Bridge Management—Using Structural Health Monitoring
9th Australian Small Bridges Conference 2019

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Agenda

- Structural Health Monitoring – the basics
  - What is it?
  - Why do it?
  - What does it cost?
  - What does it provide?
- Bridge management – the Journey
  - Origins
  - Context and practice
  - Framework and basics
- Bridge assessment – the Options
  - Framing
  - Decision making
- The key to SHM informed bridge management
Decision mapping is essential before SHM activities are scoped
SHM – the basics
Structural Health Monitoring - Definition

- AS5100.7 The use of various sensing devices and ancillary systems to monitor in situ behaviour of a structure to assess the performance of the structure and assess its condition.
Testing bridges - interesting toys?!!..but how does it help?
Why? Example Load Testing/SHM scenarios and trends

- Local authority RFQ 2017 (Engineering)
  - 50 Bridges – Level 2 and load rating
  - Behavioural tests on all bridges to establish DLA for rating
- Local authority (2018) with defective and critical bridges (AM)
  - Monitoring as part of risk and technical assurance
### Typical Load Testing/SHM project costs & benefits

<table>
<thead>
<tr>
<th>Rationale</th>
<th>Cost (AUD)</th>
<th>Typical technical focus</th>
<th>Inform decisions regarding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modal testing</td>
<td>$5–20 k</td>
<td>Determine bridge dynamic characteristics</td>
<td>Indicative overall stiffness, Dynamic response, defects and discontinuities</td>
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<td></td>
<td></td>
<td>Boundary conditions and element stiffness</td>
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<td></td>
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<td>Dynamic response verification</td>
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<td>Behavioural/diagnostic test</td>
<td>$30–100 k</td>
<td>Model calibration</td>
<td>Structural behaviour, load distribution, and assist understanding of credibility gap</td>
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<td>Indication of change in behaviour</td>
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<tr>
<td>Ambient Strain Monitoring</td>
<td>$50–100 k</td>
<td>Load spectrum and patterns</td>
<td>Structural behaviour, site load profile, distribution, and assist understanding of credibility gap</td>
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<td>Heavy load events</td>
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<tr>
<td>Proof load test</td>
<td>$100–500 k</td>
<td>“Finger print” performance and provide indication of change</td>
<td>Minimum structural capacity, assist understanding of credibility gap, – sometimes extrapolated to bridge family</td>
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</table>
Bridge Management – the Journey
Bridge (Maintenance) Management – Current Core Framework – SHM doesn’t have a home here…
Asset Management – Target Core Framework

SHM might fit here if it helps inform AM decision making…

- Organisation journey required
- Improve existing business processes
- Cultural change
- System development
- Time and investment required – continual improvement
Asset Management 101…& Bridge Management

- Cost-Risk-Performance set-point
Bridge Management - the evolving journey…

• Bridge Management state of the art
  • Bridge management systems world wide are generally similar and lack AM rigour – *Bridge Maintenance Strategies – A brief comparison among different countries around the world* (Scutaru, M. C. et al, 2018)
  • Data driven bridge management is in its infancy - *Long Term Bridge Performance Program Status and Preliminary Results* (Johnson, B. V., et al, 2018)
  • Bridge risk management needs an overhaul - *Bridge Risk Management: Credibility Gaps* (McCarten, P., 2018)

• AM has impacted other sectors to significant advantage
### Institute of Asset Management maturity rating

<table>
<thead>
<tr>
<th>Maturity</th>
<th>Description</th>
<th>Typical Bridge Owners</th>
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</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>Organisation demonstrates leading practice and maximises value consistent with objectives and operating context</td>
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<tr>
<td>Optimising</td>
<td>Organisation demonstrates systematic and consistent optimisation</td>
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<tr>
<td>Competent</td>
<td>Organisation demonstrates systematic and consistent delivery</td>
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<tr>
<td>Developing</td>
<td>Organisation has identified the means of systematically and consistently delivering – credible progress and resource plan</td>
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<tr>
<td>Aware</td>
<td>Organisation has recognised need, and evidence of intent</td>
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<tr>
<td>Innocent</td>
<td>Organisation has not recognised the need</td>
<td></td>
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</table>
### Bridge Management – Score card 2019…

