PERFORMANCE OF ULTRA-THIN FREEWAY SURFACINGS IN CANADA

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Paper prepared for presentation
at the Pavements session
of the 1997 XIIIth IRF World Meeting
Toronto, Ontario, Canada
ABSTRACT

Many of Ontario's freeway surfaces are showing signs of premature surface deterioration in the form of map cracking, ravelling, and coarse aggregate loss associated with the use of 100% steel slag coarse and fine aggregates in the hot mix wearing course. The majority of these freeways will require rehabilitation within the next few years.

In 1991 the Ministry undertook a demonstration project to determine if micro-surfacing would extend the life of freeways exhibiting this type of premature surface deterioration. Highway 403 exhibited severe map (block) cracking throughout the entire length of the project and slight to moderate ravelling in some areas. Two contractors, using two different micro-surfacing systems, placed a 3 km four-lane trial section on the Highway 403 demonstration project.

This paper describes the design, testing procedures, material characteristics, construction, and short-term performance of the micro-surfacing systems placed. It also discusses the viability of micro-surfacing as a surficial rehabilitation treatment under freeway conditions.

INTRODUCTION

In recent years many of Ontario's major freeways are showing signs of premature surface deterioration due to the use of hot mix containing steel slag coarse and fine aggregates. The Ministry subsequently banned the use of steel slag as a hot mix aggregate, but there was still a need to develop a method of extending the life of these pavements before major rehabilitation is required. Micro-surfacing appeared to be an ideal solution as it provides for a restoration of the riding surface that is both cost effective and environmentally responsible.

In order to determine if micro-surfacing was a viable alternative to a one-lift overlay on structurally sound yet distressed freeway surface, a demonstration project was undertaken in the summer of 1992 on Highway 403.

BACKGROUND

Micro-surfacing is a polymer-modified, quick-setting, cold-slurry paving system. This high-performance, thin-slurry surfacing consists of a densely-graded aggregate, polymer-modified asphalt emulsion, water, and mineral fillers [1].

The polymer-modified asphalt cement allows the material to remain stable when applied in multi-stone thicknesses [2]. The emulsifier is a proprietary product. Generally the manufacturers of these emulsifiers licence contractors to place their particular micro-surfacing product. Micro-surfacing technology was originally developed in Germany in the late sixties and early seventies [3], and was introduced to North America in the early eighties.

There are several advantages to using micro surfacing rather than a one-lift asphaltic concrete overlay, including: 1) a significant conservation of non-renewable resources such as asphalt cement and aggregates, 2) the road profile is not significantly altered [4], 3) less energy is expended as the micro-surfacing is applied at ambient temperatures, and 4) there are also no harmful emissions [4].

PROJECT DESCRIPTION

Highway 403 project consists of a 3 km, 4-lane section. The lanes were 3.65 m wide with 0.5 m partially-paved shoulders on both the inside and outside lanes. The AADT is 18,000 with 15% commercial traffic. This section of Highway 403 was exhibiting map cracking which was severe to
very severe throughout, moderate ravelling throughout, and intermittent moderate to severe transverse cracking.

The design for both projects consisted of a scratch coat and a final surface coat of micro-surfacing. The scratch coat was intended to provide transverse surface levelling by filling in distortions and minor rutting. The final coat was designed to provide a durable, dense-graded, skid-resistant surface.

Contractor A micro-surfaced the westbound lanes and Contractor B completed the eastbound lanes. As this was a demonstration project, no mix application rates were specified, but representatives from each contracting company made a site visit to assess the site conditions and determine the amount of material required in order to submit a bid.

CONSTRUCTION

A continuous application process was specified and used by both contractors, see [5] for a detailed description of the project and specific details of the mix properties used during construction.

Contractor A

The ambient temperature during placement ranged from 19°C to 32°C. The break time was approximately 1 minute and the set time was approximately 5 minutes. The scratch and surface coats were both approximately 7 mm to 11 mm in thickness. Application rates were 12.0 kg/m² for the scratch coat and 10.2 kg/m² for the surface course. These rates are within generally acceptable ranges of 8.2 kg/m² to 16.3 kg/m² [3]. The micro-surfacing was being placed at a speed of approximately 0.9 m/s.

