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National Physical Laboratory

Damage detection using environmental response of the structure

Advanced structural monitoring seminar:
25 May 2010

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Project aims

- Full-scale demonstrator - to show benefits of SHM
- Reference specimen - to assess the performance of monitoring techniques throughout the year
- Accelerated testing - to provide information suitable for lifetime prediction
- Damage detection

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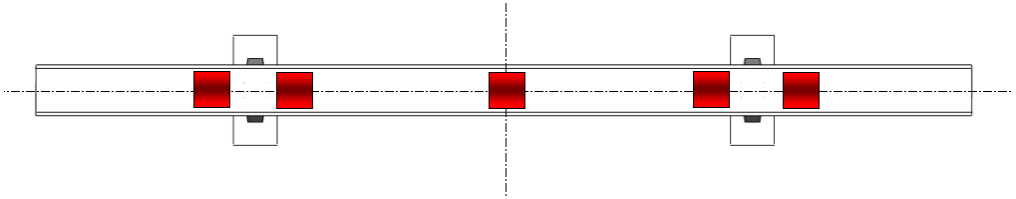
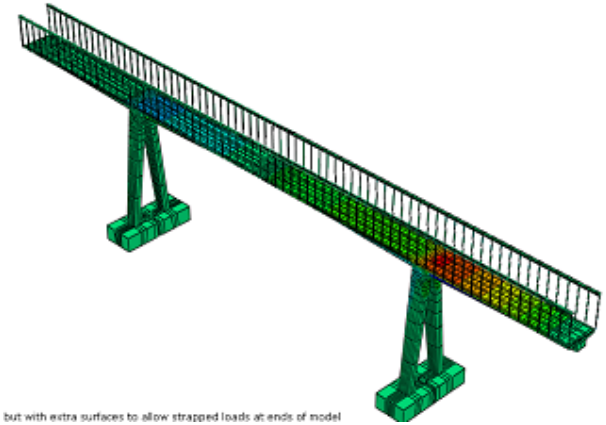
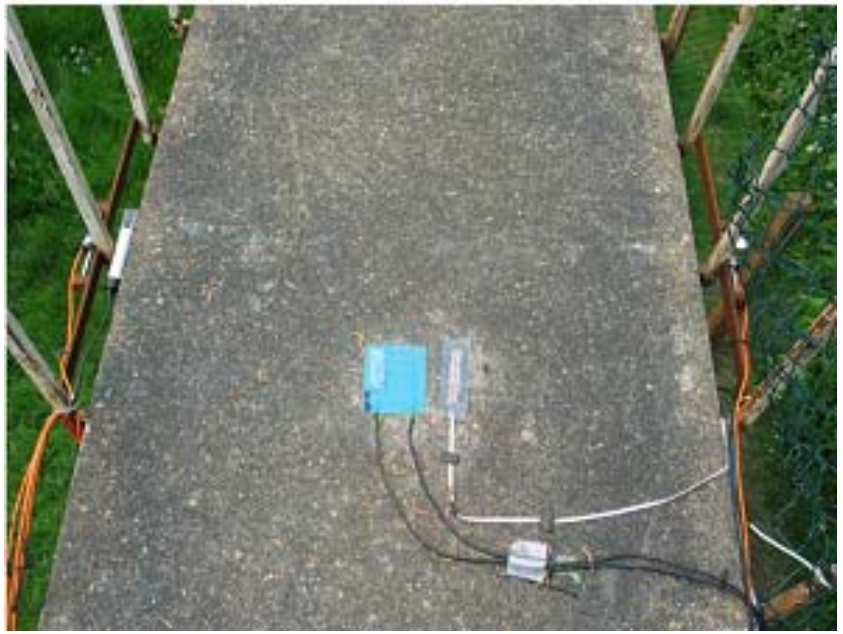
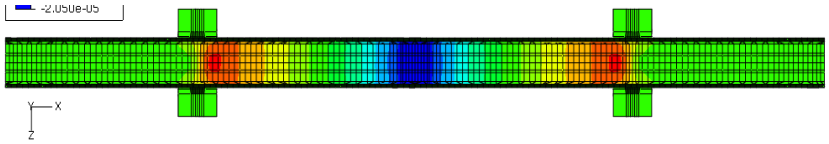
Example of sensing areas: deck



