Bridge Inspections: Assessing Defects and Details for Safety

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Overview

- The Ontario Structural Inspection Manual (OSIM) has detailed information on capturing the condition of bridges during an Inspection. Not covered today.
- This webinar will focus on addressing defects and other problematic details that a bridge owner or engineer may encounter.
- Real world examples.
- This webinar will focus on ensuring bridges are SAFE.
Introduction

WHAT IS THE PURPOSE OF A BRIDGE INSPECTION?
Introduction

What is the purpose of a bridge inspection?

1. Assess if the bridge is **SAFE** for the public to use
2. Identify major structural issues and **FOLLOW-UP** when necessary
3. Quantify the overall **CONDITION** to help with setting and prioritizing capital needs
4. Identify routine **MAINTENANCE** needs
5. Maintain a **HISTORY** of bridge condition
THE MAIN GOAL IS TO ENSURE THE BRIDGE IS SAFE
Defect Assessment
Relevancy, Severity, and Urgency of Defects
Defect Assessment

When assessing a defect, we need to think about:

1. **RELEVANCY** - Does this directly affect safety?
2. **SEVERITY** - How bad is it?
3. **URGENCY** - How quickly do we need to address this?

This is a good practice to exercise in addition to the requirements in OSIM.
Relevancy of Defects

Thinking about the relevancy of a defect is the first step to assessing safety.

- Routine issues due to natural aging and use are usually not highly relevant
  - Asphalt ravelling
  - Hairline concrete cracking
  - Snowplough damage to curb faces
- Non-Routine issues may be anomalies, and hence very relevant
  - Significant deflection of girders
  - Medium and wide flexural or shear cracks
  - Loss of material under spread footings

*Look for defects that are abnormal first.*

*These are indications of a potential safety issue.*
Relevancy of Defects

- **LOW RELEVANCY**
  - Has little to no effect on safety today or in the future
  - Localized spalls, scaling, etc.

- **MEDIUM RELEVANCY**
  - May affect safety in the near future if left unaddressed
  - Loose concrete on soffit, unevenly loaded bearing, etc.

- **HIGH RELEVANCY**
  - Directly affects safety today or in the immediate future
  - Medium to wide shear cracks, impact-damaged girder, wide flexural cracks, missing sidewalk joint cover plate
Severity of Defects

Once the relevancy of a defect is considered, think about its severity.

- How much of the structure is this affecting?
- Is this enough to cause a major issue?

The severity of a defect relates to its current state of deterioration.

A lot of the assessment is through experience and good judgement.
Severity of Defects

- **LOW SEVERITY**
  - Defect is very localized, or minor in nature
    - Light and some Medium defects
    - Most surface defects (scaling, honeycombing, flushing, etc.)

- **MEDIUM SEVERITY**
  - Defect is more widespread and/or somewhat advanced in state
    - Most medium defects
    - Some localized severe and very severe defects on non-structural components

- **HIGH SEVERITY**
  - Defect is widespread, and/or advanced in state
    - Wide flexural cracks in soffit
    - Medium or wide shear cracks in concrete
    - Severe section loss of steel member
Urgency of Defects

The URGENCY of a defect can be assessed based on its RELEVANCY and SEVERITY

LOW URGENCY
- Low Relevancy, Low Severity
- Low Relevancy, Medium Severity
- Medium Relevancy, Low Severity

MEDIUM URGENCY
- Low Relevancy, High Severity
- High Relevancy, Low Severity
- Medium Relevancy, Medium Severity

HIGH URGENCY
- High Relevancy, High Severity
- High Relevancy, Medium Severity
- Medium Relevancy, High Severity
- Bridge Details Requiring Special Attention
- Hidden Members/Connections
- Non-Redundant Members or Connections
Bridge Details Requiring Special Attention

- Some bridge design details used in the past are known today to be problematic or even high risk that require special attention.
- Special care should be taken when inspecting structures with these details.
- The Owner should be aware if their bridges with these types of details exist in their inventory.
- If it does, additional attention should be made to mitigate the risk of failure.
Hidden Members/Connections

- Modern bridges are designed to ensure all bridge components is accessible for inspection as much as possible.
- However, this was not always the case for bridges built in the past.
- Some critical details or components may be hidden and cannot be visually inspected.
- That's why inspection engineer must review all drawings including rehab drawings to make sure if such details exist or not.
- The adverse effect can be significant if those hidden components are ignored or not inspected.
Non-Redundant Members or Connections

- Special care should always be taken on bridges with little or no redundancy.
- Structural Redundancy:
  - Redundant structure:
    - Structures that have multiple load paths available
    - Failure of one main load carrying element will not result in total collapse
    - Example: Slab on multi-girder Bridges
  - Non redundant structure:
    - Structures that have single load path only
    - A single broken component can cause the collapse of the entire structure
    - Example: Truss or 2 girder bridges.
Case 1: Arch Bridge with Hidden Connection Detail

