TRB Webinar: Importance of Bridge Inspection and Management
Presentations

- **Importance of Bridge Inspection and Management**
  *Malcolm Kerley, Virginia Department of Transportation*

- **Bridge Inspection Practices (Synthesis 375)**
  *George Hearn, University of Colorado, Boulder*

- **Inspection and Management of Bridges with Fracture-Critical Details (Synthesis 354)**
  *Robert Connor, Purdue University*

- **Monitoring Scour Critical Bridges (Synthesis 396)**
  *Beatrice Hunt, STV, Inc.*

- **Guidelines for Implementing Quality Control and Quality Assurance for Bridge Inspection**
  *Glenn Washer, University of Missouri, Columbia*
Moderators and Participants

- Receiving Your Technical Questions
  Reggie Gillum, Transportation Research Board, 202-334-2382

- Session Moderator
  Lisa Berardi Marflak, Transportation Research Board

- Question and Answer Moderator
  Waseem Dekelbab, Transportation Research Board

- Question and Answer Participant
  Thomas Everett, Federal Highway Administration
Speaker information

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Synthesis Report 375

Bridge Inspection Practices

George Hearn
Synthesis Report

Method
Method
Method

Synthesis Report
Transportation Agencies

Synthesis Report

Danish Road Directorate

Statens vegvesen

TIEHALLINTO
FINNISH ROAD ADMINISTRATION

THE SOUTH AFRICAN NATIONAL ROADS AGENCY

LCPC Laboratoire Central des Ponts et Chaussées

Vägverket

Bast

HIGHWAYS AGENCY
Personnel
<table>
<thead>
<tr>
<th>Role</th>
<th>Certification or Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Federal</strong> Program Manager</td>
<td>Comprehensive Training PE or 10 years experience</td>
</tr>
<tr>
<td>Load Rater</td>
<td>PE</td>
</tr>
<tr>
<td>Team Leader</td>
<td>Comprehensive Training Certification or Experience</td>
</tr>
<tr>
<td><strong>States</strong> Program Manager</td>
<td>Comprehensive Training PE +10 years experience</td>
</tr>
<tr>
<td>Load Rater</td>
<td>PE + Training</td>
</tr>
<tr>
<td>Team Leader</td>
<td>Comprehensive Training Certification + Experience</td>
</tr>
<tr>
<td>Country</td>
<td>Role</td>
</tr>
<tr>
<td>--------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>Denmark</td>
<td>Engineer + Annual Training</td>
</tr>
<tr>
<td>Finland</td>
<td>Engineer + Annual re-certification</td>
</tr>
<tr>
<td>France</td>
<td>Engineer + Training</td>
</tr>
<tr>
<td>Germany</td>
<td>Engineer + Experience + Training</td>
</tr>
<tr>
<td>Norway</td>
<td>Regional Engineer</td>
</tr>
<tr>
<td>South Africa</td>
<td>PE</td>
</tr>
<tr>
<td>Sweden</td>
<td>Engineer + Training</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>Chartered Engineer</td>
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</table>
Inspections
<table>
<thead>
<tr>
<th><strong>US Inspections</strong></th>
<th><strong>Synthesis Report</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Damage</strong></td>
<td>Unscheduled, to assess structural damage</td>
</tr>
<tr>
<td><strong>Fracture critical</strong></td>
<td>24 months</td>
</tr>
<tr>
<td><strong>Hands-on</strong></td>
<td>Within arms length of component</td>
</tr>
<tr>
<td><strong>In-depth</strong></td>
<td>Close-up, to identify deficiencies</td>
</tr>
<tr>
<td><strong>Initial</strong></td>
<td>SI&amp;A data, baseline conditions</td>
</tr>
<tr>
<td><strong>Routine</strong></td>
<td>24 months</td>
</tr>
<tr>
<td><strong>Special</strong></td>
<td>Discretion of the bridge owner</td>
</tr>
<tr>
<td><strong>Underwater</strong></td>
<td>60 months</td>
</tr>
<tr>
<td></td>
<td>Intervals</td>
</tr>
<tr>
<td>----------------------</td>
<td>-----------</td>
</tr>
<tr>
<td></td>
<td>Short</td>
</tr>
<tr>
<td>Routine</td>
<td>11%</td>
</tr>
<tr>
<td>Fracture Critical</td>
<td>26%</td>
</tr>
<tr>
<td>Underwater</td>
<td>66%</td>
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</table>
### Oregon - Timber Boring Report

<table>
<thead>
<tr>
<th>Duration</th>
<th>Location</th>
<th>Service Life</th>
</tr>
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<tbody>
<tr>
<td>96 months</td>
<td>West of the Coast Range</td>
<td>&gt; 20 years</td>
</tr>
<tr>
<td></td>
<td>Service &gt; 20 years</td>
<td></td>
</tr>
<tr>
<td>120 months</td>
<td>Western Oregon</td>
<td>&gt; 25 years</td>
</tr>
<tr>
<td></td>
<td>Service &gt; 25 years</td>
<td></td>
</tr>
<tr>
<td>144 months</td>
<td>East of the Cascades</td>
<td>&gt; 30 years</td>
</tr>
<tr>
<td></td>
<td>Service &gt; 30 years</td>
<td></td>
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</table>
# Iowa - Access for Routine Inspection

