … in the monitored structural elements.
- ✓ Extreme action events are predicted using monitored data and Extreme Value Theories.
- ✓ Approach is economic.
- ✓ Traditional "Re-calculation" using "assessment" codes should be abandoned.

Thank you !