A Further Evaluation Of Concrete Bridge Deck Surfacing In Iowa

Highway Division
Office Of Materials

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A FURTHER EVALUATION
OF CONCRETE BRIDGE DECK
SURFACING IN IOWA

by

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ABSTRACT

The Iowa Department of Transportation has overlaid 446 bridge decks with low slump dense concrete from 1964 through October 1978. The overall performance of these decks has been satisfactory.

Nineteen bridges that were resurfaced with either low slump dense concrete (LSDC) or latex-modified concrete were analyzed for chloride content, electrical corrosion potential, delaminations or debonding, and deck surface condition. The resurfacing ages of these bridges range from 5 to 13 years.

None of the bridges showed any evidence of surface distress and the chloride penetration into the resurfacing concrete is relatively low. There are delaminations in the original decks below the resurfacing on the majority of bridges examined. The delaminations are concluded to be caused by either (A) reinforcing steel corrosion, (B) not removing all delaminated concrete prior to placing the resurfacing concrete, or (C) creating an incipient fracture in the top surface of the original deck through the use of scarification equipment.

The active corrosion of the reinforcing steel is predominately in the gutter line on the majority of bridges evaluated.

Recommendations for future deck repairs include removal of concrete to the top layer of reinforcing steel in areas where an electrical corrosion potential of -0.35V or more is detected, providing more positive methods of locating delaminated concrete, and treating the curb and gutter line to reduce the potential damage from salt water.
INTRODUCTION

The Iowa Department of Transportation has been using low-slump, dense concrete for several years as a standard repair and resurfacing technique on bridge decks. From 1964 through October 1978 a total of 446 bridges have been overlaid with the dense concrete system. The overall performance of these overlays has been satisfactory.

In June 1974, a report entitled "An Evaluation of Concrete Bridge Deck Resurfacing in Iowa" was released by the Iowa Department of Transportation. This report documented the history, use and performance of low-slump, dense concrete (LSDC)* for bridge deck repair and resurfacing in Iowa from 1964 through 1973.

*LSDC will be the terminology used throughout this report because of the widespread use of term. The reader should be aware that whenever LSDC is used it is considered to be synonymous with the "Iowa Method" which includes specific methods of deck preparation, grouting, curing, etc.

Sixteen bridges were studied for chloride penetration in 1974. Fifteen of the bridges had been resurfaced with LSDC and the other has been resurfaced with latex-modified concrete containing Dow Chemical Corporation's Modifier "B". The age of the resurfacing on the bridges selected for the study ranged from one to nine years. Data was also presented as an indication of the physical properties of the resurfacing concretes as well as the rideability of the finished structure.

Only limited data was presented at that time concerning electrical potential corrosion measurements and no data was presented
to indicate the amount of concrete delamination or debonding that was present in the decks.

In 1978, the bridges detailed in the original report were resurveyed for the purpose of updating the information on the performance of the concrete resurfacing systems. Three additional bridges were also added to the study.

SCOPe

Bridge Selection

Sixteen bridges had decks repaired and resurfaced with the LSDC system. The ages of the resurfacing at the time of the 1978 evaluations were: one deck 13 years old, one 12 years, three 11 years, two 10 years, one 9 years, three 8 years, two 7 years, two 6 years, and one 5 years.

Three bridges included in the study had been repaired and resurfaced with latex-modified concrete. One of these contained a Dow Modifier "B" latex which is no longer used because of a high chloride content. This bridge was included in the 1974 report and has been in service 6 years. The other bridges had been repaired and resurfaced with latex-modified concrete containing Dow Modifier "A" and had been in service 5 years at the time of the 1978 survey.

As previously mentioned three bridges were added to the survey in 1978. These included a set of twin bridges on Interstate 35 over the Raccoon River in Polk County. One of these bridges was was resurfaced in 1973 with the LSDC system and the other bridge
was resurfaced in 1973 with the latex-modified concrete system. Both bridges were inspected by the same personnel and have received similar salt applications since resurfacing. These bridges provide an ideal opportunity to directly compare the performance of the two systems. The other bridge added to the study is on Interstate 235 westbound across the Des Moines River. This bridge was repaired and resurfaced in 1973 with latex-modified concrete. It was selected to provide additional data on the performance of this resurfacing method.

Survey Methods

All bridges were surveyed for chloride content of both the resurfacing concrete and the old deck, delaminations of the concrete in the old deck or debonding of the resurfacing from the old deck, and corrosion of the reinforcing steel in the old deck.

Two-inch diameter cores were drilled on each deck in the approximate locations originally sampled to determine the chloride level of the resurfacing concrete and the old, underlying deck. The cores were drilled wet with a diamond bit, however, the amount of water used in the drilling operation was held to a minimum to minimize the loss of water-soluble chloride from the sample.

The cores were dry sawed in 1/2 inch increments with a carborundum blade in the laboratory to establish the chloride profile at each location. Where it was possible, the concrete in the old deck was also sliced for chloride analysis. In some instances, the original deck concrete was not analyzed due to fracturing of
the concrete at or slightly below the original concrete during the core removal operation.

Each concrete slice was coarse ground in a Chipmunk jaw crusher and fine ground to pass the No. 50 sieve in a Micro-pulverizer. After pulverizing each sample was dried in an oven for at least one hour at 105° C.

The chloride concentration was obtained by utilizing the procedure described by Clear & Harrington in Report No. FHWA-RD-77-85. The Gran endpoint determination method was selected due to the relative ease associated with this method. The equipment employed was a Corning Research Model No. 12 pH meter with an Orion chloride electrode Model 96-17.

The chloride content of the concrete sample was converted to pounds of chloride per cubic yard of concrete by assuming a dry-concrete weight of 140 pounds per cubic foot.

Each bridge deck was surveyed with a Delamtect testing device manufactured by S.I.E. Inc. of Fort Worth, Texas. The Delamtect is a small mobile, electronic, acoustical device which imparts a tapping impulse into the surface of the concrete. An oscillating solenoid mounted on two steel wheels generates this impulse. The receivers that "listen" to locate the hollow areas are two oil filled inner tube tires. A hydraphone (pressure transducer) is mounted near the bottom within each of these oil-filled tires and monitors the response from the tapping. A response from each wheel is transmitted to a dual-channel, strip-
chart recorder. Each steel transmitter wheel operates three inches from the receiver tire, thus, evaluating a three inch wide strip. The two three inch wide strips traverse nine inches center to center for each pass. The operation of the testing device in Iowa has been well documented by Marks.³

Seventeen of the nineteen bridges surveyed were sounded for delaminations on nine-inch centers for the full width and length of the deck. Only representative deck sections on I-235 in Des Moines and US 20 in Sioux City were tested because of the traffic control problems encountered at these locations.

When unsound areas on a deck were encountered, two-inch diameter cores were drilled to examine the source of the indicated delamination. It was noted whether there was debonding of the resurfacing from the original deck or if there were delaminations of the concrete in the original deck.

Electrical corrosion potential measurements were obtained on sections of all bridges included in the study in accordance with Iowa Test Method 1008. This test method utilizes the copper-copper sulfate half cell in common use for this type of measurement. A four-foot grid system of test points was laid out on each deck section to be tested. If a reading of -0.35 volts or greater was observed, the four-foot grid system was reduced to a two-foot grid to better define the limits of where active corrosion may be occurring. The areas surveyed were selected to include as much delaminated concrete as possible.
Each bridge was also photographed to provide a visual reference as to the surface condition of the deck. Any apparent surface distress was to be noted by the testing crew.

