SHM for civil engineering assets – a client view

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</tr>
<tr>
<td>Cast iron</td>
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<tr>
<td>Wrought iron</td>
</tr>
<tr>
<td>Steel</td>
</tr>
<tr>
<td>Reinforced concrete</td>
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<tr>
<td>Prestressed/post tensioned concrete</td>
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<tr>
<td>Fibre reinforced polymers</td>
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<tr>
<td>UK infrastructure networks</td>
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<tr>
<td><strong>Network Rail (Great Britain)</strong></td>
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<td><strong>London Underground (London)</strong></td>
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<td><strong>Highways Agency (England)</strong></td>
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<td><strong>Local roads (Great Britain)</strong></td>
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<td><strong>British Waterways (Great Britain)</strong></td>
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<td><strong>Water supply &amp; waste water (Great Britain)</strong></td>
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<td><strong>Transco - electricity transmission (Great Britain)</strong></td>
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<td><strong>Transco - gas transmission (Great Britain)</strong></td>
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<tr>
<td>Year</td>
</tr>
<tr>
<td>------</td>
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<tr>
<td>1832</td>
</tr>
<tr>
<td>1842</td>
</tr>
<tr>
<td>1852</td>
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<tr>
<td>1862</td>
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<tr>
<td>1872</td>
</tr>
<tr>
<td>1882</td>
</tr>
<tr>
<td>1892</td>
</tr>
<tr>
<td>1902</td>
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</table>
The growth of motorways

<table>
<thead>
<tr>
<th>Year</th>
<th>Miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1958</td>
<td>8 miles</td>
</tr>
<tr>
<td>1968</td>
<td>623 miles</td>
</tr>
<tr>
<td>1978</td>
<td>1579 miles</td>
</tr>
<tr>
<td>1988</td>
<td>1908 miles</td>
</tr>
<tr>
<td>1998</td>
<td>2112 miles</td>
</tr>
</tbody>
</table>
How most canals and railways were built
How most railways and canals were built
Network Rail’s bridges – age profile

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Age Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>70%</td>
<td>over 100 yrs old</td>
</tr>
<tr>
<td>13%</td>
<td>50 - 100 yrs old</td>
</tr>
<tr>
<td>10%</td>
<td>20 - 50 yrs old</td>
</tr>
<tr>
<td>7%</td>
<td>less than 20 yrs old</td>
</tr>
</tbody>
</table>
Network Rail’s bridges – material profile

- 50% masonry arches (average age 145 yrs)
- 40% steel or wrought iron (average age 70 years)
- 10% concrete (average age 35 years)
Do we *man what we say*?

- “Failure” is an emotive word and means different things to different people
  - I would prefer “loss of functionality” or “collapse”

- Does the public really understand the concept of “risk”?

- Does the industry really understand the concepts of “serviceability limit state” and “ultimate limit state”?
  - No owner ever wants to get near ULS, but is probably happy to approach SLS

- What is meant by “service life” or “design life”?
  - Should a structure be fully serviceable at the end of its design life?
Bridge failures

Most failures occur during construction or in early life

Those that don’t are usually due to external events
A collapse during construction
A 19th century collapse in service
20th century collapses in service
21st century collapses in service
Structural health monitoring for civil engineering
What are we monitoring for?

• An owner’s needs of a structure are quite easily defined at a basic level
  – How much functionality is left?
  – How much life is left?
### Current monitoring methods

<table>
<thead>
<tr>
<th>Infrastructure</th>
<th>Methodologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport infrastructure</td>
<td>Mainly visual</td>
</tr>
<tr>
<td>Utility infrastructure</td>
<td>Aerial surveying/thermal imaging</td>
</tr>
<tr>
<td></td>
<td>Line walking</td>
</tr>
<tr>
<td></td>
<td>“Pigging”</td>
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</tbody>
</table>
How can SHM help?
Future vision

• Sensors are unlikely to replace the human eye
  – Safety criticality

• Intelligent sensors
  – Self monitoring
  – Only react if pre-set levels exceeded
  – EMC issues
  – Remote interrogation

• Able to detect gradual deterioration
What do we want to be measured?

• Data that will assist with managing the stock/support higher assessment capacity
  – Stress
  – Strain
  – Vibration
  – Deflection
  – Load transfer
  – Dynamic effects

• Demonstrating the effectiveness of maintenance interventions
  – FRP bond line defects
Practical considerations

- Accessibility for installation and maintenance
  - Positioning and fixing of equipment
  - Operationally difficult to access sites
  - Power sources
- Data recording equipment may have to be remote
  - Wireless technology may not work or be allowed
- Equipment and data collection & management systems must be sensibly future proof
  - Smart (intelligent) systems which may be designed to give early warning of incipient failure, or other adverse event, may have to sit quietly monitoring and recording for years before being activated with their expected response
The Sustainable Bridges monitoring report

(www.sustainablebridges.net – project reports)
Roles & responsibilities

• Bridge owner
  – formulate the monitoring objectives, specify the monitoring constraints and define the budget

• Structural engineer
  – provide a theoretical model of the bridge and an interpretation scheme for the data generated by the monitoring system

• Monitoring specialist
  – collaborates with structural engineer in the design of the model monitoring system
  – designs, deploys, operates, validates, updates and maintains the physical monitoring system
Suggested monitoring methodology

1. Definition of monitoring objectives
2. Theoretical bridge model
3. Design of model monitoring system
4. Design of physical monitoring system
5. Deployment of physical monitoring system
6. Validation of model and physical monitoring system
7. Maintenance of model and physical monitoring system
8. Specification of constraints
Monitoring outputs

• Monitoring reports must use language that the bridge owner understands

• Interpretation must be left to the structural engineer

• All raw data must be provided in addition to the report
Into the future
How should future SHM R&D be organised?

• Future R&D should:
  – Seek to deal with the issues affecting existing infrastructure
  – Be a collaboration between instrumentation, communication and structural experts
  – Identify, and then seek to fill, the gaps between what existing SHM methods can measure and what the structural engineer needs to measure
  – Produce systems that can be retrofitted to existing infrastructure
  – Look carefully at future proofing
Current projects with NR involvement

• NR funded
  – Corrosion in elderly metallic structures
• NPL funded
  – Concrete demonstrator project
• TSB funded
  – IMAJINE (paper later in this event)
• EPSRC funded
  – Fibre optic corrosion detector
• EU funded
  – SmartEN (Marie Curie ITN)
Concluding remarks
Concluding remarks

• It is unlikely that SHM will be widely deployed

• Uses will continue to be targeted at specific areas
  – New structural applications
  – To answer a specific question relating to a particular structure or family of structures
  – New major “landmark” structures
A challenge to the SHM community?

On behalf of the Modern Built Environment KTN, CIRIA issued a briefing titled “Innovative approaches to life extension of infrastructure” (CIRIA ref 20-03-10), which contains the following statements:

– Unlike M&E assets residual life is not routinely considered or established for civil infrastructure

– Establishing the overall health of a structure is more important that minute performance detail

– If technologies do not provide some answers to the questions of strength and life expectancy they are of little value

– Monitoring is being heavily oversold
Thank you