<table>
<thead>
<tr>
<th>Type</th>
<th>Interval</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Limited</td>
<td>24 months</td>
<td>Bridges in good condition, Not fracture critical.</td>
</tr>
<tr>
<td>Regular, Close-up</td>
<td>72 months</td>
<td>Bridges getting Limited inspections</td>
</tr>
</tbody>
</table>
Pennsylvania - Close Up

- Vulnerable / poor condition areas
- No hands-on inspection in 72 months
- Load carrying members in poor condition
- FC member < 10 years remaining life
- Redundancy retrofit systems
- Scour critical substructure units
- Ends steel girders under deck joint
- Cantilever concrete piers in fair or lesser condition
- Precast concrete bridge parapets
# Synthesis Report

## Underwater Inspection

<table>
<thead>
<tr>
<th>State</th>
<th>Inspection Period</th>
<th>Results</th>
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</thead>
<tbody>
<tr>
<td>Alabama</td>
<td>24 months</td>
<td>State-owned bridges</td>
</tr>
<tr>
<td></td>
<td>48 months</td>
<td>Local-owned bridges</td>
</tr>
<tr>
<td>New York</td>
<td>60 months</td>
<td>General recmd. 4+</td>
</tr>
<tr>
<td></td>
<td>24 months</td>
<td>General recmd. 3</td>
</tr>
<tr>
<td></td>
<td>12 months</td>
<td>Active flag</td>
</tr>
<tr>
<td></td>
<td></td>
<td>General recmd. 1 or 2</td>
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</table>
### Interim Inspection

<table>
<thead>
<tr>
<th>Location</th>
<th>Duration</th>
<th>Condition Rating</th>
<th>Observations</th>
</tr>
</thead>
</table>
| **Florida** | 6 months | 3 | - 
| | 12 months | 4 | - |
| **Michigan** | 9 months | 3 | - Hi Load Hit - rebar exposed, weakened by deterioration, loss of bearing at 2 adjacent beams, temporary supports for beams |
| | 15 months | 4 | - Substructure condition rating, main rebar exposed, shear cracks, beam exhibits lateral movement, loss of bearing / spall |
48-Month Routine Inspection

Connecticut

In service four years
Had in-depth inspection
Condition ratings 6 or better
HS 30 inventory rating
Single span
< 100 ft span
< 75 years old
14' vertical clearance
ADT < 125000
ADTT < 10%
## Minor Structures

<table>
<thead>
<tr>
<th>State</th>
<th>Time Period</th>
<th>Structures Description</th>
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</thead>
<tbody>
<tr>
<td>Pennsylvania</td>
<td>24 months</td>
<td>Non-bridge over highway</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bridge spans 8 to 20 ft.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Noise walls. Misc. structures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Retaining walls. Sign structure</td>
</tr>
<tr>
<td>Washington</td>
<td>60 months</td>
<td>Highway lids</td>
</tr>
<tr>
<td></td>
<td>72 months</td>
<td>Pedestrian bridges</td>
</tr>
<tr>
<td></td>
<td>24 months</td>
<td>Bridge spans 6 to 20 ft</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tunnels</td>
</tr>
</tbody>
</table>
Inspections
International
<table>
<thead>
<tr>
<th>Country</th>
<th>Frequency</th>
<th>Duration</th>
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</thead>
<tbody>
<tr>
<td>Denmark</td>
<td>Daily, Routine</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Principal</td>
<td>Annual 6 years</td>
</tr>
<tr>
<td>Finland</td>
<td>Annual</td>
<td>1 year</td>
</tr>
<tr>
<td></td>
<td>General</td>
<td>5 years</td>
</tr>
<tr>
<td></td>
<td>Large Bridges</td>
<td>8 years</td>
</tr>
<tr>
<td></td>
<td>Basic</td>
<td>5 years</td>
</tr>
<tr>
<td></td>
<td>Machinery</td>
<td>1 year</td>
</tr>
<tr>
<td></td>
<td>Cables</td>
<td>15 years</td>
</tr>
<tr>
<td></td>
<td>Underwater</td>
<td>5 years</td>
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## Int'l Inspections