Sensing Areas







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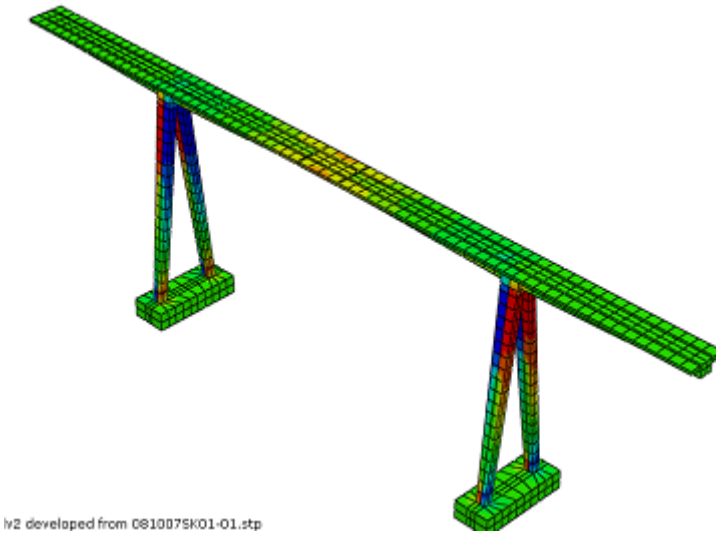
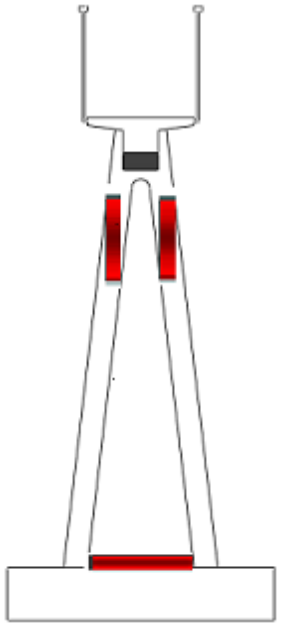
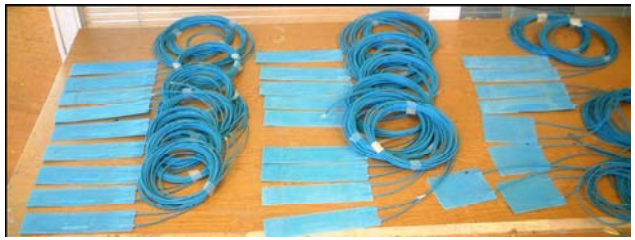
Example of sensing areas: columns





Monitoring technologies

- Traditional:
  - Resistance strain gauges
  - Electrolevel tilt sensors
  - Vibrating wire sensors
  - Digital levelling



- Optical fiber Bragg gratings
- Distributed crack sensor
- Acoustic emission sensors

- Image based:
  - Digital Image Correlation
  - 3D laser scan
  - Video gauge technique