RESULTS

Detailed results of each bridge surveyed are shown in Appendix A. Data from each bridge was plotted to illustrate chloride contents, delamination results and corrosion potential readings. Photographs illustrate general deck condition and delamination locations on the cores obtained for this purpose.

Chloride Penetration

Table No. 1 summarizes the chloride contents at various levels in the LSDC overlay concrete. It is common to find chloride contents of 3-6 lbs. per cubic yard of concrete in the underlying original decks as shown in the Appendix. When these decks were overlaid no effort was made to remove sound concrete with a high chloride content. Because of the high chloride content of the original deck, it is also common to find a relatively high chloride content in the overlay concrete directly in contact with the original. In all likelihood, the chloride migrates from the original deck upward rather than penetrating from the surface due to salting operations.

To present a more meaningful evaluation of chloride penetration properties, the chloride content of the concrete directly
in contact with the original deck was not used in averaging the chloride content of the overlay concrete. Plymouth County Design 169 was not included in Table No. 1 because the thickness of the overlay was not sufficient to plot a meaningful chloride penetration profile.

Table No. 2 summarizes the chloride data available on the latex-modified concrete deck overlays. The latex-concrete overlay on Story County bridge Design 172 contains Modifier "B". This modifier was high in chloride content and was reflected by the high chloride content in the cores from this deck. The concrete on other bridges listed contains Modifier "A".

Table No. 1
Chloride Content of LSDC System

<table>
<thead>
<tr>
<th>Bridge</th>
<th>Design No.</th>
<th>Resurfacing Age Years</th>
<th>Avg. Chloride Content - lbs/yd³</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Resurfacing Depth - In.</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>0-1/2</td>
</tr>
<tr>
<td>Polk</td>
<td>3265</td>
<td>13</td>
<td>5.0</td>
</tr>
<tr>
<td>Woodbury</td>
<td>1065</td>
<td>12</td>
<td>14.1</td>
</tr>
<tr>
<td>Polk</td>
<td>866</td>
<td>11</td>
<td>11.7</td>
</tr>
<tr>
<td>Clay</td>
<td>267</td>
<td>11</td>
<td>4.0</td>
</tr>
<tr>
<td>Clay</td>
<td>167</td>
<td>11</td>
<td>14.9</td>
</tr>
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<td>268</td>
<td>10</td>
<td>5.1</td>
</tr>
<tr>
<td>Woodbury</td>
<td>168</td>
<td>10</td>
<td>8.6</td>
</tr>
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<td>Calhoun</td>
<td>170</td>
<td>8</td>
<td>7.4</td>
</tr>
<tr>
<td>Cherokee</td>
<td>370</td>
<td>8</td>
<td>8.9</td>
</tr>
<tr>
<td>Woodbury</td>
<td>369</td>
<td>8</td>
<td>6.1</td>
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<td>Plymouth</td>
<td>171</td>
<td>7</td>
<td>2.6</td>
</tr>
<tr>
<td>Cherokee</td>
<td>172</td>
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<td>6.6</td>
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<td>Cherokee</td>
<td>272</td>
<td>6</td>
<td>7.6</td>
</tr>
<tr>
<td>Polk</td>
<td>273 NB</td>
<td>5</td>
<td>7.3</td>
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<td><strong>Avg.</strong></td>
<td></td>
<td></td>
<td>7.7</td>
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Chloride Content of Latex-Modified System

<table>
<thead>
<tr>
<th>Bridge Design</th>
<th>Resurfacing Age</th>
<th>Avg. Chloride Content - lbs/yd³</th>
<th>Resurfacing Depth - In.</th>
</tr>
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<tbody>
<tr>
<td>County No.</td>
<td>Years</td>
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<td>8.4</td>
<td>5.0</td>
</tr>
<tr>
<td>Polk</td>
<td>5</td>
<td>8.4</td>
<td>8.2</td>
</tr>
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</table>

*Concrete in resurfacing contains Modifier "B"
**Concrete in resurfacing contains Modifier "A"

Delaminations

Unsound areas as detected by the Delamtec have been plotted for each bridge deck and are summarized in Table No. 3 for the LSDC system and in Table No. 4 for the latex-modified concrete system.

Table No. 3
Delamtec Survey Results - LSDC System

<table>
<thead>
<tr>
<th>Bridge County</th>
<th>Design No.</th>
<th>Resurfacing Age</th>
<th>Deck Area-Ft²</th>
<th>Percent of Deck Area Delaminated</th>
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<tr>
<td>Polk</td>
<td>3265</td>
<td>13</td>
<td>15,444</td>
<td>11.8</td>
</tr>
<tr>
<td>Woodbury</td>
<td>1065</td>
<td>12</td>
<td>15,120</td>
<td>15.0*</td>
</tr>
<tr>
<td>Polk</td>
<td>866</td>
<td>11</td>
<td>9,436</td>
<td>12.7</td>
</tr>
<tr>
<td>Clay</td>
<td>267</td>
<td>11</td>
<td>9,724</td>
<td>11.3</td>
</tr>
<tr>
<td>Clay</td>
<td>167</td>
<td>11</td>
<td>20,256</td>
<td>28.5</td>
</tr>
<tr>
<td>Monona</td>
<td>268</td>
<td>10</td>
<td>7,410</td>
<td>16.4</td>
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<tr>
<td>Woodbury</td>
<td>168</td>
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<td>13,891</td>
<td>6.9</td>
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<td>Plymouth</td>
<td>169</td>
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<td>9,828</td>
<td>2.6</td>
</tr>
<tr>
<td>Calhoun</td>
<td>170</td>
<td>8</td>
<td>5,496</td>
<td>44.9</td>
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<tr>
<td>Cherokee</td>
<td>370</td>
<td>8</td>
<td>5,376</td>
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</tr>
<tr>
<td>Woodbury</td>
<td>369</td>
<td>8</td>
<td>4,200</td>
<td>7.0</td>
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<td>3,250</td>
<td>1.2</td>
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<td>171</td>
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<td>6,240</td>
<td>5.2</td>
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<td>Cherokee</td>
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<td>6</td>
<td>9,600</td>
<td>18.5</td>
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<tr>
<td>Cherokee</td>
<td>272</td>
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<td>2,448</td>
<td>2.2</td>
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<tr>
<td>Polk</td>
<td>273 NB</td>
<td>5</td>
<td>18,368</td>
<td>0.0</td>
</tr>
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</table>

*Representative area surveyed (5,616 Ft²)
Table No. 4
Delamteect Survey Results
Latex-Modified Concrete System

<table>
<thead>
<tr>
<th>Bridge County</th>
<th>Design No.</th>
<th>Resurfacing Age Years</th>
<th>Deck Area-Ft²</th>
<th>Percent of Deck Area Delaminated</th>
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</thead>
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<td>Story</td>
<td>172</td>
<td>6</td>
<td>6,720</td>
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<td>18,368</td>
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<td>5</td>
<td>44,720</td>
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<td>Total</td>
<td></td>
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<td>69,808</td>
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*Contains Modifier "B"
**Representative area surveyed (13,780 ft²)

Table No. 3 and 4 contain a column entitled "Percent of Deck Area Delaminated." The Delamteect device does not distinguish the difference between delaminated concrete in the underlying deck or from a lack of bond between the two concretes.

