MODIFIED COLD IN-PLACE ASPHALT RECYCLING

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ABSTRACT

Cold in-place asphalt recycling has been shown to be a technically sound, cost-effective, environmentally friendly method of strengthening and maintaining a wide range of deteriorating asphalt pavements. The overall process combines testing and mix design procedures, milling, processing and mixing units with microprocessor control of emulsion addition, compaction, placement of a wearing surface and quality assurance testing. It has been shown, in laboratory work and a number of Ontario projects the past four years, that modification of the cold in-place process to incorporate new aggregate results in an improved recycled binder course with closer voids and stability control, addressing observed conventional cold in-place asphalt recycling problems such as: high residual asphalt cement content (flushing); tine mix (high percent passing 4.75 mm and 75 pm); rutting (low initial stability with emulsion system); and adequacy of in-place material thickness. Structural equivalency factors for cold in-place recycled asphalt compared to conventional binder course hot-mix asphalt have been developed. Resilient properties of laboratory and field samples have been determined with the Nottingham Asphalt Tester (NAT) and used in standard mechanistic design programs such as BISAR. Future applications of modified cold in-place asphalt recycling to improve flexible pavements will undoubtedly include airports, which will require consideration of special features such as operational constraints.

Key Words: asphalt; recycling; cold; in-place; designs; testing; moduli; equivalency
1.0 INTRODUCTION

Cold in-place asphalt recycling has developed from the early 1980s in Oregon and New Mexico to become a key method in the range of cold and hot asphalt recycling processes - blended granular material, cold plant, full-depth cold processing, cold in-place train with emulsion (typically polymer modified high float), hot in-place surface, and hot-mix plant - for strengthening and maintaining a wide range of deteriorating asphalt pavements [1]. Ontario municipal experience since 1989, starting with the Regional Municipality of Ottawa-Carleton [2], and provincial experience since 1990 [3], coupled with considerable experience in the United States [4-8], has shown cold in-place asphalt recycling to be technically sound, cost-effective and environmentally friendly. This positive, practical experience with cold in-place recycling in Ontario has resulted in steady growth with two contractors operating cold in-place recycling trains. Three areas of cold in-place asphalt recycling technology have been identified that require further research and development activity: 1. mix designs for field cold in-place recycling train mix production guidance [3]; 2. modifications to address conventional cold in-place recycling problems such as high residual asphalt cement content, fine mix, rutting and material thickness [5]; and 3. structural equivalency factors for cold in-place mix [6]. These mix design process modifications and structural equivalency aspects of cold in-place asphalt recycling have been addressed in laboratory work, mechanistic pavement structure designs and Ontario projects over the past three years.

2.0 COLD IN-PLACE RECYCLING

The major technology components of cold in-place asphalt recycling can be summarized under high production equipment and process, pavement section evaluation for suitability, testing and design procedures, quality control and quality assurance, and advantages.

2.1 Equipment and Process

Two main types of cold in-place asphalt recycling process trains have been developed, and are being used in Ontario - multi-unit cold recyclers and single unit cold recyclers - which involve cold milling, screening, crushing (sizing), mixing, windrowing, pick-up, paving and compaction. The single unit cold recycler, being shorter (about 15 m in length), offers some urban pavement logistical advantages over the longer (about 32 m in length) multi-unit cold recyclers. Regardless, the overall cold in-place recycling process is essentially the same for both trains, with a full lane width and depth to about 150 mm milling capability, sizing of milled recovered asphalt pavement material (RAP) and microprocessor controlled pug mill mixing of emulsion, water and RAP.

Practical experience has demonstrated the following main process features of cold in-place asphalt recycling (CIP, CIR, CIPR, CIPAR): old asphalt pavement milled (typically 75 to 100 mm) and sized (screening/crushing) to minus 37 mm (some agencies specify minus 25 mm); about 1.5 percent emulsion added (typically polymer modified high float emulsion, HF 150(P), in Ontario for some early handling and strength advantage, but can be conventional high float emulsion, HF 150 for instance or recycling high float emulsion, HF-R for instance) along with water to give a total emulsion and moisture content of about 4.5 percent (some agencies specify 4 percent) in the cold in-place mix; about 30 minutes cure/dry out time after placement prior to compaction with a large rubber tired roller (28 tonne typically) followed by a vibratory steel drum roller; curing and traffic compaction time of about two weeks (moisture content less than 2 percent and minimum of 96 percent laboratory density); and placement of a wearing surface, typically a 30 to 50 mm hot-mix asphalt surface course (some agencies specify a surface treatment for less than 1000 AADT).