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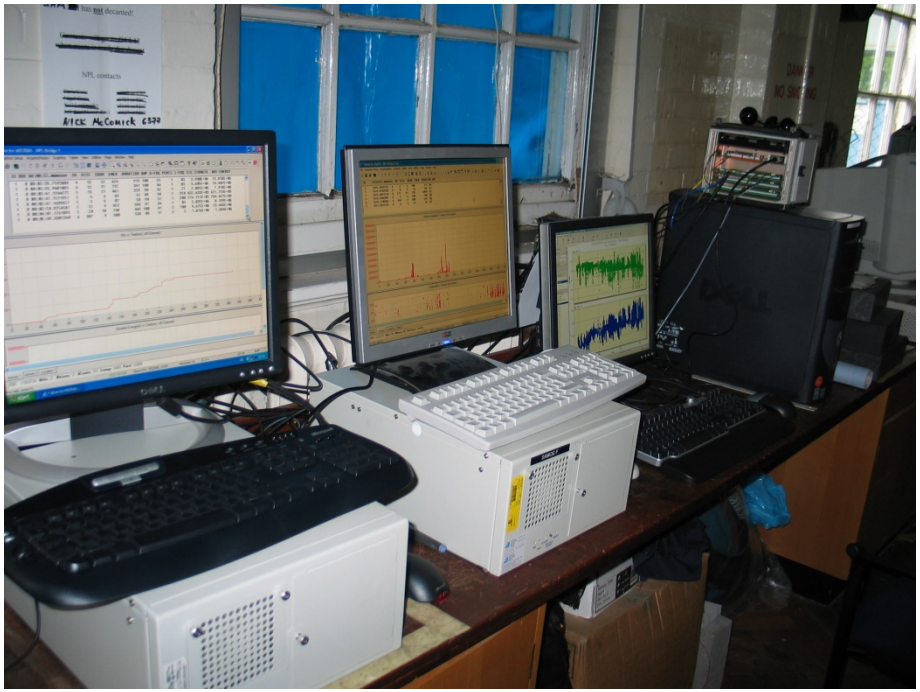
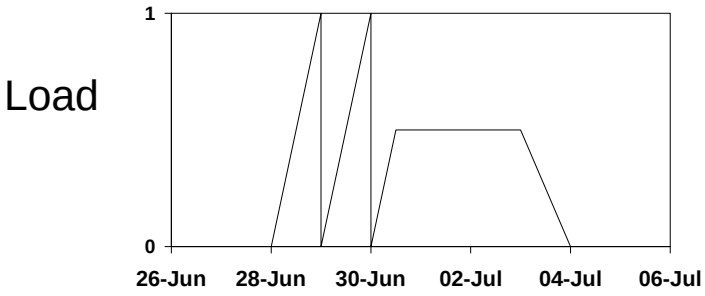
Installation summary

- 15 different technologies
- Wired and wireless sensors
  - over 100 structural sensors
  - 50 environmental sensors
- 5 monitoring acquisition systems

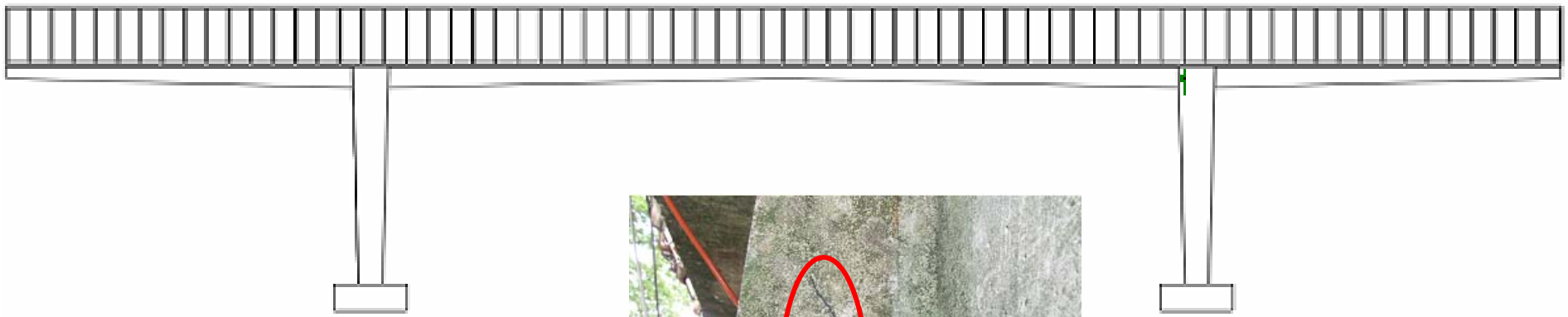


Cantilever load test

- Water tanks suspended from cantilever and filled with water
- Three sets of tests: March, June/July and August
- Schematic of loading