A linear regression analysis was performed utilizing resurfacing age and percentage of deck area delaminated as the independent variables for the LSDC system. A correlation coefficient of 0.265858 indicates no meaningful correlation exists. Due to the limited data a similar analysis was not conducted for the latex-modified concrete system.

Core photographs shown in Appendix A are included to indicate the location in the system which caused the Delamteect to respond. A careful examination of the cores reveals a failure in the concrete from the original deck below the bond line on all bridges surveyed.
It is difficult to ascertain from the photographs in Appendix A whether the failure was debonding or delamination when the fracture plane is close to the interface of the two concretes.

To avoid confusion it would be well to define debonding and delamination as used in this report. Debonding is considered to be an actual failure of the grout to bond the overlay concrete to the prepared surface of the underlying deck. Delamination will be used to describe a fracture in the original deck below the interface of the two concretes.

Most of the delaminations were located in the old concrete within 1/4" of the bonded interface. To better illustrate this type of delamination a core from the Calhoun Co. Design No. 170 bridge is shown in Figures Nos. 1 and 2. Figure No. 1 does not provide sufficient detail to indicate the exact fracture location. Figure No. 2 shows the fracture location in the old deck as evidenced by the separation of the coarse aggregate particle from the old deck.

**Electrical Potential**

Tables No. 5 and No. 6 summarize the results of the electrical potential measurements on the decks overlaid with LSDC and latex-modified concrete, respectively. The tables indicate: 1) the number and percentage of measurements -0.35V or greater for the total deck area surveyed, 2) the number and percentage of measurements of -0.35V or greater in the delaminated areas only, and 3) the number and percentage of measurements of -0.35V or greater in the gutter line only.
Fig. 1 Delamination core - side view

Fig. 2 Delamination core - end view of fracture
### Table No. 5: Corrosion Potential LSDC System Results

<table>
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<tr>
<th>County</th>
<th>Bridge Resurfacing</th>
<th>No. Years</th>
<th>Design Age</th>
<th>No. of Readings</th>
<th>% of Readings</th>
<th>No. of Readings</th>
<th>% of Readings</th>
<th>No. of Readings</th>
<th>% of Readings</th>
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<td>92</td>
<td>12</td>
<td>13.0</td>
<td>52</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Woodbury</td>
<td>No. 347</td>
<td>12</td>
<td>1065</td>
<td>62</td>
<td>25.1</td>
<td>66</td>
<td>1</td>
<td>1.5</td>
<td>63</td>
<td>45</td>
<td>71.4</td>
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<td>866</td>
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<td>66</td>
<td>6</td>
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<td>58</td>
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<td>16.5</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>4,518</td>
<td>974</td>
<td>21.6%</td>
<td>1,072</td>
<td>201</td>
<td>1,484</td>
<td>653</td>
<td>44.0%</td>
</tr>
</tbody>
</table>

#### Percent of Readings

- **0.35V or more in non-delaminated area**
  
  \[
  \text{Percent of Readings} = \frac{1,072}{4,518} = 23.6\%
  \]

- **0.35V or more in gutter line only**
  
  \[
  \text{Percent of Readings} = \frac{44}{4,518} = 0.98\%
  \]

- **0.35V or more in delaminated area only**
  
  \[
  \text{Percent of Readings} = \frac{974}{4,518} = 21.6\%
  \]
<table>
<thead>
<tr>
<th>Bridge</th>
<th>Design Age</th>
<th>No. of Readings</th>
<th>% -0.35V</th>
<th>% -0.35V or More</th>
</tr>
</thead>
<tbody>
<tr>
<td>Story</td>
<td>172</td>
<td>317</td>
<td>75</td>
<td>23.7</td>
</tr>
<tr>
<td>Polk</td>
<td>273 SB</td>
<td>218</td>
<td>4</td>
<td>1.8</td>
</tr>
<tr>
<td>Polk</td>
<td>573</td>
<td>434</td>
<td>30</td>
<td>6.9</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>969</td>
<td>109</td>
<td>11.2%</td>
</tr>
</tbody>
</table>

Percent of Readings -0.35V or more in non-delaminated area = \( \frac{109-21}{969-124} = 10.4\% \)

Percent of Readings -0.35V or more outside gutter line = \( \frac{109-44}{969-221} = 8.7\% \)
A regression analysis was conducted on the LSDC system with the percentage of readings at or exceeding -0.35V for the total deck area surveyed and resurfacing age as the independent variables. A correlation coefficient of -0.405693 indicates no meaningful correlation exists.

Deck Surface Condition

None of the bridges included in the study showed any evidence of surface distress.

DISCUSSION

All of the bridge-deck overlays examined in this investigation were constructed utilizing specifications that are not currently in use, they have since been revised. The main differences in the specifications are:

1. The overlay thickness in the bridges studied was designed at 1-1/4" exclusive of areas which required deeper patching caused by the removal of unsound concrete. The present standard overlay thickness is 1-3/4" with the same exclusions.

2. There were no consolidation requirements for the LSDC placed on these bridges. The current specification requires the concrete be consolidated to a minimum of 98% of rodded unit weight.

3. No criterion concerning electrical corrosion potential had been established to dictate concrete removal
at the time these overlays were placed. The present standard requires that the concrete in the deck be removed to the top layer of reinforcing steel where a corrosion potential measurement of -0.45 volt or more is encountered.

All of the specification changes instituted since the evaluated bridges were resurfaced are designed to increase the service life of the decks.

There has been no significant change in the levels of chloride ions in the LSDC system during the 4-year period since the decks were originally surveyed. The chloride level of the concrete in the majority of original decks under the resurfacing is considerably above the established corrosion threshold level of approximately 1.5 lbs. of chloride per cubic yard of concrete. Why the electrical corrosion potential readings did not indicate active corrosion of the reinforcing steel to a great degree over the entire deck areas surveyed is not fully explainable. A possible reason is that there is not sufficient moisture or oxygen at the reinforcing steel level to initiate corrosion or allow it to continue in any widespread manner.

The delamination survey provided data which indicate the amount of delamination in the original concrete decks is quite variable and is generally more widespread than had originally been thought. Unfortunately, no data is available to indicate whether or not delaminated areas existed immediately after construction; consequently, the progression of the delaminations
cannot be quantitatively analyzed. While some areas of unsound concrete may have remained in the old deck at the time of resurfacing, it is very doubtful that as high a percentage as found by the DelamTect on some bridges could have been overlooked in normal project inspection.

Assuming this is the case, it is probable that the delaminated areas under the resurfacing is increasing. How far this can increase prior to being manifested by surface deterioration is unknown.

Two bridges were void of delaminations. These are twin bridges that were overlaid in 1973 and are located on Interstate 35 across the Raccoon River in Polk County. One bridge was resurfaced with LSDC and the other was resurfaced with latex-modified concrete. It has been reported that the inspector on these bridges did an extremely conscientious job of insuring all unsound concrete was removed prior to resurfacing. The results from these bridges point out the importance of thorough inspection and the removal of all delaminated concrete in the underlying deck. These bridges will be monitored on a yearly basis.

It was intended to establish whether or not delaminated areas of the deck would show more active corrosion of the reinforcing steel than non-delaminated areas.

It is generally agreed that electrical potential measurements at or exceeding -0.35V indicate active corrosion of the reinforcing steel. Readings between -0.20V and -0.35V are generally
concluded to be in the "gray area"; that is, active corrosion may or may not be present.

