Use of NDT for Bridge Deck Evaluation

Victor Hong
Research Engineer, INDOT

September 17, 2013

Bridge Deck Investigation

- Is visual evaluation and chaining enough?
  - Maybe Yes, if we are looking for ......
    - Deck replacement and overlay projects ???
    - Majority agencies use visual and sounding as their primary tool for rehab projects.

- Probably not for asset management, maintenance and preservation .......
  - Better repair and rehab options
  - Better decision making process
Bridge Deck Evaluation

- Delamination survey
  - Infrared image, sounding, Impulse response
  - Spalled, patched, and delaminated area
- Corrosion activity survey
  - Half-cell, GPR, Salt (chloride) content, Carbonation depth
- Bridge deck concrete
  - Compressive strength, Permeability,
- Traffic volume info.
  - Average Daily Traffic (ADT) or Average Daily Truck Traffic (ADTT)

Bridge Deck Evaluation - Cont.

- Cracking
  - Longitudinal, Transverse, Location, and Extent and width
- NBI rating
  - Bridge deck, Wearing surface, and Deck underside
- Load rating
  - Load capacity
Delamination Investigation

- **Sounding - Chain Dragging or Hammer sounding**
  - Most common inspection method
  - Detects area has hollow sound
  - Chain dragging for general area and hammer sounding for the boundaries of delamination
  - The speed of sounding depends on the level of deterioration.

Limitations:
- Subjective results - operator's skill and hearing
- Sometimes, hollow sound is out of audible range detected by the human ear
Delamination Investigation

- **Infrared Thermography Analysis**
  - Measures temperature variation on the bridge deck
  - Delaminated area heats up faster and cools down more quickly compared to sound concrete.
  - Data collection is very fast and easy

Delamination Investigation

- **Infrared Thermography Analysis - Limitation**
  - Heavily weather-dependent
  - Works well up to 2 in deep flaw.
  - Sunlight is essential - no clouds, wind, and rain
  - Only a few hours of operation per day
Delamination Investigation

- Impulse Respond Analysis
  - Measures dynamic responds to a given impulse.
  - Evaluate the dynamic characteristics of structural elements (bridge deck, deep foundation, walls etc...)
  - Very similar to impact echo technique
  - Software calculates: void index, flexibility, mobility etc...

Delamination Investigation

- Impulse Respond Analysis: Limitations
  - Smaller defects might not detected.
  - Test results depends on selecting good test points
  - Equipment are very sensitive to use
  - Not suitable for long bridges
Corrosion Investigation

- **Half-Cell Potential Measurement**
  - This is a well known and widely used test method to evaluate the corrosion activities on the black rebar in the concrete deck.
  - Measures the potential differences between two metals as a voltage with an impedance voltmeter.

- **H-C: Limitation**
  - Works on black rebar – not epoxy covered bars.
  - Cover depth, moisture, or salt content might be an issue.
**Corrosion Investigation**

- **GPR**
  - Ground Penetrating Radar - electromagnetic wave
  - Send out high frequency wave and measures returned wave reflected by rebar
  - Can be used to determine cover depth, corrosion activities, delamination ....

**Corrosion Investigation**

- **GPR Limitation**
  - There is no standard analysis procedure
  - Moisture and salt contents influence
  - Analysis Time
  - GPR measurement is not definitive information regarding presence of corrosion, corrosion rate, or section loss.
**Salt Content Investigation**

- **Chloride Ion Profile Analysis**
  - Measures Chloride ion amount in the concrete deck
  - Concrete provides alkaline environment
  - Chloride ion is lowering the pH level of concrete due to HCl acid and break oxide film on the rebar surface.
  - Higher chloride ion concentration, higher chance of corrosion.

---

**Salt Content Investigation**

- **Chloride Ion Profile Analysis**
  - Chloride concentration to initiate the corrosion process - 1.4 kg/m^3
  - Chloride concentration to accelerate the corrosion process - 2.8 kg/m^3
Deck Condition Rating at INDOT

**NBI Deck Rating**

- **9 – Excellent Condition**: no spalls, delaminations, cracks
- **8 – 7 Good Condition**: Some minor to no problems
  - No spalls, delaminations, few transverse (insignificant) cracks, no leaking and corrosion from the bottom
- **6 – Satisfactory condition**: structural elements show some minor deterioration
  - Spalls and delamination up to 5%, map cracking up to 10%, Transverse cracking spacing at more than 5 ft
- **5 – Fair condition**: all primary structural elements are sound, but some may have minor section loss, cracking, spalling
  - Spalls and delamination up to 10%, map cracking up to 25%, Transverse cracking spacing at less than 5 ft. The underside of the deck has spalls with exposed rebars with up to 10% section loss.

- **4 – Poor Condition**: Advanced section loss, deterioration, spalling
  - (1) Longitudinal Cracks over majority of the deck. (2) Spalls and delamination up to 25%, (3) map cracking up to 50%, (4) underside has wet-looking areas. (5) full-depth failures are imminent. (6) significant efflorescence is present. (7) The underside of the deck has spalls with exposed rebars with up to 30% section loss.

- **3 – Serious Condition**: Loss of section, deterioration, spalling. Local failure are possible. Flexure and shear cracks may be present
  - (1) Full-depth failures are present. (2) Spalls and delamination more than 25%, (3) significant efflorescence is present. (4) underside has large wet-looking areas. (5) Significant exposed rebars with greater than 30 % section loss.
**Deck Condition Rating at INDOT**

- **NBI Deck Rating**
  - 2 – Critical Condition - Advanced deterioration of primary components is present. Unless closely monitored, it may be necessary to close the bridge until corrective action is taken.
  - 1 – Imminent Failure Condition: the bridge is closed to traffic

- NBI rating is based on the crack spacing and distress (patches, delamination, and potholes)

**Decision Matrix (needs more work...)**

- **How can we use the test data in decision making process?**
  - NBI rating is 7 or greater - no testing
  - NBI rating is 6 or less
    - Start with Infrared image
      - Less than 10% distress - maintenance
      - More than 10% distress - more testing
    - Testing for corrosion activities and salt content
      - Based on test results - maintenance work or overlay or rehab
Use of NDT for Bridge Deck Evaluation

**Decision Matrix (needs more work..)**

**Partial or full depth patch and deck sealers**
- Distress + Half-cell (or GPR) < 15%
- Chloride ion concentration is less than 1.4 kg/m³

**Deck Overlay**
- 15% < Distress + half-cell (or GPR) < 50%
- Chloride ion concentration is less than 2.8 kg/m³

**Do nothing and use it for remained life. Then do Structural rehabilitation**
- Distress + half-cell (or GPR) > 50%
- Chloride ion concentration is more than 2.8 kg/m³

**Questions?**