Long-Term Performance of Cold In-Place Recycled Asphalt Roads

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ABSTRACT

Within three to five years following construction of asphalt pavements, reflected cracks may be observed, one of the primary forms of distress in hot-mix asphalt overlays of flexible pavements. Reflected cracks affect ride quality when rolled down and allow water to penetrate into the pavement and the base, causing the asphalt mix to deteriorate and the base to soften. Consequently, the service life of pavements is reduced. Cold in-place recycling (CIR) provides an economical rehabilitation method that mitigates crack reflection by pulverizing the asphalt pavement surface, thus destroying the old crack pattern in the recycled layer. While the performance of recycled roads is generally good, there is some inconsistency. Several years after recycling, some roads are in excellent condition, while more cracking and rutting is observed on other roads. These differing behaviors can be observed on roads constructed in the same county by the same contractor in the same construction season. Thus, the difference in performance is probably not from such factors as weather, equipment, contractor experience, and construction procedures. Rather, other factors more prominently affect pavement performance, such as recycled pavement age, traffic volume, support conditions, and aged engineering properties of the CIR materials.

This paper discusses a partially completed investigation to identify how aged engineering properties of the CIR materials and other factors affect pavement performance. A selection matrix consisting of 18 sample roads was developed based on previous study. These 18 sample roads represent various ages (young/medium/old), traffic volumes (high/medium/low), and support conditions (strong/weak) in a geographically balanced sampling in Iowa. Pavement condition index (PCI) ratings were collected using an automated pavement distress digital image collection and analysis system. Engineering properties of CIR materials (density, compressive strength, indirect tensile strength, resilient modulus, and asphalt and aggregate content) will be examined through field and lab tests. Statistical analysis will be conducted to describe the relationships between pavement performance and the prominent factors. It is expected that the conclusions and recommendations from this study can be used to improve the performance of future CIR projects in Iowa and other states.

Key words: aged engineering properties—asphalt pavement—cold in-place recycling—pavement performance—recycling—reflected crack

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INTRODUCTION

Flexible pavements deteriorate with time. Typically three to five years following construction, reflected cracks may be observed, one of the primary forms of distress in hot-mix asphalt (HMA) overlays of flexible pavements (Myers, Roque, and Ruth 1998). When rolled down, reflected cracks affect ride quality. Moreover, reflected cracks allow water to penetrate the pavement, which accelerates the deterioration of the overlay and the underlying pavement. Soft base is formed, and hus the service life of pavements is reduced.

HMA overlay is often applied to extend the service life. Experience indicates that cracks reflect through the new overlay within two to four years (McKeen, Hanson, and Stokes 1997). This problem highlights the need for other rehabilitation methods that mitigate reflected cracks.

Cold in-place recycling (CIR) provides an economical rehabilitation procedure that mitigates crack reflection by pulverizing the asphalt pavement surface, thus destroying the old crack pattern in the recycled layer. In 1998, the Iowa DOT and Iowa Highway Research Board initiated an evaluation of the performance of CIR asphalt cement concrete roads (HR-392) (Jahren et al. 1998). Research results from 18 sample roads showed that CIR retarded the development of transverse cracking (reflected cracks). Additionally, CIR roads within the state of Iowa and with an annual average daily traffic (AADT) of less than 2,000 were predicted to have an average service life of 15 to 26 years.

PROBLEM STATEMENT

Several years after recycling, some roads are still in excellent condition with only a few minor cracks while more cracking and rutting is observed on other roads. These differing behaviors can be observed on roads that were constructed in the same county, by the same contractor, and in the same construction season. Thus, the difference in performance is probably not from such factors as weather, equipment, contractor experience, and construction procedures. Rather, other factors become more prominent in affecting pavement performance, such as the following:

- Age of the recycled pavement
- Traffic volume
- Support conditions
- Aged engineering properties of the CIR materials

RESEARCH OBJECTIVES

The objective of this paper is to answer two questions concerning CIR performance:

1. How do aged engineering properties, traffic, and subgrade conditions affect pavement performance?
2. What changes should be made with regard to design, material selection, and construction in order to improve the performance of future recycled roads?

This paper will provide a program report for the study and describe the experimental design.

EXPERIMENTAL DESIGN METHODS AND PROCEDURES

The design of this research project is shown in the flowchart in Figure 1 and further described in this section.