<table>
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<th>Frequency</th>
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<tbody>
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<td>Routine</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Annual</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>IQOA</td>
<td>3 years</td>
</tr>
<tr>
<td></td>
<td>Detailed</td>
<td>6 years</td>
</tr>
<tr>
<td></td>
<td>Underwater</td>
<td>6 years</td>
</tr>
<tr>
<td>Germany</td>
<td>Superficial</td>
<td>3 months</td>
</tr>
<tr>
<td></td>
<td>Minor test</td>
<td>3 years</td>
</tr>
<tr>
<td></td>
<td>Major test</td>
<td>6 years</td>
</tr>
<tr>
<td></td>
<td>Underwater</td>
<td>6 years</td>
</tr>
<tr>
<td>Norway</td>
<td>General</td>
<td>1 year</td>
</tr>
<tr>
<td></td>
<td>Major</td>
<td>5 years</td>
</tr>
<tr>
<td>Country</td>
<td>Types</td>
<td>Frequency</td>
</tr>
<tr>
<td>---------------</td>
<td>-------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>South Africa</td>
<td>Monitoring, Principal, Verification</td>
<td>1 year, 5 years, ~60 / year</td>
</tr>
<tr>
<td>Sweden</td>
<td>Regular, Superficial, General, Major, Underwater</td>
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<tr>
<td></td>
<td></td>
<td>1 year, 3 years, 6 years</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>Superficial, General, Principal, Underwater</td>
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<tr>
<td></td>
<td></td>
<td>2 years, 6 years, 6 years</td>
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</tbody>
</table>
Inspectors & Inspections
<table>
<thead>
<tr>
<th>Country</th>
<th>Role</th>
<th>Inspections</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>Team Leader</td>
<td>All</td>
</tr>
<tr>
<td>Denmark</td>
<td>Bridge Inspectors</td>
<td>Principal inspection</td>
</tr>
<tr>
<td></td>
<td>Road Foreman</td>
<td>Annual inspection</td>
</tr>
<tr>
<td></td>
<td>Roadmen</td>
<td>Daily inspection</td>
</tr>
<tr>
<td>Finland</td>
<td>Certified Inspector*</td>
<td>Basic inspection</td>
</tr>
<tr>
<td></td>
<td>Road Foreman</td>
<td>General inspection</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Annual inspection</td>
</tr>
<tr>
<td>France</td>
<td>Certified Inspector</td>
<td>Detailed inspection</td>
</tr>
<tr>
<td></td>
<td>Inspection Agent</td>
<td>IQOA</td>
</tr>
<tr>
<td></td>
<td>Maintenance Agent</td>
<td>Annual inspection</td>
</tr>
<tr>
<td>Country</td>
<td>Role</td>
<td>Inspections</td>
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<tr>
<td>------------------</td>
<td>----------------------------------</td>
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<tr>
<td>Germany</td>
<td>Bridge Inspector</td>
<td>Major Test, Minor Test Superficial inspection</td>
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<td></td>
<td>Maintenance Crew</td>
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<td>South Africa</td>
<td>Senior Inspector Bridge inspector</td>
<td>Verification inspections Principal inspection Annual inspection</td>
</tr>
<tr>
<td></td>
<td>Maintenance Crew</td>
<td></td>
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<td>Sweden</td>
<td>Bridge inspector Maintenance Contr</td>
<td>Major inspection</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>Supervising Engr Bridge Inspector</td>
<td>Principal inspection General inspection</td>
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Condition Ratings
## Germany - Condition Ratings

<table>
<thead>
<tr>
<th>Rating</th>
<th>Strength</th>
<th>Traffic Safety</th>
<th>Durability</th>
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<tr>
<td>0</td>
<td>No effect</td>
<td>No effect</td>
<td>No effect</td>
</tr>
<tr>
<td>1</td>
<td>Adequate</td>
<td>Adequate</td>
<td>Adequate</td>
</tr>
<tr>
<td>2</td>
<td>Little effect</td>
<td>Slight effect</td>
<td>Some loss</td>
</tr>
<tr>
<td>3</td>
<td>Affects</td>
<td>Affects</td>
<td>Repair needed</td>
</tr>
<tr>
<td>4</td>
<td>Posted</td>
<td>Restricted</td>
<td>Lost</td>
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<tr>
<td>Country</td>
<td>Scale</td>
<td>Categories</td>
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<td>Damage</td>
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<tr>
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<td>0 - 4</td>
<td>Condition, Repair, Damage</td>
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<tr>
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<td>1-3, S</td>
<td>Condition, Urgency</td>
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<tr>
<td>Germany</td>
<td>0 - 4</td>
<td>Strength, Traffic Safety, Durability</td>
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<td>Norway</td>
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<td>Strength, Traffic Safety, Cost, Aesthetics</td>
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<td>Degree, Extent, Relevancy, Urgency</td>
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<td>Condition, Function, Cost</td>
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<td>Condition, Extent</td>
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QC / QA
<table>
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<tr>
<th>QC / QA</th>
<th>Synthesis Report</th>
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**Quality Control**

<table>
<thead>
<tr>
<th>US DOTs</th>
<th>Office review of reports</th>
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<tbody>
<tr>
<td></td>
<td>Senior personnel for critical findings</td>
</tr>
<tr>
<td></td>
<td>Visits to teams in field</td>
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<tr>
<td></td>
<td>Verification inspections</td>
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## Quality Assurance

<table>
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<tr>
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<tr>
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<td>Timely execution &amp; response</td>
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<tr>
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<td>Workshops &amp; Training</td>
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<td>Field verification exercises</td>
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## International

