Ontario

Ministry of Transportation

Environmental Benefits of In-Situ Recycling of Pavements

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Prepared By:
Andrew Alkins, Becca Lane and Tom Kazmierowski
Pavements and Foundations Section
Materials Engineering Research Office
Ontario Ministry of Transportation

1201 Wilson Avenue,
Downsview, Ontario, Canada M3M 1J8
Tel: (416) 235-3533; Fax (416) 235-3919

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Introduction

Cold in-place recycling (CIR) is an innovative pavement rehabilitation method that typically processes up to 125 mm of an existing hot mix asphalt (HMA) pavement, sizes it, mixes in additional asphalt cement, and lays it back down without off-site hauling and processing. The added asphalt cement is typically emulsified asphalt, a blend of asphalt cement and water droplets. The material is then profiled and compacted to form a binder course layer. A new HMA surface is placed after the emulsion has set, and moisture and compaction requirements have been met, typically 14-30 days.

A recent development in CIR technology is the use of expanded (foamed) asphalt, rather than emulsified asphalt to bind the mix. In this new process, hot asphalt cement is pumped through an expansion chamber on the cold recycling unit, where a small amount (1%) of cold water is injected and immediately vaporizes. This creates thousands of tiny bubbles within the hot asphalt cement causing it to rapidly expand (foam). The expanded asphalt is then mixed with the reclaimed asphalt pavement. As with conventional CIR, the material is then profiled and compacted to form a binder course layer. This combination of CIR and expanded asphalt technologies is termed Cold In-Place Recycled Expanded Asphalt Mix (CIREAM).

The Ministry of Transportation has an active CIR and CIREAM program that is strongly promoted and monitored. Over the past 17 years the MTO has successfully recycled with either CIR or CIREAM approximately 3,500,000 m^2 of HMA pavement. With the increasing cost of fuel and environmental awareness, CIR/CIREAM has become a popular design alternative when selecting rehabilitation strategies for Ontario's highways and is more frequently replacing traditional techniques such as milling, full depth reclamation and new HMA paving. This submission outlines the impact CIR/CIREAM has had on the environment compared to a traditional mill and overlay treatment, its cost effectiveness and how the MTO promotes and monitors this technology.

Construction

PLACEMENT

The placement of CIR and CIREAM consists of milling the existing surface to a depth to 100 mm, processing the material through an in-situ screening/crushing machine and either infusing the reclaimed asphalt pavement with asphalt emulsion (CIR) or expanded asphalt cement (CIREAM). The material is placed to the desired profile with a hot mix paver and compacted to the desired density.
The traditional rehabilitation technique that is being compared to CIR/CIREAM consists of milling the existing asphalt surface to a depth of 100 mm, paving 130 mm of new HMA in three lifts and compacting to the desired density.

Figure 1. Cold-In-Place Recycling Train

Figure 2. Cold-In-Place Recycled Expanded Asphalt Train

Figure 3. Traditional milling operation with HMA to follow

HISTORY

To date, the MTO has completed 40 CIR and 3 CIREAM contracts that equate to over 3,500,000 m^2 of pavement recycling. The quantities by year are as follows:

