Microsurfacing: Solution for Deteriorated Freeway Surfaces

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Many of Ontario's freeway surfaces are showing signs of premature surface deterioration in the form of map cracking, raveling, and coarse aggregate loss associated with the use of 100 percent 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. The Ministry of Transportation of Ontario has reviewed various alternatives for increasing the service lives of these pavements before major rehabilitation becomes a necessity. One alternative strategy was to use microsurfacing to seal, level, and provide a thin, durable, skid-resistant wearing surface. In 1991 the Ministry undertook two demonstration projects to determine if microsurfacing would extend the lives of freeways exhibiting this type of premature surficial deterioration. The project on Highway 401 exhibited very severe map (block) cracking and raveling. The Highway 403 project exhibited severe map (block) cracking throughout the entire length of the project and slight to moderate raveling in some areas. Two contractors using two different microsurfacing systems placed a 3-km four-lane trial section on Highway 403. On the Highway 401 project one contractor placed two 500-m sections over two lanes. The annual average daily traffic at the trial locations was approximately 15,000, with 15 to 25 percent commercial traffic. The design, testing procedures, material characteristics, construction, and short-term performance of the microsurfacing systems that were placed are described. The viability of microsurfacing as a surficial rehabilitation treatment under freeway conditions is also discussed.

In recent years many of Ontario's major freeways have begun to show signs of premature surface deterioration due to the use of steel slag coarse and fine aggregates. The Ministry of Transportation of Ontario (MTO) 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 lives of these pavements before major rehabilitation is required. Microsurfacing appeared to be an ideal solution because it provides for a restoration of the riding surface that is both cost-effective and environmentally responsible.

In 1991 the Ministry placed a trial section of microsurfacing on a low-volume, secondary highway. The results for this test section were quite encouraging (*1*). The initial project demonstrated that microsurfacing is a viable alternative to a one-lift overlay on low-volume roadways with severe surface deficiencies and a structurally sound base but that it did not mitigate reflection cracking. In addition, it was concluded that the Ministry's high-quality hot-mix aggregates could be used in the microsurfacing mix and that the success of microsurfacing technology was dependent on quality construction practices and prudent mix design (*1*).

To determine if microsurfacing was a viable alternative to a one-lift overlay on structurally sound yet surface-distressed freeways, two projects were undertaken in the summer of 1992: one on Highway 403 and the other on Highway 401. Both highways are four-lane, divided, rural freeways that form part of Ontario's major freeway system.

BACKGROUND

Microsurfacing is a polymer-modified, quick-setting, cold-slurry paving system. This high-performance, thin-slurry surfacing consists of a densely graded fine aggregate, polymer-modified asphalt emulsion, water, and mineral fillers (*2*).

The polymer-modified asphalt cement allows the material to remain stable when it is applied in multi-stone thicknesses (*3*). The emulsifier is a proprietary product. Generally, the manufacturers of these emulsifiers license contractors to place their particular microsurfacing products. Micro-surfacing technology was originally developed in Germany in the late 1960s and early 1970s (*4*) and was introduced to North America in the early 1980s. The material is applied with specialized equipment that carries all of the components of the mixture, accurately measures and mixes them in a pug mill, and spreads the mixture over the width of a traffic lane as a thin, homogeneous mixture.

The use of Microsurfacing has several advantages over the use of a one-lift overlay:

- There is a significant conservation of nonrenewable resources, including asphalt cement and aggregates, since the thickness of a lift of microsurfacing is typically 9 to 12 mm, versus 40 mm for a hot-mix overlay.
- This thin surfacing does not significantly alter the road profile; therefore, the need for guiderail adjustments, the need for reductions in bridge clearances, and the need for shoulder granular material are greatly reduced (*5*).
- The cost is approximately 70 percent that of single-lift hot-mix overlay.
- Less energy is expended because the microsurfacing is applied at ambient temperatures. In addition, none of the harmful emissions often associated with hot-mix production are released (*5*).

PROJECT DESCRIPTION

The section of Highway 401 chosen for the trial is located near Chatham, Ontario, Canada, 100 km east of the Windsor, Ontario, and Detroit, Michigan, area. The Highway 403 project is located near Brantford, Ontario, Canada, 100 km west of Toronto.

Two contractors (Contractors A and B) were invited to participate on both trial projects. Contractor A was involved in both the

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Highway 401 and 403 projects, and Contractor B took part in only the Highway 403 project.

The Highway 401 project consisted of two 500-m, two-lane segments placed by Contractor A. The width placed was 7.3 m, with 0.5-m partially paved shoulders on both sides.

The Highway 403 project consisted of a 3-km, four-lane section. The lanes were 3.65 m wide, with 0.5-m partially paved shoulders on both the inside and the outside lanes. Contractor A microsurfaced the westbound lanes, and Contractor B completed the eastbound lanes.

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

These were demonstration projects; therefore, no mix application rates were specified, but to submit a bid representatives from each contracting company made a site visit to assess the site conditions and determine the amount of material required.

