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Long-term performance evaluation of Iowa concrete overlays

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Long-term performance evaluation of Iowa concrete overlays

Abstract
The use of concrete overlays has long been recognised as a cost-effective pavement maintenance and rehabilitation strategy. However, the long-term performance of various types of concrete overlays has not been fully investigated since there has not been enough performance data available to conduct such an evaluation. Concrete overlays have been regularly constructed on Iowa roadways since the late 1970s and many older projects are still in use. Performance-related data for in-service concrete overlays have been acquired from the available resources to evaluate long-term performance of concrete overlays in Iowa. The information collected includes Pavement Condition Index (PCI), International Roughness Index (IRI), overlay type, construction year, overlay thickness, joint spacing, traffic, and other construction and design-related data. Based on an evaluation of PCI and IRI changes during service life, it is observed that concrete overlays can provide at least 20 years of service life. In terms of PCI ratings, 89% of concrete overlays investigated have PCI values greater than 60% as of the time of the analysis. Similarly, 93% of concrete overlays have IRI values lower than 2.7 m/km (170 in/mile). The effects of overlays type and design features on long-term performance of Iowa concrete overlays are also discussed.

Keywords
Concrete overlays, pavement condition Index, International Roughness Index, long-term pavement performance, Iowa

Disciplines
Civil Engineering

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Long-term performance evaluation of Iowa concrete overlays

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ABSTRACT: The use of concrete overlays has long been recognized as a cost-effective pavement maintenance and rehabilitation strategy. However, the long-term performance of various types of concrete overlays has not been fully investigated since there has not been enough performance data available to conduct such an evaluation. Concrete overlays have been regularly constructed on Iowa roadways since the late 1970s and many older projects are still in use. Performance-related data for in-service concrete overlays have been acquired from the available resources to evaluate long-term performance of concrete overlays in Iowa. The information collected includes Pavement Condition Index (PCI), International Roughness Index (IRI), overlay type, construction year, overlay thickness, joint spacing, traffic, and other construction and design-related data. Based on an evaluation of PCI and IRI changes during service life, it is observed that concrete overlays can provide at least 20 years of service life. In terms of PCI ratings, 89% of concrete overlays investigated have PCI values greater than 60% as of the time of the analysis. Similarly, 93% of concrete overlays have IRI values lower than 2.7 m/km (170 in/mile). The effects of overlays type and design features on long-term performance of Iowa concrete overlays are also discussed.

Keywords: Concrete overlays; Pavement Condition Index; International Roughness Index; Long-term Pavement Performance; Iowa
Introduction

Pavement systems must be well maintained and rehabilitated if they are to continue providing good serviceability over time. One rehabilitation strategy for extending service life is to use concrete overlays (Delatte 2001). There are two major types of concrete overlays, bonded concrete overlays, and unbonded concrete overlays. In general, bonded concrete overlays are used to address surface distresses when the existing underlying pavement is in good or fair condition, while unbonded concrete overlays are used to rehabilitate pavements with some structural deterioration (Torres et al. 2012).

A bonded concrete overlay should have a bond at the interface between the concrete overlay and the existing pavement so that they work as a single unit. Bonded concrete overlays in Iowa include bonded concrete-on-concrete (BCOC) and bonded concrete-on-asphalt (BCOA) (Gross et al. 2017). Bonded concrete overlays typically range in thickness from 51-mm (2 in.) to 152-mm (6 in.) (Torres et al. 2012). Benefits of bonded concrete overlays include cost-effectiveness, improved pavement service life, and reduced road closure time during construction (Delatte et al. 1998). However, adequate bonding must be achieved and maintained to realize these benefits.

An unbonded concrete overlay is constructed with a debonding layer placed above the existing pavement, largely to prevent reflective cracking. Unbonded concrete overlays in Iowa include unbonded concrete-on-concrete (UBCOC) and unbonded concrete-on-asphalt (UBCOA) (Gross et al. 2017). Typical thicknesses are 102-mm (4 in.) to 279-mm (11 in.) (Torres et al. 2012). Unbonded concrete overlays typically are thicker than bonded concrete overlays because the new layer must be structurally independent of the lower layer.
Potential distresses that concrete overlays may experience include materials-related distresses (MRD) such as alkali-silica reaction (ASR), D-cracking, and freeze-thaw damage (Harrington and Fick 2014), and load-related distresses including transverse cracking, faulting, and joint spalling (Rasmussen et al. 2002). Existing pavement condition is also one of the most important issues affecting concrete overlay performance. The thickness and condition of the existing asphalt pavement may be especially critical in affecting concrete overlay service life (Barman et al. 2011, Mateos et al. 2015). Concrete overlays should be properly designed and constructed to prevent premature deterioration.