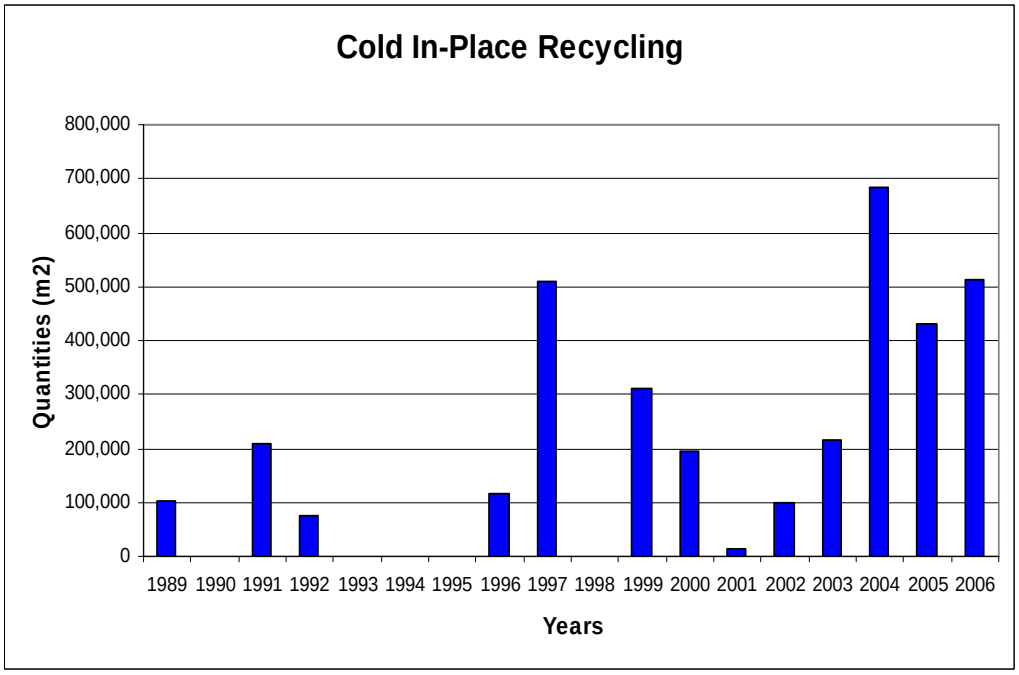

Figure 4. Quantities of Cold In-place Recycling placed 1989 to 2006

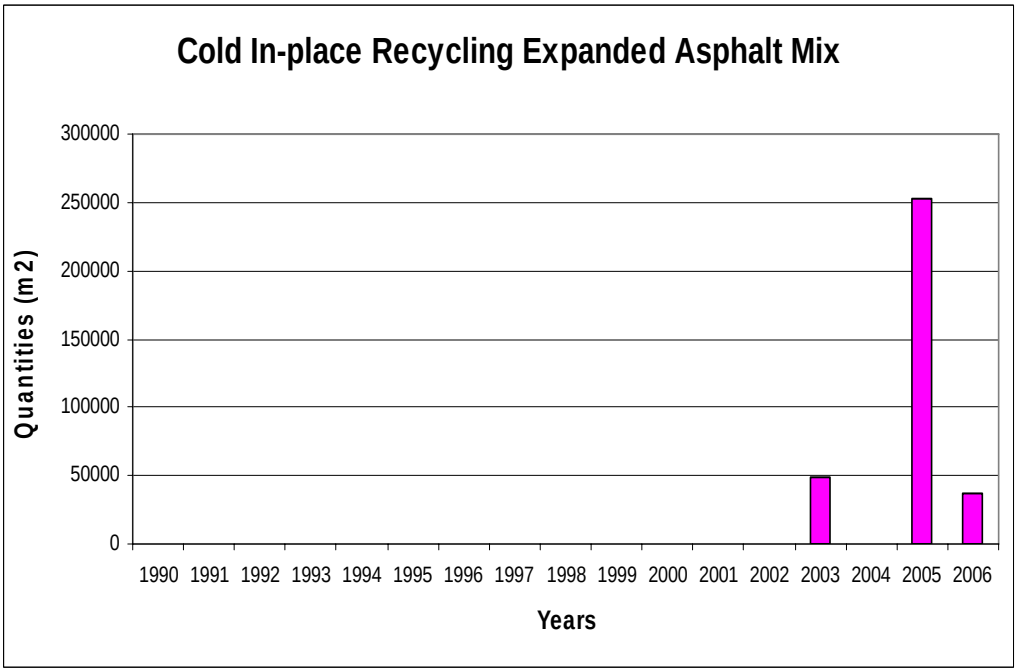

Figure 5. Quantities of Cold in Place Recycling with Expanded Asphalt placed 2003-2006

Environmental Impact

The Kyoto Protocol was adopted in late 1997 to address the problem of global warming by reducing the world's greenhouse gas emissions (GHG). As part of this, Canada committed to reducing its greenhouse gas (GHG) emissions by six percent by the time its first commitment period ends in 2012. It is important for the MTO and road construction industry to embrace these changes by proactively implementing pavement recycling technologies that will assist in achieving these goals. In-situ pavement recycling technologies such as CIR and CIREAM are well positioned to assist in achieving these goals.

