Florida Department of Transportation’s Approach to Investigating and Resolving Unknown Foundations

Southeast Bridge Preservation Partnership Annual Meeting

Orlando, Florida
April 27, 2010
Unknown Foundation Background

Early 1990’s the FHWA required all states to evaluate all bridges over water for scour susceptibility.

January 2008, Florida resolved all their bridges over water except for a number of Tidal, Scour Susceptible, and bridges with Unknown Foundations.

Florida committed to resolve all Remaining Tidal, Scour Susceptible bridges and bridges with Unknown Foundations on the interstate system by November, 2008.

FHWA issued a letter dated January 9, 2008 with a target date of November, 2010 to resolve all bridges with Unknown Foundations.

Unknown foundation inventory generally involves bridges built before 1985.
<table>
<thead>
<tr>
<th>On Federal Aid</th>
<th>Off Federal Aid</th>
<th>Off Federal Aid</th>
<th>On State System</th>
<th>Off State System</th>
<th>Grand Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>297</td>
<td>740</td>
<td>1037</td>
<td>2</td>
<td>1503</td>
<td>1505</td>
</tr>
</tbody>
</table>
Due to the “unknown” nature of the work FDOT decided to sequence the project into three phases.

1. Conduct Workshop to develop a Pilot Program.

2. Implement a Pilot Program evaluating the bridges in two counties (Collier and Alachua) to clarify and finalize the best procedure to address the remainder of the bridges, and also to secure the approval of the FHWA prior to statewide implementation.

3. Using the procedure in the Pilot Program initiate the Statewide Production Phase to address the remainder of the bridges.

Currently, FDOT has completed the Pilot Program Phase and has begun the Production Phase.
Florida Bridges
Famous Florida Bridges
Infamous Florida Bridges
Unknown Foundation Bridges
## Unknown Foundations

<table>
<thead>
<tr>
<th>Road Type</th>
<th>Rural</th>
<th>Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principal Arterial – Interstate</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Principal Arterial - Other Freeways or Expressways</td>
<td>NA</td>
<td>32</td>
</tr>
<tr>
<td>Principal Arterial – Other</td>
<td>106</td>
<td>84</td>
</tr>
<tr>
<td>Minor Arterial</td>
<td>112</td>
<td>163</td>
</tr>
<tr>
<td>Major Collector</td>
<td>218</td>
<td>NA</td>
</tr>
<tr>
<td>Minor Collector</td>
<td>193</td>
<td>NA</td>
</tr>
<tr>
<td>Collector</td>
<td>NA</td>
<td>316</td>
</tr>
<tr>
<td>Local</td>
<td>841</td>
<td>449</td>
</tr>
</tbody>
</table>

- 51% on Local Roads
- Only 9% on Principal Arterials
Unknown Foundations

- **Bridge Length**
  - 5% are 25’ or less
  - 34% are 50’ or less
  - 66% are 100’ or less

- **Traffic**
  - 14% have 50 or less ADT
  - 25% have 100 or less ADT
  - 39% have 500 or less ADT
Unknown Foundations Process

**Step 1:**
- Collect Data
  - Bridge Inspection Reports
  - Scour Evaluation Reports
  - Plans
  - Pile Driving Records
  - Other Data

**Step 2:**
- Do the Plans contain a Pile Data Table with Scour Criteria?
  - Yes: Recode item 113 for the bridge
  - No: Proceed to Step 3

**Step 3:**
- Are the in-situ foundation dimensions shown in data collected?
  - Yes: Use the foundation dimensions to complete the Scour Evaluation Process & recode item 113
  - No: Proceed to Step 4.1

**Step 4.1:**
- Calculate the Annual and Lifetime Risks of Scour Failure
  - Yes: Is the Bridge a High Priority Bridge?
    - No: Proceed to Step 4.2
    - Yes: Proceed to Step 4.3
  - No: Proceed to Step 4.5

**Step 4.2:**
- Calculate the Minimum Performance Level?
  - Yes: Prepare a Closure Plan as part of the POA
  - No: Proceed to Step 4.3