Since readings of -0.35V or more definitely indicate corrosion, the percentage of readings at this level were tabulated for delaminated and non-delaminated areas. The results exhibited in Table No. 5 show that for the LSDC system the percent of readings of -0.35V or more are nearly equivalent in the delaminated and non-delaminated areas with 18.8% and 22.4%, respectively. It should not be concluded, based upon this tabulation, that the delaminations in the underlying deck concrete are not the result of continued reinforcing steel corrosion. Conversely, it does not provide sufficient evidence to positively conclude that the increase in delaminated areas can solely be attributed to re-bar corrosion.

As mentioned earlier, the majority of the delaminations were located within 1/4" of the bonded interface. It is not unusual to find this type of delamination approximately 2 inches above the reinforcing steel with the concrete between the delamination and the re-bar appearing sound. When these cores were taken directly over the reinforcing steel there was no visual evidence of corrosion on the bar. The exact cause of this type of delamination is not known. There is a distinct possibility that an incipient fracture in the surface of the old concrete may have been created due to the impact of the scarification equipment in use at that time.
There is also a possibility that all delaminated concrete was not removed at the time of resurfacing and this area is increasing due to the mechanical action created by traffic on the bridges.

Table No. 5 also compares corrosion potential measurements in the gutter line with other areas. It is not surprising to observe the high percent (44%) of readings indicating active corrosion in the gutter line since there is a likelihood of more salt and moisture in this area. There is also a distinct possibility of the readings being influenced by corrosion of the reinforcing steel in the curb.

Table No. 6 contains comparable data for the latex-modified concrete system of deck overlays. There is only limited data available on this system; however, it does not appear the analysis of this system would be significantly different than the LSDC system.

CONCLUSIONS

The results from this study would support the following conclusions:

1. The LSDC system of resurfacing over chloride contaminated bridge decks has exhibited adequate performance through 13 years.

2. The performance of the LSDC system and the latex-modified concrete system are equivalent through 6 years.
3. Chloride penetration into the LSDC and latex-modified concrete systems is similar and not significantly changed from the previous survey. Both systems are successful in reducing chloride penetration from surface applied deicing chemicals.

4. Delaminated areas exist in the original deck under the resurfacing on the majority of bridges investigated.

5. The delaminations are probably caused by either; (A) reinforcing steel corrosion, (B) not removing all delaminated concrete prior to resurfacing, or (C) creating an incipient fracture in the top surface of the original deck through the use of scarification equipment.

6. The majority of the delaminations are within 1/4" of the bonded interface and are probably not corrosion related.

7. The areas of delamination are increasing and may eventually result in distress of the resurfacing.

8. The grouting system used to bond the overlay to the original deck is adequate as evidenced by the fact that no bond failures were noted on any of the nineteen bridges studied.

9. Steel corrosion is more prominent in the gutter line than on other areas of the bridges.
10. There is no meaningful correlation between resurfacing age and delaminations or corrosion of the reinforcing steel.

11. Thorough inspection will lessen the likelihood of the formation of delaminated areas.

RECOMMENDATIONS

The following recommendations are being offered for consideration:

1. Increased emphasis should be placed upon intensive inspection to insure all delaminated concrete in the decks being resurfaced is removed. If sufficient funds are available, Delamtect testing devices should be purchased and used on decks just prior to scarification of the deck surface. This would result in more objective determinations in locating areas of unsound concrete that should be removed. Delamtect testing should also be conducted after the placement of the overlay.

2. Concrete should be removed to the top layer of reinforcing steel if an electrical corrosion potential measurement of -0.35V or more is observed.

3. Increased protection of the concrete in the gutter line and curb should be required. This may be done by treating these areas with high quality concrete sealers.
REFERENCES


Bridge Analytical Details

APPENDIX A

- 22 -
Polk County

M-1209    Des. No. 3265
Location: 9th St. in Des Moines Over I-235
Year Overlaid 1965

Bridge Deck Dimensions
Width - 52 ft.
Length - 297 ft.
Deck Area - 15,444 ft.$^2$
Delaminated Area - 1,830.63 ft.$^2$
% Delamination - 11.85%

Indicates area where Electrical Potential Readings were taken
Details next page.
Letters indicate chloride cores.
Numbers indicate delamination cores.

Blocked out areas indicate delamination
Location: 9th St. in Des Moines
Year Overlaid: 1965

M-1209 Des. No.
Des. No. 3265

Polk County
Polk County

M-1209  Des No. 3265
Location: 9th St. in Des Moines Over I-235
Year Overlaid 1965

Electrical Potential
Negative Voltage - Copper Sulfate
Half Cell
Detail Sheet No. 2

19 18 22 26 22 20 24 24 24 22 26 19 17 20 18 21 16 20 21 20 21 17
11 10 11 10 11 10 14 11 12 11 10 10 12 11 09 12 12 16 10 10 08 13 11 12 08 11
16 15 13 12 15 15 19 18 18 21 11 11 15 11 24 20 20 18 17 17 13 16 13 14 16 15
14 13 11 14 12 14 18 22 14 16 17 15 16 15 18 17 14 18 16 18 17 19 16 19 16 15
15 15 14 13 17 16 24 20 15 15 16 12 15 16 14 14 16 18 16 18 17 20 18 24 18 17
17 16 15 14 14 18 16 16 20 17 16 15 14 16 15 16 16 16 17 20 18 19 19 24 25432317
27 23
12 13 19 19 13 10 12 17 18 18 14 14 13 16 17 22 16 13 15 16 17 13 16 20 18 14

100 ft.

Represents N.W. Cross Hatched Area

Blocked out areas indicate delamination
**Location:** Polk County  
**M-1209 Des. No. 3265**  
**9th St. in Des Moines over I-235**  
**Year Overlaid: 1965**

**Chloride Content - lbs/cu.yd.**

<table>
<thead>
<tr>
<th>Test Location</th>
<th>Old Deck</th>
<th>New Deck</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
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<tr>
<td>B</td>
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<td>C</td>
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<td>0.73</td>
</tr>
<tr>
<td>D</td>
<td>1.89</td>
<td>1.00</td>
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**Depth**

- 0.50
- 1.00
- 1.50
- 2.00
- 2.50
- 3.00
- 3.50
- 4.00
- 4.50

**Old Deck**

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<tr>
<td>B</td>
<td>2.09</td>
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<tr>
<td>C</td>
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</tr>
<tr>
<td>D</td>
<td>0.99</td>
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**New Deck**

<table>
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<th>Chloride Content - lbs/cu.yd.</th>
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</thead>
<tbody>
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<td>A</td>
<td>4.27</td>
</tr>
<tr>
<td>B</td>
<td>2.92</td>
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<tr>
<td>C</td>
<td>0.99</td>
</tr>
<tr>
<td>D</td>
<td>1.89</td>
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</tbody>
</table>
Polk County
M-1209 Des. No. 3265
Location: 9th St. in Des Moines Over I-235
Year Overlaid: 1965

DELAMINATION CORES

Core #1

Core #2

Core #3

Core #4
Location: U.S. 20 Over C.M.St. P & P RR in Sioux City

Year Overlaid: 1966

Woodbury County

Not to Scale
Electrical Potential
Negative Voltage-Copper Sulfate
Half Cell
Detail Sheet