Concrete overlays do not represent a new concept, and there is also some pertinent literature evaluating concrete overlay performance. Sufficient slab thickness, small panel size, use of macro-fiber, and surface drainage system are important factors influencing BCOA performance (King and Roesler 2014). However, the long-term performance of different types of concrete overlays has not been investigated in-depth because of a shortage of data. The aim of the work reported in this paper is to combine the data available from several sources and provide guidance for proper decision-making with respect to concrete overlays design and construction.

Objective and scope

Objective and scope The primary objective of this study is to evaluate the long-term performance of various types of concrete overlays constructed in Iowa since the 1970s. Performance data dating back to 1998 for all in-service Iowa concrete overlays constructed over the last 38 years were collected and evaluated. Performance measures utilized in this study include the Pavement Condition Index (PCI) and the International Roughness Index (IRI). The effects of overlay type and design features on long-term performance were also identified.
Methodology

General Information on Iowa Concrete Overlay Projects

Figure 1 shows the spatial distribution of the 384 concrete overlay projects included in the study. Four different types of concrete overlays have been in use in Iowa, including bonded concrete-on-concrete (BCOC), unbonded concrete-on-concrete (UBCOC), bonded concrete-on-asphalt (BCOA), and unbonded concrete-on-asphalt (UBCOA). Historically, the term whitetopping has referred to a concrete overlay of asphalt. For this study, whitetopping was divided into two categories: BCOA and UBCOA. Concrete overlays on the asphalt where slab thickness was less than or equal to 152-mm (6 in.) were designated as BCOA, whereas concrete overlays on asphalt with slab thickness of more than 152-mm (6 in.) were designated as UBCOA. This division follows historical Iowa concrete overlays practices adopted by the Iowa Department of Transportation (DOT) (Gross et al. 2017). A total of 35 overlays were known to have been reconstructed or replaced at the time of this study, but these were not considered in the analysis because there were no detailed records regarding when they were taken out of service. However, those 35 projects comprised fewer than 10% of all projects considered in the study. As shown in Table 1, 91% of the included projects were completed during the past 30 years. 82% of these projects have average daily traffic (ADT) range below 1500, meaning that most of these projects were on the county (low volume) road infrastructure system. Concrete overlays thickness ranged from 51-mm (2 in.) to 305-mm (12 in.), and transverse joint spacing ranged from 0.9-m (3 ft.) to 12.2-m (40 ft.). 94% of projects had a design thickness ranging from 102-mm (4 in.) to 203-mm (8 in.) and 92% had a transverse joint spacing of either 1.7-1.8-m (5.5-6 ft.), 3.7-3.8-m (12-12.5 ft.), or 4.6-6.1- m (15-20 ft.).
Figure 1. Spatial distribution of Iowa concrete overlay projects
Table 1. Distribution of Iowa Concrete Overlay Projects