EXISTING CONDITIONS

Both Highway 401 and Highway 403 are four-lane, rural freeways with fully controlled access.

A stretch of Highway 401 westbound in the Chatham area, approximately 20 km in length, has severe to very severe raveling throughout, and this has developed into potholing in a few locations. The distresses in this area consist of few moderate transverse cracks and some slight map cracking. The two 500-m sections chosen for the trial had distresses typical of this area. The annual average daily traffic (AADT) is 14,000, with 25 percent commercial traffic.

The 3-km section of Highway 403 was exhibiting map cracking that was severe to very severe throughout, moderate raveling throughout, and intermittent moderate to severe transverse cracking. The AADT is 18,000, with 15 percent commercial traffic.

SPECIFICATIONS

Specifications controlling the microsurfacing operation on this project included the following:

- The binder shall be a quick-set, polymer-modified, cationic-type CSS-1H emulsion.
- The aggregate shall be 100 percent crushed material from bedrock meeting the physical requirements for the Ministry's premium quality hot-mix aggregate.
- The contractor shall select a qualified laboratory to prepare the job mix formulae.
- The mix shall meet the following proportions: residual asphalt, 6 to 11.5 percent by dry mass; mineral filler, 0 to 3.0 percent by dry mass.
- The mixture shall be placed when the atmospheric temperature is at least 10°C and rising and between June 1 and September 15.
- The pavement surface shall be thoroughly cleaned of all debris.
- Water may be sprayed into the spreader box to facilitate spreading without harming the mix.
- Traffic shall be kept off the freshly placed mixture for a minimum of 30 min or whatever time is required to prevent damage to the surface.
- A 100-m-long, one-lane-width trial area of microsurfacing shall be placed off site before the commencement of the microsurfacing operation.

CONSTRUCTION

On the Highway 401 project a single load or stop–start method of applying the microsurfacing was used, where as the Highway 403 project specified the use of the continuous load process of application. A description of the two methods of microsurfacing has been provided previously (*1*).

Highway 401, Contractor A

The project consisted of two 500-m sections of two-lane highway; therefore, a continuous operation was not specified, as would normally have been the case for a highly trafficked and high-speed freeway.

The Highway 401 project was completed on August 18 and 19, 1992. The weather was typically sunny with overcast periods and a cool wind. The ambient temperature ranged from 15°C to 24°C. There was a heavy rainfall during the evening of the first day of construction.

Contractor A used a Scanroad single truck-mounted mixing unit to place the microsurfacing. The waiting time between loads was up to 40 min.

The depth of the scratch coat ranged from 0 to 10 mm. The deepest sections were in the right-lane wheelpaths. The left-lane wheelpaths ranged from 0 to 5 mm in depth. Potholes were not present in either of the two 500-m sections.

The edges and joints were finished with brooms. In general, the mix was very uniform, and few problems with drag or tear marks in the surface were encountered.

When early morning temperatures were cooler the portland cement content was 1.75 percent; as the temperature rose the cement content was lowered to 1.5 percent to delay the set time. Emulsion break occurred at approximately 1 min, and set time occurred at 15 min. A cement content of 1.25 percent was used at the warmest temperatures, and then the break time was 30 to 40 secs and the set time was 5 to 10 min.

Highway 403, Contractor A

Contractor A placed microsurfacing on the westbound lanes of a 3-km, two-lane section of Highway 403. The resurfacing was completed from August 24 to 27, 1992. The ambient temperature during this period ranged from 19°C to 32°C. It was generally sunny in the morning and humid, with some overcast periods.

A continuous load process was specified for this contract. To meet this requirement Contractor A attached a material transfer unit to a truck-mounted mixing unit (the same that was used on the Highway 401 project). Trucks in front of the equipment dumped the aggregate into a hopper where the aggregate was conveyed into the bin on the mixing unit. Water and emulsion were loaded into the appropriate compartments on the mixing unit from tanker trucks on the shoulder of the highway. This method caused some problems because the shoulders varied in width and were not always wide enough to carry the tanker trucks. Another problem was with gravel being kicked onto the roadway from the shoulder by these vehicles.

This larger-size gravel would cause tear or drag marks on the microsurfacing.

The contractor used brooms to feather and finish the edges and joints. The joint at the centerline was not feathered properly, creating a 25- to 50-mm ridge. This created a hazardous situation on a superelevated portion of the roadway where damming of the rainwater in the inner wheelpath area occurred. The contractor milled a 600-mm strip along the centerline, removing the ridge, and resurfaced the entire driving lane with microsurfacing for a distance of approximately 500 m.

The set time was approximately 5 min, and the break time was approximately 1 min. The contractor used either 1.25 or 1.5 percent portland cement content, depending on the ambient temperature.

The scratch and surface coats were both approximately 7 to 11 mm in depth.