- The connection was hidden inside the arch member at the top and not visible for inspection.
- Failure occurred due to fractures in the hanger rods which connected the deck to the overhead arch, resulting in significant deformation in the deck.
Case 2: Slab Bridge with Halving Joint

- Conditions of halving joints for slab bridge is only visible at the soffit.
- Majority of the surface (i.e. interior face) not visible for inspection
Case 3: Non-Redundant Structure & Element
Case 4: Non-Redundant Structure & Element

- Collapse was found due to corroded steel pins
- Inadequate inspection / maintenance of the pin and hanger system was to blame
Case 5: Bridge with Uplift Reaction

- Bridges may have uplift reactions at the abutments when the end span is 60% or less of the main span(s) for bridges of 3 spans or more.
- If the dead load of the end spans are not large enough to counteract the uplift due to loading on the main span. Hold down device(s) are required
- Unequal spans for 2 span bridges can also cause uplift.
- In some cases the hold down device may not be visible for inspection.

Failure of hold down devices for resisting uplift
Case 6: Bridge with Hidden Primary Structural Members

- Total collapse due to inadequate inspection / maintenance for the heavily corroded hidden main structural members

Reference: Rail Accident Report, Derailment of a freight train near Stewarton, Ayrshire 27 January 2009, Report 02/2010 February 2010, Rail Accident Investigation Branch Department of Transport, UK
Managing Hidden Components

- Identity bridge with hidden components
- Understanding risk features
- Implementing a targeted inspection regime to inspect the hidden element regularly
- Evaluation and intervention
- Mitigation works
- Make use of NDT such as ultrasonic tests
- Revisit to assess change in condition. Condition of hidden details may change over time due to:
  - Condition degradation
  - Load changes
  - Changes in load path
Example of Managing Hidden Details

- 4 spans deck truss built in 1958
- Total length 208 m. Largest span 76 m with 38 m suspended span connected by pins
- Width of structure 15.4 m
Example of managing hidden details

- Pin arresting system added as part of major rehab
Risk Remediation Approaches

If unacceptable risk remains, remedial works are required. This may include:

- Inspect the structure more frequently
- Monitoring
- Load restrictions
- Further numerical assessment/evaluation
- Component replacement
- Alternative load path provision
- Strengthening
- Bridge replacement
Case Studies

**OBJECTIVE**

We will review five case studies and determine:

1. Is the bridge safe?
2. What is/are the critical defects?
3. What is the relevancy, severity, and urgency of the critical defects?
## Case Study #1

<table>
<thead>
<tr>
<th>Bridge Type</th>
<th>Timber-Concrete Composite Slab</th>
</tr>
</thead>
<tbody>
<tr>
<td>Span Arrangement</td>
<td>7-Span Continuous</td>
</tr>
<tr>
<td></td>
<td>47.5m Length (5.5m, 5 x 7.3m, 5.5m)</td>
</tr>
<tr>
<td>Cross Section</td>
<td>11.0m Overall Width</td>
</tr>
<tr>
<td></td>
<td>2 Travelled Lanes</td>
</tr>
<tr>
<td>Location</td>
<td>Northeast Ontario</td>
</tr>
<tr>
<td>Year Built</td>
<td>1975</td>
</tr>
<tr>
<td>Last Rehab</td>
<td>None</td>
</tr>
<tr>
<td>Current BCI</td>
<td>65.5</td>
</tr>
</tbody>
</table>
Case Study #1
Case Study #1
Case Study #1
Case Study #1

Critical defect is the severe sagging of the timber deck near the deck drain.

- Loss of composite action with concrete deck; strength is compromised
- Location is at one of the mid-span sections - maximum bending
- Bridge is potentially unsafe.
  - Defect is highly relevant, is very severe in nature, and is highly urgent to address
## Case Study #2

<table>
<thead>
<tr>
<th><strong>Bridge Type</strong></th>
<th>Half Through Truss (Pony)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Span Arrangement</strong></td>
<td>1-Span</td>
</tr>
<tr>
<td></td>
<td>37.0m Length</td>
</tr>
<tr>
<td><strong>Cross Section</strong></td>
<td>8.4m Overall Width</td>
</tr>
<tr>
<td></td>
<td>2 Travelled Lanes</td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td>Southwest Ontario</td>
</tr>
<tr>
<td><strong>Year Built</strong></td>
<td>1953</td>
</tr>
<tr>
<td><strong>Last Rehab</strong></td>
<td>2012 (Minor Rehab), 2009 (Gusset Plate Strengthening), 2003 (Minor Coating Rehab), 1992 (Major rehab)</td>
</tr>
<tr>
<td><strong>Current BCI</strong></td>
<td>66.0</td>
</tr>
</tbody>
</table>
Case Study #2
Case Study #2
Case Study #2