<table>
<thead>
<tr>
<th>Age (year)</th>
<th>Percent of data based on the number of projects (%)</th>
<th>ADT (count)</th>
<th>Percent of data based on the number of projects (%)</th>
<th>Concrete overlays thickness (mm)</th>
<th>Percent of data based on the number of projects (%)</th>
<th>Joint spacing (m)</th>
<th>Percent of data based on the number of projects (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-2</td>
<td>8</td>
<td>&lt;500</td>
<td>32</td>
<td>&gt;76</td>
<td>2</td>
<td>&lt;1.5</td>
<td>1</td>
</tr>
<tr>
<td>3-5</td>
<td>25</td>
<td>501-1,000</td>
<td>34</td>
<td>102</td>
<td>13</td>
<td>1.7-1.8</td>
<td>12</td>
</tr>
<tr>
<td>6-10</td>
<td>12</td>
<td>1,001-1,500</td>
<td>16</td>
<td>127</td>
<td>9</td>
<td>2.1-3.5</td>
<td>5</td>
</tr>
<tr>
<td>11-15</td>
<td>14</td>
<td>1,501-2,000</td>
<td>5</td>
<td>152</td>
<td>48</td>
<td>3.7-3.8</td>
<td>31</td>
</tr>
<tr>
<td>16-20</td>
<td>9</td>
<td>2,001-3,000</td>
<td>5</td>
<td>178</td>
<td>11</td>
<td>4.0-4.3</td>
<td>1</td>
</tr>
<tr>
<td>21-25</td>
<td>14</td>
<td>3,001-4,000</td>
<td>2</td>
<td>203</td>
<td>13</td>
<td>4.6-6.1</td>
<td>49</td>
</tr>
<tr>
<td>26-30</td>
<td>9</td>
<td>4,001-10,000</td>
<td>4</td>
<td>229</td>
<td>2</td>
<td>12.2</td>
<td>1</td>
</tr>
<tr>
<td>&gt;31</td>
<td>9</td>
<td>&gt;10,000</td>
<td>2</td>
<td>254</td>
<td>2</td>
<td>Total</td>
<td>Total</td>
</tr>
</tbody>
</table>

Total 100 | Total 100 | Total 100 | Total 100 |

_Iowa Concrete Overlay Field Performance Data_

Concrete overlay performance data were obtained from pavement distress databases maintained by the Iowa Pavement Management Program (IPMP). The IPMP has collected data on state and local highways since 1998. The pavement distress data were collected by a vendor using an automatic road analyzer (ARAN). Prior to 2011, the distress data were collected at a spacing of 10 m (32.8 ft.) for 100% coverage of the pavement management section. Since 2011, the distress data have been collected at a spacing of 16 m (52.5 ft.). The data used spanned a 16-year interval. In addition to pavement distress data, project data was collected from the Iowa Concrete
Paving Association (ICPA), which included joint spacing, overlay thickness, type of overlay, traffic volume, and year of overlay construction.

The concrete overlay pavement performance data included distresses such as transverse cracking, longitudinal cracking, faulting, D-cracking, joint spalling, and International Roughness Index (IRI), among others. Average left wheel path and right wheel path IRI data were reported for each of the 10 m (32.8 ft.) or 16 m (52.5 ft.) sections, depending on the year of collection. The linear lengths of longitudinal wheel path and non-wheel path, as well as transverse cracking and area of patching, were summed and reported, along with evaluations of the low, medium, and high levels of severity for every 10 m (32.8 ft.) or 16 m (52.5 ft.) section. Using these pavement condition data, the IPMP calculates the PCI for each concrete overlay project using Equation (1) (Gross et al. 2017).

\[
PCI = 100 - 35 \left( \frac{IRI}{253} \right) - 25 \left( \frac{\text{number of D-crack joints per 528 ft.}}{8} \right) - 15 \left( \frac{\text{number of spalled joints per 528 ft.}}{9} \right) - 25 \left( \frac{\text{number of transverse cracks per 528 ft.}}{14} \right)
\]

(1)

Results and discussion

Performance of Concrete Overlays

Table 2 presents PCI distributions for the entire concrete overlay projects database and for the different types of overlays: bonded concrete on concrete (BCOC), unbonded concrete on concrete (UBCOC), bonded concrete on asphalt (BCOA), and unbonded concrete on asphalt (UBCOA).
From Table 2, based on PCI ratings, almost 90% of all concrete overlays constructed in Iowa are in excellent to good condition (i.e. in a PCI range of 60% to 100% according to the IPMP) when overlays were in their first 10 years of service. Among the different concrete overlay types and years of service,

Table 2. PCI Distribution for Iowa Concrete Overlays Data for Different Age Ranges

<table>
<thead>
<tr>
<th>Type of overlay</th>
<th>Distribution of data points in excellent to good condition (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age (year)</td>
</tr>
<tr>
<td></td>
<td>0-10</td>
</tr>
<tr>
<td>BCOC (Bonded concrete on concrete)</td>
<td>89</td>
</tr>
<tr>
<td>UBCOC (Unbonded concrete on concrete)</td>
<td>100</td>
</tr>
<tr>
<td>BCOA (Bonded concrete on asphalt)</td>
<td>97</td>
</tr>
<tr>
<td>UBCOA (Unbonded concrete on asphalt)</td>
<td>99</td>
</tr>
</tbody>
</table>

- First 10 years of service: all four types of concrete overlays showed similar performance.
- During 11 to 20 years of service: UBCOC, BCOA, and UBCOA performed better than BCOC.
- During 21 to 30 years of service: BCOA and UBCOA performed better than UBCOC.
- For more than 30 years of service: UBCOA performed better than BCOA.