2.2 Pavement Section Evaluation

While cold in-place recycling is an effective method of strengthening and maintaining a wide range of deteriorating asphalt pavements, it is imperative that each pavement section be evaluated for overall
suitability. This involves a consideration of drainage, structural adequacy and appropriate wearing surface. The drainage and structural adequacy considerations are the same as for any flexible pavement rehabilitation design and specification. Lack of drainage is the key cause of pavement failure. If the drainage is not adequate, or properly maintained, then it must be maintained, improved or installed as necessary.

If the structural adequacy, with consideration of possibly new aggregate addition (modified cold in-place recycling), cold in-place recycling and new hot-mix asphalt surface course, is not clearly evident, then deflection testing (falling weight deflectometer, FWD, for instance) and pavement structural designs will be required. Granular base equivalency factors (GBE or LEF) for cold in-place recycled asphalt (typically about 1.4), and mechanistic design moduli, have been developed for this purpose. A pavement section being assessed for cold in-place asphalt recycling can have significant amounts of cracking and rutting, making a structural adequacy check very important. It is important to: check for an adequate depth of old asphalt (at least 60 to 100 mm typically); determine the existing crossfall and extent of rutting; and assess the severity of cracking and shoulder condition (shoulder widening is often involved). In some cases, the pavement section condition precludes conventional cold in-place asphalt recycling and requires a modified process such as the addition of new aggregate in the case of a pavement section with rutting due to a high asphalt cement content and low voids. It must be recognized that cold in-place asphalt recycling involves the addition of emulsion (asphalt cement) so that adequate voids in-place are critical to process success.

Ontario experience has shown a 30 mm to 50 mm (typically 40 mm) hot-mix asphalt surface course (overlay) placed over the cured, compacted cold in-place recycled asphalt is a suitable wearing surface for up to about 5000 AADT (2500 AADT per lane, about 10 percent heavy vehicles). For higher AADT and/or heavy traffic conditions, the hot-mix asphalt surface course(s) should be designed in accordance with the agency’s procedures and experience. There is no upper AADT limitation on cold in-place asphalt recycling, provided a pavement structural design is completed to ensure design-life performance adequacy.

2.3 Testing and Design Procedures

The overall testing and design procedure for cold in-place asphalt recycling involves six steps:
1. evaluating pavement section for suitability (discussed previously);
2. determining properties of representative millings (RAP) for the section;
3. preparing briquettes with a range of emulsion contents;
4. testing briquettes for air voids, stability and flow;
5. selecting optimum emulsion (and water) content in terms of air voids, stability and coating; and
6. completing quality control and quality assurance testing during recycling of the section (discussed later).

It is important that a mix design is completed for each pavement section (or sub-sections if old asphalt concrete is variable). The mix design is usually completed by the contractor, who has considerable cold in-place recycling process technology expertise, within the overall specification requirements set by the agency. However, it should be noted that the mix design is for field guidance, as it will be necessary to continuously monitor the process and recycled mix and make emulsion and water content adjustments, as necessary, to produce the desired in-place recycled cold mix.

A cold in-place recycled asphalt mix design approach has been adopted, based on Oregon State/McAsphalt/JEGEL/ARRA/MTomix design experience, that is essentially a ‘cold’ Marshall method [9] that ‘simulates’ the cold in-place recycling process on a laboratory scale. A key preliminary step in the mix design is obtaining representative RAP samples of each section (small milling machine or coring/sawing, must be representative of millings produced during recycling of section) and determining the properties of these samples (moisture content, asphalt cement content, gradation and Abson recovery
asphalt cement penetration and viscosity). Actual experience has shown cored/sawn samples obtained from the section and crushed to minus 37 mm in the laboratory to be more representative than small milling machine samples.