These recycled pavements are sometimes referred to as sustainable pavements. A sustainable pavement can be defined as a safe, efficient, environmentally friendly pavement meeting the needs of present-day users without compromising those of future generations. The main criteria established for a sustainable pavement are:

- Optimizing the use of natural resources
- Reducing energy consumption
- Reducing greenhouse gas emissions
- Limiting pollution
- Improving health, safety and risk prevention
- Ensuring a high level of user comfort and safety

CIR and CIREAM address all of these criteria. These technologies support a "zero waste" approach to pavement rehabilitation where the existing road material is reprocessed and reused in place, without offsite transportation. Essentially, no resources are wasted and the need for additional pavement materials is minimized.

AGGREGATE CONSERVATION

To calculate the aggregate resource consumption of CIR/CIREAM compared to a traditional rehabilitation technique, the Ministry compared the new aggregate quantities required by CIR/CIREAM to the aggregate quantities required for mill 100mm and place130mm HMA. The analysis was based on 1 km sections with a pavement cross section of: 7.5 m width and existing 150 mm HMA depth.

New aggregate quantities for CIR/CIREAM were based on a 50 mm HMA overlay, versus 130 mm overlay for the traditional treatment. For a 1 km section, CIR/CIREAM consumed 920t of aggregate compared to 2400t for mill and three-lift overlay, a 62% savings. When the quantity is multiplied by the 3,500,000 m^2 of CIR and CIREAM completed since 1989, aggregate savings are in the order of 740,000 tonnes.

GREEN HOUSE GAS EMISSIONS

To analyze the GHG emissions of CIR / CIREAM compared to a traditional rehabilitation technique (mill 100mm and 130mm HMA) a computer model (PaLATE) created by Dr. Arpad Horvath of the University of California Berkley was used. One of the functions of the PaLATE (Pavement Life-

Cycle Assessment Tool for Environmental and Economics) model is to calculate the energy required to perform specific rehabilitation techniques and the associated GHG emissions that result from the process.

Using the PaLATE model to compare the emissions from CIR, CIREAM and a traditional rehabilitation technique the following quantity of greenhouse gas emissions were calculated. The analysis is based on 1 km sections with a pavement cross section of: 7.5 m width and existing 150 mm HMA depth.