Critical defect is the severe delamination and separation of the abutment near the truss bearing

- Failure of this area could lead to partial or total collapse of the bridge
- Bridge is potentially unsafe.
  - Defect is highly relevant, is very severe in nature, and is highly urgent to address
# Case Study #3

<table>
<thead>
<tr>
<th><strong>Bridge Type</strong></th>
<th>Steel Plate I-Girder</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Span Arrangement</strong></td>
<td>3-Span Continuous</td>
</tr>
<tr>
<td></td>
<td>158.5m Length (39.6m, 79.3m, 39.6m)</td>
</tr>
<tr>
<td><strong>Cross Section</strong></td>
<td>10.0m Overall Width</td>
</tr>
<tr>
<td></td>
<td>2 Travelled Lanes</td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td>Northwest Region - Hwy 102</td>
</tr>
<tr>
<td><strong>Year Built</strong></td>
<td>1975</td>
</tr>
<tr>
<td><strong>Last Rehab</strong></td>
<td>2011 (Minor Rehab, new asphalt), 1998 (Major Rehab)</td>
</tr>
<tr>
<td><strong>Current BCI</strong></td>
<td>68.4</td>
</tr>
</tbody>
</table>
Case Study #3
Case Study #3

Critical defect is the very severe disintegration of the abutment near the girder bearing

- Failure of this area could lead to a localized displacement of the superstructure.
- Multiple girders provide redundancy
- Bridge is likely safe, but the defect should be addressed quickly
  - Defect is medium relevancy (due to redundancy), is very severe in nature, and is somewhat urgent to address
## Case Study #4

<table>
<thead>
<tr>
<th>Bridge Type</th>
<th>Rigid Frame, T-Beam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Span Arrangement</td>
<td>3-Span Continuous</td>
</tr>
<tr>
<td></td>
<td>57.0m Length (16.0m, 25.0m, 16.0m)</td>
</tr>
<tr>
<td>Cross Section</td>
<td>13.0m Overall Width</td>
</tr>
<tr>
<td></td>
<td>2 Travelled Lanes</td>
</tr>
<tr>
<td>Location</td>
<td>East Region - Hwy 28</td>
</tr>
<tr>
<td>Year Built</td>
<td>1953</td>
</tr>
<tr>
<td>Last Rehab</td>
<td>2005 (Major Rehab, incl. new overlay)</td>
</tr>
<tr>
<td>Current BCI</td>
<td>71.0</td>
</tr>
</tbody>
</table>
Case Study #4
Case Study #4
Case Study #4

Critical defect is the very severe wide longitudinal crack in the exterior girder

- Defect indicates distress in the girder.
- Cracking can accelerate rebar corrosion (moisture, chlorides, etc.)
- Multiple beams & monolithic slab provides redundancy
- Bridge is likely safe, but the defect should be addressed quickly
  - Defect is medium relevancy (due to redundancy), is very severe in nature, and is somewhat urgent to address
# Case Study #5

<table>
<thead>
<tr>
<th>Bridge Type</th>
<th>Suspension - Steel Arch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Span Arrangement</td>
<td>Single Span 109.6m Length</td>
</tr>
<tr>
<td>Cross Section</td>
<td>12.0m Overall Width 2 Travelled Lanes</td>
</tr>
<tr>
<td>Location</td>
<td>Northeast Region - Hwy 11</td>
</tr>
<tr>
<td>Year Built</td>
<td>1960</td>
</tr>
<tr>
<td>Last Rehab</td>
<td>1992 (Major Rehab) 2004 (Deck/Girder replacement due to failure of original hanger system)</td>
</tr>
<tr>
<td>Current BCI</td>
<td>82.5</td>
</tr>
</tbody>
</table>
Case Study #5
Case Study #5
Case Study #5

Critical defect is the very severe wide vertical cracks in the abutment

- These cracks indicate tension failure of the front face rebar
  - The abutment wants to “pull apart” due to the two concentrated bearing reactions
- Some redundancy in remainder of bars, but if abutment fails the entire bridge would likely collapse
- Bridge is likely safe in the short term, but the issue must be addressed as quickly as possible
  - Defect is medium to high relevancy (due to some redundancy), is very severe in nature, and is highly urgent to address
Summary
Summary

- The #1 goal of a bridge inspection is to assess **SAFETY**
- Spend time critically thinking about the cause and effect of defects
  - How relevant is this to safety?
  - How bad is this defect?
  - How urgently should this be addressed?
- Remember that some bridges have details that require special attention, or may be hidden.
- Filling out OSIM inspection forms and quantifying defects is secondary to assessing safety
- Immediately flag urgent inspection items to Owners
  - Don’t just note these items in the OSIM report - make a phone call or send an email
THANK YOU!