<table>
<thead>
<tr>
<th></th>
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<th>Fn</th>
<th>Fr</th>
<th>Gr</th>
<th>Nr</th>
<th>SA</th>
<th>Sw</th>
<th>UK</th>
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<tbody>
<tr>
<td>Report Review</td>
<td>Y</td>
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<td>Y</td>
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<tr>
<td>Prior Compare</td>
<td>Y</td>
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<td>Y</td>
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<td>Y</td>
<td>Y</td>
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<td>Y</td>
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Comparison
### Inspection Intervals

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<tbody>
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<td>Rout.</td>
<td>Annual</td>
<td>Annual</td>
<td>Genl</td>
<td>Monit.</td>
<td></td>
<td></td>
<td>Supfcl</td>
</tr>
<tr>
<td>2 yr</td>
<td>Rout.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Genl</td>
</tr>
<tr>
<td>3 yr</td>
<td></td>
<td></td>
<td>IQOA</td>
<td>Minor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Genl</td>
</tr>
<tr>
<td>4 yr</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>5 yr</td>
<td></td>
<td></td>
<td>Genl</td>
<td></td>
<td></td>
<td>Major</td>
<td>Princ</td>
<td></td>
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</tr>
<tr>
<td>6 yr</td>
<td>Princ.</td>
<td></td>
<td>DetId</td>
<td>Major</td>
<td></td>
<td></td>
<td></td>
<td>Major</td>
<td>Princ</td>
</tr>
<tr>
<td>8 yr</td>
<td></td>
<td></td>
<td>Large</td>
<td></td>
<td></td>
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## Inspectors

<table>
<thead>
<tr>
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<th>Dk</th>
<th>Fn</th>
<th>Fr</th>
<th>Gr</th>
<th>Nr</th>
<th>SA</th>
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<th>UK</th>
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<td>Annual</td>
<td>Supfcl</td>
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<td>Monit.</td>
<td>Supfcl</td>
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<tr>
<td>Certified</td>
<td>Rout.</td>
<td>Genl</td>
<td>Large</td>
<td>IQOA Detlid</td>
<td>Minor</td>
<td></td>
<td></td>
<td>Genl</td>
<td></td>
</tr>
<tr>
<td>Engineer</td>
<td>Princ.</td>
<td></td>
<td></td>
<td></td>
<td>Major</td>
<td>Major</td>
<td>Princ</td>
<td>Genl Major</td>
<td>Princ.</td>
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## Access

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<th>Dk</th>
<th>Fn</th>
<th>Fr</th>
<th>Gr</th>
<th>Nr</th>
<th>SA</th>
<th>Sw</th>
<th>UK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drive By</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>Arms Length</td>
<td>Genl Large</td>
<td>Detld</td>
<td>Major</td>
<td>Major</td>
<td>Princ</td>
<td>Major</td>
<td>Princ</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Bridge Inspection Practices

George Hearn


http://international.fhwa.dot.gov/links/pub_details.cfm?id=559
Inspection & Management of Bridges with Fracture-Critical Details
(NCHRP Synthesis 354)

Robert J. Connor
Assistant Professor
Purdue University
March 26, 2009
Objectives of Synthesis 354

- Survey & identify gaps in the literature
- Determine practices and problems with how bridge owners define, identify, document, inspect, and manage bridges with fracture-critical details
- Identify research needs
General Findings

- Very limited number of failures of FCB
- FCP seems to be working
  - But, relatively few FCB built since introduced
  - FCB comprise about 11% of US inventory
  - Majority (75%) built before 1975
- Field inspection is a major cost
  - Variability in inspection interval
  - Available training seems adequate
- Inconsistency in classification of FCBs
General Findings  Cont'd

- Retrofit strategies have been developed
- If improved toughness of HPS steel can be utilized, data suggest that there is a potential to:
  - Eliminate special in-service inspection requirements for fracture critical structures for HPS steel
  - Reduce frequency and need for “hands-on” fatigue inspections for HPS steel
  - Eliminate of the penalty for structures with low redundancy for HPS steel
General Findings  Cont’d

- Based on FHWA scanning tour:

  “Other countries have a more liberal view of the importance of redundancy. No special design, fabrication, or inspection requirements for such bridges were apparent. The U.S. design philosophy for nonredundant bridges should be reconsidered, based upon these observations and improvements in steel toughness.”
Failures of FCB

- Only two known catastrophic failures of FC bridges
  - Silver Bridge
  - Mianus River
- Silver Bridge
  - Inspection would not likely have helped
- Mianus River
  - Material toughness not the issue
Failures of FCB

- Other fractures have been documented without catastrophic failure
  - Lafayette St, I-79 Neville Island, Hoan, SR 422, etc.
  - Bridge deflected, but in almost all cases could be repaired relatively easily
Failures of FCB

- Overall, there seems to be much redundancy in bridges traditionally classified as non-redundant
Fracture Critical vs. Redundancy

- “Fracture Critical” members are non-redundant (Failure Critical ??)