Highway 403, Contractor B

Contractor B microsurfaced the eastbound lanes of a 3.0-km, two-lane section of Highway 403. The work was performed from September 1 to 9, 1992. The ambient temperature ranged from 14°C to 22°C; the weather was sunny with intermittent clouds and slight winds.

Contractor B used a continuous truck-mounted mixing unit that included two tandem trucks and an emulsion and water truck that reloaded the mixer from the front rather than from the shoulders of the road. Although this was considered to be continuous because the emulsion, water, and aggregates were added to the mixing equipment from the roadway, the paving was halted for approximately 20 to 25 min while the emulsion and water were added from the tanker trucks.

The contractor used 1 percent portland cement at all times to achieve a set time of 5 to 10 min and a break time of under 1 min.

The scratch coat was an average of 10 mm in depth, and the final coat was 8 to 10 mm in depth.

Contractor B used a small pneumatic-tired roller along the centerline to consolidate any high areas due to overlapping of the microsurfacing lifts.

Production

The application rates for both the scratch and surface coats for Contractor A on Highway 401 were 14.6 and 10.0 kg/m^2, respectively. The rates for Contractor A on Highway 403 were 12.0 kg/m^2 for the scratch coat and 10.2 kg/m^2 for the surface course. The application ranges for the final coats used are within generally acceptable rates of 8.2 to 16.3 kg/m^2 (*4*). Application rates for Contractor B were not available.

On the Highway 401 project Contractor A traveled approximately 300 to 350 m per load for both the scratch and final coats. On the Highway 403 project Contractor A was placing the microsurfacing at a rate of approximately 0.9 m/sec. Contractor B was placing microsurfacing at approximately 0.3 m/sec on the same project.

MIX DESIGN

The mix design used by both of the contractors is shown in Table 1. Contractor A used the same mix design for both the Highway 401 and Highway 403 projects. Contractor A used the Micropave system, and Contractor B used the Micromat system.

The mix design for both contractors was completed by using the International Slurry Surfacing Association (ISSA) methodology as outlined previously (*6*). For the results of mix design see Table 2. A detailed description of the mix design process used in the test sections has been provided previously (*1*).

TABLE 1 Mix Designs

	Highway 403		Highway 401	
	Contractor A	Contractor B	Contractor A	MTO Requirements
Aggregate	Dolomitic sandstone screenings 100%	Traprock screenings 100%	Dolomitic Sandstone Screenings 100%	High quality hot mix aggregate
Mineral Filler	Type 1 Portland Cement 0.2 to 1.5%	Type 1 Portland Cement 1.0%	Type 1 Portland Cement 0.2 to 1.5%	1.5% - 3.0%
Asphalt Emulsion	ASENCO 11.5±1.1%	POLYMAC 12%	ASENCO 11.5±1.1%	---
Residual Asphalt	7.4±0.7%	7.4±0.5%	7.4±0.7%	6% - 11.5%
Water	9 - 12%	11%	9 - 12%	---
Additive	As Required	As Required	As Required	---
Latex (% solids by weight of asphalt)	Latex SBR 3.0%	Natural Latex 3.0%	Latex SBR 3.0%	Min. 3.0%

MATERIAL TESTING

Aggregate

The specifications required that the aggregate meet the quality requirements of the Ministry's premium surface course hot-mix aggregate (HL-1 designation). HL-1 aggregate is a high-quality, skid-resistant, 100 percent crushed aggregate from bedrock that is used for hot-mix surfaces on heavily trafficked highways. Each contractor chose a different type of aggregate, as shown in Table 1, and test results of the aggregate are given in Table 3. The specified gradation was verified on samples taken from the stockpiles of all three trial sections. These results are shown in Table 4 and are plotted as gradation curves in Figure 1.

The gradation results indicate that the aggregate used on the Highway 403 project by Contractor A was within the specified range. The aggregate used by Contractor B was slightly out of the specified range on the 600-μm and 4.75-mm sieves.

The aggregate was also recovered from the microsurfacing samples obtained in the field. The gradation results were similar to those obtained from the stockpile samples.

TABLE 2 Test Results from Mix Designs

Test Name	Test Number	Requirements	Highway 403 Contractor A	Highway 403 Contractor B	Highway 401 Contractor A
Wet Cohesion @ 30 minutes minimum (kg-cm)	ISSA TB-139	12 minimum	17.5	17.0	17.5
Wet Cohesion @ 60 minutes minimum(kg-cm)	ISSA TB-139	20 minimum	20.0	22.0	20.0
Excess Asphalt by LWT Sand Cohesion(g/m^3)	ISSA TB-109	538 maximum	473	N/A	473
Wet Stripping (%)	ISSA TB-114	Pass (90 minimum)	99	N/A	99
Wet Track Abrasion Loss					
@ 1 Hr. Soak (g/m^2)	ISSA TB-100	538 Maximum	135	291	135
Wet Track Abrasion Loss					
@ 6 Days Soak (g/m^2)	ISSA TB-100	807 Maximum	600	571	600
Lateral Displacement (%)	ISSA TB-147A	5 Maximum	4.7	2.5	4.7
Vertical Displacement (%)	ISSA TB-147A	10 Maximum	9.7	1.5	9.7
Specific Gravity after 1000 cycles of 57 kg		2.10 Maximum	2.01	2.01	2.01
Classification Compatibility	ISSA TB-144	(AAA, BAA) 11 Grade Pt. Minimum	AAA 12 Grade Pt.	BAA 11 pts.	AAA 12 Grade Pts.
Mix Time @25° (sec)	ISSA TB-113	Controllable to 120 Minimum	120	180	120

