Rout and Seal Cracks in Flexible Pavement—A Cost-Effective Preventive Maintenance Procedure

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The Ministry of Transportation of Ontario conducted a comprehensive study on the feasibility of a rout and seal treatment of cracks in flexible pavement as a preventive maintenance procedure. The objectives of this study were to ascertain the cost-effectiveness of this procedure on the basis of the successful treatment of the distress, the resultant extension of pavement service life, and the optimum timing for application to achieve maximum cost benefit. Implemented in 1986 across the province of Ontario, the study ensures complete coverage of different climatic and environmental conditions. Monitoring of the treatment performance and pavement conditions has been completed for a period including three winters. From the data, it has been established that (a) certain rout configurations are more effective in different regions in the province, (b) the rout and seal treatment effectively delays or even stops progressive distress deterioration, and (c) the treatment is essential to achieve maximum cost benefit, with the optimum time being from the 3rd to 5th years for initial treatment, and the 8th to 9th years for follow-up treatment.

The Ministry of Transportation (MTO) uses two maintenance treatments for cracks in flexible pavement and composite pavement; (a) the traditional spray patching with emulsified asphalt and sand or stone chips and (b) the method commonly known as rout and seal (*1*). Time has demonstrated that sealing with emulsified asphalt is not only ineffective but can create undesirable side effects (*2,3*). On the other hand, rout and seal has shown success in effective maintenance of cracks, although the question of how cost-effective this particular maintenance treatment is has not been answered (*4,5*).

In 1981, a small experimental study was initiated by MTO Pavements and Roadway Office and the Ottawa District Maintenance Office. This study provided significant, though limited, cost-effectiveness data (*2,4,5*). In 1986, the MTO's Highway Operations and Maintenance Division initiated a comprehensive study program on rout and seal treatment of cracks as a preventive maintenance procedure, with the Pavements and Roadway Office as the appointed coordinator. The scope of this later study is an extension of the 1981 study, but is now province-wide to ensure complete coverage of the different climatic and environmental conditions that exist in Ontario (*4,5*).

PROVINCIAL PROGRAM

The program's proposed course of action was to select pavement sections for study from age groups of less than 3 years, 4 to 6 years, and 7 to 9 years. Each group was to have a minimum of two test sections. Each test section was to have a minimum of five subsections of 150 mm each. These subsections were to be laid out with the control section located between the four remaining sections of rout and seal treatment. Two of the subsections were to have rout size of 40 × 10 mm. Two subsections were to have rout sizes of 19 × 19 mm, if the pavement was located in Districts 5, 7, 8, 9, 10, and upward; 12 × 12 mm if the pavement was located in Districts 1, 2, 3, 4, and 6. Low-modulus polymer sealants of Hydrotech 6165 and TREMCO THC200 were to be used in Districts 5, 7, 8, 9, 10, and upward; Hydrotech 6165 and standard Hydrotech 6160 sealants were to be used in Districts 1, 2, 3, 4, and 6. A standard crew with standardized equipment from the MTO Ottawa District was to be used to minimize installation variables. The study was to be coordinated and monitored by the Pavements and Roadway Office of the Research and Development Branch of MTO.

Program Objectives

The main objective of the program was to determine the definitions and standards for rout and seal operational specifications for both in-house and contract work in terms of the equipment, methodology, materials, and rout size for different climatic and environmental conditions.

Other objectives were to study the effectiveness of treatment, extension of pavement service life, importance of treatment timing for cost effectiveness, and consequences of deferred treatment.

Test Section Selection

A total of 37 test sections were selected from the three different age groups and from four different regions of the province as follows:

- Age Group
  —1 to 3 years, 10 sections;
  —4 to 6 years, 13 sections; and
  —7 to 9 years, 14 sections.
- Regions
  —Northern region, 6 sections;
  —Eastern region, 9 sections;
  —Central region, 2 sections; and
  —Southwestern region, 20 sections.

