Foundation Reuse for Highway Bridges

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Foundation Reuse Definition

• Foundation Reuse:
  – Using existing foundation of a bridge, as whole or in part, when the existing foundation has been evaluated for the new loads.

• Foundation reuse includes substructure reuse.

• Common applications:
  – bridge replacement
  – bridge widening
  – bridge repurposing (local to state highway)
Current State of Foundation Reuse

- Foundation reuse is not a new idea
- **Foundations reused regularly for Buildings**
- **Foundations of Bridges** have been reused in U.S.
  - Illinois DOT: Bridge Condition Report Procedures and Practices
  - Maine DOT: Bridge Design Guide - Chapter 10
  - Massachusetts DOT: LRFD Bridge Manual
- Necessity for filling the gaps and organizing the current practices:
  - North Carolina DOT
  - 2013 FHWA Workshop under Foundation Characterization Program
  - NCHRP Synthesis 505: Current Practices and Guidelines for the Reuse of Bridge Foundations
Preliminary Work

FHWA 2013 Workshop Report

TRB 2014 Workshop TechBrief

FHWA Report

- **Chapter 1** - Introduction to Foundation Reuse
- **Chapter 2** - Reuse Decision Model
- **Chapter 3** - Preliminary Desk Study
- **Chapter 4** - Integrity Assessment
- **Chapter 5** - Durability and Remaining Service Life
- **Chapter 6** - Load Carrying Capacity
- **Chapter 7** - Innovative Material and Foundation Enhancement
- **Chapter 8** - Design of New Foundations for Reuse
Chapter 1. Introduction to Foundation Reuse and Case Studies

Foundation Reconstruction Option – Replace Foundation

New Adjacent to Existing

New In-place

© JB Simpson/www.lakeexpo.com
Hurricane Deck Bridge, Lake of the Ozarks, MO

Source: MassDOT
Bridge B-23-005-M-18-002, Bridgewater, MA
Foundation Reconstruction Option – Reuse Foundation

Complete Reuse

Reuse Strengthen/Enhance

Source: URS Corporation

ABC/PBES on I95 in Virginia

©Michael Baker Int.

Milton-Madison Bridge
Chapter 1. Introduction to Foundation Reuse and Case Studies

- **Economical**
  - Reconstruction / Demolition Cost Savings
  - Right of way (ROW)
  - Utility coordination
  - User cost

- **Environmental**
  - Environmental permitting /NEPA
  - Waste disposals
  - Air quality emission

- **Social**
  - Impacts on mobility
  - Traffic management and traffic noise
  - Community impact
  - Work zone safety
  - Cultural preservation and archeology

Source: www.sustainablehighways.org
DOT Responses for Motivation

Responses from NCHRP 505 (Boeckman and Loehr, 2017)
Chapter 2. Reuse Decision Model and Risk/Cost Analysis
Chapter 3. Preliminary Desk Study

• Confirming Primary Details
  – Design Plans
  – Installation Records
  – Soil Exploration
  – Installed Pile/Drilled Shaft Length

• Assessing Past Foundation Performance
  – Inspection Records
  – Routine Inspection Data
  – Damage Inspections
  – Underwater Inspections
Chapter 4. Structural Integrity and Condition Assessment

- What are the material properties of the existing elements?
- Has deterioration reduced the current capacity of the foundation?
- Has the foundation been damaged in any way?
- Are there changes to soil system or stability issues?
Chapter 4. Structural Integrity and Condition Assessment

Integrity Assessment

- Timber Elements
  - Material Properties
  - Internal Decay
  - Marine Borers
  - Preservative Condition
  - Damage
  - Connection Deterioration

- Masonary Elements
  - Block Deterioration
  - Joint Deterioration
  - Erosion
  - Voids

- Steel Elements
  - Material Properties
  - Corrosion
  - Damage
  - Galvanic Corrosion
  - Fatigue Cracking

- Concrete Elements
  - Initial Design
  - Construction Defects
  - Concrete Degradation
  - Cracking

- Geotechnical Issues
  - Scour
  - Foundation Movement
  - Soil / Rock Conditions

