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RESEARCH PROJECT TITLE

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

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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**

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Project Selection Guidance for Cold In-Place Recycled Pavements

Proper project selection is an important step in ensuring the success of a cold in-place recycling (CIR) project. As of 2023, CIR has been successfully used in Iowa for more than 30 years. However, it is important to first decide whether CIR is the correct solution for a given pavement project because of its limited effectiveness on roads with heavy traffic and poor pavement support. After a decision is made to consider CIR, the selection of proper materials and processes is also important.

This document summarizes guidance on selecting and designing projects for CIR in Iowa based on research and typical practices in the state as well as national and international research.

1. Traffic

In Iowa, CIR is commonly used for roads with annual average daily traffic (AADT) levels of less than 2,000. In the report associated with this guide (Buss et al. 2023), the literature review cites references that recommend CIR for roads with AADT levels of up to 5,000. In addition to high traffic volumes, heavy truck traffic will likely induce compaction rutting in the CIR layer and possibly reduce the longevity of CIR pavements.

2. Existing Pavements and Subgrades

2.1. Uses and Limitations of CIR

When a CIR project is undertaken, the existing pavement is usually milled to a depth of 3 or 4 in. The machinery required for the CIR process must be supported by the pavement that remains after milling as well as the base and subgrade. Therefore, it is important to consider whether the remaining structure is sufficient to support these short-term heavy loads. In cases where machine support is a concern, it may be possible to reduce the milling depth and leave more of the existing pavement in place. However, as detailed in the report associated with this guide (Buss et al. 2023), research findings suggest that more post-construction surface roughness results when the milling depth is reduced.

CIR is most effective in mitigating reflective cracking, and researchers have found evidence that the more flexible CIR layer in the pavement section acts as a stress relieving layer that slows the progression of reflective cracks. CIR is also effective in addressing surface distresses such as raveling, flushing/bleeding, light to medium rutting, roughness as indicated by poor international roughness index (IRI) results, and edge cracking. CIR is often most successful when applied to a relatively thick pavement section that, although it exhibits cracking distress, is founded on a stable, well-drained subgrade.

A key consideration in selecting a candidate project for CIR is that the existing pavement should be well drained and structurally sound. CIR does not address poor subgrade support problems, so predesign and preconstruction desk and field work that identifies the extent and location of subgrade problem areas is a wise investment. Evidence of a structurally unsound pavement includes rutting, alligator/fatigue cracking, and significant longitudinal wheel path cracking.

2.2. Initial Assessment

The existing pavement structure can be initially assessed using a pavement management information system (PMIS), if one is available that documents the candidate road. Historical information from a PMIS can provide expected pavement thickness, subgrade support conditions, and distress data, including deterioration trends.

By reviewing the information recorded in the PMIS, an analyst can infer whether a road is a good candidate for CIR by noting traffic levels, pavement thicknesses, and distresses such as alligator cracking and longitudinal wheel path cracking that might indicate poor structural support for the pavement. A windshield survey can be conducted to confirm the results of the PMIS review and identify drainage problems that may be associated with areas where poor pavement support is suspected.

If a PMIS is not available for the candidate road, an initial windshield survey of the road can be conducted, and technicians can collect and compile some of the field data that would normally be available in a PMIS.

Additionally, if the candidate road was placed under contract using Iowa Department of Transportation (DOT) flexible pavement specifications, the project's plant reports or charts documenting the hot-mix asphalt (HMA) overlay can usually provide detailed thickness values based on cores taken during construction.

2.3. Field Testing

If CIR still seems feasible for the candidate road after the initial assessment, a field testing program can be conducted. Procedures such as falling weight deflectometer (FWD) testing, dynamic cone penetrometer (DCP) testing, and pavement coring are often conducted as a next step. FWD testing provides the most complete information and requires the most specialized equipment and personnel. Pavement cores can be taken to measure pavement thicknesses and provide specimens to test existing pavement's material properties. Knowing pavement thicknesses and the condition of the underlying pavement layers, the base, and the subgrade is helpful in judging whether the milled pavement will be able to support the CIR machinery.

