Effectiveness of High-Performance Thin Surfacings in a Wet-Freeze Environment

THOMAS J. KAZMIEROWSKI, ALISON BRADBURY, JERRY HAJEK, AND GRAHAM JONES

After a period of vigorous growth in the 1960s and 1970s, the Canadian highway pavement infrastructure is maturing, consolidating, and, through repeated use of overlays, achieving ample structural adequacy. Quite often, pavement rehabilitation does not require an increase in the pavement structural strength or in pavement thickness, but mainly a restoration or rejuvenation of the pavement riding surface. This restoration may include a need for increased skid resistance and sealing of a raveled surface texture and incipient cracks. Conventional thin asphaltic concrete overlays (35 to 40 mm or less) are expensive, and often their performance in the Canadian environment is questionable. Chip seals, in addition to their performance limitations, are often associated with windshield breakage and increased noise. The need to acquire innovative technology to deal effectively with pavement surface restoration has prompted Ontario to experiment with high-performance polymer-modified slurry systems, referred to generically as microsurfacing. The design, testing procedures, material characteristics, construction, environmental consequences, and performance of three microsurfacing treatments placed on a two-lane Canadian highway in 1990 by three contractors and suppliers are described. Preliminary results indicate that microsurfacing provides a viable and cost-effective surficial rehabilitation alternative for structurally sound pavements. Critical components to ensure the success of a microsurfacing project include a comprehensive mix design process, quality materials, and the use of a knowledgeable and experienced contractor.

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 (*1*).

The polymer-modified asphalt cement allows the material to remain stable even when applied in multistone thicknesses (*2*). The emulsifier is a proprietary product; generally the manufacturers of these emulsifiers license contractors to place their particular microsurfacing product. Microsurfacing technology was originally developed in Germany in the late 1960s and early 1970s (*3*); it was introduced to North America in the early 1980s. The material is applied using 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.

Microsurfacing appears to provide the answer to those roadways that require more than a bituminous surface treatment but do not warrant a one-lift hot-mix overlay. It is ideal for use on pavements with surficial distresses such as raveling, coarse aggregate loss, and frictional resistance loss.

In 1991 the Ministry of Transportation of Ontario undertook a demonstration project using three microsurfacing technologies. The intent of this project was to extend the service life of the two-lane pavement, evaluate and compare the performance of three types of microsurfacing in a wet-freeze environment, and develop construction and material guidelines.

ADVANTAGES AND DISADVANTAGES

Microsurfacing is an attractive alternative to conventional hot-mix overlays for rehabilitating surficially distressed flexible pavements. The material is documented to resist deformation, and, because of the polymer content, it will resist movement at high temperatures and cracking at low temperatures (*4*). Several agencies have used this process for filling in wheelpath ruts where the rutting has stabilized and was not subject to additional plastic deformation. Other reported advantages include the following:

- Less energy is expended because the microsurfacing is applied at ambient temperatures; in addition, there are also no harmful emissions often associated with hot-mix production (*4*).
- Because the thickness of a lift of microsurfacing is typically 9 to 12 mm versus 40 mm for a hot-mix overlay, the result is a significant conservation of nonrenewable resources—asphalt cement and aggregates.
- The thin surfacing does not significantly alter the road profile; therefore, the need for guide rail adjustments, the reduction of bridge clearances, and the need to reinstate shoulder granulars are greatly reduced (*4*).
- The cost is approximately 60 to 65 percent of a single-lift hot-mix overlay.
- Compared with surface treatment, there is not a problem with loose aggregates damaging vehicles (*4*).

There are also some disadvantages to microsurfacing:

- It does not inhibit reflective cracking or provide structural support.
- Placement must be during warm, dry weather (at least 10°C).
- An experienced contractor and proper mix design are critical to the success of the process.

Ministry of Transportation of Ontario, 1201 Wilson Avenue, Downsview, Ontario, Canada M3M 1J8.

PROJECT DESCRIPTION

Three contractors were invited to participate in the demonstration project. Contractor A, based in Ontario, is licensed to place the Elsamex system from Spain; the emulsifier was produced by Ergon in the United States. Contractor B, based in New York, is licensed to use the Ralumac system from Germany; the emulsion was produced by Koch Materials in Pennsylvania. Contractor C, based in Ontario, is associated with an American contractor from New York and uses the Micromat System produced in the United States. The American partner also provided the equipment and crew for Contractor C.

The demonstration project consisted of three sections of two-lane highway: approximately 5 km long for Contractors A and B, and 1.4 km long for Contractor C. Within each section were monitoring and control subsections to compare the performance of existing and microsurfaced sections in detail and to determine how quickly reflection cracking would occur.