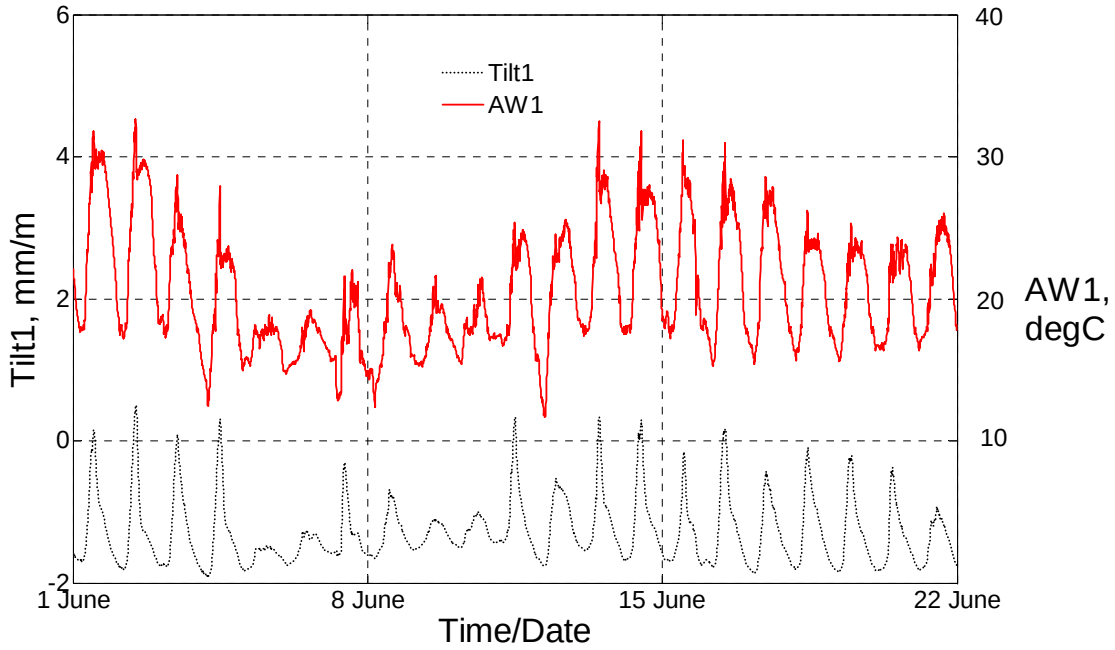
Damage accumulation: D1



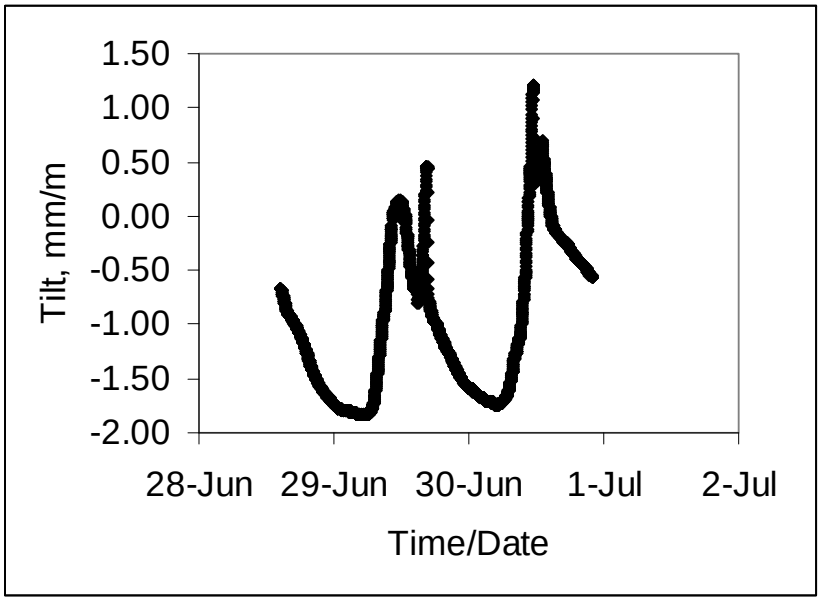
Damage accumulation: D2

Environmental response:

