Cold In-Place Recycling Project Selection and Guidance for Iowa Roadways

tech transfer summary

When designed effectively and used on appropriate candidate pavements, cold in-place recycling can successfully address distresses such as raveling, rutting, roughness, and especially cracking.

July 2023

RESEARCH PROJECT TITLE
Cold In-Place Recycling Project Selection and Guidance for Iowa Roadways

SPONSORS
Iowa Highway Research Board
(IHRB Project TR-774)
Iowa Department of Transportation
(InTrans Project 19-695)

PRINCIPAL INVESTIGATOR
Chuck Jahren, Professor
Construction Management and Technology,
Iowa State University
515-294-3829 / cjahren@iastate.edu
(orcid.org/0000-0003-2828-8483)

CO-PRINCIPAL INVESTIGATOR
Hosin "David" Lee, Professor
Iowa Technology Institute
University of Iowa
(orcid.org/0000-0001-9766-1232)

MORE INFORMATION
intrans.iastate.edu

Asphalt Materials and Pavements Program,
Institute for Transportation
Iowa State University
2711 S. Loop Drive, Suite 4700
Ames, IA 50010-8664
515-294-8103
ampp.intrans.iastate.edu

The Asphalt Materials and Pavements Program (AMPP) at InTrans specializes in improving asphalt materials and pavements through research and technology transfer and in developing students' technical skills in asphalt.

Objective

The objective of this project was to investigate the deterioration processes experienced by CIR projects in Iowa with the goal of ultimately improving project selection, design, construction, and maintenance.

Background

Cold in-place recycling (CIR) is an asphalt pavement rehabilitation technique in which approximately 2 to 4 in. of the existing hot-mix asphalt (HMA) surface layer is milled off, mixed with stabilizing agents, and compacted into a new base layer. Typical practice in Iowa is then to cover the recycled layer with an HMA overlay, though other surface treatments can be used.

CIR is typically used on low-volume roads, defined in Iowa as roads with annual average daily traffic (AADT) volumes of less than 2,000. Because the treatment adds little to the pavement structure, it is not recommended for pavements with poor subgrades or for projects where the remaining pavement after milling is too thin to support the recycling equipment.

Performance studies have shown that CIR can effectively mitigate reflective cracking in Iowa pavements, with CIR outperforming alternatives such as mill and fill, overlay, rubblization, and heater scarification.

Problem Statement

However, not all pavements are good candidates for CIR, and the differences between good and poor candidates can be difficult to identify. The long-term performance of a CIR project depends considerably on the selection of an appropriate candidate pavement.

Additionally, performance can vary depending on the quality of the existing materials, subgrade conditions, traffic loading, and climate conditions. Further understanding how CIR projects deteriorate can aid in the development of project selection guidelines and strategies to prevent and mitigate deterioration.

Iowa State University
Institute for Transportation

Research Description

A multifaceted investigation was undertaken involving data analysis, field and laboratory testing, and a meta-analysis of the literature.

Analysis of Performance Data from CIR Projects

Performance, traffic, and structural data related to 44 CIR projects across Iowa for the years 1998 through 2019 were extracted from the Iowa Pavement Management Information System (PMIS) and supplemented with plan sets from the Iowa Department of Transportation's (DOT's) digital repository.

The PMIS data were prepared to remove duplicate values and likely erroneous data, and analyses of the prepared data were conducted, including descriptive statistics, an analysis of traffic volumes, a survival analysis, and a multivariate analysis.

Field and Laboratory Testing on Field Cores from CIR Pavement Sections in Iowa

Field cores were collected in November 2021 from CIR pavement sections featuring HMA overlays on US 34 in Mills and Wapello Counties, Iowa. From the cores, the thickness, cracking resistance, binder contents, and gradations of both the CIR and HMA layers were determined.

Cracking resistance (in terms of flexibility index [FI]) was determined through semicircular bending (SCB) tests. Higher FI values indicate that specimens are more flexible and less likely to crack. Binder contents and aggregate gradations were determined through burn-off tests and sieving, respectively.

Forensic Case Study of Two Low-Volume CIR Pavements

Two poorly performing CIR sections in Iowa, one in Story County and one in O'Brien County, were analyzed to investigate why performance targets were not met. Field data were obtained through coring and FWD testing, and design plan sets were obtained from the Iowa DOT.