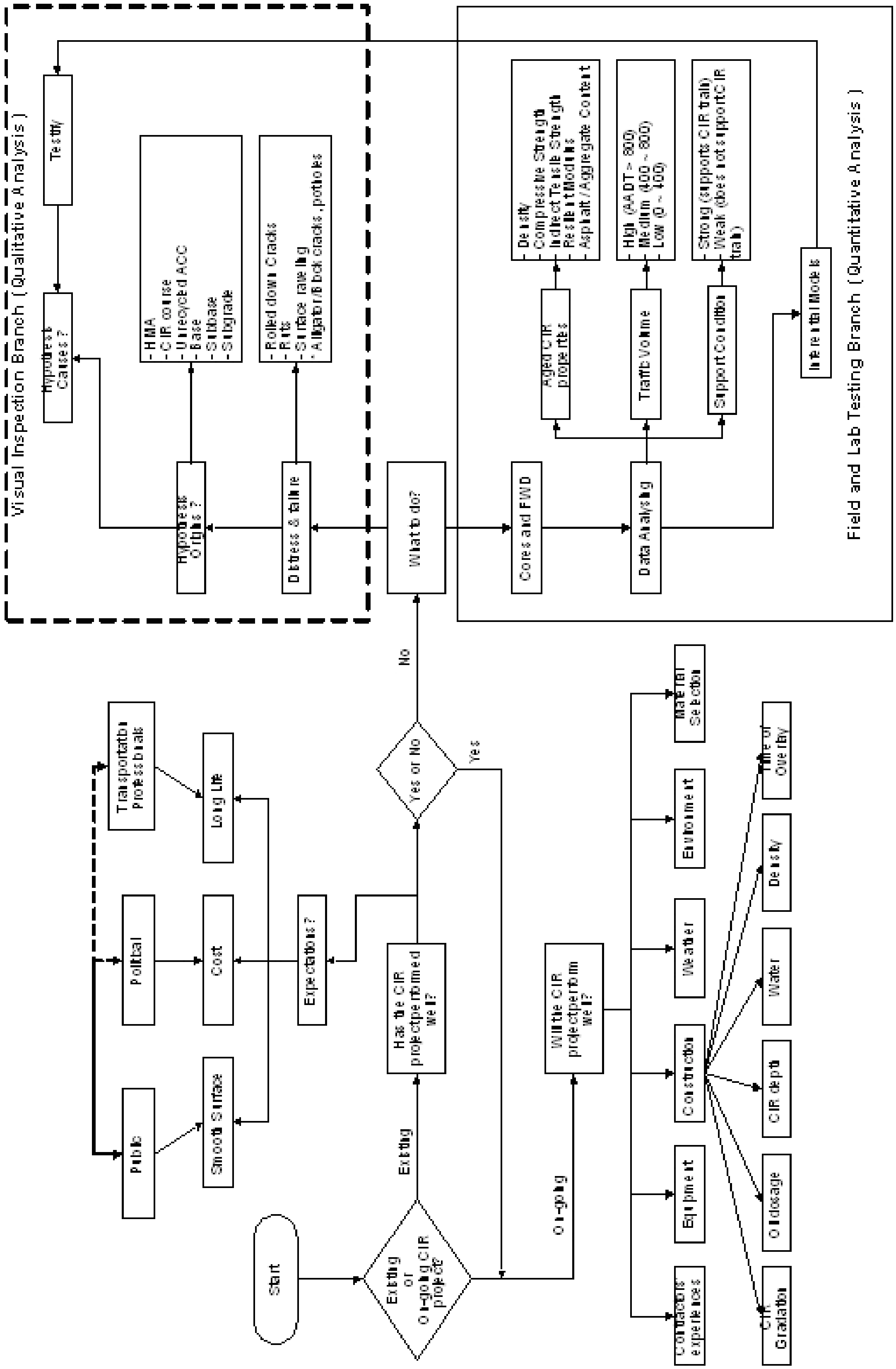

Figure 1. Research design

Scope of the Study

When this study is completed, the final report will summarize the results of a comprehensive evaluation of test results from field distress surveys, field samples, and lab tests from 18 projects constructed between 1986 to 2003 at various locations throughout the state of Iowa. Of these 18 projects, 12 projects were selected from the sample roads in the previous research (HR-392). Six projects were selected among newly constructed CIR projects in Iowa after 1999.

Design Considerations

Three factors are believed to have the most influence on the performance of recycled pavement: the age of the recycled pavement, traffic volume, and support conditions. Each factor was considered to be a multiple-level factor. The breakdown of the structures of the three factors are shown in Table 1:

Table 1. Factors believed to influence CIR performance

Age	Young	1999 ~
	Medium	1993 ~ 1998
	Old	1986 ~ 1992
Traffic (AADT)	High	> 800
	Medium	400 ~ 800
	Low	0 ~ 400
Support	Strong	Supports recycling train
	Weak	Does not support recycling train

Sampling

The 18 projects were selected to represent all Iowa counties, project ages, traffic levels, and support conditions, as shown in Figure 2.