Existing Conditions

Highway 141 is a two-lane arterial highway approximately 200 km north of Toronto. The pavement structure consists of 50 mm of hot mix over 150 mm of crushed granular base and 600 mm of granular subbase. It was constructed in 1981. The pavement is 7.0 m wide with granular shoulders varying from 0.5 to 2.0 m.

Before construction, the roadway had slight frequent longitudinal cracking and coarse aggregate loss. The pavement exhibited extensive moderate transverse cracking, intermittent alligator pavement edge cracking, and intermittent slight to moderate centerline cracking. There was also frequent moderate to severe rutting, particularly in the outside wheelpath. The rutting appeared to be caused by fatigue of the thin pavement structure. The rut depth ranged from barely noticeable to more than 25 mm. There were also frequent moderate distortions. The ride was considered comfortable.

The annual average daily traffic on this section of highway is 900 vehicles—a volume that almost doubles during the summer months because it is a recreational area. The commercial traffic is about 14 percent.

Rehabilitation Design

The design strategy was to assess the durability and effectiveness of microsurfacing in a wet-freeze environment while monitoring its resistance to traffic and snowplow abrasion. The design for all three sections consisted of a scratch coat and a final coat of microsurfacing. This strategy did not address moderate depressions in outside paths (no rut box was specified). 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, densely graded, skid-resistant surface. Because this was a demonstration project, no mix application rates were specified, but representatives from each contractor visited the sites to assess the conditions and amount of material required to submit bids. Quantities were determined by the contractor using a manual measurement of surface geometry, visual assessments, and the experience on similar projects.

Typically, the rehabilitation method for this section of highway would be to resurface with a single-lift overlay plus hot-mix padding where required for filling any depressions.

Specifications

Since the completion of the project, and as the result of the project, the ministry's microsurfacing specifications have been updated. Specific portions of the specifications controlling the microsurfacing operation, on this project, are highlighted:

- 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 surface course hot-mix aggregates.
- The contractor shall select a qualified laboratory to prepare the job mix formulas.
- The mix shall meet the following proportions:
  - –Residual asphalt: 6 to 11.5 percent by dry mass
  - –Mineral filler: 1.5 to 3.0 percent by dry mass
  - –Polymer-based modifier (latex): minimum 2.5 percent solids based on bitumen mass
- The mixture shall be placed when atmospheric temperature is at least 10°C and rising and between June 1 and September 15.
- 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 at least 30 min or whatever time is required to prevent damage to the surface.

CONSTRUCTION

Microsurfacing was applied using specialized equipment that carried all mix ingredients and accurately proportioned and mixed the raw materials continuously. The mineral filler (portland cement) was added manually into the hopper as required. The mixing took place in a twin-shaft pug mill at the back of the vehicle; mixing time was approximately 45 sec. From the pug mill the microsurfacing was placed into a spreader box (*1*). The spreader box contained two augers that spread the microsurfacing across the width of the box. At the back of the spreader box was a metal or rubber strike-off that leveled and textured the surface.

Construction was done during August and September 1991. For all sections, traffic was controlled around the work site using a pilot truck.

Single- Versus Continuous-Load Process

Two methods were used to place microsurfacing—the single-load (or stop-start) process, and the continuous-load process—although both used the self-propelled mixing equipment as described.

With the single-load process, the truck-mounted mixing unit was refilled with the mix components after each load was placed on the roadway. The spreader box was taken off the truck and placed on the roadway while the truck returned to be refilled with the microsurfacing components. The spreader box was cleaned during this time so that the microsurfacing mixture did not set in the spreader or on the strike-off.

The single-load method had transverse joints after every load (approximately every 400 m). These joints required intensive hand work and finishing to ensure that they were not visually apparent or result in localized roughness. This method also slows the construction, especially if it is a long distance from the work area to the material stockpiles.

With the continuous-load process, the self-propelled unit was fed continuously with a nurse truck. The nurse truck supplied the aggregate, emulsion, and water. The cement was added manually into a hopper as required. Once the nurse truck had emptied its supply, the mixer was still full, which gave time for one nurse truck to replace the other. The nurse truck was mechanically attached to the mixer, and the self-propelled mixer pushed the nurse truck, similarly to a hot-mix paver. This resulted in a quicker operation and higher production rates with only a few transverse joints required.

For freeway projects or extensive highway contracts, the continuous process or single-load method with more than one truck-mounted mixing unit should be specified.

