Review of Cold In-Place Asphalt Recycling in Iowa

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A research project was undertaken to evaluate the performance of cold in-place recycled (CIR) asphalt projects in the state of Iowa. A sample of eighteen roads was selected. Then performance was evaluated in two ways: pavement condition indices (PCI) were calculated and overall ratings were given on ride and appearance. A regression analysis was extrapolated predict the future service life of CIR roads. The results were that CIR roads within the state of Iowa with less than 2000 annual average daily traffic (AADT) have an average predicted service life of fifteen to twenty-six years. Overall, CIR roads in Iowa are performing well. It appears that the development of transverse cracking has been retarded and little rutting has occurred. Contracting agencies must pay special attention to the subgrade conditions during project selection. Because of its performance, CIR is a recommended method for rehabilitating aged low volume (< 2000 ADT) asphalt concrete roads in Iowa. Key words: cold in-place recycling, rehabilitation, asphalt.

BACKGROUND

Cold in-place recycling has been in regular use in Iowa since 1986. It is a method to rehabilitate asphalt roads that, although structurally sound, have suffered from the effects of aging. It involves milling and crushing the existing asphalt pavement, rejuvenating the existing asphalt cement, and finally placing and compacting the material to a specified thickness. This process is performed in-place, so there is little need to load and transport the material. Detailed descriptions of CIR design and construction procedures are available elsewhere *(1)*.

This paper summarizes a study that reviewed the performance of CIR roads in Iowa *(2)*. The study commenced in 1996, ten years after CIR started seeing regular use in Iowa.

CIR ROADS IN IOWA

As of the 1996 construction season, 97 CIR projects had been completed in Iowa (Figure 1). Before recycling, most roads had most roads had 102 and 254 mm (4 to 10 in.) of asphalt materials which was weathered and heavily cracked. Generally the top 76 to 102 mm (3 to 4 in.) is recycled. After recycling, 51 to 102 mm (2 to 4 in) of hot mix is placed on top of the recycled material. Between 1993 and 1996, average cost of four inches of CIR for one kilometer of road (two lane kilometers) has been $8,000 to $10,000 ($13,000 to $16,000 per mile). The costs for 25 mm (1 in.) of hot mix asphalt overlay was about the same *(2)*.

Eighteen roads were selected for detailed analysis. For these roads, researchers conducted the performance surveys described below. During the selection process, researchers were careful to obtain roads with a variety of average annual daily traffic (AADT) counts, ages, and geographic locations. The AADT ranged from 300 to 2000. This is considered to be in the range of *low volume* traffic. The percent of trucks varied from five to eighteen percent. A variety of subgrade conditions were obtained by selecting roads from portions of the state that experienced a variety of geomorphological processes. Geomorphology refers to the process that formed the landscape. Contractors that have constructed CIR roads in Iowa use *similar* processes, and follow the same specifications. Due to the similarities, it is unlikely that the contractors had much influence on pavement performance. Table 1 gives information on the characteristics of the roads before and after recycling.

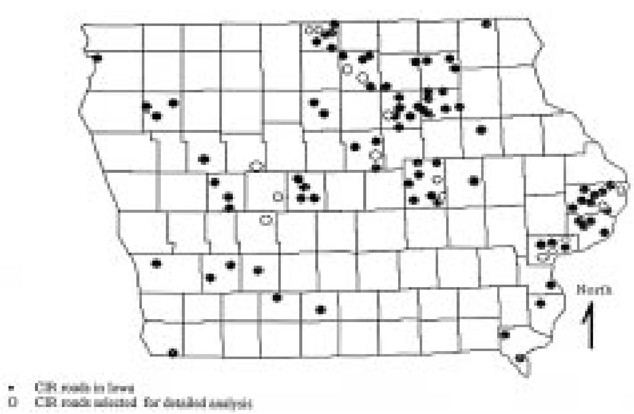

Figure 1 CIR roads in 1996.