Once the representative RAP samples have been characterized, the mix design can proceed. A mix design for a typical cold in-place recycling project incorporating 25 percent new aggregate (modified cold in-place recycling) is summarized in Table 1 with the mix design charts given in Figure 1.

The steps in the mix design procedure, which reflect the Marshall method [9] and MT0 procedures for preparing cold in-place recycled mix briquettes [10], and selecting the optimum emulsion addition level, can be summarized as follows:

1. prepare briquettes for range of emulsion additions
   0.5, 1.0, 1.5, 2.0 and 2.5 percent emulsion addition
   typically has been a polymer modified high-float emulsion
   HF- 150M(P) for example
   (MTO Option A)
   (MTO Option B) is HF- 150M
   batch 3500 gm sample of representative millings for briquettes (also MRD sample)
   determine moisture content of air dried sample
   place in 60°C oven for 1 hour
   add water and emulsion to estimated field liquid content (4.5 percent)
   add warm emulsion (60°C)
   mix to check coating
   spread mixed sample in pan, cover and allow to cure
   60°C for 1 hour
   simulates time between laydown and initial compaction
   compact cured sample in Marshall mold
   rod and compact each face 50 blows
   cure sample and recompact
   20±4 hours in mold at 60°C
   each face 25 blows
   cure recompacted sample
   24 hours in mold on its side at 60°C
   extrude ‘briquette’
   allow to cool to room temperature
   cure for 72 hours at room temperature.

2. test briquettes for each emulsion addition level
   determine bulk relative density
   three briquettes
   determine maximum theoretical density for mix
   compute air voids
   determine marshall1 stability and flow
   two briquettes at 22°C (room temperature)
   one briquette at 60°C.

3. Select optimum emulsion content
   plot density, air voids and stability (22°C and 60°C) against percent added emulsion
   optimum emulsion content
   - minimum stability at 22°C - 8900 N
   - minimum stability at 60°C - 4500 N
   - air voids - 8 to 12 percent range
   - adequate coating.
TABLE 1
MIX DESIGN FOR A TYPICAL COLD IN-PLACE ASPHALT RECYCLING PROJECT INCORPORATING 25 PERCENT NEW AGGREGATE

ASPHALT CEMENT CONTENT, MOISTURE CONTENT, GRADATION AND ABSON RECOVERY DATA

<table>
<thead>
<tr>
<th>SIEVE SIZE</th>
<th>HL 8 STONE</th>
<th>RAP</th>
<th>MIX BLEND*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Percent Passing)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26.5 mm</td>
<td>100.0</td>
<td></td>
<td>100.0</td>
</tr>
<tr>
<td>19.0 mm</td>
<td>97.4</td>
<td></td>
<td>99.3</td>
</tr>
<tr>
<td>16.0 mm</td>
<td>76.3</td>
<td></td>
<td>94.1</td>
</tr>
<tr>
<td>13.2 mm</td>
<td>54.0</td>
<td>100.0</td>
<td>88.5</td>
</tr>
<tr>
<td>9.5 mm</td>
<td>31.6</td>
<td></td>
<td>73.8</td>
</tr>
<tr>
<td>4.75 mm</td>
<td>1.6</td>
<td></td>
<td>46.7</td>
</tr>
<tr>
<td>2.36 mm</td>
<td>1.0</td>
<td></td>
<td>38.5</td>
</tr>
<tr>
<td>1.18 mm</td>
<td>1.0</td>
<td></td>
<td>30.9</td>
</tr>
<tr>
<td>600 μm</td>
<td>1.0</td>
<td></td>
<td>22.6</td>
</tr>
<tr>
<td>300 μm</td>
<td>1.0</td>
<td></td>
<td>15.3</td>
</tr>
<tr>
<td>150 μm</td>
<td>0.9</td>
<td></td>
<td>9.4</td>
</tr>
<tr>
<td>75 μm</td>
<td>0.5</td>
<td></td>
<td>6.5</td>
</tr>
<tr>
<td>Asphalt Cement, %</td>
<td>5.47</td>
<td></td>
<td>5.08</td>
</tr>
<tr>
<td>Moisture, %</td>
<td>2.0</td>
<td></td>
<td>0.22</td>
</tr>
<tr>
<td>Penetration (dmm)</td>
<td>38</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kinematic Viscosity (mm²/s)</td>
<td>530</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Fines Generated By Grinding = 2.0%, Minus 4.75 mm Gradation Adjusted.