Contractor A

Contractor A's section was 4.5 km long and contained three monitoring subsections of 150 m and two control subsections each 60 m long. Contractor A's application equipment consisted of one truck-mounted mixing unit. This caused a delay of up to 30 min between loads in order for the truck to travel to the storage site, get reloaded, and return to the work area.

The edges of the microsurfacing were feathered using squeegees and an artificial turf pad. The microsurfacing mixture was very homogeneous; there were no problems with premature setting even though the ambient temperatures ranged from 10°C in the morning to 25°C in the afternoon. The material set within 5 min of placement. The traffic was allowed onto the treated area within 30 min.

The major concern with this section was the poor quality of the joints, both longitudinal and transverse. The joints were ragged and stepped at times, indicative of poor hand work. These problems were attributed to the inexperience of the crew.

Contractor B

Contractor B was equipped with a continuous-load process, including one truck-mounted mixing unit and three nurse trucks. The 4.6-km section that Contractor B paved included an extensive swamp crossing where the pavement exhibited significant distortions and alligator cracking. Within this section were two 150-m-long monitoring subsections and two control subsections, of 90 and 120 m.

Contractor B experienced problems at the beginning getting its mix under control. It was setting too quickly and lumps were forming in the mix before it was placed on the roadway. This and some of the larger aggregate caused drag marks in the scratch coat. The scratch coat was placed as a true scratch coat: no covering in some areas and up to 75 mm in others. The strike-off was very tight to the surface of the pavement. The crew used squeegees to finish and feather the edges.

After trying three strike-off configurations, the contractor adopted a thinner short piece of rubber that performed adequately. There were still some scratch marks left in the surface course, but they disappeared over a few weeks as traffic kneaded the mix.

During the surface and scratch course placements, the operation had to be stopped on several occasions so that the spreader box could be cleaned out because of the fast-setting material, especially during the afternoon when temperatures increased. The ambient temperatures ranged from 15 to 28°C.

Contractor B's mix did not cure as quickly as the other two mixes, and traffic was unable to use this section for 1 to 2 hr.

Contractor C

Contractor C's section was 1.4 m long; it had two monitoring subsections, of 100 and 150 m, and a control area 60 m long. Contractor C was equipped with two truck-mounted units and one spreader box. The crew consisted of five very experienced members who had been together for more than 2 years. The crew used rakes and brooms to feather the edges.

The ambient temperatures ranged from 13 to 38°C. This temperature range required careful control of the mix to ensure that it did not set while still in the mixer or spreader.

The mix was very uniform and easy to place. The scratch coat was more like a final coat, because there were only a few minor distortions in the 1.4-km section in which Contractor C was working. The experience of the crew alleviated some of the concerns about poor joints even though this was a single-load operation. Once both lanes were completed, a rubber-tired roller was run along the centerline to eliminate any unevenness that might be present. No other contractor used a compaction unit after placement.

The microsurfacing set within 5 to 10 min, and traffic was on the new surface within 30 min.

Production

Contractors A and C used truck-mounted units, so their production rates per load were measured. Contractor A was measured at 350 m/load for both the scratch and final coats; Contractor C was recorded at 420 m/load for the surface coat. The width of application was one-lane width (3.5 m). The application rates for the scratch coat were 11.6, 7.8, and 9.1 kg/m^2 for Contractors A, B, and C, respectively. The surface coat application rates for Contractors A, B, and C were 11.6, 14.9, and 9.7 kg/m^2, respectively.

The application ranges for the final coat are within generally acceptable rates of 8.2 to 16.3 kg/m^2 (*4*).

MIX DESIGN

The specification did not outline a specific method of mix design procedures to be used. It did require certain limits on the proportion of mix components (see Table 1). The contractors used the method of mix design of their own choosing.

Contractor A used the mix design method as outlined by the International Slurry Surfacing Association (ISSA) (*6*), and Contractor C also used most of the ISSA tests. Contractor B used a system based on the Marshall mix design.

The components of the microsurfacing mix designs used by the contractors are shown in Table 1.

To develop a job mix formula, it is important to first determine if the aggregates are compatible with the particular emulsion used. Microsurfacing bonds chemically and does not require compaction during construction. In some cases, a highly reactive aggregate will cause a premature or a delayed set in the microsurfacing mixture.

Specialized tests done on the aggregates, which had also met the gradation and quality requirements of the ministry, were methylene blue and sand equivalent. The methylene blue test gives an overall indication of the surface activity of an aggregate by determining the amount of harmful clays, organic matter, and iron hydroxides (*5*). The sand equivalent test gives similar results by indicating the clay content of the aggregate; a high clay content can be an indication of mix design problems. Results of these tests are shown in Table 2.