Material Properties
Block Deterioration
Joint Deterioration
Erosion
Voids
Corrosion
Damage
Galvanic Corrosion
Fatigue Cracking
Initial Design
Construction Defects
Concrete Degradation
Cracking
Scour
Foundation Movement
Soil / Rock Conditions
Chapter 4. Structural Integrity Assessment

• Available Methods
  – Visual/Physical Inspection
  – Sample Testing
  – Coring and Logging
  – NDT/NDE

<table>
<thead>
<tr>
<th>NDT Method</th>
<th>Issues Investigated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultrasonic Pulse Velocity and Impact Echo</td>
<td>Location of voids, weak zones, honeycombing, and cracks</td>
</tr>
<tr>
<td>Ground Penetrating Radar</td>
<td>Rebar layout, voids, cover depth</td>
</tr>
<tr>
<td>Electrical Resistivity (ER)</td>
<td>Presence of water, chlorides, and salts</td>
</tr>
<tr>
<td>Half Cell Potential</td>
<td>Potential for Corrosion</td>
</tr>
<tr>
<td>Sonic Echo/ Impulse Response</td>
<td>Defects, voids, element bottom</td>
</tr>
<tr>
<td>Ultraseismic</td>
<td>Defects, voids, element bottom</td>
</tr>
<tr>
<td>Parallel Seismic</td>
<td>Defects, element bottom</td>
</tr>
<tr>
<td>Wireline Logging</td>
<td>Element bottom</td>
</tr>
<tr>
<td>Crosshole Tomography</td>
<td>Volumetric Imaging</td>
</tr>
</tbody>
</table>
Corehole Logging

Geophysical Wireline Logging Methods

1. **Mapping Cracks** – Optical/Acoustic Televiewer
2. **Elastic Properties** – Full waveform Sonic (FWS), Focused density
3. **Material Properties** – Gamma/Spectral gamma, thermal neutron
4. **Corrosion** – Resistivity, Dual Induction, Magnetic susceptibility
5. **Structural Integrity** – Downhole seismic, full waveform sonic, gamma-density.
Corehole Logging

Willow Valley Bridge, Pier2-RT-B2

- Depth
- Density
- OBI Image-Corr
- Oriented Mag North
- Caliper
- Description

Willow Valley Bridge, Abut1-LT-B5

- Depth
- OBI Image-Corr
- Oriented Mag North
- Caliper
- Description
Corehole Logging

Pier 1 B1
Physical Properties
(Elastic Moduli) Logs
Cross-Corehole Tomography
3-D Geophysical (Seismic) Survey – Site Characterization
Chapter 5. Durability and Remaining Service Life

• How much remaining service life does the foundation have?
• Will the advanced age of the reused components increase life cycle costs?
Chapter 5. Durability and Remaining Service Life

Preliminary Evaluation

<table>
<thead>
<tr>
<th>Evaluation Procedure</th>
<th>Reason/Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Records Review</td>
<td>Review of past inspection allows for assessment of the time history of bridge performance.</td>
</tr>
<tr>
<td>Env. Conditions</td>
<td>Dictate the types of deterioration expected. Include exposure to deicing salt / salt water, fresh water, contaminated soil; water, humidity, stray currents, or freeze/thaw conditions.</td>
</tr>
</tbody>
</table>

Field Measurements and Testing (concrete, steel, timber masonry)

<table>
<thead>
<tr>
<th>Available Testing</th>
<th>Issue identified during preliminary evaluation</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cover Measurement</td>
<td>Corrosion, chloride exposure, carbonation</td>
<td>Cover thickness important for other durability issues.</td>
</tr>
<tr>
<td>Chloride Testing</td>
<td>Exposure to chlorides</td>
<td>Chloride diffusion into cover concrete. Initial testing limited to surface samples.</td>
</tr>
<tr>
<td>pH testing</td>
<td>Carbonation</td>
<td>Depth of carbonation penetration.</td>
</tr>
<tr>
<td>Half-cell potentials</td>
<td>Active corrosion</td>
<td>Half-cell potential testing in areas of suspected corrosion.</td>
</tr>
<tr>
<td>Electrical Resistivity</td>
<td>Potential for corrosion</td>
<td>Finding areas of / susceptible to corrosion.</td>
</tr>
</tbody>
</table>
Ground Penetrating Radar