**Step 4.3:**
- Is Lifetime Risk < $15,000?
  - Yes: Prepare a Closure Plan as part of the POA
  - No: Proceed to Step 4.5

**Step 4.4:**
- Is Lifetime Risk > $100,000?
  - Yes: Reclassify the bridge and recode item 113
  - No: Proceed to Step 4.5

**Step 4.5:**
- Is a Phase 2 Scour Evaluation needed?
  - Yes: Complete the Phase 2 Scour Evaluation
  - No: Proceed to Step 6.2

**Step 6.1 & 6.2:**
- Use the Estimated Pile Embedment and re-evaluate the Phase 1 Scour Evaluation
  - Yes: Reclassify the bridge and recode item 113
  - No: Proceed to Step 6.3

**Step 6.3:**
- Complete the Phase 2 Scour Evaluation
  - Yes: Prepare a Closure Plan as part of the POA
  - No: Proceed to Step 6.4

**Step 6.4:**
- Are SPT borings available?
  - Yes: Obtain SPT borings
  - No: Proceed to Step 6.7

**Step 6.5:**
- Is Automated Monitoring (AM) provisionally warranted?
  - Yes: Prepare a Closure Plan as part of the POA
  - No: Proceed to Step 6.7

**Step 6.6:**
- Is the bridge High Priority or does bridge not meet MPL or is the Lifetime Risk > $100,000?
  - Yes: Perform the Phase 4 Scour Evaluation and assess various countermeasure options
  - No: Proceed to Step 6.7

**Step 6.7:**
- Prepare a Closure Plan as part of the POA

**Step 6.8:**
- Are countermeasures warranted?
  - Yes: Prepare and install an AM Plan and a Closure Plan as part of the POA
  - No: Proceed to Step 6.9

**Step 6.9:**
- Use NDT results to complete the Scour Evaluation Process

* See Procedural Manual: Reclassify Unknown Foundation Bridges for a description of these steps and procedures.
Unknown Foundations Process

Data Gathering

Risk Assessment

Embedment Prediction

Phase 2 and 3 Scour Evaluations

Phase 4 Scour Evaluation

*See Procedural Manual Reclassify Unknown Foundation Bridges for a description of these steps and procedures.*
Risk Calculation

• Follows the Procedure in NCHRP Web Only Document 107
  – Cost of failure
  – Probability of failure
  – Risk of failure

• Basic Equation:

  Risk = Cost of Failure  \times  Probability of Failure
Modifications to NCHRP Process

• Florida Costs
  – Including duration of detour

• Rate of Failure due to Scour
  – Florida Failure Rate
  – Correction for Scour Vulnerability of 5

• Tidal Bridges
Cost of Failure

- Component Costs are:
  - Bridge replacement cost
  - Detour cost
  - Loss of life

- NBI data used to calculate
  - Bridge Length
  - Bridge Width
  - Maximum Span Length
  - Average Daily Traffic
  - Average Daily Truck Traffic (% of ADT)
  - Detour Length
Probability of Failure

• National Failure Rate:
  Approximately 1 in 5000 annually

• Florida Failure Rate based on survey
  Approximately 1 in 13,500 annually

• Florida Failure Rate based on procedure
  Approximately 1 in 8,000 annually
## Annual Probability of Failure

<table>
<thead>
<tr>
<th>Scour Vulnerability</th>
<th>Overtopping Frequency / Scour Event Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Remote (R)</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0.01</td>
</tr>
<tr>
<td>2</td>
<td>0.005</td>
</tr>
<tr>
<td>3</td>
<td>0.0011</td>
</tr>
<tr>
<td>4</td>
<td>0.0004</td>
</tr>
<tr>
<td>5</td>
<td>0.00018</td>
</tr>
<tr>
<td>6</td>
<td>0.000077</td>
</tr>
<tr>
<td>7</td>
<td>0.000077</td>
</tr>
<tr>
<td>8</td>
<td>0.0000017</td>
</tr>
<tr>
<td>9</td>
<td>0.0000011</td>
</tr>
</tbody>
</table>
Annual Probability of Failure