In determining the mix design, several combinations of emulsion, water, mineral filler, and aggregate are mixed together on a trial basis to determine if they meet the basic requirements in terms of mix time and adhesion, as per ISSA Technical Bulletin 113 (TB-113) (*5*). The mixes that meet these requirements are tested further to determine job mix formula including the optimum binder content.

Although not required according to the original contract specifications, all three contractors submitted the mix design test results of the recommended job mix formula. Table 3 gives the results for Contractors A and C, which both used the ISSA test procedures (*5*). The tests recommended by the ISSA are summarized as follows:

- Wet cohesion (TB-139) evaluates the speed of cohesive strength buildup during the setting of the microsurfacing slurry to determine the set time, or the time when traffic can be allowed on the surface.
- Excess asphalt (TB-109) determines the maximum amount of binder permitted in the mix without causing flushing or bleeding.
- Wet stripping (TB-114) measures the amount of aggregate remaining coated after boiling a sample in water and provides an indication of aggregate suitability in terms of binder-aggregate adhesion.
- Wet track abrasion (TB-100) measures the wearing qualities of the mixture under wet abrasion conditions. The test establishes the minimum permissible binder content of the mix.

TABLE 1 Mix Designs

	Contractor A	Contractor B	Contractor C	MTO Requirements
Aggregate	Dolomitic sandstone screenings 100%	Quartzitic Granite 100%	Traprock Screenings 100%	High quality hot mix aggregate
Mineral Filler	Type 1 Portland Cement 2.5±0.5%	Type 1 Portland Cement 1.0±0.5%	Type 1 Portland Cement 1%	1.5% - 3.0%
Asphalt Emulsion	ASENCO 11.5±1.1%	RALUMAC 11%	MICROMAT 10%	----*
Residual Asphalt	7.4±0.7%	7.0±0.5%	6%	6%-11.5%
Water	10-12%	As Required	6%	----*
Additive	0-8% (1% solution)	As Required (0.5% solution)	As Required	----*
Latex (% solids by weight of asphalt)	3.0% Synthetic	3.4% Natural	3.0% Natural	min. 2.5%

* Not specified

TABLE 2 Aggregate Test Results

Test Name	Test Number	Requirement	Results		
			Contractor A	Contractor B	Contractor C
Methylene Blue	ISSA TB-145 RTMII 6	Max. 15 ml	1.5	6	3
Sand Equivalency	ASTM D2419	Min. 60 units	70	63.1	75

- Lateral and vertical displacement (TB-147A) simulates compaction by traffic and measures the displacement of the microsurfacing under a load wheel. It ensures a rut-resistant mix design.
- Classification compatibility (TB-144) determines, using the Schultze-Breuer and Ruck procedures, the compatibility and binding characteristics of the aggregate (passing 0.710 mm) and the emulsified asphalt residue.

Contractor B used a modified Marshall method to determine the optimum mix design. Again several small samples are mixed (similar to TB-113) to determine mix time and set time. At 20 min after mixing the mixture is tested for cohesion. This is a subjective test done by experienced laboratory technicians by compressing the material in their hands and classifying the cohesion as good or poor. The Schultze-Breuer test is used to determine the compatibility of the aggregate with the residue. The test procedure is similar to TB-144.

The feasible mixes from these tests are then checked using a Marshall mix design method. These tests determine the maximum and minimum residue required on the basis of stability and flow of the mixture. The Marshall briquettes are

TABLE 3 Test Results from Mix Designs (5)

Test Name	Test Number	Requirements	Contractor A	Contractor C
Wet Cohesion @ 30 Minutes Minimum	ISSA TB 139	12 kg-cm Minimum	17.5 kg-cm	17.3 kg-cm
Wet Cohesion @ 60 Minutes Minimum	ISSA TB 139	20 kg-cm Minimum	20.0 kg-cm	19.75 kg-cm
Excess Asphalt by LWT Sand Cohesion	ISSA TB 109	538 g/m^2 Maximum	462 g/m^2	N/A
Wet Stripping	ISSA TB 114	Pass (90% Minimum)	99%	N/A
Wet Track Abrasion Loss @ 1 Hr Soak	ISSA TB-100	538 g/m^2 Maximum	140 g/m^2	421 g/m^2
Wet Track Abrasion Loss @ 6 Days Soak	ISSA TB-100	807 g/m^2 Maximum	682 g/m^2	N/A
Lateral Displacement	ISSA TB 147A	5% Maximum	4.5%	4.65%
Vertical Displacement	ISSA TB 147A	10% Maximum	9.8%	8.5%
Specific Gravity after 1000 Cycles of 57 kg	ISSA TB-147A	2.10 Maximum	2.02	1.94
Classification Compatibility	ISSA TB 144	(AAA, BAA) 11 Grade Pt. Minimum	AAA 12 Grade Pt.	N/A
Mix Time @25°C	ISSA TB 113	Controllable to 120 sec. Minimum	120 sec.	N/A