Blocked out areas indicate delamination
Woodbury County
UN-20-1(2)--41-97 Des. No. 1065
Location: U.S. 20 Over CM St.
P & RR In Sioux City
Year Overlaid: 1966

<table>
<thead>
<tr>
<th>Depth (Inches)</th>
<th>Chloride Content (Lbs./cu. yd.)</th>
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</thead>
<tbody>
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</tr>
<tr>
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<tr>
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Year overlaid: 1966
Location: U.S. 20 over CM St. P & RR in Sioux City
UN-20-1(2)--41-97 DES. NO. 1065
Woodbury County
Woodbury County
UN-20-1(2)--41-97 Des. No. 1065
Location: U.S. 20 Over CM ST. P & P RR In Sioux City
Year Overlaid: 1966

DELAMINATION CORES

Core #1

Core #2

Core #3
Electrical Potential
Negative Voltage - Copper Sulfate
Half Cell
Detail Sheet

100 Ft.

* 4" Core Hole

Blocked out areas indicate delamination
**Location:** IA, 141 Over Little Beaver Creek

**Year Overlaid:** 1967

**Polk County FN-60-4(2)--21-77 Des. No. 866**

<table>
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<tr>
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<th>Test Location</th>
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<th>Old Deck</th>
<th>Old Deck</th>
<th>Old Deck</th>
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Polk County
FN-60-4(2)--21-77 Des. No. 866
Location: IA. 141 Over Little Beaver Creek
Year Overlaid: 1967

DELAMINATION CORES

Core #1

Core #2

Core #3
LOCATION: IA 374 OVER LITTLE SIOUX RIVER

YEAR OVERLAID: 1967

LOCATION: IA 374 OVER LITTLE SIOUX RIVER

CLAY COUNTY
Clay County
FN-374-1(1)--21-21 Des. No. 267
Location: IA. 374 Over Little Sioux River
Year Overlaid: 1967

Electrical Potential
Negative Voltage - Copper Sulfate
Half Cell
Detail Sheet

** Represents N.E. Cross Hatched Area

*Represents S.W. Cross Hatched Area

Blocked out areas indicate delamination
Clay County

FN-374-1(1)--21-21 Des. No. 267
Location: IA. 374 Over Little Sioux River
Year Overlaid 1967

<table>
<thead>
<tr>
<th>Chloride Content Lbs/cu Yd</th>
<th>Test Location</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
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</thead>
<tbody>
<tr>
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<td>1.46</td>
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Note: The table above shows the chloride content in Lbs/cu yd at different test locations.

Year Overlaid 1967
Location: IA. 374 Over Little Sioux River
FN-374-1(1)--21-21 Des. No. 267
Clay County
Clay County
FN-374-1(1)--21-21 Des. No. 267
Location: IA 374 Over Little Sioux River
Year Overlaid 1967

DELAMINATION CORES

Core #1

Core #2

Core #3
Location: U.S. 18 Over Little Sioux River in Spencer
UN-18-2(5)--41-21 Des. 167
Clay County

Year Overlaid 1967

Bridge Deck Dimensions

- Width: 48 Ft.
- Length: 422 Ft.
- Deck Area: 20,256 ft²
- Delaminated Area: 5,780.38 ft²
- % Delamination: 28.54%

Electrical Potential Readings were taken

Details next page

Numbers indicate chloride cores
Letters indicate delamination cores

Bridge Deck Dimensions

©
Clay County
UN-18-2(5)--41-21 Des. 167
Location: U.S. 18 Over Little Sioux River in Spencer
Year Overlaid 1967

Electrical Potential
Negative Voltage - Copper Sulfate
Half Cell
Detail Sheet No. 1

*Manhole

Represents N.E. Cross Hatched Area

Blocked out areas indicate delamination
Location: U.S. 18 over Little Sioux River in Spencer

UN-18-2(5)-41-21 Des. 167
Clay County
Clay County
UN-18-2(5)--41-21  Des. 167
Location: U.S. 18 Over Little Sioux River in Spencer
Year Overlaid: 1967

<table>
<thead>
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<th>Conc. Depth Inches</th>
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<tbody>
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</table>

Chloride Content - Lbs/cu.yd.
Location: U.S. 18 Over Little Sioux River in Spencer

Year Overlaid: 1967

Clay County

DELAMINATION CORES

Core #1

Core #4

Core #2

Core #5

Core #3

Core #6
Monona County
INP-29-6(27)114--15-67  Des. No. 268
Location:  IA. 175 Over I-29
Year Overlaid:  1968

Bridge Deck Dimensions
Width = 30 ft.
Length = 247 ft.
Deck Area = 7,410 ft.²
Delaminated Area = 1,219.25 ft.²
% Delamination = 16.45%

Monona County
INP-29-6(27)114--15-67  Des. No. 268
Location:  IA. 175 Over I-29
Year Overlaid:  1968

Indicates areas where Electrical Potential Readings were taken
Details next page

Letters indicate chloride cores.
Numbers indicate delamination cores.

Blocked out areas indicate delamination

Not to Scale
Year Overlaid: 1968
Location: IA. 125 over I-29
INP-29-6(27)114-15-67 DES. NO. 268
Monona County
Monona County
INP-29-6(27)114--15-67 Des No. 268
Location: IA. 175 Over I-29
Year Overlaid: 1968

<table>
<thead>
<tr>
<th>Depth (Inches)</th>
<th>Test Location</th>
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</thead>
<tbody>
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<td>2.50 Old Deck</td>
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<td>3.50</td>
<td></td>
</tr>
</tbody>
</table>
Monona County

INP-29-6 (27) 114--15-67 Des. No. 268

Location: IA. 175 Over 1-29

Year Overlaid: 1968

DELAMINATION CORES

Core #1

Core #2

Core #3

DELAMINATION CORES
Woodbury County
INP-29-6(28)143--15-97  Des. No. 168
Location: I-29 Over C & NW R.R. & Wall St.
Year Overlaid: 1968

Bridge Deck Dimensions
Width - 29 ft.
Length - 479 ft.
Deck Area - 13,891 ft.²
Delaminated Area - 960.75 ft.²
% Delamination - 6.92%

Indicates areas where Electrical Potential Readings were taken
Details next page

Letters indicate chloride cores.
Numbers indicate delamination cores.

Blocked out areas indicate delamination

Not to Scale
Woodbury County
INP-29-6(28)143--15-97 Des. No. 168
Location: I-29 Over C & NW R.R. & Wall St.
Year Overlaid: 1968

<table>
<thead>
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<th>Conc. Depth (Inches)</th>
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</thead>
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Woodbury County
INP-29-6(28)143-15-97 Des. No. 168
Location: 1-29 Over C & NW R.R. & Wall St.
Year Overlaid: 1968

DELAMINATION CORES

Core #1

Core #2

Core #3

Core #4

INP-29-6(28)143-15-97 Des. No. 168
Woodbury County
Plymouth County
FN-75-5(4)--21-75 Des. No. 169
Location: U.S. 75 Southbound Over Floyd River in LeMars
Year Overlaid 1969

Bridge Deck Dimensions
Width - 28 Ft.
Length - 351 Ft.
Deck Area - 9,828 Ft.²
Delaminated Area 254.50 Ft.²
% Delamination - 2.59%

Indicates areas where Electrical Potential Readings were taken
Details next page

Letters indicate chloride cores.
Numbers indicate delamination cores.