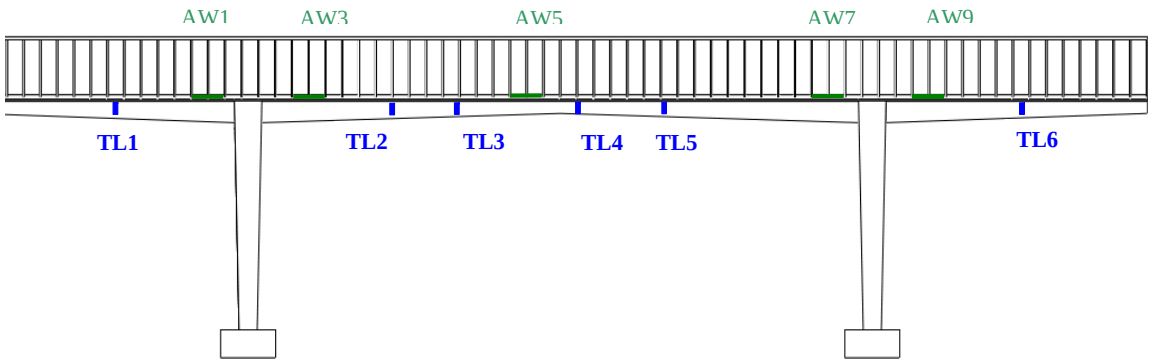
examples of the data between the tests

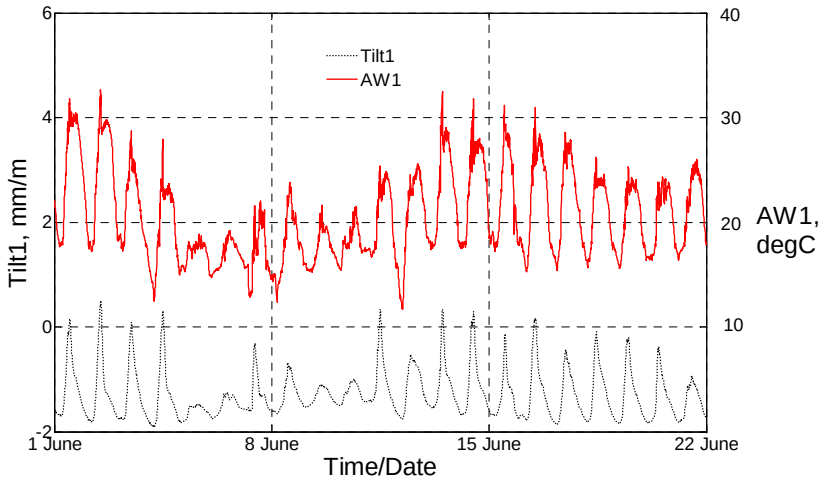


examples of the data two days of tests



Damage detection analysis based on environmental bridge response





- Change in response – change in the structure
- Introduction of FOM – moments calculated over 24h
- Statistical analysis - moving regression analysis, analysis of covariance etc