- Non-redundant is a broader term because it also includes:
  - Substructures
  - Members that may not be susceptible to fracture, such as:
    - compression members, but still could lead to collapse if damaged by overloading, earthquakes, fire, terrorism, ship or vehicle collisions, etc.; and,
    - members made of materials other than steel.
Three Types of Redundancy

- **Internal Redundancy (Member Redundancy)**
  - Member comprised of multiple elements. A fracture that formed in one element cannot propagate directly into the adjacent elements

- **Structural Redundancy**
  - External static indeterminacy and can occur in a two or more span continuous girder or truss

- **Load-Path Redundancy**
  - Internal static indeterminacy arising from having three or more girders or redundant truss members
Failure or Fracture Critical?
Inspection Costs

- Huge variation in the survey response
- Most agencies indicated increases between 200% and 500% for FCB
- Common reasons for increases:
  - Specialized access equipment
  - Rigging required for hands-on inspection
  - Traffic control to close lanes
  - Additional man-hours for hands-on inspection
  - More frequent use of NDT
  - Greater frequency of inspection for FCB
  - Cost to traveling public ????
## Classification of FCB

<table>
<thead>
<tr>
<th>Structure Description</th>
<th>Fracture Critical</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Two girder bridges</td>
<td>38</td>
</tr>
<tr>
<td>Three girder bridges</td>
<td>9</td>
</tr>
<tr>
<td>Three girder bridges with girder spacing &gt; 15ft</td>
<td>10</td>
</tr>
<tr>
<td>Multi-girder bridges with girder spacing &gt; 15ft</td>
<td>3</td>
</tr>
<tr>
<td>Truss bridges</td>
<td>34</td>
</tr>
<tr>
<td>Two girder bridges fabricated using HPS70W steel</td>
<td>31</td>
</tr>
<tr>
<td>Truss bridges fabricated using HPS70W steel</td>
<td>28</td>
</tr>
<tr>
<td>Single steel “tub” girder bridges</td>
<td>32</td>
</tr>
<tr>
<td>Twin steel “tub” girder bridges</td>
<td>22</td>
</tr>
<tr>
<td>Multi steel “tub” girder bridges</td>
<td>0</td>
</tr>
<tr>
<td>Other (post tensioned, timber, steel cross girders, etc.)</td>
<td>13</td>
</tr>
</tbody>
</table>
Designing and Retrofitting to Improve Redundancy

- Guidance needed on how to design new or evaluate existing bridges traditionally classified as FC to be non-FC
- Methods which have been used
  - Advanced analysis to demonstrate capable alternate load paths exist
  - Addition of components to improve internal member redundancy
  - Addition of supplementary members
Utilization of Advanced Analysis Techniques
Advanced Analysis

Various “what if” scenarios can be studied
Retrofit of Cross Girder

- Existing cross girder
- Newly added cross girders on each side of cross girder
- New steel support columns (typ.)
Addition of Redundancy Plates

In New Design

As a Retrofit
Pin and Hanger Retrofits

“Catcher” beam

Location of former pin and hanger
Post Tensioned Tied Arch Bridge
### Identified Research Needs

<table>
<thead>
<tr>
<th>Research Topic</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop advanced analyses techniques and procedures to investigate alternate load paths, redundancy, and bridge collapse</td>
<td>10</td>
</tr>
<tr>
<td>Field monitoring for fracture critical bridges</td>
<td>10</td>
</tr>
<tr>
<td>Develop advanced fatigue-life calculation procedures taking into account lack of visible cracks for fracture critical bridges</td>
<td>9</td>
</tr>
<tr>
<td>Develop guidelines related to advanced structural analysis procedures to better predict service load behavior in fracture critical bridges</td>
<td>8</td>
</tr>
<tr>
<td>Establish evaluation procedures for advanced large deformation and member loss</td>
<td>7</td>
</tr>
<tr>
<td>Crack arrest capabilities of bridge steel</td>
<td>3</td>
</tr>
<tr>
<td>Develop rational inspection criteria related to inspection interval and level of detail on ADT, age, and fatigue detail categories present</td>
<td>2</td>
</tr>
<tr>
<td>Develop retrofit procedures to add redundancy</td>
<td>1</td>
</tr>
</tbody>
</table>
Get Your Copy Today!!

Monitoring Scour Critical Bridges
(NCHRP Synthesis 396)

Beatrice E. Hunt, P.E.
Principal Hydraulic Engineer
STV Inc.
March 26, 2009
Outline

- Bridge scour and countermeasures
- Fixed scour monitors
- Scour monitoring practices
- Conclusions
Causes of Bridge Failures in the U. S.

Number of Bridge Failures
1966 to 2005 (1,502 Total)

Cause

Data courtesy of Mike Sullivan, NYSDOT
Figure courtesy of J-L Briaud, Texas A&M University
NYS Thruway over Schoharie Creek

1987
Bridge Scour

- Approximately 60% of bridge failures in the U.S. are due to scour

- About 590,000 bridges in the National Bridge Inventory
  - Over 484,500 are over water
  - 20,904 have been declared scour critical
Scour Critical Bridge

A scour critical bridge is one with abutment or pier foundations rated as unstable due to the observed scour at the bridge site or scour potential as determined from a scour evaluation study.