It appears that UBCOAs performed better than BCOAs in terms of PCI values. Overlays of asphalt appeared to perform better than overlays of concrete.

Figures 2 and 3 show PCI and IRI distributions of Iowa concrete overlays over the last 38 years. Although, the data set is noisy, and the coefficient of determination ($R^2$) is poor, PCI and
IRI trends appear to be valid. As seen in Figures 2 and 3, the PCI data follow a downward trend while the IRI data follow an upward trend as the overlays age, both as expected. Based on the PCI data illustrated in Figure 2, concrete overlay performance can be rated on average, from excellent to good during the first 34 years of service before trending below 60% into fair condition.

Acceptable initial International Roughness Index (IRI₀) values for newly-constructed PCC pavements range between 1.00 m/km (63 in/mile) and 1.18 m/km (75 in/mile) in Iowa (Iowa DOT 2016). Based on the IRI data illustrated in Figure 3, the IRI trend line did not increase above an unacceptable value of 2.7 m/km (170 in/mile) during 38 years of service (Arhin et al. 2015).

Figure 2. Iowa concrete overlays PCI history for all projects
Effect of Overlay Type on Concrete Overlay Performance

Figure 4 displays changes in PCI with age for each type of concrete overlay.

Based on the PCI trend in Figure 4(a), BCOC PCI values were above 60% (Good to Excellent) during the first 12 years of service. Figure 4(b) illustrates that the PCI trend of UBCOC dropped below 60% after 23 years of service. Figure 4(c,d) illustrates the changes in PCI values with age for BCOA and UBCOA, respectively. The PCI trends of BCOA and UBCOA did not fall below 60% during the first 38 years of service.

Similar to Figures 2 and 3, the data set in Figure 4 is noisy and the correlation coefficients are poor, but these trends indicate that the BCOA and UBCOA PCI trends change with age at a slower rate compared to those of BCOC and UBCOC. The observation indicates that PCC overlay structures on existing asphalt pavement performed better than one of existing
concrete pavement. Also, between the two types of overlays of asphalt, UBCOA, in general, has a longer service life than BCOA. It is because that UBCOAs have greater overlay thickness than BCOAs, and greater overlay thickness leads to increased service life.

Figure 4. Iowa concrete overlays PCI history categorized by overlays types: (a) BCOC, (b) UBCOC, (c) BCOA, and (d) UBCOA

Figure 5 shows IRI changes with age for each type of concrete overlay.

As seen in Figure 5(a), the IRI trendline for BCOC remains below 2.7 m/km (170 in/mile) during the first 20 years of service. Figure 5(b) illustrates that IRI values of UBCOC significantly increased with age to greater than 2.7 m/km (170 in/mile) after 27 years.

According to Figure 5(c,d), IRI values of BCOA and UBCOA also increased slowly with age, remaining below 2.7 m/km (170 in/mile) during the full-service life.

These observations indicate that most Iowa concrete overlays perform well in terms of IRI values.
Figure 5. Iowa concrete overlays IRI history categorized by type of overlays: (a) BCOC, (b) UBCOC, (c) BCOA, and (d) UBCOA

Effect of Average Daily Traffic on Concrete Overlays Performance

Figures 6 and 7 show changes in PCI and IRI values with age under various traffic conditions. According to Table 1, projects with more than 1,500 ADT accounted for only 18% of the projects. With limited data for higher traffic volumes, PCI variation with age could not be clearly identified.

Based on Figure 6, the PCI values categorized by traffic levels decreased with age and, in general, most of the data sets (90% of data points) remained above 60% during the 38 years of service. This result must be qualified because of the low traffic volumes carried by most of the roadways analyzed in this study.
Figure 7 illustrates the changes in IRI values with age. Similar to findings for PCI, the traffic level was not found to be a significant factor influencing changes in IRI values in this study. Also according to Table 3, the sensitivity analysis shows that traffic (i.e. the p-value is 0.1128 for PCI values, and 0.1061 for IRI values) is not a significant factor for both concrete overlays PCI and IRI values. In addition, age and PCC slab thickness are the most significant factor for concrete overlays performance analysis. Historically, concrete overlays have been designed without taking traffic-related variables into account (Harrington et al. 2007).