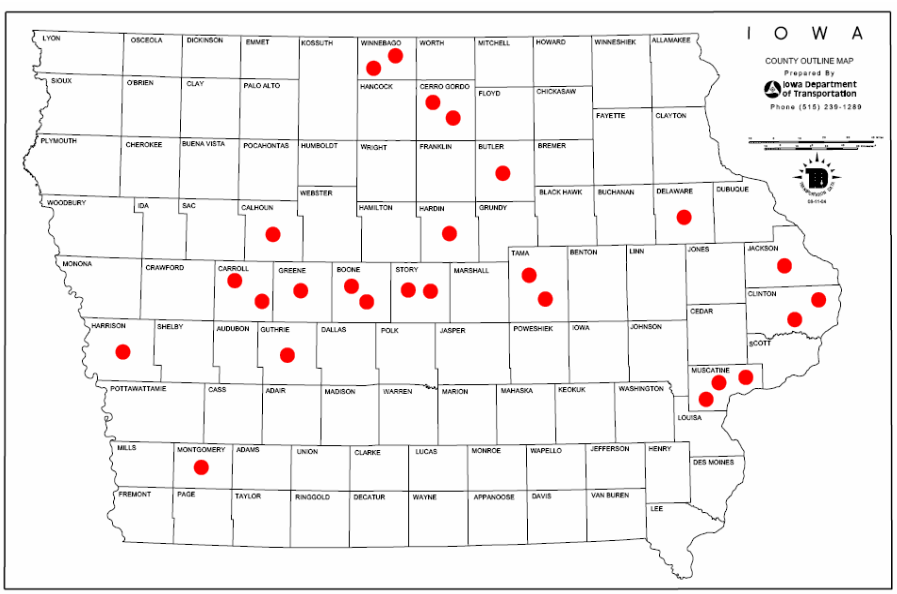

Figure 2. Distribution of candidate roads

Data Collection

Selection matrix

Interviews with county engineers, Iowa DOT personnel, and forepersons were conducted in order to obtain information on the pavement support conditions. The results were used to select candidate roads to complete the selection matrix (Figure 3).

		Good Support / Drainage			Poor Support / Drainage		
		Low Traffic (0~400)	Medium Traffic (400~800)	High Traffic (>800)	Low Traffic (0~400)	Medium Traffic (400~800)	High Traffic (>800)
Age of Pavement	Young (1999~)	N-58 (Carroll)	IA-44 (Harrison) S-14 (Story)	US-20 (Delaware) US-61 (Jackson) S-27 (Story)	N of Breda (Carroll)		IA-48 (Montgomery)
	Medium (1993~ 1998)	R-34 (Winnebago)	V-18 (Tama)	IA-175 (Calhoun) IA-4 (Guthrie)		T-16 (Bulter)	F-70 (Muscatine)
	Old (1986~ 1992)	Boone (E-52)	B-43 (Cerro Gordo) Z-30 (Clinton)	E-66 (Tama)	198th (Boone)	E-50 (Clinton) S. S. (Cerro Gordo)	Y-14 (Muscatine)

Figure 3. Selection matrix

Pavement Condition Index Ratings

An automated pavement distress digital image collection and analysis system was used to perform distress surveys. This survey was conducted by researchers at the University of Iowa under Dr. Hosin Lee. The pavement condition index (PCI) rating of each road was calculated with the aid of computer software. In order to obtain inferences on a longitudinal study similar to the previous research, the digital pavement crack analysis was conducted on the same portions of the 18 roads previously surveyed.

Field and Laboratory Testing

It is expected that the following parameters will be measured to obtain the AEP of CIR materials (Robert et al. 1996):

- Density
- Compressive strength
- Indirect tensile strength
- Resilient modulus
- Asphalt and aggregate content

Data Analysis

The goal of the data analysis is to identify the effects of the aged engineering properties of CIR materials, age of the pavement, traffic, and support conditions on the performance of recycled asphalt roads. Aged engineering properties, age of pavement, traffic, and support conditions are explanatory variables. Performance is the response variable that can be defined by PCI ratings. Three steps are planned for the data analysis phase of this project.

In the first step, the aged engineering properties of CIR materials will be estimated within each cell of the selection matrix. This estimation will be performed by the regression function obtained from statistical regression analysis of observed pavement data (density, compressive strength, indirect tensile strength, resilient modulus, and asphalt and aggregate content).

In the second step, PCI ratings will be estimated by aged engineering properties, age of the pavement, traffic, and support conditions. It seems likely to the research team that the PCI ratings are strongly influenced by the performance of the HMA overlay. Serving as a base for the HMA overlay, the condition of the CIR layer can be quantitatively defined by the aged engineering properties. Thus, an association between PCI and aged engineering properties exists theoretically. It is rational to infer that relationships exist between PCI and other explanatory variables.

In the third step, a fitted model will be developed by fitting the expected PCI ratings (obtained in the second step) against the observed PCI ratings (obtained from the automated distress surveys performed by researchers from the University of Iowa). The resulting relationships will provide a method to evaluate the individual contribution that each variable has the performance of CIR roads. These relationships can be used on other CIR roads in Iowa to evaluate the field performance of asphalt pavements.

If the degree of variability of the observed data is too large to establish significance, neural network analysis may be performed to draw inferences in future research.

CONCLUSIONS / RECOMMENDATIONS

It is expected that this investigation will provide answers regarding how aged engineering properties, traffic, and subgrade conditions affect the pavement performance; it is also expected that this research will suggest changes that should be made with regard to design, material selection, and construction in order to improve the performance of future recycled roads. Recommendations will also be provided for future researches regarding field performance of CIR asphalt roads. It is possible that some of these recommendations can be generalized to geographic locations outside of Iowa.

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