Blocked out areas indicate delamination
Plymouth County
FN-75-5(4)--21-75 Des. No. 169
Location: U.S. 75 Southbound Over Floyd River in LeMars
Year Overlaid: 1969

<table>
<thead>
<tr>
<th>Location</th>
<th>Plymouth County</th>
</tr>
</thead>
<tbody>
<tr>
<td>FN-75-5(4)--21-75 Des. No. 169</td>
<td>Location: U.S. 75 Southbound Over Floyd River in LeMars Year Overlaid: 1969</td>
</tr>
</tbody>
</table>

**Chloride Content - Lbs/cu.yd.**

<table>
<thead>
<tr>
<th>Test Location</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
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<tbody>
<tr>
<td>Old Deck</td>
<td>10.69</td>
<td>9.79</td>
<td>10.58</td>
<td>11.37</td>
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<tr>
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<td>2.32</td>
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<td>13.61</td>
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<td>Old Deck</td>
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<td>3.82</td>
<td>5.10</td>
<td>7.03</td>
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**Diagram:**

- Old Deck
- New Deck
- Chloride Content - Lbs/cu.yd.

**Table:**

<table>
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<tr>
<th>Conc. depth Inches</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
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<tr>
<td>0.50</td>
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<tr>
<td>1.00</td>
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<tr>
<td>2.00</td>
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</table>
Plymouth County

FN-75-5(4)--21-75 Des. No. 169

Location: U.S. 75 Southbound Over Floyd River

Year Overlaid: 1969

DELAMINATION CORES

Core #1

Core #2

Core #3

Core #4
Calhoun County
FN-175-5(3)--21-13 Des. No. 170
Location: Ia. 175 Over Raccoon River
Year Overlaid: 1970

Bridge Deck Dimensions
Width - 24 Ft.
Length - 229 Ft.
Deck Area - 5,496 Ft.²
Delaminated Area - 2,469.25 Ft.²
% Delamination - 44.93%

Not To Scale

Indicates areas where
Electrical Potential Readings
were taken
Details next page

Letters indicate chloride cores.
Numbers indicate delamination cores.

Blocked out areas indicate delamination
Calhoun County

FN-175-5(3)--21-13 Des. No. 170
Location: IA. 175 Over Raccoon River
Year Overlaid: 1970

Electrical Potential
Negative Voltage - Copper Sulfate
Half Cell
Detail Sheet

Blocked out areas indicate delamination

100 Ft.
**Location:** IA. 175 Over Raccoon River

**Year Overlaid:** 1970

<table>
<thead>
<tr>
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<th>Depth (Inches)</th>
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</tr>
<tr>
<td></td>
<td>B</td>
</tr>
<tr>
<td></td>
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<td>H</td>
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<tr>
<td></td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>J</td>
</tr>
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</table>

**Cone Test Location:**

- Old Deck (4.91, 0.99, 0.39)
- Old Deck (2.99, 1.63, 1.59)
- Old Deck (2.00, 3.97, 2.79, 1.93)
- Old Deck (3.05, 2.75, 2.75, 2.50)
- Old Deck (3.00, 2.75, 2.75, 2.50)

**Cone Test Location - Ibs./cu. yd.**

- 2.79, 1.49, 1.26, 1.13
- 1.00, 0.39, 0.39, 1.99
- 0.39, 0.39, 1.99, 1.63
- 2.09, 1.49, 1.26, 1.13
- 1.50, 1.50, 1.50, 1.50
Calhoun County

FN-175-5(3)--21-13 Des. No. 170

Location: IA. 175 Over Raccoon River

Year Overlaid: 1970

DELAMINATION CORES

Core #1

Core #2

Core #3

DELMINATION CORES

Year Overlaid: 1970
Location: IA. 175 Over Raccoon River
PN-175-5(3)--21-13 Des. No. 170
Calhoun County
Cherokee County
FN-59-7(11)--21-18 Des. No. 370
Location: U.S. 59 Over Gray Creek
Year Overlaid: 1970

Bridge Deck Dimensions
Width - 24 ft.
Length - 224 ft.
Deck Area - 5,376 ft.²
Delaminated Area - 531.70 ft.²
% Delamination - 9.89%

Indicates areas where Electrical Potential Readings were taken Details next page
Letters indicate chloride cores Numbers indicate delamination cores

Blocked out areas indicate delamination

Not to scale
Cherokee County
FN-59-7(11)-21-18 Des. No. 370
Location: U.S. 59 Over Gray Creek
Year Overlaid: 1970

<table>
<thead>
<tr>
<th>Test Location</th>
<th>A</th>
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<th>C</th>
<th>D</th>
<th>E</th>
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<td>6.88</td>
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<td>0.53</td>
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<tr>
<td>Old Deck</td>
<td>0.26</td>
<td>0.49</td>
<td></td>
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<tr>
<td>Old Deck</td>
<td>0.23</td>
<td>0.67</td>
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</tbody>
</table>
Cherokee County

Location: U.S. 59 Over Gray Creek
Year Overlaid: 1970

DELIAMINATION CORES

FN-59-7(11)--21-18 Des. No. 370
Cherokee County

Core #1

Core #2

Core #3
Woodbury County
FN-20-1(20)--21-97 Des. No. 369
Location: U.S. 20 Over Elliott Creek WB Bridge
Year Overlaid: 1970

Bridge Deck Dimensions
Width - 28 Ft.
Length - 156 Ft.
Deck Area - 4,200 Ft.²
Delaminated Area - 295.68 Ft.²
% Delamination - 7.04 %

Indicates areas where electrical potential readings were taken
Details next page
Letters indicate chloride cores.
Numbers indicate delamination cores.

Blocked out areas indicate delamination
Not To Scale
Woodbury County

Location: U.S. 20 over Elliott Creek W.B. Bridge

Year Overlaid: 1970

Location: U.S. 20 over Elliott Creek W.B. Bridge

FN-20-1(20)--21-97 Des. No. 369

Woodbury County
Woodbury County
FN-20-1(20)--21-97 Des. No. 369
Location: U.S. 20 Over Elliott Creek WB Bridge
Year Overlaid: 1970

<table>
<thead>
<tr>
<th>Conc. Depth Inches</th>
<th>Test Location</th>
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<tbody>
<tr>
<td>0.50</td>
<td>A  10.01</td>
</tr>
<tr>
<td></td>
<td>A  0.74</td>
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<tr>
<td>1.00</td>
<td>A  0.23</td>
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<tr>
<td>1.50</td>
<td>A  0.07</td>
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<tr>
<td>2.00</td>
<td>A  0.40</td>
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</tr>
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<td>3.50</td>
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</tr>
<tr>
<td>4.00</td>
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Chloride Content - Lbs/cu.yd.
DELAMINATION CORES

Year Overlaid: 1970
Location: U.S. 20 over Elliott Creek W.B. Bridge
PN-20-1(20)--21-97 Des. No. 369
Woodbury County
Plymouth County
FN-3-1(8)--21-75  Des.No. 271
Location: IA. 3 Over Mink Creek
Year Overlaid: 1971

Bridge Deck Dimensions:
Width - 26 ft.
Length - 125 ft.
Deck Area = 3,250 ft.$^2$
Delaminated Area = 40.63 ft.$^2$
% Delamination = 1.25%

Indicates areas where Electrical Potential Readings were taken
Details next page
Letters indicate chloride cores.
Numbers indicate delamination cores.