made with a molding temperature of 134°C and tested with 50 blows per side. Test results for the job mix formula used by Contractor B are given in the following table:

Test	*Requirements*	*Results*
Stability	8900 N	12 566 to 13 378 N
Flow	6 to 16	10.2 to 11.5

It should be noted that the Marshall method mainly indicates an optimum binder content and does not define microsurfacing performance.

MATERIAL TESTING

Aggregate

The aggregate used had to meet (and met) the quality requirements of the ministry's premium surface course (HL-1 designation) aggregate, but the contractors were allowed to choose their own sources from the designated list. HL-1 aggregate is a high-quality, skid-resistant, 100 percent crushed aggregate that is used for hot-mix surfaces on 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 all three contractors. These are plotted as gradation curves in Figure 1.

The Contractor A material was somewhat gap-graded and was also slightly out of specification on the 0.600-mm sieve. The Contractor B material was coarser than the other two aggregates and was out of specification on the 0.600-mm sieve; it was slightly gap-graded. The Contractor C material, although out of specification on the 4.75-mm sieve (making it slightly finer than specified), was the most open-graded material.

Emulsion

The specification required a quick-set cationic CSS-1H emulsion. Although this appears to be a contradiction in terms

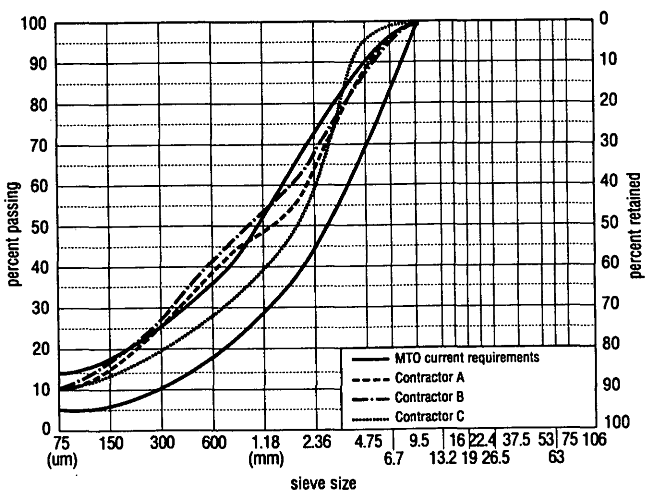

FIGURE 1 Gradation curves for aggregate used in microsurfacing.

(quick-set cationic slow-setting emulsion), because the emulsion and emulsifier are proprietary products, the term is understood by the contractors and manufacturers.

Tests done on the emulsions included determining the residue content after distillation. All met the required minimum of 62 percent.

From the samples of polymer-modified emulsion provided by the contractor, the polymer-modified emulsion was tested to determine if it met the ministry's requirements for softening point, penetration, and kinematic viscosity. These results are shown in Table 4. All emulsions met the requirements.

From the field samples of microsurfacing material, the recovered binder was also tested to determine if it still met the ministry requirements. Only the recovered binder supplied by Contractor A did not meet softening point and kinematic viscosity specifications for the original binder (Table 4). A certain degree of hardening of the binder can be expected.

Polymer Modifier

The specification does not state the type of polymer modifier or latex to be used. Contractor B and Contractor C used a natural rubber, and Contractor A used a synthetic latex.

The minimum amount of polymeric modifier was specified to be 2.5 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.

PAVEMENT PERFORMANCE

Pavement Condition

Before the microsurfacing, Highway 141 had a pavement condition index of 59 (scale of 0 to 100), indicating that rehabilitation would be required within the ministry's 5-year construction program.

After one winter of microsurfacing, the cracks in the original pavement have reflected through as expected. The microsurfacing was not damaged by snowplow action, and there was no evidence of delamination.

Crack Mapping

Each of the three test sections contains one or more monitoring subsections and one or more control subsections. The purpose of these subsections is to enable more intensive and detailed performance monitoring than that conducted on the entire pavement test sections. The monitoring and control sections were chosen to represent pavement areas exhibiting a typical pavement performance of the individual sections before construction.