MIX DESIGN DATA

<table>
<thead>
<tr>
<th>TESTS</th>
<th>SELECTED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emulsion, %*</td>
<td>0.5</td>
</tr>
<tr>
<td>Water Added, %</td>
<td>4.0</td>
</tr>
<tr>
<td>Bulk Specific Gravity</td>
<td>2285</td>
</tr>
<tr>
<td>Maximum Specific Gravity</td>
<td>2546</td>
</tr>
<tr>
<td>Air Voids (%)</td>
<td>10.2</td>
</tr>
<tr>
<td>Stability (N) @ 60°C</td>
<td>5359</td>
</tr>
<tr>
<td>Marshall Flow (0.25 mm)</td>
<td>18554</td>
</tr>
<tr>
<td>Stability (N) @ 25°C</td>
<td>19361</td>
</tr>
</tbody>
</table>

* Polymer Modified Emulsion Tested To Check For Specification Conformance.

COLD IN-PLACE ASPHALT MIX RECOMMENDED PROPORTIONS

<table>
<thead>
<tr>
<th>Aggregate</th>
<th>Mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing Asphalt Concrete (RAP)</td>
<td>75.0%</td>
</tr>
<tr>
<td>HL 8 Stone</td>
<td>25.0%</td>
</tr>
<tr>
<td>HF- 150(P) Emulsion</td>
<td>15.0%</td>
</tr>
<tr>
<td>(Total Asphalt Cement Content = 5.08%)</td>
<td>100.0%</td>
</tr>
</tbody>
</table>
With the recommended proportions of the cold in-place asphalt mix available, the contractor can proceed with the process, making field adjustments to emulsion and/or water content as necessary.

2.4 Quality Control and Quality Assurance

With the high production rate equipment involved, potential section variability and sensitivity of the recycled asphalt mix to emulsion (fluids) content, it is very important that the contractor has a quality control system and makes any necessary field adjustments. This is then followed up by agency quality assurance activities that typically involve:

- testing the emulsion
taking dry cut core or slab samples (typically by contractor)
representative
‘strength’ adequate when cutting possible
determining moisture content and thickness
determining bulk density (in-place density)
determining recompacted (60°C) density
reporting
emulsion test results
site and sample location
moisture content and thickness
bulk and recompacted density
percent compaction
(conformance with specification)
testing of hot-mix asphalt overlay may also be involved.

For Ontario, the major specification requirements are that the cured/compacted cold in-place recycled asphalt mix has a moisture content of less than 2 percent and percent compaction of at least 96 percent of laboratory recompacted density. This is typically achieved in 10 to 14 days after recycling and secondary delayed rolling is not usually necessary.

2.5 Advantages

In addition to the rehabilitation of deteriorated asphalt pavements by reusing the existing pavement structure, which has resource conservation advantages (asphalt cement, aggregate, fuel and landfill), cold in-place asphalt recycling has demonstrated other important advantages. For suitable pavement sections, cold in-place asphalt recycling results in a ‘new’ pavement at significant life-cycle cost savings compared to conventional flexible pavement reconstruction methods (30 to 60 percent savings over milling, granular base strengthening and recycled hot-mix asphalt binder course/hot-mix asphalt surface course, for instance) [2-8]. As a single lane requirement for the process is involved, the road user inconvenience is minimized. The proper grade and cross slope is established with the cold in-place recycled asphalt mix so that a uniform overlay can be placed. It has been shown that cold in-place asphalt recycling significantly reduces reflective cracking of overlays (Region of Ottawa-Carleton for instance) [2]. This reflective cracking mitigation is probably the most important attribute of cold in-place asphalt recycling and makes it an important potential rehabilitation process for general aviation (municipal) airport pavements.