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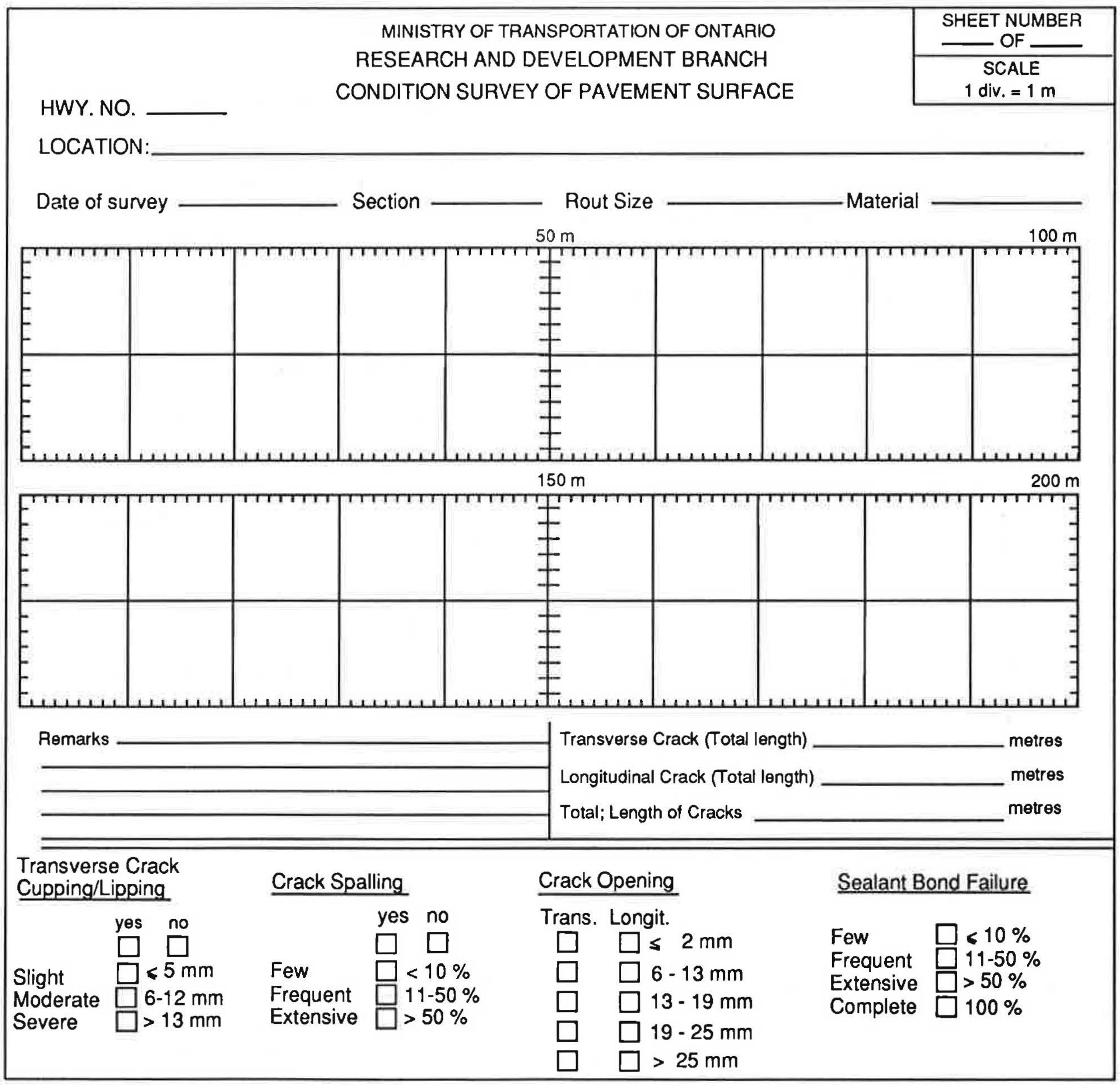
Procedures

Monitoring

A condition survey was to be carried out using the Condition Survey of Pavement Surface form shown in Figure 1. The same form will be used for subsequent monitoring during the successive winters (months of January or February, or both).

The pavement sections under study were to be identified from completion of the following form:

Item	*Explanation*	
1.	Highway No.	Number of highway.
2.	Location	Proximity to the nearest town or city, major highway interchanges, or any other prominent landmarks.
3.	Date of survey	Date the condition survey is taken.
4.	Section	Test section number on the basis of predetermined number provided. For example, if test section number is 20, then section number should be 20–1, 20–2, 20–3, or 20–4. The control section where no rout and seal work is to be carried out will be labeled "Control."
5.	Rout size	Size of rout designated and used on the section, that is, 12 × 12 mm, 19 × 19 mm, or 40 × 10 mm.
6.	Material	The sealant material used for sealing of the rout crack. Brand name and type designation must be given, for example, Hydrotech 6165.
7.	Crack mapping	The form is set up for a 200-m, 2-lane section, in 10-m increments. The cracks should be drawn as accurately as possible on the form.
8.	Transverse crack (total length)	The total length of transverse cracks (sealed and unsealed) in the section will be measured (to the nearest meter) with a measuring wheel.