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

TABLE 3 Aggregate Test Results

Test Name	Test Number	Requirement	Highway 403 Contractor A	Highway 403 Contractor B	Highway 401 Contractor A
Methylene Blue	ISSA TB-145 RTMII 6	Max. 15 ml	2.0	3.5	2.0
Sand Equivalency	ASTM D2419	Min. 60 units	64	75	64

TABLE 4 Aggregate Gradation from Stockpile Samples (Percent Passing)

MTO Sieve Designation (mm)	MTO Requirements	Highway 403 Contractor A (n = 1)	Highway 403 Contractor B (n = 2)	Highway 401 Contractor A (n = 1)
9.500	100	100.0	99.7	100.0
4.750	70 - 90	87.3	82.9	91.0
2.360	45 - 70	60.1	54.8	66.5
1.180	32 - 54	46.9	38.5	53.0
0.600	23 - 38	37.1	29.3	44.0
0.300	16 - 29	24.1	19.8	28.5
0.150	9 - 20	15.9	13.5	19.0
0.075	5 - 15	9.6	8.7	12.5

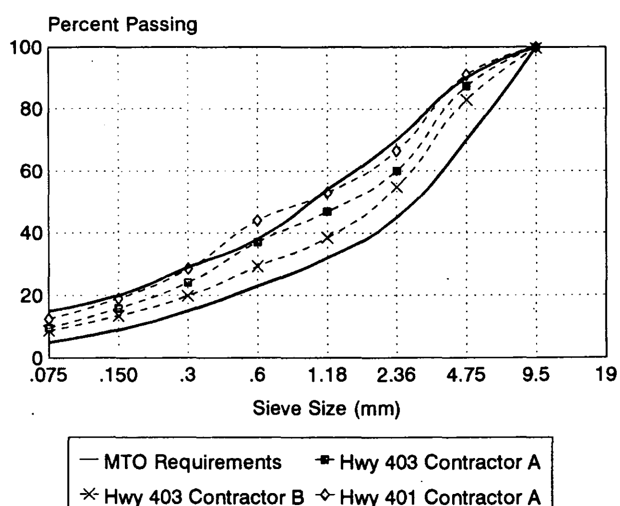

FIGURE 1 Gradation curves for aggregate used in microsurfacing.

Emulsion

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

The emulsion used on Highway 403 for both contractors was tested from tanker samples. The emulsions were tested to determine if they met the Ministry's requirements for a CSS-1H emulsion, as required in the specifications. Tests included softening point, penetration, kinematic viscosity, and elastic recovery. The sample from Contractor B did not meet the requirements for kinematic viscosity. The results for emulsion testing are shown in Table 5. The amount of residue was also measured, with all contractors meeting the minimum requirement of 62 percent.

The binders recovered from the field samples of microsurfacing from both contractors on the Highway 403 project were also tested to determine if they still met Ministry standards. The samples from both contractors were low in the requirements for softening point,

TABLE 5 Test Results for Polymer-Modified Emulsified Asphalt Samples

			Highway 403		Highway 401
Test Name	Test Number	Requirements	Contractor A (n = 1)	Contractor B (n = 2)	Contractor A (n = 1)
Softening Point (°C)	ASTM D36	57°C Min.	58.0°C	57.5°C	63.9°C
Penetration @ (25°C, 100 g, 5 s, 0.1 cm)	MTO LS-200	40 - 90	85	88	N/A**
Kinematic Viscosity @ 135°C(mm²/s)	ASTM D2170	650 Min.	994	601	N/A**
Elastic Recovery @ 10C (20 cm extension)	N/A*	Not Specified	47.5	35.4	N/A**
(Length)			20	15	
Residue Distillation (%)	MTO LS-219	62	62.7	64.0	63.9

* Proposed ASTM standard test.
** Sample not tested.

and the sample from Contractor A was low in the requirements for kinematic viscosity. The results are presented in Table 6.

The residue from the emulsion samples of Contractor A had a penetration of 85 and a kinematic viscosity of 994 mm^2/sec, yet the results from the recovered residue showed an increased penetration of 86.7 and a lower kinematic viscosity of 617 mm^2/sec, indicating that the residue is softer. The results from the emulsion used by Contractor B show the residue becoming stiffer after mixing. The penetration went from 88 to 57.5 and the kinematic viscosity went from 601 to 1188 mm^2/sec.