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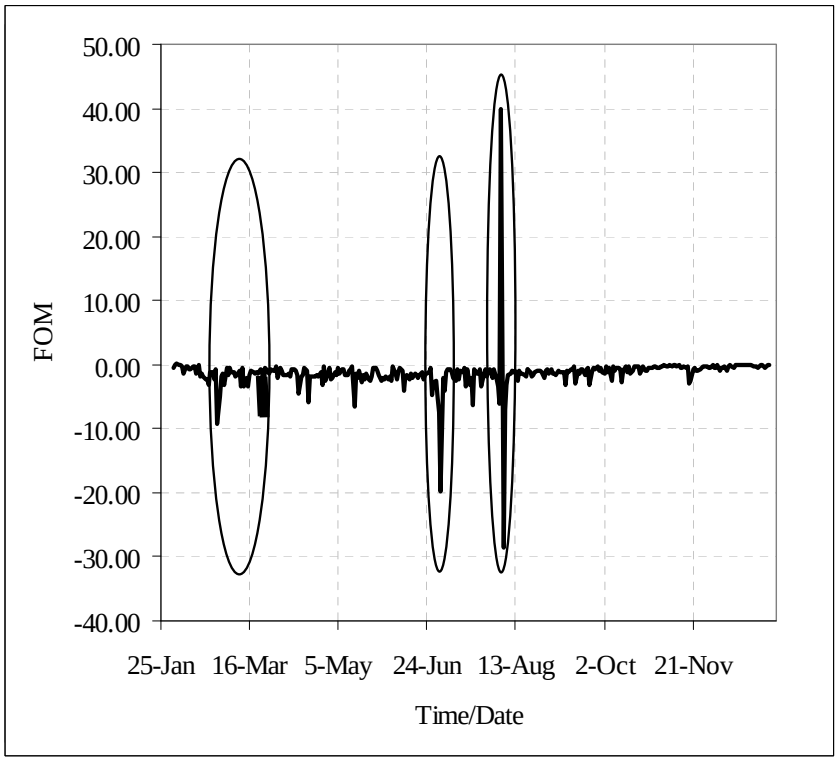
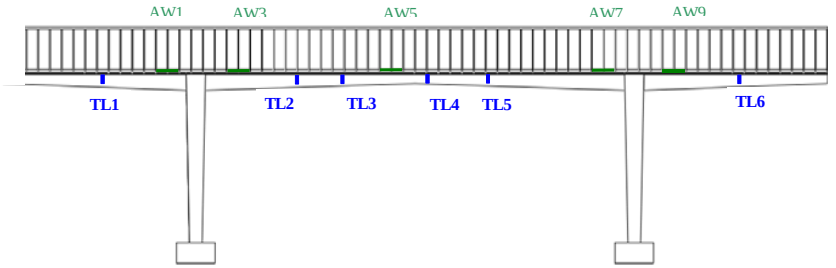
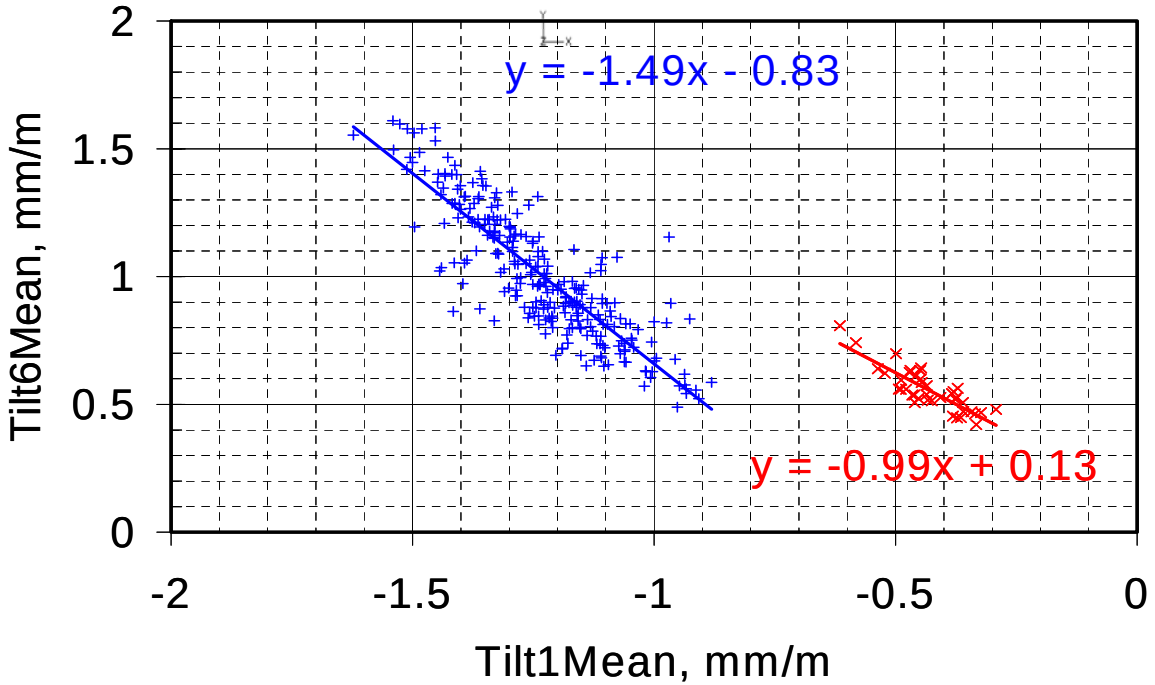
Example of damage detection analysis based on experimental data over 2009: event identification