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TABLE 1 Characteristics of Roads Before and After Recycling

										Hot Mix Overlay					
County	Road	Age	AADT	Start Date	Finish Date	Existing Asphalt mm (in)	Base mm (in)	CIR	Emulsion	Overlay mm (in)	Asphalt	AC %	Void %	Size mm (in)	Native Soil[1]
Muscatine	G-28	5	940	15-Sep	22-Sep	203 (8)	152 (6)	102 (4)	CSS-1	51 (2)	AC-5/10	4.9	4.5	19 (0.75)	3
Tama	V-18	5	550	24-Sep	11-Jul	0 (0)	152 (6)	102 (4)	HF-300RP, CSS-1	51 (2)	AC-5	6.1	6.5	13 (0.5)	2
Boone	E-52	5	290	25-Jun	28-Jun	203 (8)	152 (6)	102 (4)	CSS-1	51 (2)	AC-10	5.1	4	13 (0.5)	1
Clinton	Z-30	7	850	13-Jun	19-Jun	127 (5)	254 (10)	102 (4)	CSS-1	51 (2)	AC-10	6.5	6	13 (0.5)	2
Muscatine	F-70	3	950	26-Aug	20-Sep	102 (4)	203 (8)	102 (4)	CSS-1	76 (3)	AC-5	5.7	7	13 (0.5)	3
Butler	T-16	3	470	26-Jul	10-Aug	152 (6)	152 (6)	102 (4)	CSS-1	51 (2)	AC-5	5.5	7	13 (0.5)	2
Tama	E-66	6	1080	12-Jul	28-Jul	102 (4)	203 (8-pcc)	102 (4)	HF-300RP	51 (2)	AC-5	5.9	7	13 (0.5)	2
Clinton	E-50	10	520	Na	20-Aug	140 (5.5)	165 (6.5)	102 (4)	CSS-1	51 (2)	AC-10	5.1	4	13 (0.5)	2
Winnebago	R-34	6	620	18-Jul	30-Jul	152 (6)	152 (6)	102 (4)	HF-300RP	51 (2)	AC-5	5.7	4.1	13 (0.5)	1
Cerro-Gordo	B-43	7	570	30-Jul	7-Aug	152 (6)	152 (6)	102 (4)	CSS-1	51 (2)	AC-10	5.2	5.6	13 (0.5)	2
Boone	198TH	8	300	na	na	152 (6)	152 (6)	102 (4)	CSS-1	51 (2)	AC-10	5.7	3.6	13 (0.5)	1
Hardin	D-35	4	665	9-Jul	20-Jul	165 (6.5)	152 (6)	76 (3)	CSS-1	51 (2)	AC-10	5.5	6.5	13 (0.5)	1
Cerro-Gordo	S.S	6	600	8-Aug	17-Aug	203 (8)	152 (6)	102 (4)	CSS-1	51 (2)	AC-10	6.2	5	13 (0.5)	3
Winnebago	R-60	6	340	13-Jul	18-Jul	127 (5)	152 (6)	102 (4)	HF-300RP	51 (2)	AC-5	5.5	4.3	13 (0.5)	1
Muscatine	Y-14	9	990	22-Jun	4-Jul	152 (6)	152 (6)	102 (4)	HFE-150S, CSS-1, HFMS	64 (2.5)	AC-10	6	5.75	19 (0.75)	3

[1] Native Soil is defined from different geological regions:
Area 1 - Fresh glacial drift, no loess cover, areas of level terrain
Area 2 - Thin, discontinuous loess or loam over drift, gently rolling terrain
Area 3 - Alluvial features, thick sequences of clay, silt, sand and gravel

PERFORMANCE EVALUATION

Road performance was evaluated both quantitatively and qualitatively. The quantitative evaluation involves surveying the roads for severity and type of distresses. By analyzing the results at the network level, predictions may be made concerning the future performance of the road network for various maintenance and rehabilitation treatments. Economic analysis may be used to choose the best plan of action.