Contractor B

The ambient temperature ranged from 14°C to 22°C; the weather was sunny with intermittent clouds and slight winds. The break time under a minute and the set time was between 5 and 10 minutes.

The scratch coat had an average thickness of 10 mm and the final coat 8 to 10 mm. The placement speed was approximately 0.3 m/s. A small pneumatic-tired roller was used along the centreline to consolidate any high areas due to overlapping of the micro-surfacing lifts at the longitudinal joint.

MIX DESIGN

The mix design used by both of the contractors is shown in Table 1. Contractor A used the MICROPAVE system and Contractor B used the MICROMAT system. The mix design used by both contractors conformed to ISSA Methodology as outlined in [6]. The test results of the mix design process are listed in Table 2. For a detailed description of the process used see [5].

MATERIAL TESTING

Aggregate

The specifications require the aggregate to meet the quality requirements of the Ministry's premium surface course hot mix aggregate; a high-quality, skid-resistant, 100% crushed from bedrock
aggregate that is used for heavily-trafficked highways. Each contractor chose a different type of aggregate as shown in Table 1.

The specified gradation was verified on samples taken from the stockpiles of both contractors. The gradation results indicate that the aggregate was within the specified range.

**Emulsion**

Micro-surfacing requires a quick-set cationic CSS-1H emulsion. The emulsifier used to produce the emulsion is a proprietary product. The manufacturer/contractor is usually licensed by the manufacturer of the emulsifier to produce the emulsion and place the micro-surfacing.

The emulsion was tested from tanker samples. The samples were tested to determine if they met the Ministry's requirements for a CSS-1H emulsion as specified. Tests included softening point, penetration, kinematic viscosity, and elastic recovery. The sample from Contractor B did not meet the requirements for kinematic viscosity. For the detailed test results see [5]. The percentage of residue was also measured with all contractors meeting the minimum requirement of 62%.

**Polymer Modifier**

Contractor A used a SBR latex (synthetic polymer) while Contractor B used a natural latex. The minimum amount of polymer modifier was specified to be 3.0% by weight of asphalt cement. However, binder temperature susceptibility characteristics (defined in the specifications by penetration index, softening point, and kinematic viscosity) are often considered to be more important than the quantity of the polymer. In other words, a certain amount of modifier is required to achieve the desirable temperature susceptibility of the binder.

**PAVEMENT PERFORMANCE**

**Pavement Condition**

The section completed by Contractor A exhibits slight to moderate reflection cracking, both map and transverse, but no is ravelling apparent at the cracks. Very slight chattering is still evident and very slight longitudinal streaking is apparent due to the original burlap drag. A centreline ridge is still pronounced enough to lightly affect steering when driven over. After three years this section was delaminating intermittently, the areas of delamination were up to 1 m² and generally in the centre of lane 2. There is no ravelling of the edges of these areas and the cause of the delaminations is unknown.

On the section completed by Contractor B, other distresses noted in this section were few, slight to moderate transverse reflection cracking: intermittent, slight, reflective map cracking. There were no occurrences of delamination, ravelling or coarse aggregate loss. This section also appeared to be in good condition with no snowplow damage.

**Rutting**

Rutting surveys were done before and after construction with the Automatic Road Analyzer (ARAN). The ARAN utilizes a 3.75 m long "smart bar" on its front bumper equipped with ultrasonic sensors placed at 100 mm intervals. These sensors bounce signals off the pavement and record the relative distance between the bar and the surface. This data is interpreted to give a transverse profile of the pavement lanes [7].

Figure 1 shows the average rut depths. Prior to construction the rut depths in lane 2 (driving lane)
of the westbound (contractor A) and eastbound (contractor B) were similar with rut depths at 7.6 mm and 6.9 mm, respectively. Results of the ARAN testing 9 months and 21 months after construction reveal that both contractors had very similar results. The results of testing in lane 2 show similar results with an insignificant decrease in rut depth 21 months after construction, at 6.1 mm in the westbound and at 5.8 mm in the eastbound. Four years after construction the depths have increased similarly for Contactor A and Contractor B to 8.9 mm and 8.1 mm respectively.