If it is not possible to mobilize FWD testing equipment and personnel, DCP tests can be conducted through core holes. If coring is not possible, DCP testing can be conducted through jackhammer drill holes. Even if FWD testing is performed, it may nevertheless be worthwhile to perform DCP testing and other material sampling and testing to confirm subgrade support conditions and provide additional details about the candidate pavement.

Core and DCP test locations can be set at regular intervals and at places selected to characterize the best and worst pavement support conditions based on the existing knowledge of the designer. Further tests can be conducted to map the extent of suspected locations of poor pavement support. If the locations of poor pavement support are found to be limited, it may be possible to continue with a CIR project and substitute higher quality materials or emulsion in the design to compensate for weak areas.

If subgrade moisture sensitivity is a concern, this can be mitigated by improving surface drainage and/or adding longitudinal pavement drainage tiles.

3. Design Selection

To design a CIR pavement, it is important to have documentation of the underlying pavement structure and an understanding of the pavement system's structural capacity, including subgrade support. Tools such as DCP evaluation of the subgrade, FWD testing, and coring of pavement materials provide helpful information for the design process.

Section 2318 of the Iowa DOT Standard Specifications (Iowa DOT 2023) addresses CIR pavements, and important aspects of that document are highlighted below where applicable.

3.1. Milling Depth

Typical CIR layer thicknesses are 3 to 4 in., and the existing roadway must have an adequately thick HMA layer to accommodate the depth of milling needed to produce a sufficiently thick CIR layer and for the remaining asphalt layer to support the construction equipment. The CIR layer helps reduce or delay reflective cracking, and research has shown that a 4 in. CIR layer generally performs better than a 3 in. layer for crack mitigation. In Iowa, CIR has typically performed well on composite pavements where several HMA overlays have been placed on a portland cement concrete (PCC) pavement.

3.2. Binder

3.2.1. Emulsion

For Iowa DOT CIR projects on primary or Interstate roads, the standard asphalt emulsion grade is HFMS-2s. Projects on other roads may use either a CSS-1 or HFMS-2s emulsion. An engineered emulsion may be used for projects on any type of road if specified in the contract documents. Emulsions are not permitted when CIR occurs during nighttime operations.

3.2.2. Foamed Asphalt

Iowa DOT CIR projects using foamed asphalt use an asphalt binder grade of PG 52-34S. Section 2318 of the Iowa DOT Standard Specifications require the following (as of May 2023):

Foamed asphalt using PG 52-34S asphalt binder meeting the requirements of Section 4137 may be used on Interstate, Primary, Secondary, and local projects. For projects using PG 52-34S as the cold in-place stabilizing agent, meet the following requirements:

- Minimum $G^*/\sin\delta$ of 0.70 kPa for the original asphalt binder,
- Minimum $G^*/\sin\delta$ of 1.5 kPa for RTFO aged binder (Jnr waived), or
- Maximum $G^*/\sin\delta$ of 5000 kPa for PAV aged binder (Jnr waived).

3.3. Gradation of Milled Materials

The CIR construction train can control the gradation of the milled material by varying the speed and dwell time of the milling machine. Slower speeds and longer dwell times result in finer gradations. Section 2318 of the Iowa DOT Standard Specifications lists two gradation requirements for CIR: (1) 98% to 100% of the milled material must pass the 1.5 in. sieve and (2) 90% to 100% of the milled material must pass the 1 in. sieve. Additionally, the top size of the material should not exceed 50% of the depth of the compacted recycled mat. Gradation revisions may be approved by the engineer.

3.4. CIR Binder Application Rates and Possible Mixture Designs

A variety of mixture design procedures and methods are available for CIR projects. However, CIR contractors have expressed that many CIR mixture design methods used for Iowa pavements result in similar designs. As a result, default application rate values were established for Iowa DOT CIR projects in Section 2318 of the Iowa DOT Standard Specifications.

Always refer to the project's contract documents to determine whether a CIR mixture design is needed. If not, the following application rates are used:

- Standard asphalt emulsion: 0.30 gal of emulsion/yd²/in.
- Foamed asphalt: 0.0011 tons of asphalt binder/yd²/in.

3.5. Surfaces and Overlays

When the design is feasible and the project budget allows, a 4 in. CIR layer has been shown to perform better than a 3 in. CIR layer.