• Electromagnetic evaluation of concrete
  – Reinforcement layout
    • Location of embedded metals
  – Cover Depth
  – Qualitative condition of reinforced concrete
    • Chlorides, moisture, and concrete deterioration attenuate GPR signal
Corrosion Potential Measurements

- Corrosion potential, also known as half-cell potential
  - ASTM C876
    - Measures the potential difference between the steel reinforcement and a reference electrode to identify the probably of active corrosion.
Physical Condition

- % of physical damage
  - What needs to be repaired now?
- Extent of corrosion and other internal deterioration processes
  - What will become physical damage over the next 10 years?
Electrochemical Chloride Extraction

Current paths

Temporary Anode
Conductive Media

DC Power Source

Concrete

Reinforcement

OH⁻
Chapter 6. Load Carrying Capacity

- What are the new loads on the foundation?
- What are the material properties?
- How has capacity been affected by age? (from integrity assessment)?
- How will capacity be affected by projected changes (from durability assessment)?
- How have codes affected capacity assessment?
- What is the capacity for an existing deep foundation?
- What is the capacity of shallow foundations?
Loading on Reused Foundations

- Dead loads to remain after reuse
- Dead loads to be removed
- Replacement dead loads
- Future live loads
Capacity of Driven Piles

• 5 Categories of reuse:
  – Capacity taken from design drawings & test data
    • Resistance factor of 0.75 for static tests (can be lowered to account for uncertainties)
  – Capacity taken from design drawings without test data
    • Resistance factors for design equations range from 0.25 to 0.45
    • Cone penetrometer test (CPT)-based method allows for factor of 0.50
    • Capacity can be determined from wave equations if hammer energy and pile driving logs available
  – Capacity taken from proof load testing
  – Capacity taken from individual pile testing
  – Capacity based on past loading history
Proof Testing Driven Piles

- Loads pile group simultaneously
- Individual pile capacity can be found by assuming in-site variation of pile capacity
- The capacity of the foundation after reuse can be determined considering possible changes to dead loading
Individual Testing of Driven Timber Piles

• Excavate pile cap and remove portion of pile
• Place hydraulic jack, test frame and test according to normal criterion
• Repair old pile with concrete section and rebar

(Photos courtesy of Maine DOT)
Chapter 7. Innovative Material and Foundation Repair and Strengthening

• Strengthening and Repair of Structural Elements
  – Concrete Elements
  – Steel Elements
  – Timber Elements
  – Masonry Structures

• Dead Load Reduction
  – Innovative Materials (FRP decks panels, lightweight concrete, Geofoam/ lightweight fill)

• Addition of Geotechnical Elements

• Ground Improvement
Foundation Strengthening & Enhancement

- Technologies Can be employed while superstructure is in-use
- Encasement
- Doweling
- Micropiles
- Cover Replacement
- Chloride extraction
Micropiles

- Micropiles produce very low vibrations and disturbance to surrounding soil
- Often drilled directly through existing foundation
- Can sometimes be drilled directly from bridge deck
Other Innovative Materials

- Lightweight concrete
- FRP deck panels
- Superstructure changes
- Lighter deck may cost more on its own, but reduction in time/costs associated with reuse may outweigh costs

FRP Bridge deck system

© 2007 West Virginia University
Chapter 8. Design of New Foundations for Future Reuse

- Design Considerations
  - Geometry
  - Substructure Selection
  - Footings
  - Deep Foundations
  - Installation of Sensors into Foundation Elements

- Monitoring
  - Integrity Monitoring
  - Durability Monitoring
  - Capacity Monitoring
## ABC CASE EXAMPLES