Before the resurfacing, all surface distresses, including all cracks, were carefully mapped. The process of distress mapping was repeated about 10 months after the construction.

TABLE 4 Test Results of Polymer-Modified Emulsified Asphalt Samples

Test Name	Test Number	Requirements	Contractor A	Contractor B	Contractor C
From Emulsion Samples					
Softening Point (°C)	ASTM D36	57°C Min.	59.7°C	62.3°C	57.1°C
Penetration @ (25°C, 100 g, 5 s, 0.1 cm)	MTO LS-200	40 - 90	81	68	73
Kinematic Viscosity @ 135°C	ASTM D2170	650 cSt/sec Min.	1063 cSt/sec	2285 cSt/sec	1972 cSt/sec
Elastic Recovery @ 10C (20 cm extension)	N/A*	Not Specified	62.5%	40%**	27.5%
Force Ductility Ratio (Load @ 30 cm/ Peak Load)	N/A*	Not Specified	0.12	0.07***	0.09
From Micro-Surfacing Samples					
Softening Point (°C)	ASTM D36	57° Min.	50.3°C	58.4°C	55.9°C
Penetration @ (25°C, 100 g, 5 s 0.1 cm)	MTO LS-200	40 - 90	85	54	56
Kinematic Viscosity @ 135°C	ASTM D2170	650 cSt/sec Min.	624	1336	1289

* Proposed ASTM standard test.
** Sample did not reach 20 cm extension. Result based on 9 cm extension.
*** Sample broke before 30 cm extension. Ratio calculated as "load at breaking point/peak load."

On the monitoring subsections, the mapping was instrumental in quantifying the amount and type of reflective cracking and documenting any additional visible surface distresses. On the control subsections, the mapping enabled the documentation of the additional pavement deterioration in the absence of any maintenance or rehabilitation treatment.

Monitoring of partial- and full-width transverse cracks (probably reaching to the bottom of asphaltic concrete layer) indicates that nearly all these cracks are reflected. There is no, or very little, spalling at the reflected cracks.

Most of the secondary cracks (which appear not to reach the bottom of asphaltic concrete layer) reflected in the new surface as hairline cracks. There is no spalling at these cracks.

Rutting

Rutting surveys were done before and after construction with the Automatic Road Analyzer (ARAN) for the entire length of the project, and manual measurements were taken in the monitoring and control sections with a 1.8-m straight edge. Rutting occurred primarily in the right wheelpath.

The ARAN uses a 3.75-m-long "smart bar" on its front bumper equipped with ultrasonic sensors spaced 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 (*6*).

Surveys were initially taken along Highway 141 at the test section with the ARAN to determine the size and extent of the rutting before construction.

Rut surveys were taken in May 1991 before construction and afterward in April 1992 with the ARAN for the westbound and eastbound lanes.

The average rut depth for all three sections before construction was 10 mm. This rutting took place almost entirely in the right wheelpath. Seven months after construction the average rut depth was 9 mm.

The detailed rut classification surveys for the eastbound lanes shows that there has been a slight decrease in the amount of moderate to severe ruts in these lanes (Figure 2). The

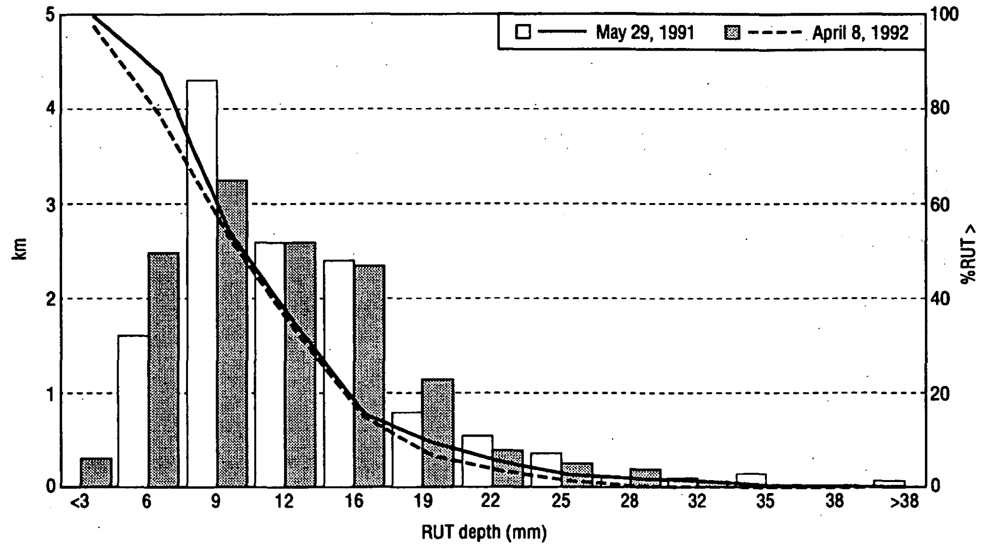

FIGURE 2 Rut classification, Highway 141 eastbound.

westbound lanes had a slight reduction in the distribution of ruts less than 9 mm but a slight increase in ruts greater than 9 mm.