3.0 MODIFIED PROCESS

Asphalt pavement features that limit the applicability of cold in-place asphalt recycling have been recognized for several years [5]. These conventional cold in-place asphalt recycling problems include: high residual asphalt cement content (flushing); fine milled mix (high percent passing 4.75 mm and 75 \(\mu\text{m}\)); rutting (low initial stability with emulsion system); and adequacy of in-place material thickness (pavement structure capacity). As the cold in-place asphalt recycling process involves the addition of about 1.5 percent emulsion (typically about 60 to 70 percent asphalt cement content, i.e. about one percent additional binder), such a rutted pavement section would suffer even more severe plastic deformation (instability) rutting unless the mix properties are considerably improved during processing. It has been shown, in laboratory work and for a number of Ontario projects the past four years, that modification of the cold in-place process to incorporate new aggregates results in an improved recycled binder course with closer voids and stability control, addressing the gradation and stability concerns.

The modified cold in-place asphalt recycling process involves the addition of 20 to 25 percent new aggregate to the recycled cold mix during processing. This is readily accomplished and has been shown to give the desired gradation and stability control. A typical modified cold in-place recycled asphalt mix
design is given in Table 1 and Figure 1. In addition to gradation and stability control, the incorporation of new aggregate increases the cold in-place asphalt mix thickness by 20 to 25 percent, contributing to the pavement structure, particularly with a GBE of about 1.4, as discussed in the next section. As the stability is improved, there appears to be no need to use a polymer modified high float emulsion, which results in considerable savings when an ordinary high float emulsion is substituted. The increase in pavement structure, and decrease in emulsion cost, more than cover the additional cost for the new aggregate addition.

A second cold in-place asphalt recycling modification is to use a recycling high float emulsion (HF-R for instance) to make more of the old asphalt cement ‘effective’ during the process. This is still at the developmental stage, but has been satisfactorily demonstrated for several Ontario projects in 1994 and 1995. As a next step in the HF-R use development, GBE and mechanistic design moduli for HF-I 50(P) and HF-R cold in-place recycled asphalt mixes are to be compared.

4.0 GUNULAR BASE EQUIVALENCY

In order to complete pavement structure designs for cold in-place asphalt recycling, it is necessary to have some measure of structural equivalency such as the granular base equivalency factor (GBE or LEF) for cold in-place recycled asphalt mix compared to conventional binder course hot-mix asphalt. The resilient property characterization of laboratory cold recycled mix briquettes and cold in-place recycled asphalt mix cores in the JEGEL Nottingham Asphalt Tester (NAT) has shown the often assumed GBE ‘guesstimate’ of 1.4 to be appropriate for the mixes considered. The resilient properties characterization in the NAT, BISAR mechanistic design analysis and GBE evaluation are summarized in Table 2.

The typical Ontario binder course HL 8 Marshall briquettes and cores were obtained from a current major project north of Toronto. Comparison cold in-place recycled asphalt mix (reheated in laboratory to form briquettes) and cores were obtained from a 1994 project in the Region of Waterloo. Resilient moduli of the briquettes (3 for each mix) and cores (3 for each mix) were determined at 21°C in the Nottingham Asphalt Tester. These moduli were then used to calculate strains at critical points of the pavement structure. Since rutting was found to be the critical performance parameters (thin surface course has excellent fatigue endurance), the vertical compressive strain at the top of the subgrade was the leading criterion to determine the granular base equivalency factors as summarized in Table 2. This essentially involved determining the thickness of the cold in-place recycled asphalt layer for which the vertical compressive stress is the same as for the HL 8 binder course. For the typical flexible pavement structures analyzed, the GBE of cold in-place recycled asphalt was found to be 1.4 for a ‘thick’ granular base/subbase layer and 1.35 for a ‘thin’ granular base/subbase layer.

The availability of granular base equivalency factors for cold in-place recycled asphalt will allow for more representative pavement structure designs and comparison of various process modification such as new aggregate addition and HF-R use.