- FOM = coefficient of variation
- Stdev/Mean
- Identify overloading

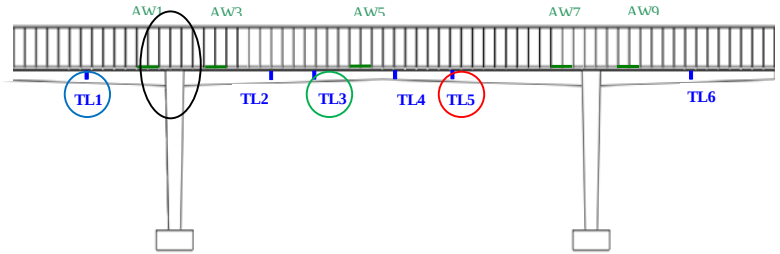


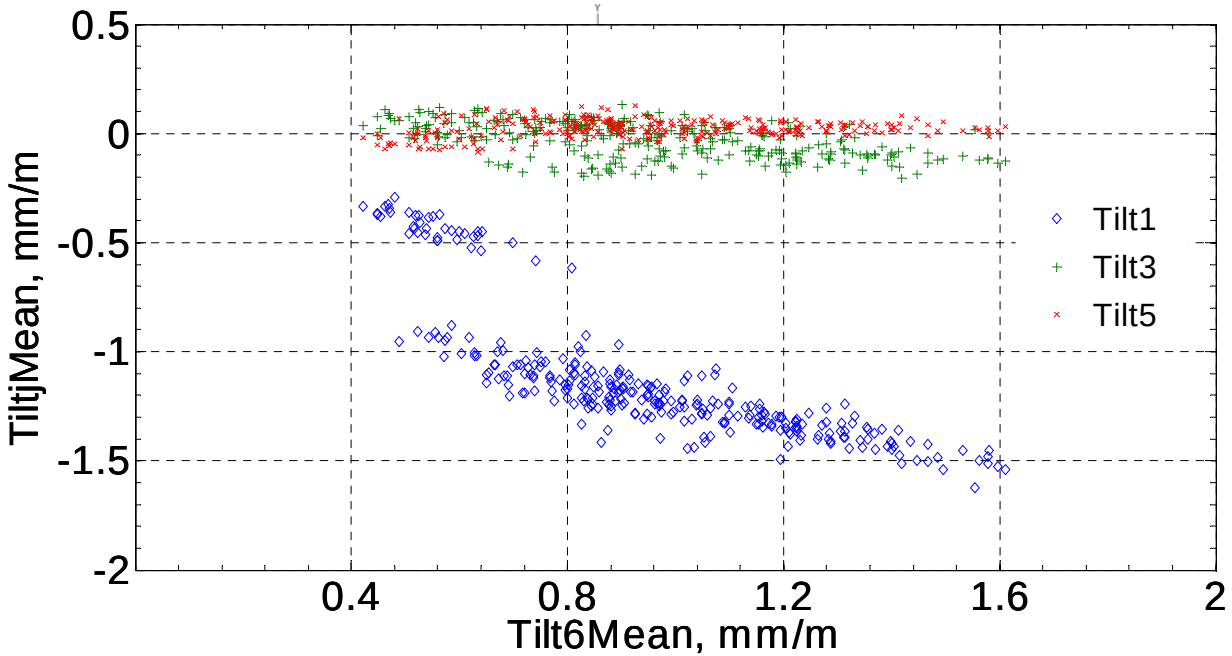
Example of damage detection analysis based on experimental data over 2009