The scratch coat did not eliminate all the ruts or depressions in the right wheelpath. This may be a function of the shape of these distortions both transversely and longitudinally as well as their location primarily in the outside wheelpath. The operating procedures used by the contractor were also a factor; the slower the operation during the scratch coat application, the more likely the ruts would be filled. In addition, the measurements taken in the control sections indicate that there was an increase in the rut depth of approximately 1 to 8 mm during the 10 months between ARAN surveys. This could explain why the improvement in rut depths on the microsurfaced areas is not high since they were measured only once, 7 months after construction. It is important to note that this project was not designed as a rut fill application (no rut box was used); therefore, significant reduction in rut depth was not anticipated.

Roughness

Roughness surveys were taken using a Portable Universal Roughness Device (PURD) shortly after construction and 5 months later.

The PURD is a trailer-mounted accelerometer-based measuring device operated at a constant speed on the highway. It uses the root mean square of vertical acceleration of the trailer axle (PURD) to measure roughness. These are converted into a riding comfort rating (RCR) as follows (*6*):

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

Figure 3 shows the detailed roughness surveys for the eastbound lane. The westbound lane had similar results. Surveys were taken in October 1991 (1 to 2 months after construction) and in January 1992 (5 to 6 months after construction).

Figure 3 also shows the average roughness for each of the contractors' sections in the eastbound lanes. For the Con-

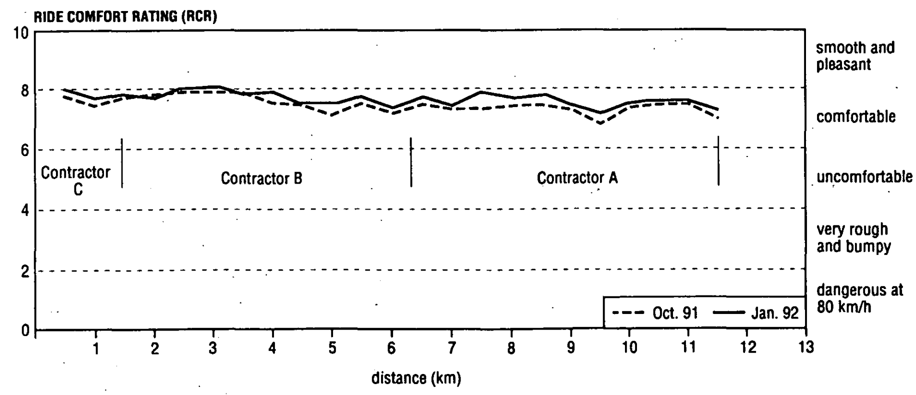

FIGURE 3 Roughness survey, Highway 141 eastbound.

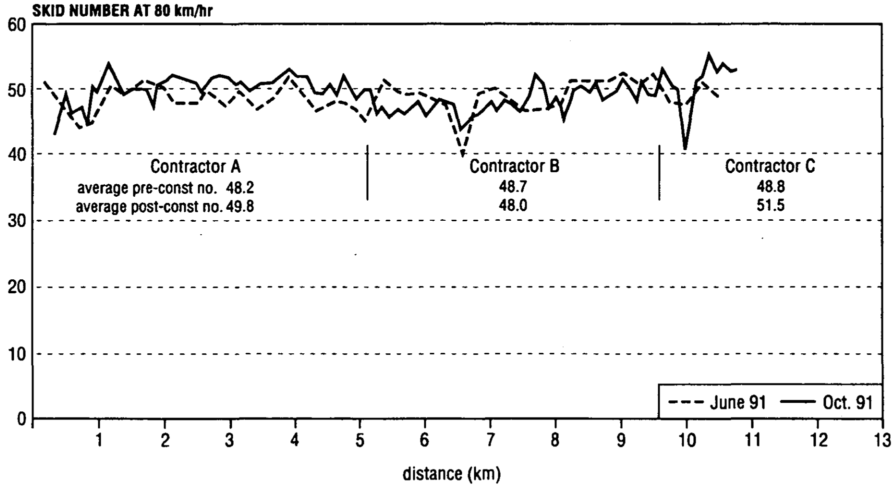

FIGURE 4 Skid resistance survey, Highway 141 eastbound.

tractor A and Contractor B sections there was a slight increase in the RCR from October 1991 to January 1992 in both the eastbound and westbound lanes. The Contractor C section exhibited a slight decrease in the RCR in the east and westbound lanes for the same period.