Samples of the emulsion and microsurfacing from the Highway 401 project were not taken.

Polymer Modifier

Contractor A used an SBR latex (synthetic polymer), whereas Contractor B used a natural latex.

The minimum amount of polymer modifier was specified to be 3.0 percent by weight of asphalt cement (Table 1). 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.

TABLE 6 Test Results for Polymer-Modified Emulsified Asphalt

			Highway 403		Highway 401
Test Name	Test Number	Requirements	Contractor A (n = 3)	Contractor B (n = 2)	Contractor A
Softening Point (°C)	ASTM D36	57°C Min.	48.9	56.8	N/A*
Penetration @ (25°C, 100 g, 5 s) 0.01 cm	MTO LS-200	40 - 90	86.7	57.5	N/A*
Kinematic Viscosity 135°C (cSt/Sec)	ASTM D2170	650 Min.	617	1188	N/A*

* Not available; samples not tested

PAVEMENT PERFORMANCE

Pavement Condition

The pavement conditions of all three trial sections have been reviewed periodically since construction. In the summer of 1994, approximately 20 months after the work was completed, the following characteristics were noted.

Highway 401, Contractor A

This section had an excellent ride with a uniform texture throughout. There was no snowplow damage in the two 500-m sections. There was no raveling, delaminations, or deformations. All working transverse cracks had reflected through, although there was no spalling. A slight chatter, which occurred during construction, still remains. Slight buildup occurred at the centerline.

Highway 403, Contractor A

Overall, this section is in good condition, with no sign of any snowplow damage.

Slight to moderate reflection cracking, both map and transverse, was apparent, but no raveling was apparent at the cracks. Very slight chattering was still evident, and very slight longitudinal streaking was apparent because the original burlap drag was still apparent. The centerline ridge was still pronounced enough to lightly affect steering when a vehicle drives over the ridge.

Highway 403, Contractor B

This section also appeared to be in good condition, with no snowplow damage and a uniform texture.

Other distresses noted in this section were few, slight to moderate transverse reflection cracking and intermittent, slight, reflective map cracking. No occurrences of delamination, raveling, or coarse aggregate loss were found.

Rutting

Rutting surveys were done before and after construction with the Automatic Road Analyzer (ARAN). On the front bumper of the ARAN is a 3.75-m-long "smart bar" 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. These data are interpreted to give a transverse profile of the pavement lanes (*7*).

The average rut depths on the Highway 401 project are given in Figure 2. The rut depths were averaged for both 500-m sections. Although the original rut depths on this project were slight, the average rut depth in both lanes was reduced after construction. The average rut depth in lane 1 decreased to 3.3 mm from 8.5 mm, and in lane 2 it decreased to 4.9 mm from 7.9 mm. Twenty-one months after construction the rut depth in lane 1 increased slightly to 5.0 mm, and it remained unchanged at 4.2 mm in lane 2.

Figure 3 shows the average rut depths for the Highway 403 project. Before construction the rut depths in both the eastbound and the westbound lanes were similar and very slight: lane 1 at 4.6 and 5.1 mm and lane 2 at 7.6 and 6.9 mm, respectively. Results of the ARAN testing at 9 and 21 months after construction reveal that the results were very similar for the sections constructed by both contractors. The average rut depths in lane 1 remain virtually unchanged 21 months after construction, with depths of 4.5 mm in the westbound lanes and 4.3 mm in the eastbound lanes. The results of ARAN testing in lane 2 showed similar results, with an insignificant decrease in rut depth 21 months after construction: 6.1 mm in the westbound lane and at 5.8 mm in the eastbound lane.

Roughness

Before construction roughness surveys were taken with a portable Universal Roughness Device (PURD). PURD is a trailer-mounted, accelerometer-based measuring device operated at a constant speed on the highway. It uses the root mean square of the vertical acceleration of the trailer axle (PURD) to measure roughness. These are converted into a riding comfort rating (RCR) as follows (*7*):

$$RCR = 26.64 - 7.38 \cdot \log_{10} (PURD)$$

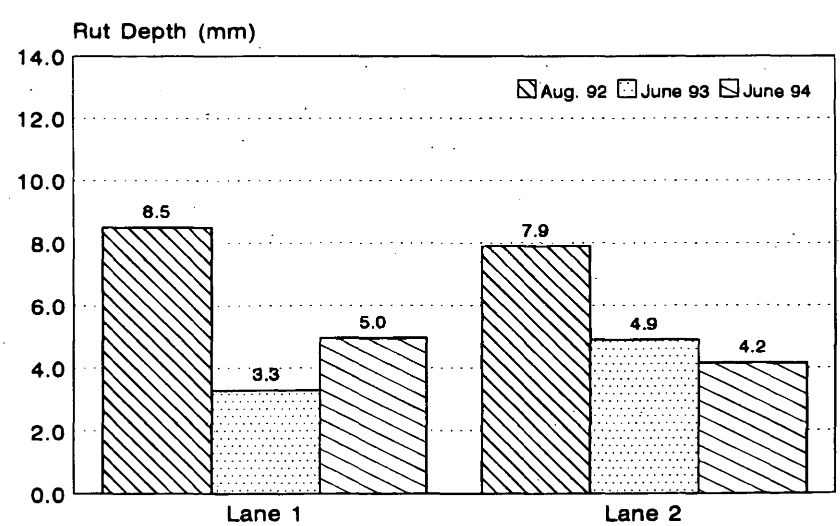

FIGURE 2 Average rut depths for Highway 401.