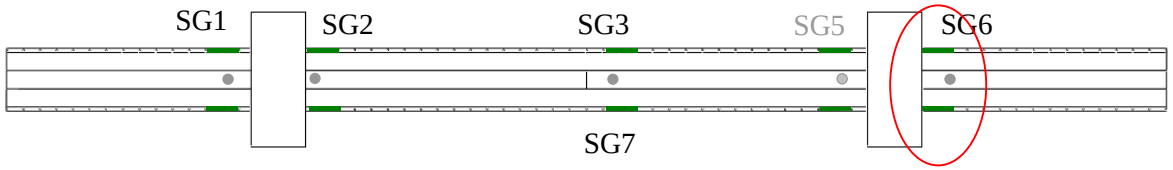


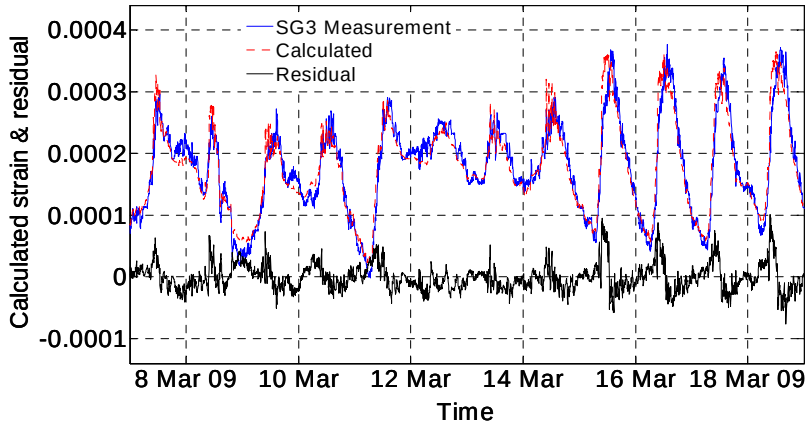
Example of damage detection analysis based on experimental data over 2009: damage location

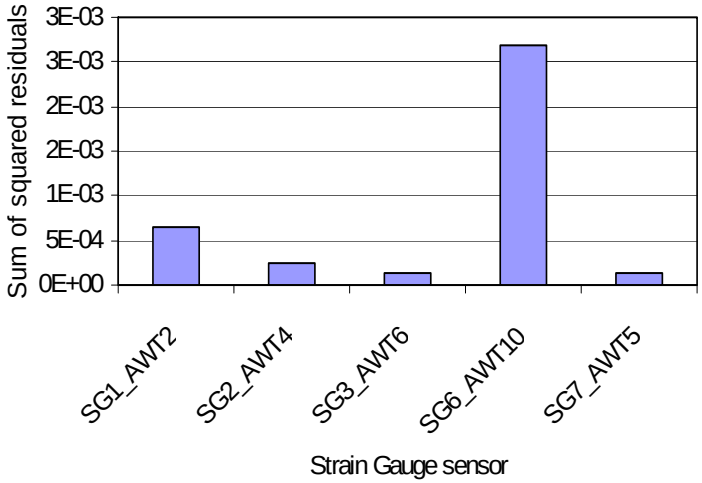




Example of damage detection analysis based on experimental data over 2009: analysis of residuals







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Important findings so far

- Environmental response of the bridge can be used for damage detection:
  - When,
  - Where,
  - Applicable to various type of sensors with output as time series.
- A significant data reduction can be achieved without loss of data quality.
- High sensitivity – early damage detection.

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Concluding remarks and further work

- Calibration and validation of statistical methods for SHM.
- This method can be extended to other parameters, such as waves or wind measured by appropriate sensors.
- Every large structure is unique and damage accumulation is complex.
- Simple examples as building blocks show how SHM can be used for assessment and management.

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Acknowledgments to SHM IAG members

Capris
Cardiff University
City University London
The Concrete Society
Fujitsu Laboratories of Europe
Highway agency
Imetrum
Imperial College
John Moores University
National Physical Laboratory
Network Rail
Physical Acoustics
Sellafield Ltd
Sencieve
SPPS SensorBox
SmartFibres
SciSite
Soil Instruments
Strainstall
Transport for London
University of Surrey

Welcome new members

Concrete repairs
Environmental agency
Pruftechnik
Sagentia

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