FHWA Memorandum on “Revision of Coding Guide, Item 113 – Scour Critical Bridges” dated 04/27/01
NBIS - Code of Federal Regulations

Requirements for scour critical bridges:

“Prepare a plan of action to monitor known and potential deficiencies and to address critical findings. Monitor bridges that are scour critical in accordance with the plan.”

23 CFR 650.313, Subpart C, September 13, 2005
Scour Countermeasure Groups

- Hydraulic
- Structural
- Biotechnical
- Monitoring
Types of Scour Monitoring

- Portable Instrumentation
- Visual Monitoring
- Fixed Instrumentation
Guidance on Fixed Monitors

TRB NCHRP Report 396

FHWA HEC-23
Types of Fixed Scour Monitors

- Sonar
- Tilt Sensor
- Time Domain Reflectometer
- Magnetic Sliding Collar
- Float-out
Data loggers

Indoors – Pier Tower

Bridge Pier

Box for Bridge Railing

Nearby Building
Powering the System

Commercial Power

Solar Power
Data Retrieval

On-site

Telephone Land line

Satellite

Cellular
Internet Data Retrieval

Sensor Locations

Select any of the five remotes to display sensor data
Sonar Scour Monitors

- Bridge deck
- Sonar instrument enclosure with solar panel, attach to bridge.
- Above water serviceable transducer mounting assembly
- Flow
- Pier 3-West Mounted Sensor

FHWA HEC-23
Magnetic Sliding Collars
Float-out Devices

Texas A&M
Tilt Sensors

Texas A&M
Time Domain Reflectometers

CRREL, USCOE
Use of Fixed Scour Monitors

- 33 states and the District of Columbia
- Over 120 bridges identified
- The majority reported a history of bridge scour or were scour critical by calculation
States with Fixed Scour Monitors

Alabama
Alaska
Arizona
Arkansas
California
Colorado
Connecticut
Delaware
District of Columbia
Florida
Georgia
Hawaii
Indiana
Iowa
Kansas
Maine
Maryland
Michigan
Minnesota
Nevada
New Hampshire
New Jersey
New Mexico
New York
North Carolina
Ohio
Oregon
Rhode Island
Tennessee
Texas
Vermont
Virginia
Washington
Wisconsin

States with Fixed Scour Monitoring Installations
(based on survey responses and research)
Data Being Collected

- Streambed elevations
- Bridge movements
- Water Stage
- Velocity measurements
- Rainfall
Bridge Information

- Average Daily Traffic (ADT) ranged from 100 to 175,000 vehicles per day
- Bridge lengths: 12.5 m (41 ft) to 3,921 m (12,865 ft)
- Bridges constructed between 1901 and 1988
- Monitors installed between 1991 and 2008 and some to be installed
Substructure Information

- 83% piers; 3% abutments; 8% other
- Foundations: 60% piles; 35% spread footings; 2% drilled shafts; 2% unknown foundations
- Problems cited:
  - Complex pier geometry
  - Lack of as-built plans
  - Installation on large or tall bridges
Site Conditions

- Riverine and tidal
- Intermittent to perennial flows
- Water depths: < 3 m to 30 m (<10 ft to 75 ft)
- Soil conditions: clay, silt, sand, cobbles, gravel, organics, riprap, rock and concrete
Figure 20 Extreme Site Conditions at Scour Monitoring Locations

<table>
<thead>
<tr>
<th>Condition</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Debris Loading</td>
<td>37</td>
</tr>
<tr>
<td>Extreme Temperatures</td>
<td>1</td>
</tr>
<tr>
<td>Sediment Loading</td>
<td>31</td>
</tr>
<tr>
<td>Ice Flows</td>
<td>29</td>
</tr>
<tr>
<td>High Velocity Flows</td>
<td>36</td>
</tr>
</tbody>
</table>

Note: Air entrainment was surveyed, but no cases were reported.
Interference and Damage

Figure 21  Site conditions that caused interference or damage to the fixed scour monitoring systems

Note: "Other" responses included damage due to vibration, high water velocities, and equipment being buried over time.

<table>
<thead>
<tr>
<th>Condition</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ice Flows</td>
<td>22</td>
</tr>
<tr>
<td>Debris</td>
<td>32</td>
</tr>
<tr>
<td>Solar Power Interruptions</td>
<td>3</td>
</tr>
<tr>
<td>Corrosion or Electrolysis</td>
<td>4</td>
</tr>
<tr>
<td>Collisions</td>
<td>1</td>
</tr>
<tr>
<td>Vandalism</td>
<td>8</td>
</tr>
<tr>
<td>Other</td>
<td>9</td>
</tr>
</tbody>
</table>
Installation and Future Maintenance
Heightened Security and Access

Original Woodrow Wilson Memorial Bridge
Diving Inspections & Maintenance
Scour Monitoring Data

Sonar Scour Monitor Data for Wantagh Parkway over Goose Creek
Daily Minimum Streambed Elevation

NOTE:
1. Stream Elevation is ~40 ft.
2. NE Bascule Pier has not been operational since May 24, 2004.
3. SE Bascule Pier has not been operational since November 15, 2004.
4. Continuity Not Available in FT-575 or below.
5. Critical Notification is EL-68 ft or below.