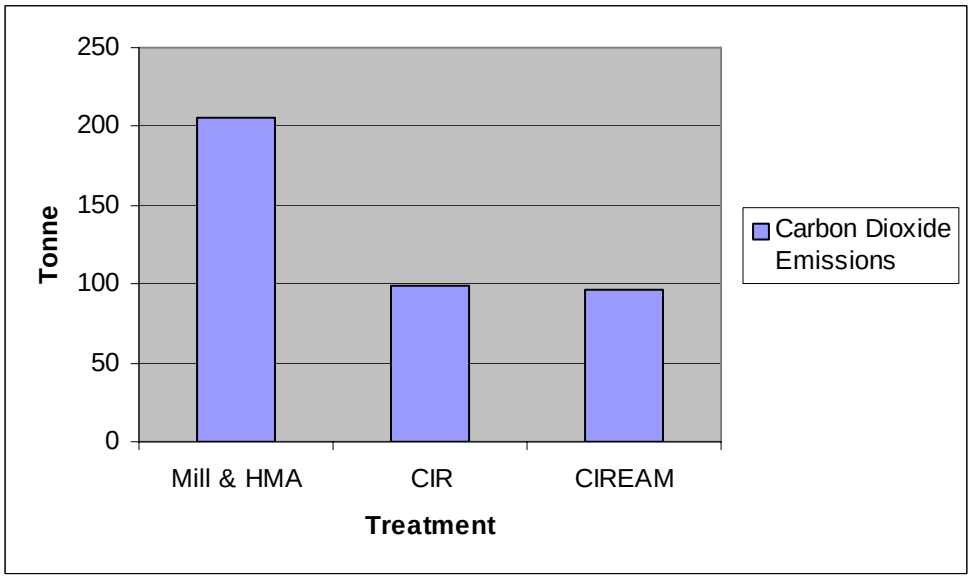

Figure 6. Carbon Dioxide emissions according to rehabilitation strategy

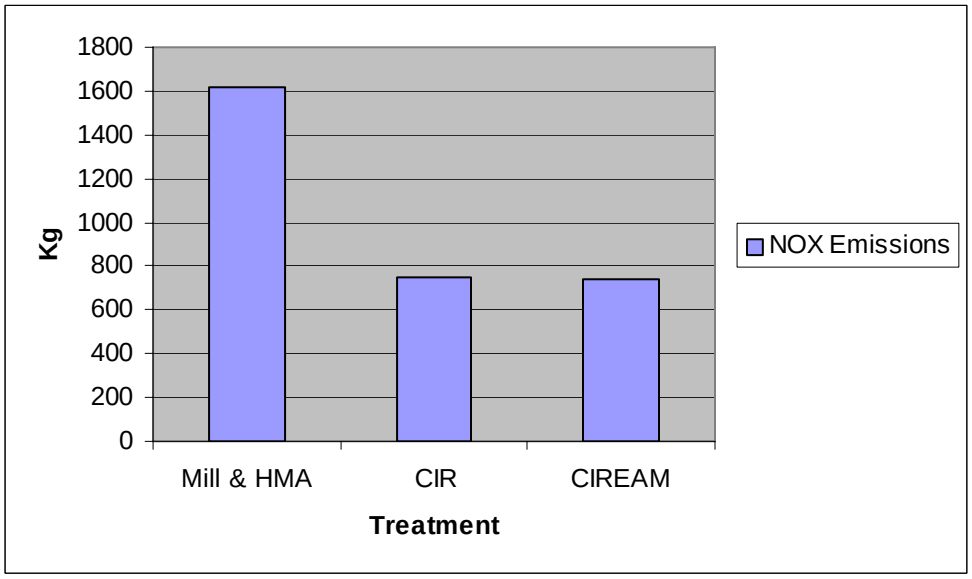

Figure 7. Nitric Oxide emissions according to rehabilitation strategy

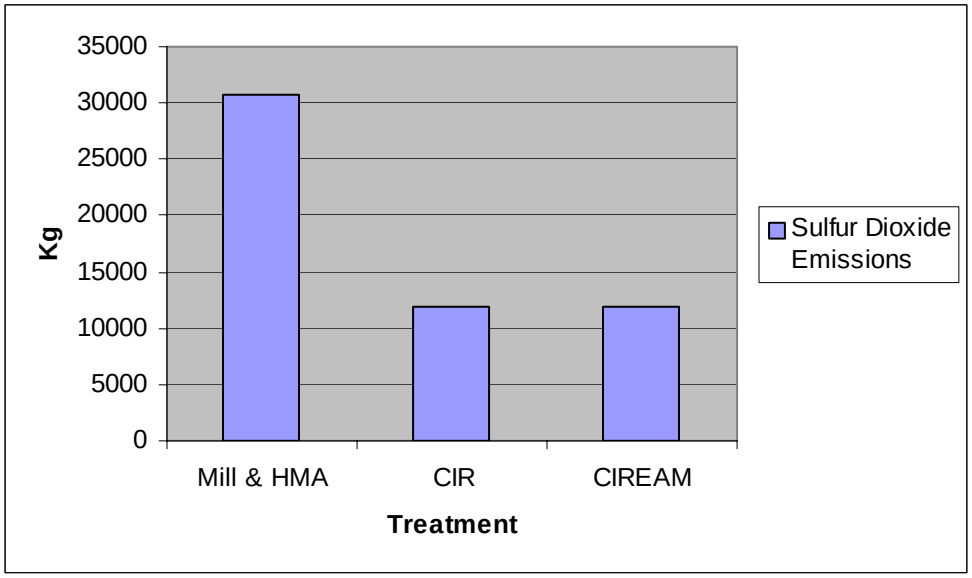

Figure 8. Sulphur Dioxide emissions in accordance with rehabilitation strategy

Illustrated above, CIR and CIREAM emit significantly less GHG compared to a traditional rehabilitation technique. When the quantity is multiplied by the amount of CIR and CIREAM completed since 1989, MTO has reduced emission of carbon dioxide by 54,000 tonnes (52%), nitric oxide/ nitrogen dioxide by 440 tonnes (54%) and sulphur dioxide by 9,400 tonnes (61%) when compared to a traditional rehabilitation technique. By promoting and using CIR/CIREAM, MTO is striving towards its own environmental goals and assisting Canada attain its Kyoto Protocol commitments.