MINISTRY OF TRANSPORTATION OF ONTARIO
RESEARCH AND DEVELOPMENT BRANCH
CONDITION SURVEY OF PAVEMENT SURFACE

SHEET NUMBER ____ OF ____
SCALE 1 div. = 1 m

HWY. NO. ______

LOCATION: ______

Date of survey ______ Section ______ Rout Size ______ Material ______

50 m 100 m

150 m 200 m

Remarks ______

Transverse Crack (Total length) ______ metres
Longitudinal Crack (Total length) ______ metres
Total; Length of Cracks ______ metres

Transverse Crack Cupping/Lipping
yes ☐ no ☐
Slight ☐ ≤ 5 mm
Moderate ☐ 6-12 mm
Severe ☐ > 13 mm

Crack Spalling
yes ☐ no ☐
Few ☐ < 10 %
Frequent ☐ 11-50 %
Extensive ☐ > 50 %

Crack Opening
Trans. Longit.
☐ ☐ ≤ 2 mm
☐ ☐ 6 - 13 mm
☐ ☐ 13 - 19 mm
☐ ☐ 19 - 25 mm
☐ ☐ > 25 mm

Sealant Bond Failure
Few ☐ ≤ 10 %
Frequent ☐ 11-50 %
Extensive ☐ > 50 %
Complete ☐ 100 %

FIGURE 1 Condition Survey of Pavement Surface form.

9.	Longitudinal crack (total length)	The total length of cracks (sealed and unsealed) other than transverse cracks in the section will be measured (to the nearest meter) with a measuring wheel.
10.	Total length of cracks	Combined length in meters of all cracks, from Items 8 and 9.
11.	Transverse crack, cupping/lipping	If present, check either slight, moderate, or severe, on the basis of the general condition of the transverse cracks with cupping or lipping.
12.	Crack spalling	If present, check either few, frequent, or extensive, for all cracks in the section. Percentage is based on the number of cracks that have spalled.
13.	Crack opening	For unsealed cracks only. Check the appropriate square for transverse crack openings and for longitudinal crack openings on the basis of the general condition of the section.
14.	Sealant bond failure	For sealed sections only. Check the appropriate square for bond failure of the sealant. Failure includes one-side debonding, both-side debonding, and sealant splitting. Percentage is based on proportion of total length of all sealed cracks in the section.

Roughness Measurement

The roughness (ride quality) measurement was to be made by the MTO Pavement Design and Evaluation Office with the Mays Meter at the original position. The measurement was taken in summer, and was to be repeated 5 years after or at termination of the study, and in the same time frame as the original measurement.

Treatment Operation

Crew Complement	*Number*
Foreman/woman	1
Router operator	2
Hot lance operator	1
Kettle operator	1
Tow vehicle operator	1
Total	6

Safety personnel are to be supplied by local patrol where work is located.

Equipment Complement	*Number*
Router	2
Hot lance	1
Kettle	2
Tow vehicle	2
Crew cab, 1 ton	1
Total	8

Safety personnel are to be supplied by local patrol where work is located.

Work procedures are as follows:

1. Both kettles are to be used at the same time, each specifically for one designated sealant material;
2. One router is set up permanently for 40 × 10 mm;
3. One router is set up for 12 × 12 mm or 19 × 19 mm, depending on locality of work; and
4. Hot lance is used just ahead of kettle.

SUMMARY OF FIELD OPERATIONS

The field operation began in June 1986 and was completed in September 1986, a month behind schedule because of a record-breaking rainy summer, the worst experienced by the province in the last 50 years.

Test Sections 5 and 24 were deleted because major maintenance was performed on Section 5 before rout and seal treatment, and Section 24 exhibited massive multiple cracking with spalling, making it impractical to use for the study purpose. Section 36 was simplified to a 40 × 10 mm test section, and Hydrotech sealed under a postconstruction arrangement for a rehabilitation contract.

Although low-modulus polymer sealant TREMCO THC200 was ordered, the manufacturer supplied the standard TREMCO THC205 in error. Sections 31 to 34, inclusive, in District 8 were also sealed with Hydrotech 6160 because not enough TREMCO was available.