5.0 FUTURE DEVELOPMENTS

The use of modified cold in-place asphalt recycling, with new aggregate addition, is now well established in Ontario. It is important in this regard, that any cold in-place recycling specification development (OPSS for instance [11]), ‘encourage’ such developments and contractor responsibility for mix design and materials performance. The agency should evaluate the pavement section(s) to ensure that it is a satisfactory candidate for cold in-place asphalt recycling, and then set the broad specification requirements, with the recycling process, emulsion and potential aggregate addition as separate pay items. The contractor then takes over and completes the work with quality control to ensure specification compliance as monitored by agency quality assurance.
**TABLE 2**
**COLD IN-PLACE ASPHALT RECYCLING**
**GRANULAR BASE EQUIVALENCY (GBE) EVALUATION**

<table>
<thead>
<tr>
<th>Type of Material</th>
<th>Binder Course Layer</th>
<th>Compressive Strain at the top of Subgrade, $\varepsilon_v$ (microstrain)</th>
<th>Granular Base Equivalency Factor, GBE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Resilient Modulus (MPa)</td>
<td>Thickness (mm)</td>
<td></td>
</tr>
<tr>
<td><strong>a. Granular A 150 mm and Granular B 300 mm</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HL 8 (briquettes)</td>
<td>4500</td>
<td>100</td>
<td>304</td>
</tr>
<tr>
<td>Cold In-Place (briquettes)</td>
<td>750</td>
<td>100</td>
<td>355</td>
</tr>
<tr>
<td></td>
<td>750</td>
<td>145</td>
<td>301</td>
</tr>
<tr>
<td>HL 8 (cores)</td>
<td>1600</td>
<td>100</td>
<td>335</td>
</tr>
<tr>
<td>Cold In-Place (cores)</td>
<td>300</td>
<td>100</td>
<td>383</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>145</td>
<td>333</td>
</tr>
<tr>
<td><strong>b. Granular A 100 mm and Granular B 150 mm</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HL 8 (briquettes)</td>
<td>4500</td>
<td>100</td>
<td>758</td>
</tr>
<tr>
<td>Cold In-Place (briquettes)</td>
<td>750</td>
<td>100</td>
<td>963</td>
</tr>
<tr>
<td></td>
<td>750</td>
<td>150</td>
<td>757</td>
</tr>
<tr>
<td>HL 8 (cores)</td>
<td>1600</td>
<td>100</td>
<td>885</td>
</tr>
<tr>
<td>Cold In-Place (cores)</td>
<td>300</td>
<td>100</td>
<td>1070</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>150</td>
<td>882</td>
</tr>
</tbody>
</table>

(Briquettes were prepared in the laboratory and cores were taken from a typical project.)

The use of conventional and modified cold in-place asphalt recycling for high AADT sections is also well established in Ontario. The availability of structural equivalency and materials moduli for pavement structure design purposes should foster this high AADT use. An obvious extension of cold in-place asphalt recycling is then to general aviation (municipal) airports where the mitigation of reflective cracking is a serious concern. There is no technical reason why cold in-place asphalt recycling cannot be applied to runways, taxiways and aprons, provided airport operational constraints can be met. It will be necessary to use scheduling, crosswind runways and accelerated curing methods (preheating the asphalt pavement for instance) to provide an adequate curing time before use. For example, a municipal airport with a crosswind runway (secondary runway) could schedule operations to allow the cross over portion cold in-place asphalt recycling to be completed first, with accelerated curing and compaction to allow aircraft use after about three days. The remainder of the runway cold in-place asphalt recycling would then proceed on a normal schedule followed up by the hot-mix asphalt overlay. It is hoped that this cold in-place asphalt recycling approach will be demonstrated with Transport Canada in 1996.

**6.0 CONCLUSIONS**

There is still much scope to extend the technology and application of cold in-place asphalt recycling. It should be possible to develop cold plus cold technology - cold in-place asphalt recycling with open graded in-place cold mix surface course - to economically virtually eliminate reflective cracking for secondary municipal roads, for instance. The development of cold in-place asphalt recycling evaluation methodology, mix design methods, modifications such as new aggregate addition to address quality and stability concerns, and pavement structure equivalency factors, should foster the extension of this technically sound, cost-effective, environmentally friendly, method of rehabilitating asphalt pavements.
7.0 ACKNOWLEDGEMENTS

We would like to thank the many provincial and municipal pavements technology practitioners who have fostered the growth of cold in-place asphalt recycling in Ontario since 1989. The technical contributions of Graham Zeisner (Regional Municipality of Ottawa-Carleton) and Tom Kazmierowski (Ontario Ministry of Transportation) have been particularly important.

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