Appendix A
Bridge Deck Section Images
Figure A1. Bridge deck R13, fabricated at the FHWA NDE Validation Center.

Figure A2. Bridge deck R12, fabricated at the FHWA NDE Validation Center.
Figure A3. Bridge deck R11 from Utah.

Figure A4. Bridge deck R10 from Utah.
Figure A5. Bridge Deck R9, from North Carolina.

Figure A6. Bridge Deck R8, from North Carolina.
Figure A7. Bridge deck R7, from North Carolina.

Figure A8. Bridge deck R6, from Washington, DC.
Figure A9. Bridge deck R5, from Washington DC.

Figure A10. Bridge deck R4, from Washington, DC.
Figure A11. Bridge deck R3, from Washington, DC.

Figure A12. Bridge deck R2, from Washington, DC.
Appendix B
Chain Drag Test Results
Comments: The response at 320cm length 90cm width was significantly less noticeable than the other three, which were clearly distinguishable.

Shallow Response - High frequency response indicative of near surface distress.
Deep Response - Low frequency response indicative of distress significantly below the surface.

*Figure B1. Chain drag results from bridge deck R13.*
Comments: All three responses were due to significant changes in the chain drag sound.

Shallow Response - High frequency response indicative of near surface distress.
Deep Response - Low frequency response indicative of distress significantly below the surface.

Figure B2. Chain drag results from bridge deck R12.
Comments: A strong response was heard in the indicated location.

Shallow Response - High frequency response indicative of near surface distress.  
Deep Response - Low frequency response indicative of distress significantly below the surface.

*Figure B3. Chain drag results from bridge deck R11.*
Comments: No response was observed.

Shallow Response - High frequency response indicative of near surface distress.
Deep Response - Low frequency response indicative of distress significantly below the surface.

Figure B4. Chain drag results from bridge deck R10.
Shallow Response - High frequency response indicative of near surface distress.
Deep Response - Low frequency response indicative of distress significantly below the surface.

Comments: One deep response was present, but was difficult to detect. Only a small change in sound was heard in the area of the deep response.

*Figure B5. Chain drag results from bridge deck R9.*
Comments: No responses were observed.

Shallow Response - High frequency response indicative of near surface distress.
Deep Response - Low frequency response indicative of distress significantly below the surface.

Figure B6. Chain drag results from bridge deck R8.
Comments: No response was observed.

Shallow Response - High frequency response indicative of near surface distress.
Deep Response - Low frequency response indicative of distress significantly below the surface.

Figure B7. Chain drag results from bridge deck R7.
Appendix C
FHWA Concrete Bridge Deck Sections
Figure C1. Plan view of bridge deck R13 design with simulated distress and mean reinforcing steel cover depths.
Figure C2. Plan view of bridge deck R12 design with mean reinforcing steel cover depths.
Figure C3. Plan view of bridge deck R11 with delamination cracking and mean reinforcing steel cover depths
Figure C4. Plan view of bridge deck R10 with delamination cracking and mean reinforcing steel cover depths.
Figure C5. Plan view of bridge deck R9 with mean reinforcing steel cover depths.
Figure C6. Plan view of bridge deck R8 with mean reinforcing steel cover depths.
Figure C7. Plan view of bridge deck R7 with concrete cracking and mean reinforcing steel cover depths.
Figure C8. Plan view of bridge deck R6 with concrete cracking and mean reinforcing steel cover depths.
Figure C9. Plan view of bridge deck R5 with concrete cracking and mean reinforcing steel cover depths.
Figure C10. Plan view of bridge deck R4 with concrete cracking and mean reinforcing steel cover depths.
Figure C11. Plan view of bridge deck R3 with concrete cracking and mean reinforcing steel cover depths.
Figure C12. Plan view of bridge deck R2 with concrete cracking and mean reinforcing steel cover depths.
Appendix D
Error Calculations
Error calculations are presented in this appendix for three measurement techniques used to determine mean concrete cover depth. These calculations present the method for determining error bounds at 1 $\sigma$. Each measurement type is indicated with a heading in bold.

**Measurement with a ruler:**

Error contributions

Error due to the precision of the ruler (measurements were made to the nearest $\frac{1}{4}$ inch or 0.6 cm).

$\sigma_r = 0.6$ cm

Error due to cover depth variation within a deck section.

$\sigma_{cv} =$ varies for each field bridge deck section (calculated using the standard deviation of cover depths measured at each piece of reinforcing steel that is visible at the specimen edge).

$\sigma_d = 0.6$ cm for fabricated deck sections.

Therefore, for field extracted deck sections:

$\sigma_{\text{ruler}} = (\sigma_r^2 + \sigma_{cv}^2)^{1/2}$

and for fabricated deck sections:

$\sigma_{\text{ruler}} = (\sigma_r^2 + \sigma_d^2)^{1/2}$

Example for bridge deck R7:

$\sigma_{\text{ruler}} = ((0.6)^2 + (0.32)^2)^{1/2}$

$\sigma_{\text{ruler}} = 0.7$ cm

**Measurement based on expert evaluation of data:**

Human error (based on possible interpretations by an expert).