Public perception of road condition is based on qualitative assessments that are made as users drive over the roads. These perceptions are communicated to transportation officials who also drive over the roads and make qualitative assessments before they make maintenance and rehabilitation decisions. Thus it is reasonable to include both a quantitative and qualitative component to the performance evaluation process for CIR roads.

The quantitative assessment procedure for this project was developed using the method outlined by the US Army Corps of Engineers *(3)*. This evaluation technique requires an in-depth survey of the pavement surface. Surface distresses are recorded and classified by severity. The severity level is determined by guidelines that included in the USACE manual. Then numerical deductions are assigned for each severity and type of distress. These deductions are combined mathematically to provide a pavement condition index (PCI), which can range between zero and 100. The higher numbers indicating a pavement that is in better condition.

The qualitative assessment procedure was developed using guidelines from the American Association of State Highway and Transportation Officials (AASHTO) *(4)*. The qualitative evaluation provided separate ratings for appearance and ride (Table 2). The two evaluations were averaged to produce the PSI rating.

The results of the evaluations are provided in Table 3. The roads are sorted in order of increasing age. The PSIs ranged from 90 to 51 while the PCIs ranged from 100 to 52. The averages of the PCI and PSI ranged from 95 to 56.4. Clinton County E-50 was the first road that was recycled in Iowa. It had a PSI of 51, a PCI of 81 and an average of 66.2. A rating of 25 was chosen to be the point when a road should be rehabilitated. This corresponds to the rating where

TABLE 2 PSI Rating Scale

PSI	Ride Rating	Appearance Rating
100	New – No roughness or cracks.	Looks dark and smooth.
80	Minor roughness. Cracks cannot be felt while driving.	Minor cracks are barely visible.
60	Noticeably rough. Cracks can be felt while driving.	Cracks are clearly visible. Weathered surface.
40	Very rough	Tranverse cracks at short intervals. Longitudinal cracks present
20	Very rough. Difficult to maintain speed.	Heavily distressed. Tranverse, longitudinal and block cracking present.

TABLE 3 CIR Roads Surveyed 1996 and 1997

County	Road	AADT	Age	Alligator Cracking	Block Cracking	Edge Cracking	Longitudinal Cracking	Raveling	Rutting	Slippage	Shoving	Transverse Cracking	PSI	PCI	(PSI+ PCI)/2
Guthrie	IA-4	820	2	0	0	0	0	0	0	0	0	0	90	100	95.0
Butler	T-16	470	3	0	0	0	0	0	0	0	0	0	81	100	90.7
Calhoun	IA-175	1920	3	0	0	0	0	0	0	0	0	0	81	100	90.7
Muscatine	F-70	950	3	0	0	0	0	0	0	0	0	0	82	100	90.8
Hardin	D-35	665	4	0	8	0	0	0	3	0	0	8	65	85	75.0
Boone	E-52	290	5	0	0	3	0	0	0	0	0	2	73	95	83.8
Muscatine	G-28	940	5	0	0	0	0	0	0	0	0	2	73	98	85.3
Tama	V-18	550	5	0	0	0	0	0	0	0	0	0	70	100	85.0
Cerro Gordo	S.S	600	6	0	0	0	4	0	1	0	0	14	61	81	71.2
Tama	E-66	1080	6	0	0	0	0	0	0	0	0	6	61	94	77.7
Winnebago	R-34	620	6	0	0	0	0	0	0	0	0	10	63	90	76.3
Winnebago	R-60	340	6	0	28	0	0	0	0	0	0	0	63	72	67.3
Cerro Gordo	B-43	570	7	0	12	0	11	0	8	0	14	3	68	77	72.3
Clinton	Z-30	850	7	0	0	0	0	0	0	6	0	1	64	93	78.4
Greene	IA-144	1110	7	33	1	0	4	0	17	0	0	7	58	60	59.0
Boone	198TH	300	8	18	0	0	3	0	17	0	0	0	59	71	64.9
Muscatine	Y-14	990	9	0	0	0	5	16	9	54	0	7	61	52	56.4
Clinton	E-50	520	10	0	0	0	1	0	10	0	0	15	51	81	66.2

the USACE pavement condition scale changes from poor to very poor. This indicates that none of the roads that have been recycled thus far in Iowa are in need of rehabilitation.