Figure 6. Iowa concrete overlays PCI history categorized by ADT
Figure 7. Iowa concrete overlays IRI history categorized by ADT

Table 3. The relative importance of variables in the multiple regression model

<table>
<thead>
<tr>
<th>Target response</th>
<th>Model effects (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCI</td>
<td>Age ($&lt; 10^{-20}$)</td>
</tr>
<tr>
<td></td>
<td>PCC Slab Thickness ($&lt; 10^{-20}$)</td>
</tr>
<tr>
<td></td>
<td>Joint Spacing ($&lt; 10^{-20}$)</td>
</tr>
<tr>
<td></td>
<td>Overlay Type (0.0411)</td>
</tr>
<tr>
<td></td>
<td>Average Daily Traffic (0.1128)</td>
</tr>
<tr>
<td>IRI</td>
<td>Age ($&lt; 10^{-20}$)</td>
</tr>
<tr>
<td></td>
<td>PCC Slab Thickness ($&lt; 10^{-20}$)</td>
</tr>
<tr>
<td></td>
<td>Joint Spacing ($1.9 \times 10^{-14}$)</td>
</tr>
<tr>
<td></td>
<td>Overlay Type ($1.2 \times 10^{-10}$)</td>
</tr>
<tr>
<td></td>
<td>Average Daily Traffic (0.1061)</td>
</tr>
</tbody>
</table>
Effect of PCC Slab Thickness on Iowa Concrete Overlay Performance

Figure 8 shows changes in PCI values with age for different overlay thicknesses, separated based on overlay type. Note that the individual plots in Figure 8 does not include all types of concrete overlays since each overlay type has a different thickness range.

Figure 8(a) presents changes in PCI values for two overlays types (BCOC and BCOA) in the 102-mm (4 in.) overlays thickness range. Although the coefficient of determination (R²) is low, it can be concluded based on PCI values that BCOA performed better than BCOC, and BCOAs had a longer service life.

As seen in Figure 8(b), at the 127-mm (5 in.) overlay thickness range, the PCI values for BCOA remained above 60% during the first 30 years of service, while PCI values for UBCOC dropped below 60% after just 20 years of service.

From Figure 8(c), it can be observed that the 152-mm (6 in.) PCC slab thickness group has more data points than other thicknesses. Data were available for two different overlay types: BCOA and UBCOC. The BCOA remained above 60% after the 38 years of service. On the other hand, the trend of UBCOC dropped below 60% after 23 years. Similar to other figures, R² values were low, but the trends showed BCOA performed better than UBCOC in this thickness category.

Figure 8(d,e) presents PCI values for UBCOA and UBCOC in the 178-mm (7 in.) and 203-mm (8 in.) slab thickness ranges, respectively. At these thicknesses, the trends show that UBCOA performed better than UBCOC and that PCI did not change much with age. The PCI trend of UBCOC remained above 60% during the first 20 years of service, while the PCI trend of UBCOA remained above 60% during the first 35 years of service.
Together, these observations from Figure 8 indicate that thicker concrete overlays tend to perform better since overall structural capacity of concrete overlay increases as the PCC overlays thickness increases. When overlay thickness is between 102-mm (4 in.) and 203-mm (8 in.), the PCI trends of UBCOC, BCOA, and UBCOA were all above 80% during the first 10 years of service.

Figure 8. Iowa concrete overlays PCI history categorized by the thickness (cube legends: BCOC, diamond legends: UBCOC, circle legends: BCOA, triangle legends: UBCOA): (a) PCC slab thickness 102-mm, (b) PCC slab thickness 127-mm, (c) PCC slab thickness 152-mm, (d) PCC slab thickness 178-mm, and (e) PCC slab thickness 203-mm
Figure 9 presents changes in IRI values with age for overlay thicknesses, separated based on overlay type.