Between 1986 and 1989, Sections 16 and 31 were lost because of major maintenance or rehabilitation.

MONITORING RESULTS FOR 1986 TO 1989

Monitoring of the rout and seal test sections and their corresponding control sections was conducted between January and March of 1987, 1988, and 1989. All three winters experienced a similar pattern: below-average snowfalls and prolonged periods of above-average temperatures with short durations of intense cold days.

Equipment and Methodology

The equipment and work procedures developed by the Pavements and Roadway Office and the Ottawa District Maintenance Office used for the study proved to be highly efficient and productive in successfully waterproofing the cracks in the pavement surface. Details were provided by Chong and Phang (*5*).

Materials and Rout Configuration

After three winters of monitoring, the performance evaluation on the basis of bond failure occurrences, gave the following ranking orders:

Materials Performance (see Figure 2)

1. TREMCO 205.
2. HYDROTECH 6160.
3. HYDROTECH 6165.

Material Matched With Rout Configuration (see Figure 3)

1. 12 × 12 mm with TREMCO 205.
2. 12 × 12 mm with HYDROTECH 6165.
3. 40 × 10 mm with TREMCO 205 or HYDROTECH 6160, 12 × 12 mm with HYDROTECH 6160.

4. 40 × 10 mm with HYDROTECH 6165.
5. 19 × 19 mm with TREMCO 205.
6. 19 × 19 mm with HYDROTECH 6160.
7. 19 × 19 mm with HYDROTECH 6165.

Rout Configuration (All Ontario) (see Figure 4)

1. 12 × 12 mm and 40 × 10 mm.
2. 19 × 19 mm.

Rout Configuration (Cold Region) (see Figure 5)

1. 40 × 10 mm.
2. 19 × 19 mm.

Rout Configuration (Milder Region) (see Figure 6)

- Equal for 12 × 12 mm and 40 × 10 mm.

Crack Development

Crack development was assessed on the basis of the value of the crack factor F_c—the total linear length L_c (in meters) of transverse cracks and longitudinal cracks on the pavement surface divided by the total surface area (in square meters) of the pavement section. That is,

$$F_c = \frac{L_c}{A} \times 100 \qquad (1)$$

Figure 7 shows the crack factor for various pavement ages from 1 to 12 years. It appears that crack development begins from Year 1 of the pavement service life and increases steadily until Year 6. It then becomes static until the 11th year, when the increase becomes quite dramatic.

Figure 8 shows the crack factor for transverse and longitudinal cracks separately for various pavements from 1 to 12 years old. It appears that transverse cracks develop fully in the 1st year of the pavement service life and remain quite static until the 11th year, when a sharp increase begins to take place.

Figures 7 and 8 also show that the initial crack factor is generated nearly solely by transverse cracks, and that increases between Year 1 and Year 6 are from longitudinal crack development. The figures also show that pavement with a low crack factor will remain static in crack development over its service life.

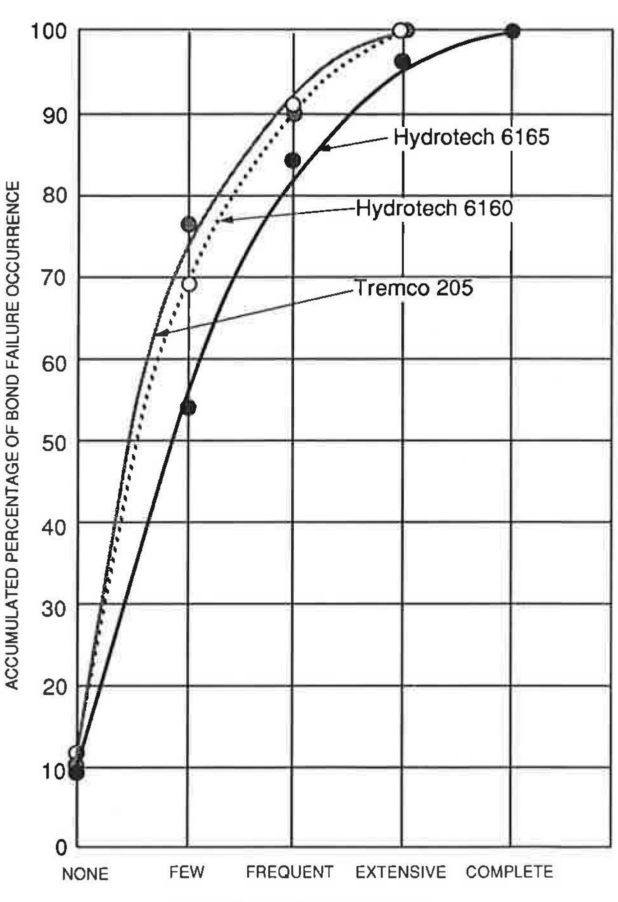


FIGURE 2 Ranking of materials on bond performance.