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CIR/CIREAM Promotion and Technology Transfer

Since 1989 MTO has actively promoted in-situ recycling technologies such as CIR, and more recently CIREAM as viable rehabilitation options on its capital contracts and as a sustainable pavement. This has been done both on a National and International level through technical papers and presentations:

- B. Lane, *MTO Experience with in-place recycling, Presentation, 2007 Ontario Good Roads Association Seminar on Preservation and Rehabilitation, January 2007.*

- Abdelzaher Mostafa, Burkan Isgor, Abd El Halim O. Abd El Halim, Steve Goodman and Becca Lane, "*Curing of Cold in Place Recycled Asphalt Mixtures: Toward a Standard Test Method*", Canadian Technical Asphalt Association, Proceedings of the 51st Annual Conference, November 2006.

- T.J. Kazmierowski, *Evolution of In-situ Recycling in Ontario*, Proceedings, International Conference of Asphalt Pavements, August 2006, Quebec.

- Becca Lane and Tom Kazmierowski, "*Short Term Performance of an Innovative Cold In-Place Recycling Technology in Ontario*" Proceedings of the Annual Conference of the Transportation Association of Canada, September 2005, Calgary, Alberta.

- T.J. Kazmeirowski, *Asphalt Recycling at the Ministry of Transportation*, Proceedings Asphalt Reclaiming and Recycling Association Conference, 2005, Niagara Falls.

- B. Lane, *Cold In-Place Recycling with Expanded Asphalt Mix*, Proceedings, Asphalt Reclaiming and Recycling Association Conference, 2005, Niagara Falls.

- Becca Lane and Tom Kazmierowski, "*Implementation of Cold In-Place Recycling with Expanded Asphalt Technology in Canada*", Transportation Research Board Annual Meeting, January 2005, Washington.

- Becca Lane, Tom Kazmierowski, Susanne Chan and Melissa Buelow, "*Evaluation Of Cold In-Place Recycling With Expanded Asphalt on Highway 7, Perth, Ontario*" Canadian Technical Asphalt Association, Proceedings of the 48th Annual Conference, November 2004, Montreal, Quebec.
- Susan Tighe, Becca Lane, and Thomas Kazmierowski, "*Multi-Criterion Examination of Expanded Asphalt Stabilization as a Possible Pavement Rehabilitation Alternative*", International Conference on Highway Pavement Data, Analysis & Mechanistic Design Applications, September 2003, Columbus, OH.

- Becca Lane and Tom Kazmierowski, "E*xpanded Asphalt Stabilization on the Trans-Canada Highway*", Transportation Research Board Annual Meeting, January 2003, Washington.

- Becca Lane and Tom Kazmierowski, "*Expanded Asphalt Stabilization on the Trans-Canada Highway in Ontario*", Canadian Technical Asphalt Association, Proceedings of the 46th Annual Conference, November 2002, Toronto

- B. Lane, *Full Depth Reclamation with Expanded Asphalt*, Proceedings, Asphalt Reclaiming and Recycling Association Conference, Toronto, 2002.

- T.J. Kazmierowski et al., *Ten-Year Performance Review of In-Situ Hot Mix Recycling in Ontario*, Proceedings, Technical Research Board, Washington, 1999.

Cost Effectiveness

When analyzing the cost effectiveness of CIR and CIREAM compared to a traditional rehabilitation technique, identical 1 km sections were analyzed. Costs per kilometre were obtained using an MTO produced spreadsheet.

	CIR / CIREAM	Mill & Overlay
Depth - Milling	-	100 mm
Depth - CIR	100 mm	-
Width	7.0 m	7.0 m
Surface Course	50 mm	40 mm
Binder Course	-	90 mm
Price	$100,000 / km	$173,000 / km

CIR / CIREAM cost 42% less than a traditional rehabilitation technique.