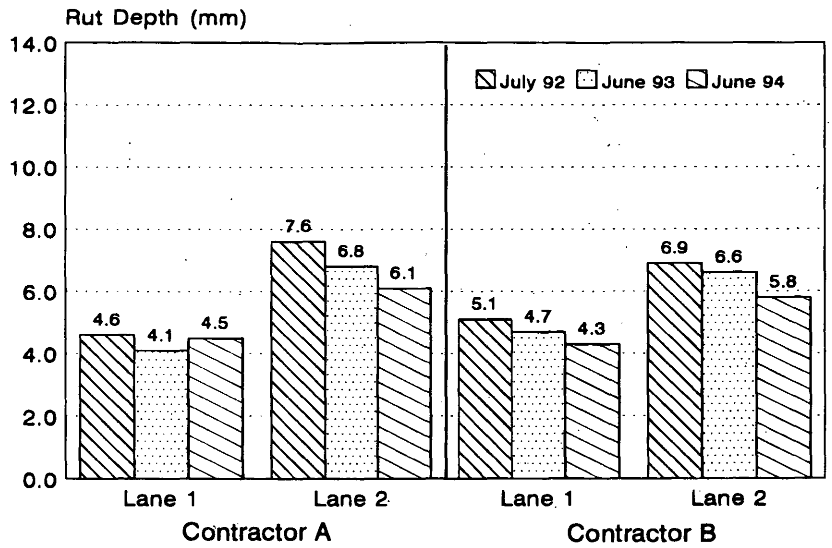

FIGURE 3 Average rut depths for Highway 403.

One of the limitations of the PURD is the inability to filter out the effect of the pavement's macrotexture from overall roughness results. This becomes a significant concern when measuring tined surfaces or surface treatments (such as microsurfacing), in which there can be an aggressive macrotexture. For this reason roughness measurements after construction were taken with a Mays Ride Meter (MRM). MRM is a road response-type measuring device that is mounted onto the rear axle of a vehicle or trailer operated at a constant speed.

MRM uses the vertical distance that the vehicle travels with respect to the rear axle in inches per mile to measure the roughness. Measurements taken with MRM are currently converted to RCR by the following transfer function:

$$RCR = 9.38 - 0.0177 \cdot (MAYS)$$

The average roughness results for the Highway 401 project are given in Figure 4 for lanes 1 and 2. The roughness results for both 500-m sections were averaged together. The RCRs before construction were 6.3 and 6.4 in lanes 1 and 2, respectively, which are in the lower end of the comfortable category. Nine months after construction the readings for lanes 1 and 2 were 7.5 and 7.6, respectively. Readings 21 months after construction are almost identical at 7.5 and 7.7 for lanes 1 and 2, respectively. The micro-surfacing improved the rides on these short sections to the upper portion of the comfortable range.

Figure 5 provides the average RCRs for both contractors on the Highway 403 project for lanes 1 and 2.

The roughnesses of the eastbound and westbound lanes before construction were very similar, with RCR of 7.4 to 7.8, putting the ride in the upper portion of the comfortable category.

The westbound lanes, Contractor A's section, showed an increase in the ride characteristics after construction. The RCR over the 21-month evaluation period places it in the middle portion of the smooth range, with an RCR of 8.8 for both lanes.

The results of the Mays roughness testing on the eastbound lanes indicated that the ride is very similar to that on the westbound lanes. The RCR in both lanes 9 months after construction was 8.3, and

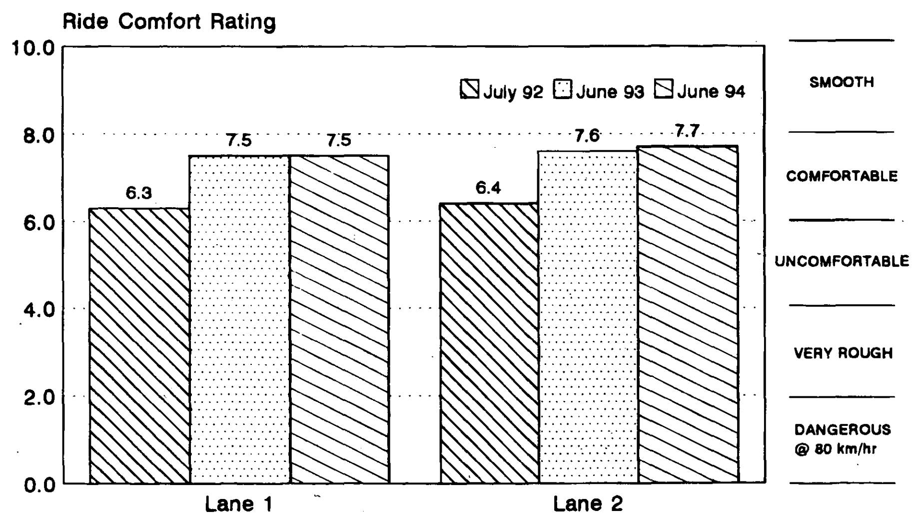

FIGURE 4 Average roughness for Highway 401.