Blocked out areas indicate delamination

Not To Scale
Plymouth County
FN-3-1(8)--21-75 Des. No. 271
Location: Ia. 3 Over Mink Creek
Year Overlaid: 1971

<table>
<thead>
<tr>
<th>Chloride Content - Lbs/cu.yd.</th>
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</thead>
<tbody>
<tr>
<td>Test Location</td>
</tr>
<tr>
<td>A</td>
</tr>
<tr>
<td>6.43</td>
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<tr>
<td>2.99</td>
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<tr>
<td>0.74</td>
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</tr>
<tr>
<td>1.11</td>
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<tr>
<td>3.49</td>
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</table>

Conc. Depth
Inches

0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00

Old Deck

Old Deck
Location: U.S. 20 over Elliott Creek Wp Bridge
FN-20-1(20)-21-97
Des. No. 369
Woodbury County

Year Overlaid: 1970

Bridges Deck Dimensions

Not To Scale
Woodbury County
FN-20-1(20)--21-97 Des. No. 369
Location: U.S. 20 Over Elliott Creek WB Bridge
Year Overlaid: 1970

<table>
<thead>
<tr>
<th>Conc. Depth Inches</th>
<th>Test Location</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
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<tbody>
<tr>
<td>0</td>
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<tr>
<td>4.00</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
Not to Scale

% Delamination - 1.25%
Delaminated Area - 40.63 ft.²
Deck Area - 3,250 ft.²

Length - 125 ft.
Width - 26 ft.

Bridge Deck Dimensions

Location: IA, 3 over Mink Creek
FN-3-1 (8)-21-75 Des. No. 271
Plymouth County

Year Overlaid: 1971

Metallic Indicate Chloride Cores.

Notations next page
Regressed Porcellain Readings
Indicate areas where indicated area delaminated cores.
Plymouth County
FN-3-1(8)--21-75 Des. No. 271
Location: Ia. 3 Over Mink Creek
Year Overlaid: 1971

<table>
<thead>
<tr>
<th>Conc. Depth Inches</th>
<th>Test Location</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
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<tr>
<td>0.50</td>
<td>6.43</td>
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<tr>
<td>1.00</td>
<td>2.99</td>
</tr>
<tr>
<td>1.50</td>
<td>0.74</td>
</tr>
<tr>
<td>2.00</td>
<td>0.77</td>
</tr>
<tr>
<td>2.50</td>
<td>1.11</td>
</tr>
<tr>
<td>3.00</td>
<td>0.49</td>
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<td>3.50</td>
<td></td>
</tr>
<tr>
<td>4.00</td>
<td></td>
</tr>
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</table>

Chloride Content - Lbs/cu.yd.

Old Deck

Old Deck

Old Deck
Year Overlaid: 1971
Location: IA. 3 Over W. Branch of Floyd River
PN-3-1(8)-21-75 Des. No. 171
Plymouth County
Plymouth County
FN-3-1(8)--21-75 Des. No. 271
Location: IA. 3 Over Mink Creek
Year Overlaid: 1971

DELAMINATION CORES

Core #1

Core #2

Core #3
LOCATION: IA. 3 OVER W. BRANCH OF FLOYD RIVER
PN-3-1(8)-21-75  DES. NO. 171
Plymouth County
Plymouth County
FN-3-1(8)--21-75 Des. No. 171
Location: Ia. 3 Over W. Branch of Floyd River
Year Overlaid: 1971

Electrical Potential
Negative Voltage - Copper Sulfate
Half Cell
Detail Sheet

Blocked out areas indicate delamination
Plymouth County  
FN-3-1(8) -- 21-75 Des. No. 171  
Location: Ia. 3 Over W. Branch of Floyd River  
Year Overlaid: 1971  

<table>
<thead>
<tr>
<th>Depth Inches</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
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<td>2.56</td>
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<td>3.00</td>
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Plymouth County
FN-3-1(8)--21-75 Des. No. 171
Location: IA. 3 Over W. Branch of Floyd River
Year Overlaid: 1971

DELAMINATION CORES

Core #1

Core #2

Core #3
Location: Ia. 3 over Little Sioux River
Des. No. 172

Bridge Dimensions:
- Width: 30 ft.
- Length: 320 ft.
- Deck Area: 9,600 ft.²
- Delaminated Area: 1,296 ft.²
- % Delamination: 13.5%

Electrical Potential Readings:

Not to scale

Cherokee County

Year Overlaid: 1972
Cherokee County
FN-3-2(7)--21-18 Des. No. 172
Location: IA. 3 Over Little Sioux River
Year Overlaid: 1972

Electrical Potential
Negative Voltage - Copper Sulfate
Half Cell
Detail Sheet

Blocked out areas indicate delamination
Cherokee County

Location: IA 3 Over Little Sioux River
Year Overlaid: 1972

<table>
<thead>
<tr>
<th>Depth (inches)</th>
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<tbody>
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<td>0.0 - 0.50</td>
<td>7.94</td>
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</tr>
<tr>
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<td>6.96</td>
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<tr>
<td>4.0 - 4.50</td>
<td>8.28</td>
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<tr>
<td>4.5 - 5.00</td>
<td>6.88</td>
</tr>
</tbody>
</table>

Old Deck | 0.53 | 6.09 | 1.92 | 2.65 |

Current Deck | 5.97 | 0.56 | 4.19 | 9.05 |

Note: The diagram shows a cross-section of the bridge with the old deck and current deck highlighted. The depth measurements are given in inches, and the test locations are marked with various measurements and annotations.
Cherokee County
FN-3-2(7)--21-18 Des. No. 172
Location: IA. 3 Over Little Sioux River
Year Overlaid: 1972

DELAMINATION CORES

Core #1

Core #2

Core #3
Cherokee County
FN-59-7(14)-21-18 Des. No. 272
Location U.S. 59 Over Gray Creek
Year Overlaid 1972

Bridge Deck Dimensions
Width - 24 ft.
Length - 102 ft.
Deck Area - 2,448 ft.²

Delaminated Area - 53.25 ft.²
% Delamination - 2.18%

Indicates areas where Electrical Potential Readings were taken. Details next page.
Letters indicate Chloride cores. Numbers indicate delamination cores. Blocked-out areas indicate delamination cores.

Year Overlaid 1972
Location U.S. 59 Over Gray Creek
FN-59-7(14)-21-18 Des. No. 272
Cherokee County
Cherokee County  
FN-59-7(14)-21-18 Des. No. 272  
Location: US 59 Over Gray Creek  
Year Overlaid: 1972

Electrical Potential  
Negative Voltage - Copper Sulfate  
Half Cell  
Detail Sheet

<table>
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<th>41</th>
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<td>25</td>
<td>24</td>
<td>23</td>
<td>22</td>
<td>21</td>
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</tbody>
</table>

Blocked out areas indicate delamination.
**Location U.S. 59 Over Gray Creek**

**Year Overlaid 1972**

<table>
<thead>
<tr>
<th>Depth (in)</th>
<th>3.31</th>
<th>0.59</th>
<th>0.33</th>
<th>1.23</th>
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</tr>
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</tr>
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<td>1.72</td>
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<tr>
<td>0.77</td>
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</tbody>
</table>

**Cherokee County**

**FM-59-7(14)--21-18 Des. No. 272**
Cherokee County
FN-59-7(14)--21-18 Des. No. 272
Location: U.S. 59 Over Gray Creek
Year Overlaid: 1972

DELAMINATION CORES

Core #1

Core #2

Core #3
Location: I-35 Over Raccoon River Northbound
Year Overlaid: 1973
Polk County

Delaminated Area - 0.00 %
Electrical Potential Readings
Letters indicate chloride cores.