Post-Construction Monitoring

As part of the Ministry of Transportation's commitment to continuously improve its business, the performance of CIR/CIREAM contracts are being monitored and compared using performance measures based on the Pavement Condition Index (PCI) and International Roughness Index (IRI).

PCI is an indicator of the overall condition of a pavement section calculated based on measurements of pavement roughness and distress data. It is a composite index reflecting measures of both riding quality and surface deficiencies of a pavement (PCI = 100 (perfect pavement), PCI = 50-65 (rehabilitation needed)). The IRI is a profile index that evaluates the pavement riding quality in terms of roughness. An IRI value of 0 indicates absolute smoothness; an IRI value of 4 or more represents a rough, unpaved road.

Data is collected and analyzed in the ministry's Pavement Management System (PMS2). This system includes prediction models for various reconstruction and rehabilitation strategies. These pavement prediction models have been programmed through expert knowledge-based procedures into the decision trees developed for optimization analysis within PMS2. The following figures illustrate performance trends of CIR/CIREAM compared to a traditional rehabilitation technique (mill and overlay).

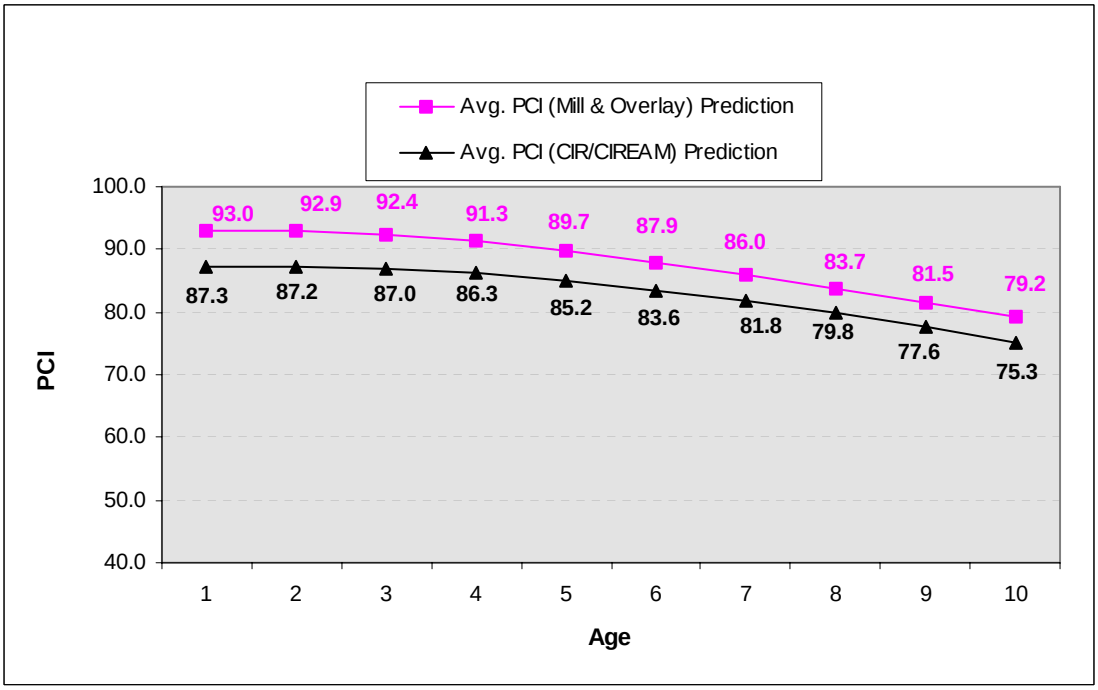

Figure 9. Pavement Condition Index (PCI) comparison

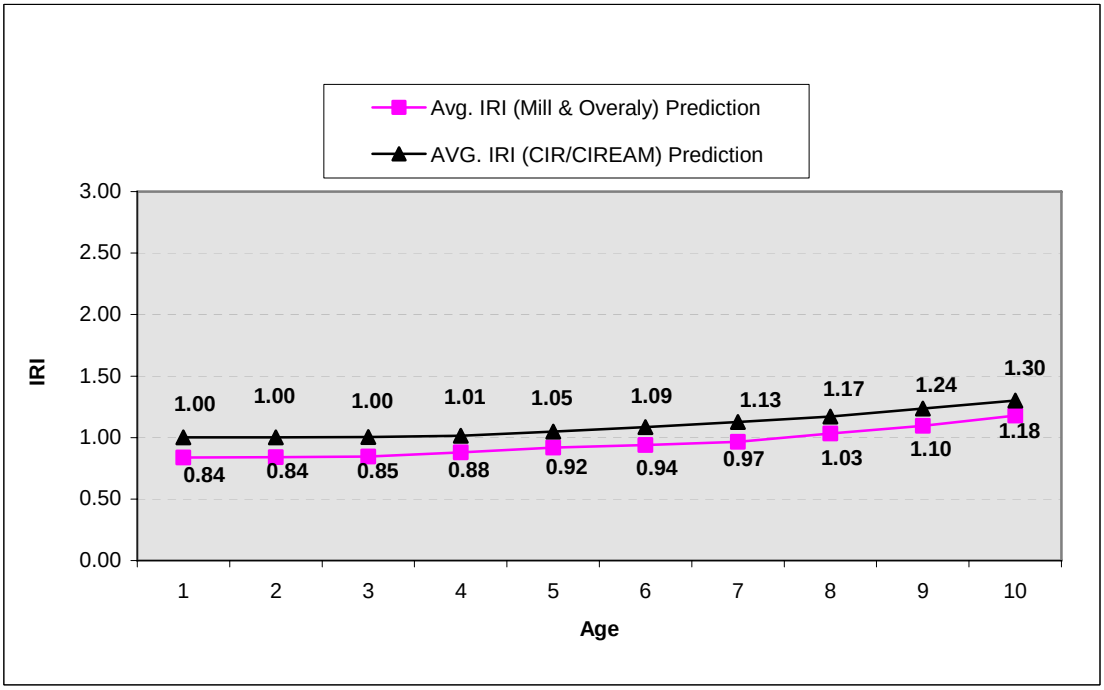

Figure 10. International Roughness Index (IRI) comparison

Performance of the two rehabilitation techniques is similar, however the traditional mill and overlay technique is marginally smoother to start, resulting in slightly different performance. The life cycle cost analysis (LCC) results for a 30 year period show that the CIR/CIREAM is the more cost effective solution in terms of life cycle cost which includes maintenance and future treatments.

Conclusions