### Massachusetts DOT 93Fast14

<table>
<thead>
<tr>
<th>Bridge Name</th>
<th>Substructure Placement</th>
<th>Issue/Work</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-80 Bridge over Dingle Ridge Road, NY</td>
<td>SIBC 1</td>
<td>New abutments on drilled shafts added in front of existing abutments on shallow footing</td>
<td></td>
</tr>
<tr>
<td>I-215/4500 South Bridge, UT</td>
<td>SPMT 2</td>
<td>Abutments replaced in front of existing abutments, new deck (with lightweight concrete) placed on abutments over a weekend. Eliminate 3 center piers: 4-span bridge replaced with single span.</td>
<td></td>
</tr>
<tr>
<td>Well Road Bridge, LA</td>
<td>SPMT 4</td>
<td>Existing substructure strengthened by adding concrete footing between existing concrete drilled shafts. Abutments were widened using additional drilled shafts</td>
<td></td>
</tr>
<tr>
<td>I-44 Bridge over Gasconade River, MO</td>
<td>SIBC 3</td>
<td>Existing substructure repaired and reused. Temporary substructure built to hold bridge before slide</td>
<td></td>
</tr>
<tr>
<td>Route 4 over Ottauquechee River, VT</td>
<td>CHLE 4</td>
<td>Existing substructure encased while in service. Old bridge removed and replaced with new prefabricated elements.</td>
<td></td>
</tr>
<tr>
<td>Cedar Street Bridge, MA</td>
<td>SPMT 3</td>
<td>Full substructure reuse following capacity analysis from driving logs without test data</td>
<td></td>
</tr>
</tbody>
</table>

### I-95 Richmond Corridor, VA

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<thead>
<tr>
<th>Bridge Name</th>
<th>Substructure Placement</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-95 Richmond Corridor, VA</td>
<td>CHLE 3/4</td>
<td>11 bridges replaced with full substructure reuse. 9 bridges installed with cathodic protection, 1 with ECE, 1 with ECE and cathodic protection</td>
</tr>
<tr>
<td>Fast-14 replacement project, MA</td>
<td>CHLE 3</td>
<td>14 bridges replaced on original substructures with minimal repairs</td>
</tr>
</tbody>
</table>

Source: Pete Connors, MassDOT
- FIU Project DB
- FIU In-depth Web Training

Source: URS Corporation
- FIU Project DB
Milton-Madison Bridge, IN & KY

- Slide-in-place construction
- Complete encasement of existing piers
- Lengthening of span to remove piers
  - Removed two piers with most chloride damage
- Doweling of caissons

©2015 Michael Baker International

- FIU Milton Madison Bridge Reuse Webinar
- FIU Milton Madison In-Depth Web Training
- FIU ABC Project Database
In-Depth Inspection of the Pier Face
Lift line with Concrete Deterioration Leading to Exposed Rebar
Coring Through the Deck and Pier Face
Mobility Survey Examples from Impulse Response Test

1 PIER 5 NORTH FACE MOBILITY

1 PIER 8 SOUTH FACE MOBILITY

Courtesy CTL Group
Coring and Insertion of Reinforcement from Inside of Coffer Dam

Courtesy Michael Baker International
Pier Strengthening

1. Drill holes into ex. caisson
2. Grout Rebar into Caisson
3. Add Stem Reinforcement
4. 2’ thick encapsulation
5. Pier Cap Reinforcement
6. Cast new Pier cap
7. Scour Countermeasure

Courtesy: Michael Baker International
Publications

FHWA Publications

Magazine Articles

Public Roads; Nov/Dec 2015

Reusing Bridge Foundations

by Frank Jalinoo

Some owners are building on existing elements when widening and replacing structures. Here is how the strategy can help expedite construction and sustainability needs.

The Indiana Department of Transportation and the Kentucky Transportation Cabinet used accelerated construction and a prefabricated bridge system to replace the Milton-Madison Bridge between Milton, KY, and Madison, W. Crews reused and strengthened the existing foundation, and then replaced the superstructure with a preassembled steel truss.
Download the Report

Google Search:

FHWA Foundation Reuse
1st entry PDF file
(March 14, 2019)
Thanks!!!

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