LEGEND:
- NW Bascule Pier
- NE Bascule Pier
- SW Bascule Pier
- SE Bascule Pier

Nassau County, New York
NYDOT Region 10

Oct 23, 2005

BIN 1-50650-8
## Fixed Instrumentation Selection Matrix

<table>
<thead>
<tr>
<th>Type of Fixed Instrumentation</th>
<th>Local Scour</th>
<th>Contraction Scour</th>
<th>Stream Instability</th>
<th>Waterway Type</th>
<th>Stream Habitat</th>
<th>Water Depth</th>
<th>Bed Material</th>
<th>Extreme Conditions</th>
<th>Foundation Type</th>
<th>Installation Experience by State from Surveys</th>
<th>Additional Installation Experience by State Other Sources</th>
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</thead>
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<tr>
<td>Abutments</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<td>CO, NM, OR, RI, WI</td>
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<td>1</td>
<td>1</td>
<td>3</td>
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<td>1</td>
<td>1</td>
<td>CA, HI, IN, MN, NJ, NY</td>
<td>CO, FL, NE, MI, NH, RI, TX, WI</td>
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<tr>
<td>Vertical Lateral</td>
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<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>CA, WA</td>
<td></td>
</tr>
<tr>
<td>Tilt Sensors</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>AL, CA, NV</td>
<td>AZ</td>
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<td>Float Out Device</td>
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<td>1</td>
<td>3</td>
<td>1</td>
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<td>1</td>
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<td>1</td>
<td>AR, IA, NY</td>
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<tr>
<td>Time Domain Reflectometers</td>
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<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>VT</td>
<td></td>
</tr>
</tbody>
</table>

(Note: Stakes in bold have indicated they plan to use fixed instrumentation in the future)
Benefits of Scour Monitoring Systems

- Provides **safety** for the traveling public
- May provide a **reduction** in the number of required **diving inspections and fathometer surveys**
- **Early identification** of a problem prior to inspections
- Insight into site-specific **scour processes**
- One component of a comprehensive **Plan of Action**
- Appropriate for **large bridges and deep water conditions**
Benefits of Scour Monitoring Systems

- May be quickly designed and installed
- Continuous monitoring of streambed elevations (sonars)
- Capable of measuring scour and infill conditions (sonars)
- May be used to extend the life of a bridge
- May be combined with other scour countermeasures
- Provide data useful for replacement bridges and scour research
Future Needs for Scour Monitoring Technology

- More robust devices - increased reliability and longevity
- Decreased costs
- Less maintenance
- Devices more suitable for larger bridges
- Combine scour monitors with devices that measure additional hydraulic variables and/or structural monitors
- Funding for the scour monitoring program post-installation
Conclusions

- Fixed scour monitoring is being used on a wide variety of bridges and sites

- Custom-designed and site-specific - Bridge, channel, topography and risk

- Major challenges are in the implementation:
  - Maintenance and repairs
  - Developing and maintaining a response protocol and responsibilities
Guideline for Implementing Quality Control and Quality Assurance for Bridge Inspection

Glenn A. Washer, Ph.D., P.E.
Assistant Professor
University of Missouri
Columbia, MO
Agenda

- Introduction
- Goals and Objectives
- QC Reviews
- QA Models
- Conclude
Introduction

- Revisions to the NBIS require systematic QC and QA to maintain a high degree of accuracy and consistency
- AASHTO/FHWA/NCHRP scan in 2007 “Bridge Evaluation Quality Assurance Scan”
  - Assist in NBIS regulation implementation
  - Explore effective bridge inspection systems in other countries
    - QC/QA procedures and methodologies
    - Review types of data collected by other countries
- Scanning tour found some innovative QA approaches, technical decision making process for inspection scope and schedule, ….
In the US, implementation methods for meeting NBIS are diversified

- Different organizational structures for State DOT’s
  - State bridges, counties, cities, towns, townships, communities, etc.
  - Consultants, State Forces, local forces, etc.
- Different levels and status of QC/QA implementation
  - Some States have existing, comprehensive systems
  - Some States have development needs
  - Some States would like to improve/validate their approach

FHWA framework for QC/QA provided guidance and example State program data

- Assistance / examples of how the framework is implemented within a bridge inspection program was needed
- Assist States in identifying QC/QA practices suitable within their own program structures, resources and needs
Goals and Objectives

• Goal: To improve bridge safety by developing guidelines for implementing advanced QC/QA procedures