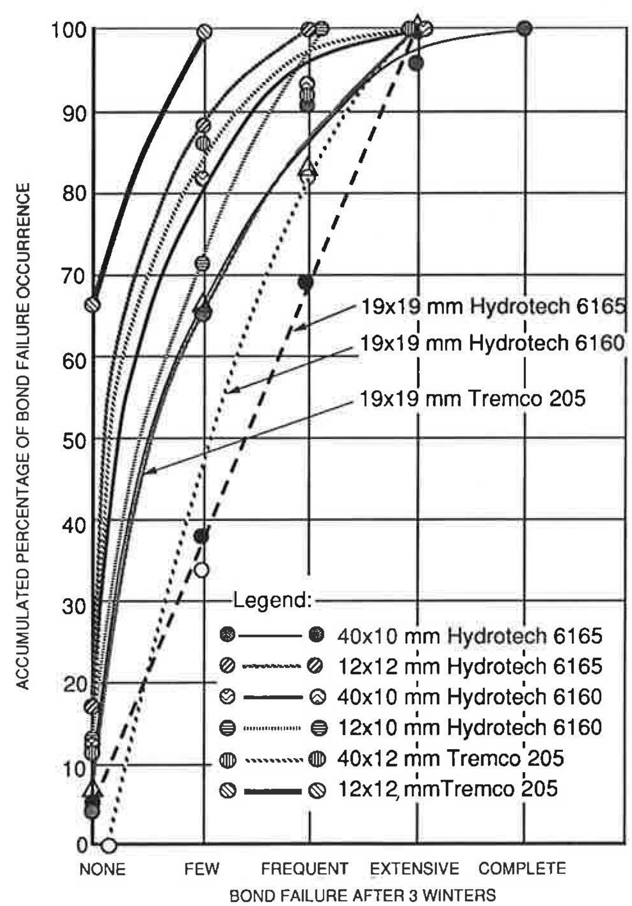


FIGURE 3 Ranking of material/rout configuration on bond performance.

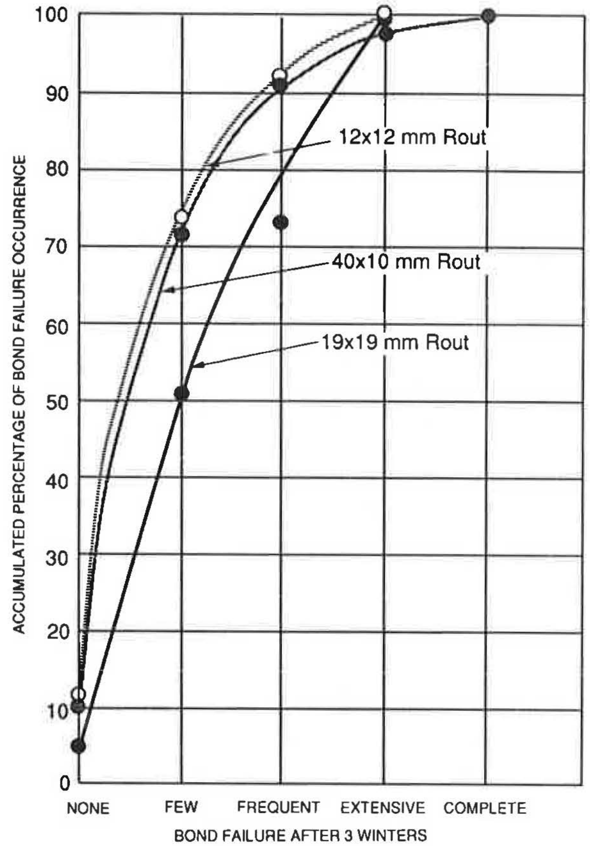


FIGURE 4 Ranking of rout configuration on bond performance (all Ontario).