According to Figure 9(a), IRI for BCOC did not change much with age, while IRI for BCOA increased more quickly than BCOC. It is possible that BCOC has a lack of data for this thickness range. For both of these overlay types, IRI values did not exceed 2.7 m/km (170 in/mile) during 35 years of service. As a result, in terms of IRI trends, BCOA performed as good as BCOC during the first 15 years of service.

Based on Figure 9(b,c), the IRI of BCOA increased gradually with age when the overlays thicknesses were 127-mm (5 in.) and 152-mm (6 in.), respectively. As seen in these figures, about 90% of concrete overlay projects did not exceed an IRI of 2.7 m/km (170 in/mile) during 35 years of service. BCOA and UBCOC had similar IRI values during the first 10 years of service, but the IRI trend of UBCOC rose more quickly than BCOA, so in terms of IRI BCOA performed better than UBCOC over the long-term.

Figure 9(d) presents data for the 178-mm (7 in.) overlays thickness range. The UBCOA and UBCOC had similar IRI values during the first 10 years of service, but IRI values for UBCOC increased at a greater rate than UBCOA, so the UBCOA performed better than UBCOC in terms of IRI in the long-term. Figure 9(e) indicates that IRI for UBCOC did not change with age when the thickness of the overlay was 203-mm (8 in.). This is probably due to the lack of data for this relatively higher thickness. On the other hand, IRI for UBCOA did increase with age, with four IRI data points higher than 2.7 m/km (170 in/mile). Together, these observations from Figure 9 indicate that, with respect to IRI trends, thicker concrete overlays perform better. In view of the fact that the pavement structural capacity increases as the PCC overlays thickness increases.
Figure 9. Iowa concrete overlays IRI history categorized by the thickness (cube legends: BCOC, diamond legends: UBCOC, circle legends: BCOA, triangle legends: UBCOA): (a) PCC slab thickness 102-mm, (b) PCC slab thickness 127-mm, (c) PCC slab thickness 152-mm, (d) PCC slab thickness 178-mm, and (e) PCC slab thickness 203-mm

**Effect of Joint Spacing on Iowa Concrete Overlays Performance**

Figure 10 shows changes in PCI values with age for different transverse joint spacing types. Similar to Figures 8 and 9, the individual plots in Figure 10 do not cover all concrete overlay types because particular joint spacings were sometimes only used on certain types of overlays.
Based on Figure 10(a), the PCI trends for BCOA and UBCOC were greater than 60% during the first 10 years of service when using 1.7–1.8 m (5.5-6 ft.) of transverse joint spacing.

Based on Figure 10(b), BCOA performed better than other types of overlays in terms of PCI trends for 3.7–3.8 m (12–12.5 ft.) transverse joint spacing. In the first 10 years of service, the PCI values for UBCOC and UBCOA were close to one another, but the PCI of UBCOA dropped more rapidly over time than UBCOC, indicating that UBCOC performed better than UBCOA in the long-term.

Figure 10(c) presents PCI data for a 4.6–6.1 m (15–20 ft.) joint spacing range for different types of overlays. BCOA and UBCOA performed better than BCOC and UBCOC. PCI values for UBCOC, BCOA and UBCOA are close to one another during the first 10 years of service, but PCI of BCOC is lower than the other types of overlays over the first 10 years and decreased more rapidly than BCOA and UBCOA over time.

Shorter joint spacing reduces concrete slab tensile stresses under mechanical and environmental loadings, so smaller slab sizes are recommended over larger ones (Mack et al. 1998). Previous studies have recommended that the length and width of joint spacing in feet for concrete overlays should be no more than 1.5 times the thickness in inches; for overlays equal to or less than 152-mm (6 in.), therefore, the recommended joint spacing is 2.7-m (9 ft.).

These studies indicate that the joint spacing is an important parameter influencing concrete overlay performance and that shorter slab sizes (transverse joint spacing between 1.7 and 1.8 m) should provide better performance for concrete overlays than longer slab sizes. Shorter concrete overlays slab sizes have only been used in Iowa during the last ten years, and they have demonstrated good performance to-date based on the results in Figure 10. Performance data from the older Iowa concrete overlays in Figure 10 have also shown that larger slab sizes
(transverse joint spacing higher than 3.7 m) can also deliver good long-term performance, particularly when used in BCOA and UBCOA applications.