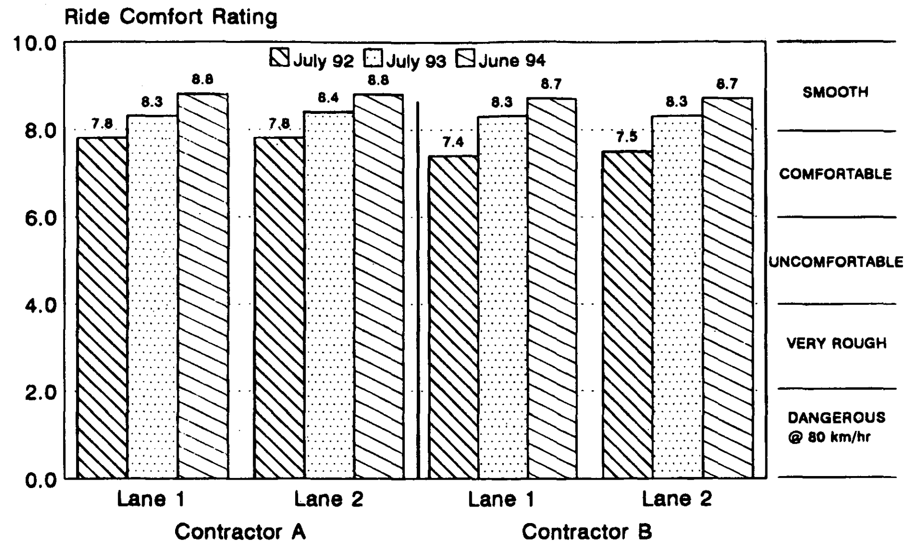

FIGURE 5 Average roughness for Highway 403.

after 21 months the RCR was 8.7, again placing the ride in the lower portion of the smooth category.

Skid Resistance

The relative skid resistance of a pavement is given in terms of a skid number (SN). This number was obtained by field measurements by using an ASTM brake force trailer (*7*).

Figure 6 shows the results of the skid resistance survey for the Highway 401 project, lane 2. It indicates that the skid resistance immediately after construction was at a high level, with an SN of 44, and the level remained high after 8 and 20 months after construction, at SNs of 45 and 53, respectively. The results for lane 1 were similar.

Figures 7 and 8 show the skid surveys for lanes 2 of both the westbound and eastbound lanes of the Highway 403 project. The westbound lane 2 (Contractor A) indicated a high skid level, with an SN of 41 before construction: Nine months after microsurfacing the value increased to an SN of 46 and remained consistent with an SN of 47 after 20 months. In lane 2 of the eastbound lanes, Contractor B's section, the results are similar to those for Contractor A's section; the original SN of 41 rose to an SN of 49 nine months after construction and fell slightly to 43 twenty months after construction.

The results of the skid testing indicate that the microsurfacing surfaces on both projects and for both contractors exhibits a high frictional resistance, similar to those of freeways with a premium-quality hot-mix surface.

CONCLUSIONS

This paper summarized the design and construction of two trial microsurfacing projects on freeways. On the basis of the short-term results of this project coupled with the positive results of the Ministry's first microsurfacing project (*1*), it appears that microsur-

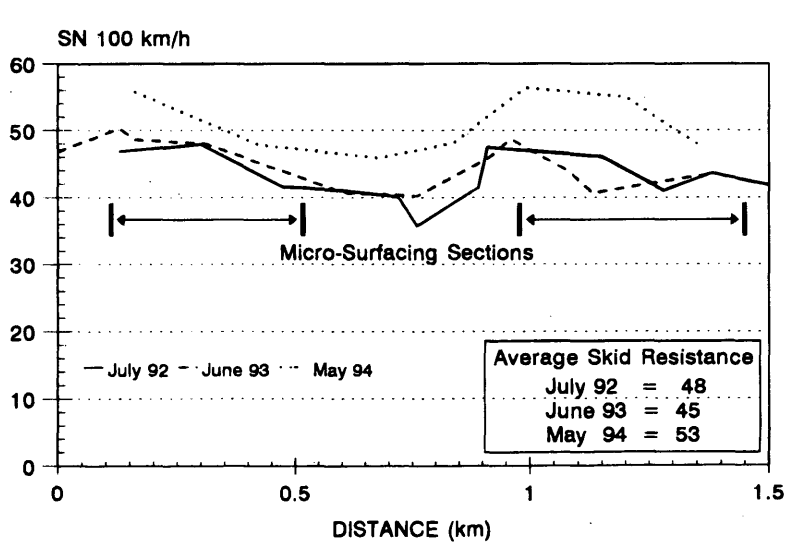

FIGURE 6 Skid resistance survey, Contractor A, Highway 401, Lane 2.