<table>
<thead>
<tr>
<th>What we do OK…</th>
<th>What we don’t do well…</th>
<th>What does it mean…</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increasing use AM principles</td>
<td><strong>Focus on decision inputs</strong></td>
<td>Limited effectiveness and efficiency</td>
</tr>
<tr>
<td>Collect historical data…?</td>
<td><strong>Document decisions</strong></td>
<td>Better decisions faster</td>
</tr>
<tr>
<td>Collect condition data</td>
<td>Document basis for decisions</td>
<td>Increased liability</td>
</tr>
<tr>
<td>Collect capacity data…?</td>
<td>Link decisions (line of site)</td>
<td>Limited continual improvement</td>
</tr>
</tbody>
</table>
Bridge Assessment – the Options
Bridge Assessment – Frameworks to incorporate SHM

- **Technical Framing – AS5100.7**
  - Prediction of loads and capacities
  - Underpinned by conventional engineering processes
  - Requires condition to be understood
  - Accommodates the use of load testing/structural health monitoring

- **Management framing – AS/ISO13822**
  - Risk informed management of assets
  - Cognisant of business outcomes
  - Significant benefits, but requires more sophisticated management processes

- Framing is organisation specific
AS5100.7 – Process and context – SHM framework?

Assists quantification of structural behaviour

**Process**
- Understand condition
- Identify technical factors
- Determine loads
- Determine capacity
- Calculate rating
- Optional refinement
- Report

Business Management

Asset Management

Structural Engineering

Structural Analysis
AS13822 Process and context - SHM Framework?

Assists quantification of risk and performance

Process
• Define Objectives
• Scenarios
• Preliminary assessment
• Detailed assessment
• Report
• Iterate

Structural Analysis
Structural Engineering
Asset Management
Business Management
SHM can inform decisions…

<table>
<thead>
<tr>
<th>#</th>
<th>Decision Frame</th>
<th>Attribute quantification</th>
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<tbody>
<tr>
<td>1</td>
<td>Structural analysis</td>
<td>Boundary conditions and element stiffness</td>
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<td></td>
<td></td>
<td>Frequency response verification</td>
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<td></td>
<td></td>
<td>Analytical model calibration</td>
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<td>2</td>
<td>Structural engineering</td>
<td>Quantification of ambient load profile</td>
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<td></td>
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<td>Probabilistic load assessment</td>
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<td></td>
<td></td>
<td>Redundancy, Inspectability and Ductility (RID) considerations</td>
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<tr>
<td></td>
<td></td>
<td>Reliability prediction</td>
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<tr>
<td>3</td>
<td>Asset management</td>
<td>“Finger print” performance and provide indication of change</td>
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<td>Risk assurance</td>
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<td></td>
<td>Due diligence</td>
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<tr>
<td></td>
<td></td>
<td>Inform whole of life cost parameters</td>
</tr>
<tr>
<td>4</td>
<td>Business management</td>
<td>As for (1) to (3) to meet business objectives</td>
</tr>
</tbody>
</table>
Where does SHM fit into asset data hierarchy?

• AM Data Hierarchy
  1. Asset register
  2. Specification of functional
  3. Inspection (Condition) records
  4. Capacity records
  5. Maintenance records
  6. **Structural Health Monitoring** records

• SHM has different applications
  – Capital bridges
  – Watchlist bridges
  – Stock standard bridges
Summary – Bridge Management - use of SHM

• Knowing more technically doesn’t help unless it informs better decisions

• **Decision mapping is essential before SHM activities are scoped** – this means
  – Knowing what decisions SHM is trying to inform
  – Knowing what the likely outcomes are, and hence, how the data will be used
  – Targeting of SHM technologies to comprehensively meet objectives
  – Understanding the SHM value proposition

• Industry frameworks are available, but they are not always wisely selected or applied

• SHM can typically inform performance or risk – but comes at a significant cost

• SHM will increasingly be a service to AM in addition to engineering
Summary – SHM in local government

• Put resources into
  – Inventory and condition data, and act on it – bridge servicing and maintenance is good value
  – Build your maintenance action and cost data – so you can self learn to get better value
  – Assemble the most economical capacity data available – this is the starting point for SHM

• Sharpen the focus on the Performance-Risk-Cost trade-off
  – Understand you the objectives and strategy of your particular organisation – what is priority and what is secondary
  – Balance the risks between functional and technical performance
  – Collect your cost data properly and understand what it means for your LTFP
  – Where and how will SHM add value to the PRC trade-off

• Decision timeframes
  – Knowing what decisions need to be made and when – understand the minimum data inputs for your decisions
  – Stage decision making and procure accordingly
  – Technical input is generally an input to decisions, it may not drive decisions in all cases.
Questions?