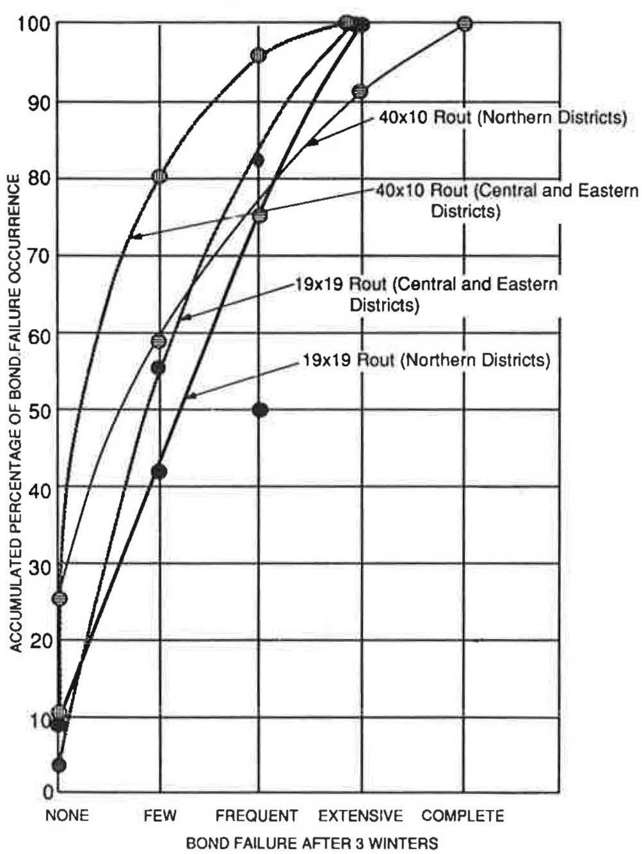


FIGURE 5 Ranking of rout configuration on bond performance (central, eastern, and northern districts).

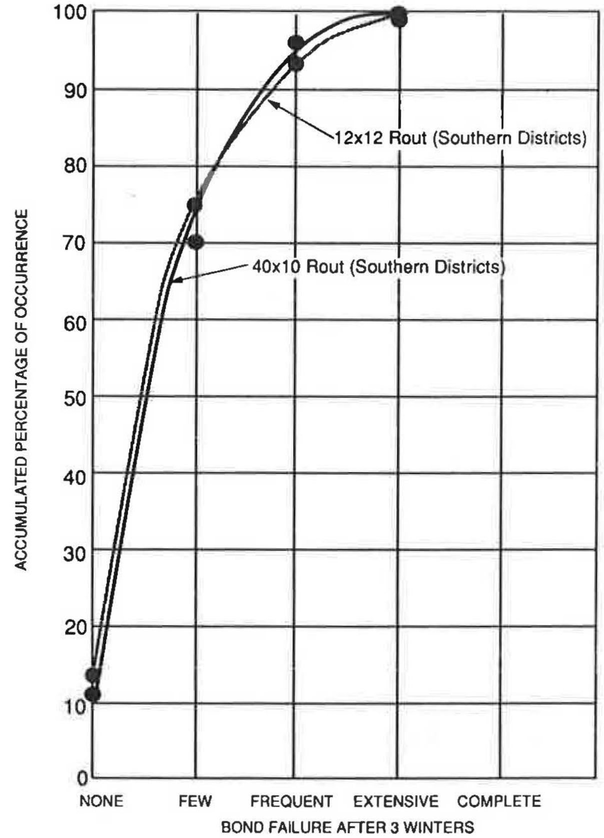


FIGURE 6 Ranking of rout configuration on bond performance (southern districts only).

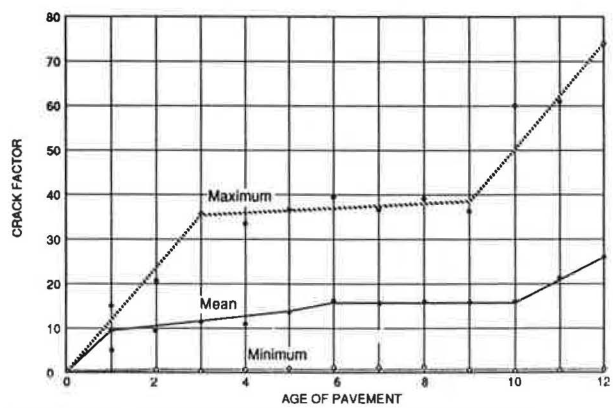


FIGURE 7 Crack factor for transverse and longitudinal crackings combined.