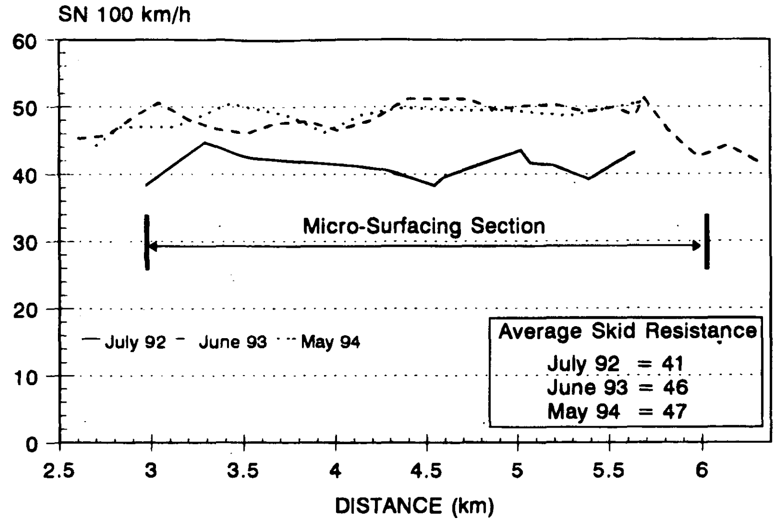

FIGURE 7 Skid resistance survey, Contractor A, Highway 403, westbound Lane 2.

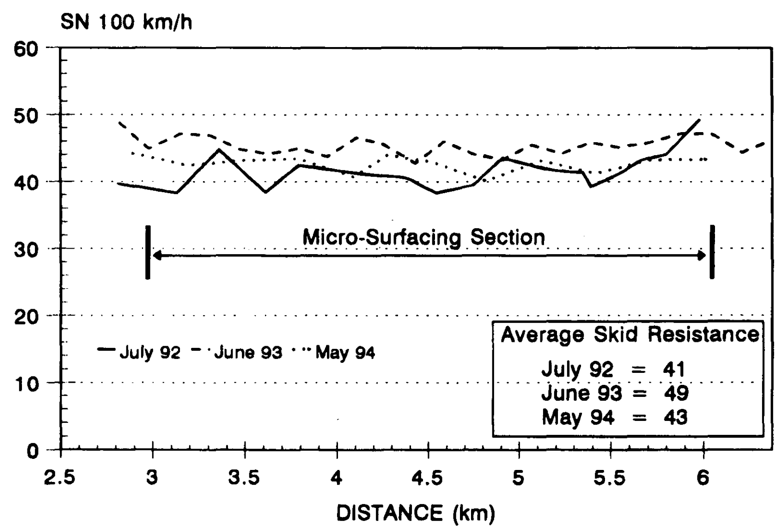

FIGURE 8 Skid resistance survey, Contractor B, Highway 403, eastbound Lane 2.

facing can provide a viable alternative rehabilitation technique for extending the pavement lives of high-speed, highly trafficked freeways suffering from severe surficial distresses.

The following short-term conclusions are made on the basis of the results of the two projects described in this paper.

- Microsurfacing provides a durable, highly skid-resistant surface comparable to the Ministry's premium hot-mix surfaces.
- Microsurfacing appears to have the potential to extend the life of a pavement suffering from the distresses associated with the use of steel slag aggregates in the wearing surface, at least in the short term.
- The microsurfacing provides a uniform surface that rides within the comfortable to smooth range on the basis of MRM testing.
- The weather conditions have a considerable effect on the constructability of microsurfacing; this underscores the need for an experienced, skilled, and knowledgeable crew that can make the slight adjustments to the mix design that may be required as the ambient weather conditions change during the operation.
- Both contractors designed and placed an acceptable microsurfacing product on both trial projects, and both projects have exhibited similar performance results to date, although it is noted that care must be taken to minimize the amount of overlap between lanes, especially on superelevated pavements.

RECOMMENDATIONS

The following areas require further study and development.

- By monitoring and testing, establish the mid- to long-term performance characteristics of microsurfacing on freeway facilities in a wet–freeze environment.

- Additional trials are required to determine the effectiveness of microsurfacing as a rut fill material and possible crack and pothole fill material.
- A quick field methodology is required to assess application rates and check on mix design.
- Rationalize quality assurance testing to characterize surface texture and mix design requirements.
- An equitable 2-year warranty specification should be developed (*8*).

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Publication of this paper sponsored by Committee on Pavement Rehabilitation.