The Ministry of Transportation's Environmental Bill of Rights has a mission statement to support its mandate of being a provincial leader in cost effective transportation, supporting the province's broader economic, social, and environmental objectives:

> *"We will facilitate the mobility of people and goods, and promote the development of industries that provide transportation systems, services, and products, in ways that reflect the needs of Ontario's diverse population and support the broader economic, social and environmental objectives of the province."*

One of the main environmental commitments of the Ministry is to protect air, water and land resources for future generations and the long-term survival of plants, animals and aquatic life. As part of putting this environmental commitment into action, the MTO is reducing construction-related air emission (greenhouse gases) by promoting, monitoring and encouraging pavement recycling techniques such as CIR and CIREAM.

Both these innovative techniques are helping meet the Kyoto Protocol commitments and refining highway rehabilitation to achieve a zero waste, environmentally conscious, rehabilitation contract. To date, CIR and CIREAM are the most cost effective and environmental friendly pavement rehabilitation options in terms of reducing costs, re-using existing non-renewable resources, minimizing use of new material, reducing transportation of construction materials and lowering greenhouse gas emissions.

The Ministry of Transportation has contributed and continues to contribute to the protection and enhancement of the environment though implementation and promotion of innovative in-situ pavement recycling techniques such as Cold In-place Recycling (CIR) and Cold In-place Recycling with Expanded Asphalt Mix (CIREAM).

Reference

Hovrath, A. (2004) A Life-Cycle Analysis Model and Decision-Support Tool for Selecting Recycled Versus Virgin Materials for Highway Applications. Final report for RMRC Research Project No. 23, University of California at Berkeley, March 2004.