• Objective: Develop a guideline document that can be used by State DOT’s for implementing QC/QA procedures within their bridge inspection programs
  – Document current practices in the US
  – Provide a guideline that allows owners to consider practices that best fit their programmatic needs
Approach

• Collect data on existing QC and QA programs and methods
  – Interview State DOT personnel
  – Review available literature and available documentation of State practices
  – FHWA data compiled by the office of bridge technologies on innovative practices
• Develop generic models of QA procedures, such that the overall model can be easily adjusted to meet programmatic needs
• Document current QC and QA procedures
Quality Control (QC) and Quality Assurance (QA)

- **QC**: Procedures that are intended to maintain the quality of a bridge inspection and load rating at or above a specified level (NBIS)
- **QA**: The use of sampling and other measures to assure the adequacy of quality control procedures in order to verify or measure the quality level of the entire bridge inspection and load rating program (NBIS)
- What is Quality?
Quality

• “Quality” is inversely proportional to variability
  – *The good quality of an entity means that its quality dimensions have little or no variation from target values*
  – For Bridge inspection, this means that procedures meet requirements, practices correctly implement procedures, and the inspection results meet target values.
    • Vertical clearance, condition rating (1-9), scheduling of inspections, scour action plans, etc.
QC vs. QA

- QC is done within a work group to ensure the adequacy of *specific bridge inspection reports*
  - Sometimes delegated to consultants, local bridge owners, district/regional office

- QA: Conducted from outside the work group to evaluate:
  - Effectiveness of QC
  - Consistency of inspection results
  - Corrective actions for requirements and procedures
    - Inspection requirements
    - Rating manuals
    - Training needs
    - Annual bridge inspector meetings
QC vs. QA

- Requirements
- Procedures
- Practices
- Results

QA

QC
Dimensions of Quality

- A “quality dimension” is a characteristic that provides a measure of quality. For example, conformance of an inspection to established procedures is *dimension* of quality
  - Consistency of NBI ratings
    - Adequacy of notes/photos/sketches
  - Accurate CoRE selection
    - Condition state allocation
  - Critical findings
    - Identification and resolution
  - Inventory items
    - Clearance, waterway profile, width, length, location, etc.
  - Inspection scheduling
  - Underwater inspections, scour POA
  - Many others….
Quality Control Review Procedures

- QC Office review
  - Review reports for consistency, procedure, documentation (photos and sketches)
- QC Field Review
  - Confirm inspection results by visiting bridge site; check accuracy of ratings, inventory items, documentation (photos, sketches and notes)
- QC Field Performance Review
  - Review the performance of inspection team in the field by observing inspection practice
- Typically conducted by a QC personnel with
  - Independence from original inspection
  - Full and operational knowledge of inspection program requirements, procedures and intended practices.
Hierarchical QC Structure

- **Advantages:**
  - Redundant QC procedures
  - Review of the reviewer
  - Management features and oversight

- **Disadvantages**
  - Costly, time consuming
QA Models in the US

- **Independent Oversight Model**
  - Re-inspection of bridges by a 3rd party

- **Control Bridge Model**
  - All inspectors inspect the same 2-3 bridges
  - Compare with expert team (control inspection)

- **Collaborative Peer Review Model**
  - Peer team and inspectors re-inspect bridges

- **Field Verification Model**
  - Field check of inspection results by program manager (or other supervisor)
Independent Oversight Model

- Independent 3rd party conducts a independent re-inspection of sampling of bridges
- Document variations between re-inspection and original inspection result
- Corrective actions for teams through team-specific report; system-wide report developed from integrating data from individual reviews
Control Bridge Model

- 2-3 bridges selected as “Control Bridges”
  - Inspection conducted by “expert team” to provide a “control inspection”
- Inspectors (from across the State) conduct independent inspection of the same bridges
- Compare with control inspection; discuss in annual inspectors meeting, identify corrective actions
- “Calibration,” apples to apples comparison, inspector buy-in
Collaborative Peer Review Model

- Collaborative, independent re-inspection of bridges with peer team assembled from other districts, central office, design, etc.
- Discussion of ratings/condition states, element selection, etc during the collaborative inspection
- Compare results of collaborative inspection with original inspection results
- Discuss differences and resolve issues
- Collect data from CPR reviews for system/programmatic analysis
Comments and Conclusion

• Documentation is a critical element in the quality process
  – Who does what, when, how, where, etc….
  – Allows for understanding of the program, oversight and review, and promotes good communication

• Positive environment for review
  – The goal of QC/QA is to ensure high-quality results, everyone wants that…
  – The goal is not to identify deficient personnel, teams or districts
    • This may be an outcome, but not the focus
    • Positive environment of communication and teamwork will yield more effective results, help raise quality across the program
NCHRP 20-07 (252) Status

• Draft final report submitted to NCHRP
  – Report describes current practices for QC/QA
  – Motivations and approaches
  – Allow owners to consider different methodologies that best fit their programmatic needs
• Comments from panel currently being addressed
Questions?

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