Not to Scale
Electrical Potential
Negative Voltage - Copper Sulfate
Half Cell
Detail Sheet

| Location: | I-35 Over Raccoon River Northbound |
| Location: | Year Overlaid: | 1973 |

<p>| 26 Ft. | 100 Ft. | 38 | 30 | 29 | 38 | 29 | 28 | 31 | 29 | 29 | 46 | 29 | 28 | 28 | 27 | 30 | 26 | 28 | 30 | 24 | 25 | 28 | 32 | 30 | 27 | 32 | 28 | 38 | 24 |
| 23 | 34 | 20 | 25 | 19 | 21 | 18 | 24 | 18 | 19 | 19 | 25 | 21 | 17 | 17 | 21 | 20 | 20 | 20 | 20 | 21 | 20 | 21 | 20 | 22 | 19 | 26 | 21 |
| 21 | 22 | 21 | 20 | 21 | 23 | 24 | 24 | 24 | 18 | 17 | 19 | 25 | 21 | 23 | 21 | 22 | 18 | 19 | 14 | 17 | 19 | 16 | 23 | 18 | 17 | 29 |
| 21 | 23 | 20 | 19 | 18 | 21 | 21 | 18 | 17 | 20 | 18 | 21 | 17 | 16 | 22 | 14 | 23 | 17 | 15 | 11 | 13 | 14 | 15 | 14 | 19 | 17 |
| 21 | 23 | 19 | 19 | 23 | 27 | 22 | 18 | 17 | 22 | 22 | 24 | 16 | 18 | 20 | 13 | 13 | 13 | 13 | 12 | 09 | 11 | 12 | 11 | 13 | 13 | 14 |
| 21 | 18 | 23 | 23 | 24 | 31 | 18 | 27 | 20 | 18 | 18 | 30 | 22 | 29 | 19 | 16 | 17 | 17 | 23 | 17 | 41 | 12 | 10 | 15 | 15 | 18 | 13 | 15 |
| 25 | 21 | 30 | 28 | 30 | 23 | 22 | 18 | 18 | 18 | 18 | 19 | 20 | 21 | 25 | 21 | 19 | 18 | 22 | 12 | 11 | 13 | 20 | 12 | 17 | 19 |
| 30 | 35 | 34 | 20 | 23 | 27 | 22 | 38 | 30 | 23 | 22 | 18 | 18 | 18 | 18 | 19 | 20 | 21 | 25 | 21 | 19 | 18 | 22 | 12 | 11 | 13 | 20 | 12 | 17 | 19 |
| 27 | 32 | 27 | 32 | 22 | 38 | 34 | 34 | 28 | 46 | 35 | 31 | 10 | 21 | 33 | 41 | 33 | 32 | 25 | 34 | 26 | 21 | 36 | 25 | 27 | 19 | 27 | 16 | 18 | 29 | 23 | 14 | 25 | 22 |</p>
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<th>New Deck</th>
<th>Date</th>
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**Year Overlaid:** 1973

**Location:** I-35 Over Raccoon River Northbound

I-35-2 (129) 69-01-77 Des. No. 273

**Polk County**
Story County
FN-65-5(5)--21-85 Des. No. 172
Location: U.S. 65 Over U.S. 30
Year Overlaid: 1972

Bridge Deck Dimension
Width - 30 ft.
Length - 224 ft.
Deck Area - 6,720 ft.²
Delaminated Area - 650.13 ft.²
% Delamination - 9.67%

- Indicates areas where Electrical Potential Readings were taken
- Details next page

Letters indicate chloride cores.
Numbers indicate delamination cores.

Blocked out areas indicate delamination

Not to Scale
**Story County**  
**FN-65-5(5)--21-85 Des. No. 172**  
**Location:** U.S. 65 Over U.S. 30  
**Year Overlaid:** 1972

<table>
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<th>B</th>
<th>C</th>
<th>D</th>
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*Old Deck*
Story County

FN-65-5(5) -- 21-85 Des. No. 172

Location: U.S. 65 Over U.S. 30
Year overlaid: 1972

DELAMINATION CORES

Core #1

Core #2

Core #3

A-69
Polk County
Des. No. 273
Location: I-35 Over Raccoon River Southbound
Year Overlaid: 1973

Bridge Deck Dimensions
Width = 28 ft.
Length = 860 ft.

Total Deck Area = 38,368 ft.²
Delaminated Area = 0.00 ft.²
% Delamination = 0.00%

Indicates areas where Electrical Potential Readings were taken.
Details next page.
Letters indicate chloride cores.
Polk County
Des. No. 273
Location: 1-35 Over Raccoon River Southbound
Year Overlaid: 1973

<p>| | | | | | | | | | | | | | | | | | | | | |</p>
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</table>

Represents E. Cross Hatched Area

100 Ft.

Representative Vertical-Copper Sulphate Protective Potential

Location: I-35 Over Raccoon River Southbound
I-35-Z(129)69-01-77 Des. No. 273
Polk County
Polk County
I-35-2(129)69--01-77 Des.No. 273
Location: I-35 Over Raccoon River Southbound
Year Overlaid: 1973

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<tr>
<td>Old Deck</td>
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</tbody>
</table>
Polk County
Location: I-235 over Des Moines River
Westbound Bridge

Year Overlaid: 1973

Test Section in Westbound Lane
From East Abutment to First Expansion Joint

Width - 52 ft.
Length - 860 ft.
Deck Area - 44,720 ft.²
Delaminated Area - 669.75 ft.²
% Delamination - 4.06%

Letters indicate chloride cores.
Numbers indicate delamination cores.

Electrical Potential Readings were taken in the details next page.

% Delamination

Decks:
- Width: 52 ft.
- Length: 860 ft.
- Deck Area: 44,720 ft.²
- Delaminated Area: 669.75 ft.²
- % Delamination: 4.06%

Test Section in Westbound Lane:
- From East Abutment to First Expansion Joint.

Chloride cores and delamination cores are indicated by letters and numbers, respectively.

Details are continued on the next page.
Polk County
I-235-2(134)81-01-77 Des. No. 573
Location: I-235 Over Des Moines River Westbound Bridge
Year Overlaid: 1973

Electrical Potential
Negative Voltage - Copper Sulfate
Half Cell
Detail Sheet

Blocked out areas indicate delamination

100 Ft.
Polk County

Location: I-235 Over Des Moines River Westbound Bridge

Year Overlaid: 1973

Location: I-235-2(134)-81-01-77 Des. No. 573

Polk County

<table>
<thead>
<tr>
<th>Test Location</th>
<th>Cone. Depth</th>
<th>Chloride Content - lbs/cu. yd.</th>
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<tr>
<td>C</td>
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<tr>
<td>F</td>
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</tbody>
</table>

Test Location

Depth

Chloride Content - lbs/cu. yd.
Polk County
I-235-2(134)81-01-77 Des. No. 573
Location: I-235 Over Des Moines River Westbound Bridge
Year Overlaid: 1973

DELAMINATION CORES

Core #1

Core #2

Core #3

Core #4

Core #5

Delamination at the Steel