![Graph showing annual probability of failure versus scour vulnerability. The graph compares different scenarios such as NCHRP Doc. 107 Remote (R), NCHRP Doc. 107 Slight (S), NCHRP Doc. 107 Occasional (O), and Proposed Remote (R), Proposed Slight (S), Proposed Occasional (O), proposing Remote (R), Proposed Slight (S), Proposed Occasional (O), Proposed Frequent (F).]
Risk Thresholds

• Lifetime Risk < $15,000
  – The minimum cost to provide any kind of protection at a bridge is at least $15,000.
  – Prepare a Plan of Action that includes a Closure Plan for the bridge.

• Lifetime Risk > $100,000
  – Do not estimate embedment depths with the techniques in Step 5
  – Recommend either Countermeasures or Non Destructive Testing
Unknown Foundations Process

Data Gathering

Risk Assessment

Embedment Prediction

Phase 2 and 3 Scour Evaluations

Phase 4 Scour Evaluation
Embedment Predictions

• Two methods:
  – Artificial Neural Network (ANN)
  – Geotechnical Analysis

• Design Pile Load
  – Plan Value
  – ANN
  – Reverse Engineering
Artificial Neural Networks

- Computational Tool That Mimics Pattern Recognition Capabilities of Human Brain
- Concept Initiated in 1943 by McCulloch and Pitts
- Used in Many Fields Including:
  - Engineering
  - Science
  - Business
Artificial Neural Networks

- **How They Work**
  - Like the brain, the ANN has to be trained
    - Requires cases where the answers are known
      (for this application must have number of bridges with known foundations)
    - Resulting program can be tested
      - Known foundation data set divided, 80% for training, 20% for testing/verification
• Properties:
  – Trained using 113 bridges from four FDOT districts
  – Embedments deeper than 70 ft are capped at 70 ft
  – Minimum embedment depth is 10 ft
  – Requires bridge and boring information
  – Outputs minimum embedment per bridge and per bent
CPILE ANN Input Parameters

- Pile size
- Pile Design Load
- Slope of the bearing capacity curve between 0 and 20 ft
- Slope of the bearing capacity curve between 20 and 40 ft
- Pile construction year
CPILE Testing Per Bridge

Min Embed. per Bridge (ft), 0.7*ANN

Predicted

Measured
Geotechnical Considerations

• Geotechnical Aspects
  – Collect and Review Existing Bridge Foundation Data
  – Analyze the Existing Soils Information
    • SPT Boring Data
  • Wash Borings
  • No Boring Data
Geotechnical Considerations

• Analyze the Existing Data
  – SPT Data
    • Run FB-Deep on soils borings (adjust for boring location)
    • Use the “Allowable Capacity” curve unless LRFD was used in design, then the “Davisson Capacity” curve would be used.
    • Was hard rock/cap rock encountered?
    • Determine Estimated Pile Penetration
    • Take the Estimated Pile Penetration and multiply it by 0.8
  – Wash Borings

• No Data
Geotechnical Considerations

570081 - 18 inch Piles

Estimated Capacity (tons)

Depth (feet)

B-1
B-2
Comparison of Methods

- Geotech (0.8)
- ANN (0.7)
- Hybrid (1.0)
NDT

• Data gathering
  – Literature search
  – Survey of States using NDTs
  – Survey of experts in the field

• Guidance on selecting the best NDT

• Guidance on estimating the cost of NDT
Summary of Process

• Perform Risk Analysis
  – Low risk, finished
  – High risk, NDT and/or countermeasures
  – Medium Risk
    • Analyze bridge
Summary of Process

• Analyze bridge
  – Determine pile load
    • Use plan values, PLOAD, or Reverse Engineering
  – If concrete piles, use CPILE and Geotechnical Analysis
  – If steel or timber, use Geotechnical Analysis
  – Perform Scour Evaluation
Summary

• A risk assessment is a cost effective way to prioritize unknown foundation evaluations
• Reasonably conservative pile embedment estimates can be made and used to evaluate the scour susceptibility of a bridge

Questions?