**Roughness**

Prior to construction, roughness surveys were taken using a Portable Universal Roughness Device (PURD). The readings are converted into a Riding Comfort Rating (RCR), for details of the PURD and RCR calculations see [5,7]

One of the limitations of the PURD is the inability to filter out the effect of the pavement's macro-texture from overall roughness results. This becomes a significant concern when measuring tined surfaces or surface treatments (such as micro-surfacing) where there can be an aggressive macro-texture. For this reason, roughness measurements after construction were taken with a Mays Ride Meter (MRM) and converted into an RCR. For details on the MRM and RCR conversions see [5,7]

The roughness of lane 2 of the eastbound and westbound lanes prior to construction were very similar with RCR values of 7.4 to 7.8, putting the ride in the upper portion of the comfortable category, see Figure 2.

The westbound lanes show an increase in the ride characteristics after construction. The RCR value over the 21-month evaluation period place it in the middle portion of the "smooth" range with an RCR value of 8.8 for both lanes. The results of the Mays roughness testing on the eastbound lanes indicate that the ride is very similar to the westbound lanes. The RCR value in both lanes 9 months after construction was 8.3 and after 21 months was at 8.7, again placing the ride in the lower portion of the "smooth" category. After three years the ride still remains in the "smooth" category with RCR values of 8.5 and 8.4 for Contractors A and B respectively.

**Skid Resistance**

The relative skid resistance of a pavement is given in terms of a skid number (SN). Based on field measurements using an ASTM brake force trailer [7].

Figure 3 shows the average skid resistance surveys for lane 2 of both the westbound and eastbound lanes of the 403 project. The westbound lane 2 (Contractor A) indicated a high skid level with an SN of 41 prior to construction. Nine months after micro-surfacing the value increased to an SN of 46, and remains consistently high with an SN of 52 after four years. In lane 2 of the eastbound lanes, Contractor B's section, the results are similar, the original SN of 41 rose to an SN of 48 four years after construction.

The results of the skid testing indicate that the micro-surfacing for both contractors exhibits a high frictional resistance, similar to freeways with a premium quality hot mix surface.

**WARRANTY SPECIFICATION**

As was concluded from the results of the demonstration project on Highway 403 the success of micro-surfacing is dependent on quality materials, a good mix design and quality construction but there was also a lack of quality assurance testing procedures that make it difficult to develop end-result specifications. In consultation with the industry the Ministry decided to develop a two year micro-surfacing warranty specification. For more details of the development of the warranties specification see [9].

The use of a warranty would be advantages to both the Ministry and industry. The Ministry
would not have to conduct any material testing and develop quality assurance testing procedures; also savings could be realized through reduced contract inspection, administration, and maintenance costs due to pre-mature failures. The contractor would have less restrictions imposed on their operations including being solely responsible for the mix design changes during construction and in determining if the weather conditions are suitable for construction.

The performance criteria developed for the micro-surfacing were based on the Highway 403 demonstration and subsequent contracts. At the end of the warranty period the micro-surfacing must exhibit no evidence of coarse aggregate loss/ravelling and flushing that is slight in severity must not exceed 10% of the contract.

The contractor is still required to produce a mix design that meets the ISSA criteria [1] as per the original micro-surfacing specification and the aggregates must still meet the high quality requirements as would be used in a premium quality hot mix. The appearance of the micro-surfacing will still be inspected at the end of the contract for such defects as scratch marks, poor or over-built joints and edges, rippling and longitudinal streaking.

Due to monetary constraints there has only been one micro-surfacing warranty contract to-date. Future work with the warranty specification includes; (1) meeting with industry and revising the performance criteria as required, (2) determining the need for a separate evaluation manual for micro-surfacing, and (3) possible removal of the remaining equipment and end result requirements in the specification.

CONCLUSIONS

Based on the short-term results of this project coupled with the positive results of the Ministry’s first micro-surfacing project [1], it appears that micro-surfacing can provide a viable alternative rehabilitation technique for extending the pavement life of high-speed, high-trafficked freeways suffering from severe surficial distresses. The following short-term conclusions are made based on this report.

- Micro-surfacing provides a smooth durable, highly skid-resistant surface, comparable to the Ministry’s premium hot mix surfaces.
- Micro-surfacing appears to have the potential to extend the life of a pavement suffering from the distresses associated with the use 100% of steel slag aggregates in the wearing surface.
- The weather conditions have a considerable affect on the constructability of micro-surfacing; this underscores the need for an experienced, skilled, and knowledgeable crew that can make the slight adjustments required to the mix design as the ambient weather conditions change during the operation.