After the CIR layer has been placed and cured, the typical practice in Iowa is to provide a 3 in. HMA overlay

in two 1.5 in. lifts. Using two lifts provides a smoother surface compared to a single lift. Occasionally, a double seal coat has instead been used to provide a surface for a very low volume road or as a temporary holding strategy in anticipation of securing sufficient future funding for an HMA overlay.

According to Section 2318 of the Iowa DOT Standard Specifications, one of the following three moisture requirements must be met before an overlay or surface is placed on the CIR layer:

1. The average moisture content of the CIR layer is less than 3.5%. (An alternative method for determining the appropriate average moisture content is available in Materials I.M. 504 [Iowa DOT 2018].)
2. The average moisture content of the CIR layer has reached a plateau of less than 5.0% and has remained constant (within $\pm 0.3\%$) for a minimum of 3 calendar days.
3. The CIR layer has been completed for 21 calendar days.

For foamed asphalt binder, Woods et al. (2012) recommends the following method to predict drying time based on research conducted in Iowa:

$$\Delta MC/hr = -0.21785 + 0.028769 \text{ IMC} + 0.001483 \text{ Temp} + 0.000562 \text{ Hum} + 0.012455 \text{ Wind}$$

where $\Delta MC/hr$ is change in percent moisture content per hour, IMC = initial moisture content in percent, Temp = air temperature in °F, Hum = relative humidity in percent, and Wind = wind speed in mph.

For example, the following calculation is used to determine the drying rate of a CIR layer with a foamed asphalt binder when the initial moisture content of the CIR layer is 3%, the air temperature is 72°F, the relative humidity is 60%, and the wind speed is 2 mph:

$$\Delta MC/hr = -0.21785 + 0.028769 (3) + 0.001483 (72) + 0.000562 (60) + 0.012455 (2)$$

$$\Delta MC/hr = 0.032963$$

Thus, $1/0.032963 = 30$ hours would be required for the moisture content of the CIR layer to decrease by 1% according to this method.

3.6. Drainage

CIR pavement systems should be well drained. Contractors have noted instances in which the design of a CIR pavement system did not allow proper drainage in the CIR layer. One example was when the CIR layer was “inlayed” in the roadway and shoulders were not included as part of the project, which left the CIR layer susceptible to water ingress. In poor draining areas, rain during the CIR curing time can delay curing and reduce pavement strength.

4. Density and Air Voids

The performance history of CIR projects in Iowa has shown that CIR helps reduce reflective cracking when used in conjunction with an HMA overlay. It is especially important in this context that the CIR layer, like any flexible pavement, balances the flexibility needed to reduce cracking against the stability needed to resist rutting. To achieve this balance, density is an important aspect of field performance.

The Iowa DOT Standard Specifications for CIR compaction and density require the following minimum field densities:

- The CIR layer on Interstate and primary roads must be compacted to 94% of laboratory density based on the dry weight of the compacted material according to Materials I.M. 504 (Iowa DOT 2018).
- The CIR layer on all other roads must be compacted to 92% of laboratory density.

5. Training

Training should be considered for employees who are new to designing and constructing CIR projects.

Employees at all levels within an organization can benefit from visiting a CIR project under construction to understand the scale of the equipment and the need for good pavement support during the construction process. Additionally, most construction crews at visited sites will be able to provide examples of challenging projects and give examples of the difficulties of dealing with inadequate pavement support.

A visit to an active CIR project can also provide the owner's construction representative with valuable experience than can inform his or her engineering judgment. During construction, the contractor and the contracting agency may sometimes adjust the application rates of the stabilizing agents in response to changing conditions of the milled asphalt (such as a higher asphalt content in a recent patch). Since these adjustments are often made based on engineering judgement, the owner's construction representative will benefit from observing experts in the field. For such visits, projects staffed with experienced and competent contractor personnel or owner's representatives are preferred.

Training in interpreting PMIS data, interpreting test results, conducting windshield surveys, designing pavement layer thicknesses given traffic and support conditions, and developing contract documents is also beneficial.

6. References

Buss, A., I. Pinto, H. Lee, B. Moon, C. T. Jahren, Y. Zhang, and X. Hu. 2023. *Cold In-Place Recycling Project Selection and Guidance for Iowa Roadways*. Institute for Transportation, Ames, IA.

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