$\sigma_h = 0.6$ cm
Error based on radar precision (layer thickness of reconstructed data).
\[ \sigma_r = 0.1 \text{ cm} \]

Error based on rail and cart fixture position.
\[ \sigma_c = 0.5 \text{ cm} \]

Error due to cover depth variation within a deck section.
\[ \sigma_{cv} \text{ varies for each field bridge deck section (calculated using the standard deviation of cover depths measured at each piece of reinforcing steel that is visible at the specimen edge).} \]
\[ \sigma_d = 0.6 \text{ cm for fabricated deck sections.} \]

Error due to estimate of dielectric properties (using a range of \( \varepsilon = 4.5 \) to \( \varepsilon = 6 \) for concrete).
\[ \sigma_{est} = 7\% \text{ of the measured cover depth.} \]

For field extracted deck sections:
\[ \sigma_{expert} = \left( \sigma_h^2 + \sigma_r^2 + \sigma_c^2 + \sigma_{cv}^2 + \sigma_{est}^2 \right)^{1/2} \]

For fabricated deck sections:
\[ \sigma_{expert} = \left( \sigma_h^2 + \sigma_r^2 + \sigma_c^2 + \sigma_d^2 + \sigma_{est}^2 \right)^{1/2} \]

Example for bridge deck R7:
\[ \sigma_{expert} = \left( (0.6)^2 + (0.1)^2 + (0.5)^2 + (0.3)^2 + (0.3)^2 \right)^{1/2} \]
\[ \sigma_{expert} = 0.9 \text{ cm} \]

Measurement based on algorithm evaluation of data:

Error due to repeatability (based on 5 individual scans of the same deck analyzed using the pattern recognition algorithm):
\[ \sigma_{rep} = 0.6 \text{ cm} \]

Error due to radar precision (layer thickness of reconstructed data):
\[ \sigma_{pr} = 0.1 \text{ cm} \]
Error based on rail and cart fixture position:

\[ \sigma_{r} = 0.5 \text{ cm} \]

Error based on cover depth variation within a deck section:

\[ \sigma_{cv} \text{ varies for each field bridge deck section (calculated using the standard deviation of cover depths measured at each piece of reinforcing steel that is visible at the specimen edge).} \]

\[ \sigma_{d} = 0.6 \text{ cm for fabricated deck sections.} \]

Error due to estimate of dielectric properties (using a range of \( \varepsilon = 4.5 \) to \( \varepsilon = 6 \) for concrete).

\[ \sigma_{est} = 7\% \text{ of the measured cover depth.} \]

For field extracted deck sections:

\[ \sigma_{alg} = \left( (\sigma_{rep})^2 + (\alpha_t)^2 + (\alpha_{cv})^2 + (\alpha_{sl})^2 + (\sigma_{est})^2 \right)^{1/2} \]

For fabricated deck sections:

\[ \sigma_{alg} = \left( (\sigma_{rep})^2 + (\alpha_t)^2 + (\alpha_{cv})^2 + (\sigma_{d})^2 + (\sigma_{est})^2 \right)^{1/2} \]

Example for bridge deck R7:

\[ \sigma_{alg} = \left( (0.6)^2 + (0.1)^2 + (0.5)^2 + (0.3)^2 + (0.3)^2 \right)^{1/2} \]

\[ \sigma_{alg} = 0.9 \text{ cm} \]
Appendix E
Concrete Mix Designs for Fabricated Deck Sections
<table>
<thead>
<tr>
<th>Component</th>
<th>Composition</th>
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</thead>
<tbody>
<tr>
<td>Cement (kg/m³)</td>
<td>272</td>
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<tr>
<td>Slag (kg/m³)</td>
<td>147</td>
</tr>
<tr>
<td>Fine aggregate (kg/m³)</td>
<td>845</td>
</tr>
<tr>
<td>Coarse aggregate (kg/m³)</td>
<td>907</td>
</tr>
<tr>
<td>Air entraining admixture (kg/m³)</td>
<td>0.4</td>
</tr>
<tr>
<td>Water reducer (kg/m³)</td>
<td>0.8</td>
</tr>
<tr>
<td>Water (kg/m³)</td>
<td>140</td>
</tr>
<tr>
<td>High range water reducing agent (kg/m³)</td>
<td>2.1</td>
</tr>
<tr>
<td>Slump (mm)</td>
<td>72</td>
</tr>
<tr>
<td>Water/cement ratio (by weight)</td>
<td>0.51</td>
</tr>
</tbody>
</table>

*Table E1. Concrete mix design for bridge decks R12 and R13.*

<table>
<thead>
<tr>
<th>Component</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement (kg/m³)</td>
<td>715</td>
</tr>
<tr>
<td>Water (kg/m³)</td>
<td>331</td>
</tr>
<tr>
<td>Sand (kg/m³)</td>
<td>1723</td>
</tr>
<tr>
<td>Water/cement ratio (by weight)</td>
<td>0.46</td>
</tr>
</tbody>
</table>

*Table E2. Concrete mix design for experimental deck 1, (no reinforcing steel used).*

<table>
<thead>
<tr>
<th>Component</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement (kg/m³)</td>
<td>746</td>
</tr>
<tr>
<td>Water (kg/m³)</td>
<td>358</td>
</tr>
<tr>
<td>Coarse aggregate, #57 (kg/m³)</td>
<td>2251</td>
</tr>
<tr>
<td>Slump (mm)</td>
<td>97</td>
</tr>
<tr>
<td>Air content (%)</td>
<td>3.6</td>
</tr>
<tr>
<td>Water/cement ratio (by weight)</td>
<td>0.48</td>
</tr>
</tbody>
</table>

*Table E3. Concrete mix design for experimental deck 2 with variable depth reinforcing steel.*