With continued monitoring and testing the mid to long-term performance characteristics of micro-surfacing on freeway facilities in a wet-freeze environment can be established. In the absence of appropriate quality assurance/control testing methodology, the development of an equitable 2-year warranty specification is necessary with this specialized technology [8].
REFERENCES


TABLE 1  Mix Designs

<table>
<thead>
<tr>
<th></th>
<th>Contractor A</th>
<th>Contractor B</th>
<th>MTO Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate</td>
<td>Dolomitic sandstone</td>
<td>Traprock screenings</td>
<td>High quality hot mix aggregate</td>
</tr>
<tr>
<td>Mineral Filler</td>
<td>P.C. Type 1 0.2 to 1.5%</td>
<td>P.C. Type 1 1.0%</td>
<td>1.5% - 3.0%</td>
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<tr>
<td>Asphalt Emulsion</td>
<td>ASENCO 11.5±1.1%</td>
<td>POLYMAC 12%</td>
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<tr>
<td>Residual Asphalt</td>
<td>7.4±0.7%</td>
<td>7.4±0.5%</td>
<td>6% - 11.5%</td>
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<tr>
<td>Water</td>
<td>9 - 12%</td>
<td>11%</td>
<td>---</td>
</tr>
<tr>
<td>Latex (% solids by</td>
<td>Latex SBR 3.0%</td>
<td>Natural Latex 3.0%</td>
<td>Min. 3.0%</td>
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<tr>
<td>weight of asphalt)</td>
<td></td>
<td></td>
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### TABLE 2  Test Results from Mix Designs

<table>
<thead>
<tr>
<th>Test</th>
<th>Test Number</th>
<th>Requirements</th>
<th>Contractor A</th>
<th>Contractor B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet Cohesion @ 30 minutes minimum (kg-cm)</td>
<td>ISSA TB-139</td>
<td>12 minimum</td>
<td>17.5</td>
<td>17</td>
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<td>Wet Cohesion @ 60 minutes minimum (kg-cm)</td>
<td>ISSA TB-139</td>
<td>20 minimum</td>
<td>20</td>
<td>22</td>
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<td>Excess Asphalt by LWT Sand Cohesion (g/m³)</td>
<td>ISSA TB-109</td>
<td>538 maximum</td>
<td>473</td>
<td>N/A</td>
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<td>Wet Stripping (%)</td>
<td>ISSA TB-114</td>
<td>Pass (90 minimum)</td>
<td>99</td>
<td>N/A</td>
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<td>Wet Track Abrasion Loss</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>@ 1 Hr. Soak (g/m²)</td>
<td>ISSA TB-100</td>
<td>538 Maximum</td>
<td>135</td>
<td>291</td>
</tr>
<tr>
<td>Wet Track Abrasion Loss</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>@ 6 Days Soak (g/m²)</td>
<td>ISSA TB-100</td>
<td>807 Maximum</td>
<td>600</td>
<td>571</td>
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<tr>
<td>Lateral Displacement (%)</td>
<td>ISSA TB-147A</td>
<td>5 Maximum</td>
<td>4.7</td>
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<td>Vertical Displacement (%)</td>
<td>ISSA TB-147A</td>
<td>10 Maximum</td>
<td>9.7</td>
<td>1.5</td>
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<tr>
<td>Specific Gravity after 1000 cycles of 57 kg</td>
<td></td>
<td>2.10 Maximum</td>
<td>2.01</td>
<td>2.01</td>
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<td>Classification Compatibility</td>
<td>ISSA TB-144</td>
<td>(AAA, BAA) 11 Grade Pt. Minimum</td>
<td>AAA 12 Grade Pt.</td>
<td>BAA 11 pts.</td>
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<td>Mix Time @ 25° (sec)</td>
<td>ISSA TB-113</td>
<td>Controllable to 120 Minimum</td>
<td>120</td>
<td>180</td>
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</table>

**Notes:**
1. Requirements as specified by "ISSA Recommended Performance Guidelines For Micro-Surfacing, A143 (Revised) Jan. 1991"
2. N/A = Not Available
Figure 1, Average Rut Depths (Lane 2)

Figure 2, Average Ride Comfort Rating (Lane 2)

Figure 3, Average Skid Resistance (Lane 2)