The cores were examined for compliance with the layer thicknesses, volumetrics, and gradations in the plan sets. Using design and core thicknesses, a structural number was calculated for each project and compared with a structural number obtained from the FWD data. A structural strength index (SSI) was also calculated based on FWD data and compared to the bounds for good and poor pavements.

Comparison of Aggregate Gradations of CIR and HIR Millings

The aggregate gradations of millings obtained from a recent hot in-place recycling (HIR) project on IA 22 in Wellman, Iowa, were compared to the gradations of CIR millings obtained from previous research projects conducted in nine counties in Iowa.

Collection of cores from US 34

Side view (left) and top view (right) of a cracked core with an insufficient HMA layer thickness

Key Findings

- Extensive data preparation was required to use the PMIS database records from 1998 to 2019, including converting between metric and imperial units, ensuring that indices were calculated uniformly, excluding data recorded during years when observations were not made, removing outliers, and separating pre- and post-construction data.
- The PMIS data analysis suggested that, in many cases, noticeable deterioration occurred 10 to 15 years after CIR. Rutting and cracking contributed most to the deterioration, with rutting most quickly triggering concern for pavement condition, following by cracking. Thicker CIR layers performed better than thinner layers.
- Laboratory testing of the US 34 cores indicated that the HMA layers had lower FI values than the CIR layers. This suggests that HMA overlays are more brittle and less flexible than CIR layers, which confirms previous assessments in the literature. The asphalt contents among CIR samples varied noticeably, and CIR specimens with higher asphalt binder contents exhibited higher FI values.
- The forensic case study indicated that performance targets were not met for three reasons: (1) pavement layers were thinner than the plans required, (2) CIR gradations were finer than the plans required and finer than typically expected in Iowa, and (3) the pavement structure was inadequate given the likely subgrade strength.
- The comparison of CIR and HIR gradation data confirmed that HIR millings were coarser than CIR millings.

Conclusions and Recommendations

Based on previous studies and the findings from this research, the following deterioration process is proposed to explain the observed rutting and wheel path cracking in CIR pavements: The more flexible CIR layer has a relatively high air void content and differentially compacts in the wheel paths under heavy wheel loads. The less flexible HMA overlay longitudinally cracks in the wheel paths as it conforms to the CIR layers below.

The following recommendations are based on the results of this research:

- Develop a common data preparation process for researchers using the PMIS database that would reduce future data preparation efforts and more easily link project data to performance data. Input from likely users would help make the process valuable to a range of analyses.
- To address the proposed deterioration process described above, consider project selection, design, construction, and maintenance strategies such as designing more flexible HMA layers that are less likely to crack, using rut filling treatments after ruts form, or limiting the use of CIR when heavy wheel loads might induce compaction rutting in the CIR layers.
- For low-volume roads where CIR is being considered, conduct more thorough predesign investigations of subgrade strength, ensure adequate pavement layer thicknesses through improved quality control and quality assurance, and adjust expectations for the structural strengths of CIR layers where milling gradations are finer than typically recommended.
- For HIR construction, investigate changes in project selection, design, and construction in light of the fact that HIR millings have been found to be, on average, coarser than CIR millings.
- For CIR using foamed asphalt, asphalt binder contents may vary significantly across the pavement's width due to a limited number of spraying nozzles and subsequent mixing operations. To ensure more consistent binder contents, more evenly distribute and mix asphalt binder across the width of the pavement.
- Take steps to ensure that the correct binder content is used in the CIR material. Binder contents that are too high will likely result in a CIR layer that is susceptible to shear rutting, while those that are too low may result in compaction rutting. Minimizing rutting in the CIR layer will likely reduce any wheel path cracking in the HMA layer that would likely occur as the less flexible HMA layer conforms to the ruts in the CIR layer.
- Consider a CIR mixture design to optimize the binder content based on the actual anticipated gradation.

Implementation Readiness and Benefits

CIR has been used successfully to address distresses such as raveling, bleeding (flushing), rutting, and roughness and is especially effective in addressing cracking. The CIR layer has been shown in previous research to mitigate the propagation of reflective cracks by serving as a stress relieving layer.

CIR also offers several environmental benefits, such as reducing the need to use virgin materials and reducing fuel use for trucking and materials processing.

When CIR is used with an HMA overlay, strategies for project selection, design, construction, and maintenance should account for the higher flexibility of the CIR layer relative to the HMA layer, the fineness of the CIR millings, and the issues underlying the common deterioration process for CIR pavements.