These differences are very slight and insignificant, being all within the comfortable ride rating range.

Skid Resistance

The relative skid resistance of a pavement is given in terms of a skid number. This number was obtained by field measurements using an ASTM brake force trailer and correlation with measurements from similar highway facilities (*6*).

Measurements were taken in June 1991 (2 months before construction) and in October 1991 (1 month after construction). The results are shown in Figure 4 for the eastbound lane. Again, the westbound lane had similar results. There was an insignificant difference between the before and after construction skid numbers for all three test sections. The existing pavement had an HL-4 mix with a limestone coarse aggregate and a natural sand fine aggregate that exhibited very good frictional properties. The aggregate in the microsurfacing was 100 percent crushed from bedrock, so high skid numbers were again expected.

CONCLUSIONS

Microsurfacing is an alternative rehabilitation technique for pavements that suffer from surficial distress but that are structurally adequate. At one-quarter to one-third the thickness of a single-lift overlay, microsurfacing appears to provide a durable and environmentally possible alternative for extending the serviceability of Ontario's pavements.

On the basis of the short-term results of the microsurfacing project, the following specific conclusions can be made:

- Microsurfacing provides a practicable alternative to a one-lift overlay on roadways with surficial deficiencies and a structurally sound base in a freeze-thaw environment; it provides a uniform, dense-graded, highly skid resistant surface. Microsurfacing exhibits potential to address performance deficiencies in skid resistance, raveling, and coarse aggregate loss.
- High-quality construction practices (skilled crew and specialized equipment) coupled with a comprehensive mix design process are crucial to ensure the success of microsurfacing.
- All three contractors designed and placed an acceptable microsurfacing product on this project. All three products have exhibited similar performance results to date.
- The high-quality surface course mix aggregates on the ministry's designated sources list can be used in a microsurfacing mix.
- Microsurfacing does not eliminate reflection of structural cracks.
- The single-load method with only one truck-mounted mixer is too slow to be used on large jobs, particularly on heavily trafficked highways.

For judiciously selected applications, microsurfacing is a viable pavement maintenance and rehabilitation treatment of asphaltic concrete pavements in a wet-freeze environment. However, its success must be safeguarded by prudent mix design and by high-quality construction practices.

The following areas require further study:

- Additional demonstration projects to test the effectiveness of microsurfacing as a rut fill material and as a premium overlay on a high-speed, heavily trafficked highway.
- Less subjective methods of field testing the mix characteristics and performance of the microsurfacing during construction.
- Continued monitoring of the pavement performance on Highway 141.

REFERENCES

1. *Microsurfacing Pavement Resurfacing*. International Slurry Surfacing Association, Washington, D.C.
2. M. P. Doyle and K. R. Kramer. Comparison of Mix Design Meth-

ods to Determine Optimum Bitumen Content in Microsurfacing Systems. *ISSA Proceedings*, International Slurry Surfacing Association, Washington, D.C., Feb. 1989, pp. 35–136.
3. C. M. Pederson, W. J. Schuller, and C. D. Hixon. Microsurfacing with Natural Latex-Modified Asphalt Emulsion: A Field Evaluation. In *Transportation Research Record 1171*, TRB, National Research Council, Washington, D.C., 1988, pp. 108–112.
4. G. Reinke, W. R. Ballou, S. L. Engber, and T. M. O'Connell. Studies of Polymer Modified Microsurfacing Materials in Highway Maintenance. *ISSA Proceedings,* International Slurry Surfacing Association, Washington, D.C., Feb. 1989, pp. 45–83.
5. *Recommended Performance Guidelines for Microsurfacing.* Design Technical Bulletin A143 (revised). International Slurry Surfacing Association, Washington, D.C., Jan. 1991.
6. *Pavement Design and Rehabilitation Manual.* Report SDO-90-01. Surveys and Design Office, Ministry of Transportation of Ontario, Downsview, 1990, Chapter 5.

Publication of this paper sponsored by Committee on Pavement Maintenance.