Figure 10. Iowa concrete overlays PCI history categorized by joint spacing (cube legends: BCOC, diamond legends: UBCOC, circle legends: BCOA, triangle legends: UBCOA): (a) joint spacing 1.7-1.8 meters, (b) joint spacing 3.7-3.8 meters, and (c) joint spacing 4.6-6.1 meters

Figure 11 shows changes in IRI values with age for different joint spacing types. According to Figure 11(a), the IRI values of UBCOC and BCOA increased with age, but with the lack of long-term data, IRI values overall did not increase much and remained below 2.7 m/km (170 in/mile).

Figure 11(b) illustrates the relationship between IRI values and age for the 3.7–3.8 m (12–12.5 ft.) joint spacing range. While three different overlays types’ IRI values are close to one another during the first 10 years, the IRI trend of BCOA increased more gradually compared to those of UBCOC and UBCOA, indicating that BCOA performed better than UBCOC and
UBCOA in the long-term. Figure 11(c) illustrates the relationship between IRI and age for a 4.6–6.1 m (15–20 ft.) joint spacing range. Four different overlays types’ IRI trends were close to one another during the first 10 years of service, with the IRI of UBCOC increasing more rapidly with age than other overlays types. It is possible that the different of existing pavement types (i.e. PCC and HMA) and broad of thickness range (from 127-mm (5 in.) to 203-mm (8 in.)). As a result, IRI of UBCOA and BCOA did not change much with age.

Some observations indicate that concrete overlay performance may suffer when thinner slabs and large slab sizes are used together, but most concrete overlay projects in this data set have IRI values below 2.7 m/km (170 in/mile) and performance trendlines for different joint spacings are close to one another.

Figure 11. Iowa concrete overlays IRI history categorized by joint spacing (cube legends: BCOC, diamond legends: UBCOC, circle legends: BCOA, triangle legends: UBCOA): (a) joint spacing 1.7-1.8 meters, (b) joint spacing 3.7-3.8 meters, and (c) joint spacing 4.6-6.1 meters
Conclusions

This study evaluated the long-term performance of various types of concrete overlays built in Iowa over the last 38 years. Historical performance data for in-service concrete overlays in Iowa were collected through ICPA records and the IPMP database. This information includes PCI, IRI, overlay type, construction year, overlay thickness, joint spacing, traffic levels, and other construction- and design-related information. Changes in PCI and IRI during service life have been investigated as performance change indicators. The effects of overlay types and design features (including overlay thickness and joint spacing) on long-term performance were also identified. The major findings can be summarized as follows:

- According to PCI ratings, 89% of concrete overlay projects have PCI values greater than 60%. About 93% of concrete overlay projects have IRI values lower than 2.7 m/km (170 in/mile). This finding indicates that concrete overlays are effective in expanding the service life of existing pavements. For example, the PCI values of UBCOCs were higher than 60% up to 20 years, and the IRI values of UBCOCs were lower than 2.7 m/km (170 in/mile) up to 25 years. The PCI values of UBCOA and BCOA were higher than 60% up to 35 years, and the IRI values of UBCOA and BCOA were lower than 2.7 m/km (170 in/mile) up to 35 years.

- Performance and service life varied for different types of concrete overlays. In the first 10 years of service, all four types of concrete overlays showed similar performance. During 11–20 years of service, UBCOC, BCOA and UBCOA performed better than BCOC. Between 21 and 30 years of service, BCOA and UBCOA performed better than UBCOC. For more than 30 years of service, UBCOA performed better than BCOA.
Pavement thickness can affect concrete overlay performance and service life. In general, greater overlay thickness leads to increased service life. UBCOA can provide better performance in terms of PCI and IRI trends than other concrete overlay types. UBCOC is a concrete overlay type with a broader thickness range (from 127-mm (5 in.) to 203-mm (8 in.)) than the other concrete overlay types. The performance of UBCOC is similar to UBCOA in the thickness ranges of 152-mm (6 in.) to 203-mm (8 in.).

Joint spacing can also affect concrete overlay performance and service life. Shorter joint spacings (i.e. 1.7–1.8 m (5.5– 6 ft.)) for UBCOC may present more advantages than larger joint spacing (i.e. longer than 3.8 m (12 ft.)), but BCOA and UBCOA projects with joint spacing larger than 4.6 m (15 ft.) still show performance comparable to joint spacing shorter than 4.6 m (15 ft.).

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