With regard to rutting, only one third of the roads had deductions for rutting, as shown in Table 3. This indicates that rut depths were greater than 0.25 in for these roads. Of the roads that did have deductions, none exceeded 17. Explanations are available for the two roads that had rut deductions of 17. In Boone County, 198th Street was originally a cold mix pavement laid on earth subgrade. In locations where rutting occurred, the county engineer recalls the occurrence of equipment breakdowns that resulted in extra water being introduced in the RAP. In Greene County IA 144 was constructed during a cold, rainy period that was not favorable to CIR construction. Note that these two roads are the only roads that received deductions for alligator cracking. With these exceptions, rutting has not been a performance issue in Iowa.

The highest deduction for transverse cracking was 15. More than a third of the roads received no deduction for transverse cracking. The number of transverse cracks per kilometer ranged from zero to 126 (202 per mile). Figure 2 shows the frequency of transverse cracks. Only two of the roads exceeded 75 cracks per km (120 per mile) and more than two thirds had fewer than 36 cracks per km (58 per mile). Records were not kept regarding the original number of cracks per mile. However, it is the writers' experience that before recycling, most roads in Iowa have transverse cracks every 7 to 10 m (20 to 30 ft). This is equivalent to 110 to 160 cracks per km (175 to 260 cracks per mile). This would indicate that CIR has been effective in mitigating transverse cracks.

Muscatine County Y-14 has deductions for raveling and slipping. These deductions were the result of defects in the hot mix overlay and are not related to CIR performance.

How long will CIR roads last in Iowa? This is a difficult prediction to make in the absence of any actual experience. However, regression analysis was used to estimate the service life. First the analysis was performed on the age vs. PCI and age vs. PSI separately. Linear regression lines were extrapolated into the future and 95% confidence intervals were determined. The confidence interval indicates that if the relationship actually is linear, then with a confidence of 95% the mean response will fall within the interval. Thus the assumption is made that the roads will be maintained

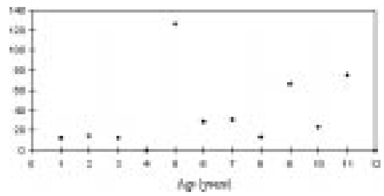

FIGURE 2 Frequency of transverse cracking.

TABLE 4 Indices Evaluation

Index	R^2	Equation	Minimum average life	Maximum average life
PSI	78.2%	=91.7-4.19*Age	14	19
PCI	49.4%	=114.97-4.84*Age	14	38
(PSI+ PCI)/2	72.9%	=101-4.56*Age	15	26

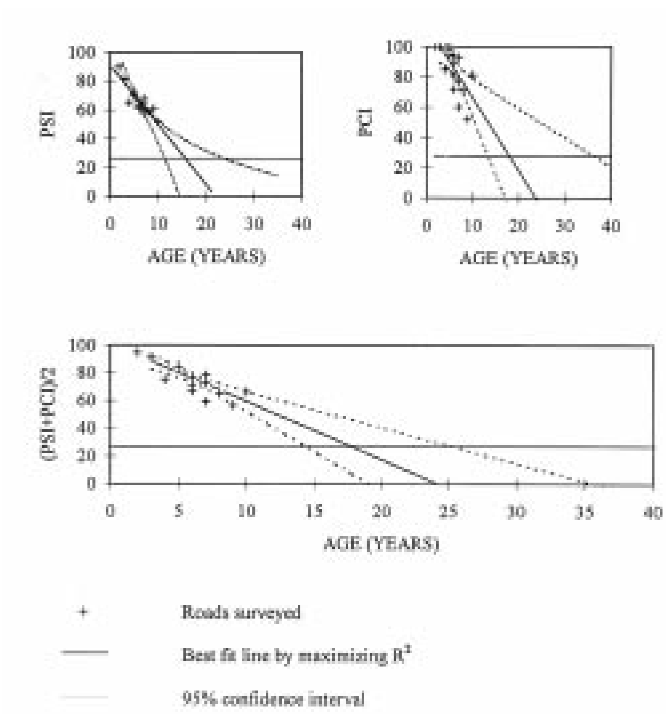

FIGURE 3 Life expectancy.

in the future so that a linear relationship between age and pavement condition will continue. If the roads are not maintained, sudden deterioration will occur at some point and the relationship between age and pavement condition will not be linear. Similarly, by applying very vigorous maintenance it may be possible to slow the deterioration of pavement condition with age, thus creating a non-linear relationship. It was also assumed that the roads reach the end of their service life, that is, they must be rehabilitated when the pavement performance index reaches 25.

The regression equations, R^2, and minimum and maximum average expected service life are shown in Table 4. The R^2 indicates the percentage of the variation of the data that is explained by the regression equation. A graphical representation of the regression analysis is presented in Figure 3. Considering the PSI only, the mean predicted service life is 14 to 19 years. Considering the PCI only, the mean predicted service life is 14 to 38 years. Considering the average of the indices, the mean predicted service life is 15 to 26 years. Since rehabilitation decisions are often a combination of a qualitative and quantitative input, the writers have chosen the average of the PSI and PCI as the best prediction. Note that the predicted lifetime will vary depending on the terminal index chosen for rehabilitation.

SUBGRADE STABILITY

The importance of proper project selection with regard to subgrade stability has been shown in Iowa. There have been three projects where recycling equipment "broke through" the remaining unrecycled asphalt due to a lack of subgrade stability: Iowa 92 in Adair County (May 1994), Louisa County G40 (May 1996), and Pleasant Creek State Park in Linn County (May 1997). These problems occurred during wet weather. In each case, subgrade conditions were so consistently inadequate that the contracting agency abandoned CIR and used alternate construction methods. Although such overwhelming subgrade stability problems are rare (only three projects out of more than 100 attempted), they can cause great difficulty for all concerned. Therefore, the research team developed quick and inexpensive test to detect possible subgrade stability problems during the planning stages of the project. The test involves drilling a two inch hole in the pavement with a hammer drill and taking a blowcount with a dynamic cone penetrometer *(2)*. The test procedure was verified during the 1997 construction season.

SUMMARY AND CONCLUSIONS

A systematic performance study has been conducted on a sample of 18 CIR roads in Iowa. They have been rated both quantitatively and qualitatively. The performance of these roads have been generally good. CIR has been effective in mitigating cracking and few problems with rutting were noted. Past experience has shown that subgrade instability is the worst problem that a CIR project is likely to face in Iowa. A dynamic cone penetrometer test was found to be effective in detecting such problems.

Specific conclusions are as follows:

1. A performance evaluation should be a combination of a systematically conducted distress survey and a qualitative rating based on ride and appearance.
2. In general performance of CIR roads in Iowa have been good. Current design and construction procedures appear to be adequate.
3. Few rutting distresses have been noted.
4. CIR appears effective in mitigating cracking. Little cracking occurs in the first five years of a typical road's life. When cracks do develop, they have a lower frequency when compared to the road before it was recycled.
5. The predicted service life is 15 to 26 years based on a terminal index of 25.

6. A four-inch depth of recycling is equivalent in cost to one inch of hot mix overlay.
7. Subgrade stability failure is the problem that is most likely to stop a CIR project in Iowa.

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