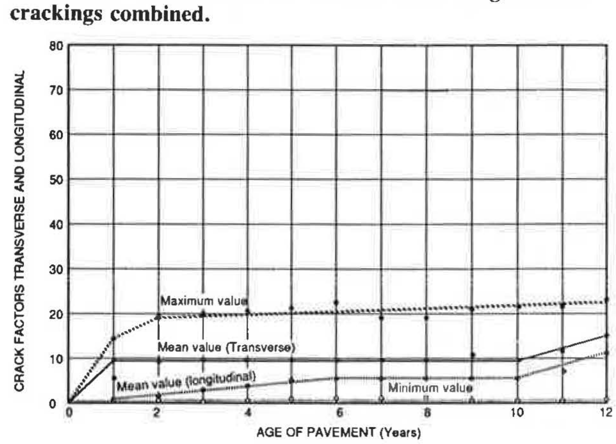


FIGURE 8 Crack factors for transverse and longitudinal crackings only.

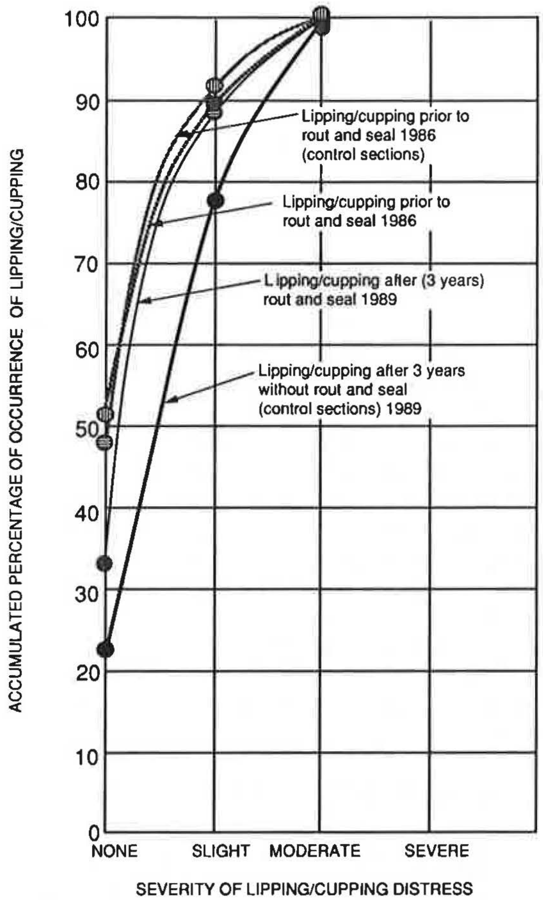


FIGURE 9 Crack deterioration after three winters.

Crack Deterioration by Lipping and Cupping

Crack deterioration is assessed on the basis of evaluation of deformations in the form of lipping or cupping. Figure 9 shows the different rates of deterioration for rout and seal treated cracks and nonsealed cracks from the control sections after three winters of service life. The rout and seal cracks remain static in performance, whereas the cracks in the control sections show significant increase in lipping and cupping deterioration after three winters.

DISCUSSION OF RESULTS

Cost-Effectiveness of Maintenance Treatment

The cost-effectiveness of a maintenance treatment depends on

1. How the treatment changes the existing condition; that is, how effectively it corrects the existing distress.
2. How well the treatment effectively delays the distress deterioration process, thereby extending the pavement service life.
3. Whether there is a particular condition or time during the progression of the cracking distress when appropriate maintenance can be most effective.

The information needed to establish cost-effectiveness must therefore quantify

1. The effectiveness of treatment—that is, (a) performance of sealant materials over time, and (b) performance of various rout width and depth sizes over time to establish the most efficient rout configuration.
2. The extension of pavement service life—that is, (a) retarding of additional crack development and (b) delaying the deterioration process of the existing distress.
3. The influence of time—the point in the pavement's life cycle at which the treatment is applied most cost-effectively.

Effectiveness of Treatment

Material Performance

All three materials are approved and included in the Ministry Designated Sources List. Performance, on the basis of the criteria of bond failure, indicates that TREMCO 205 and Hydrotech 6160, which both conform to ASTM D-1190, are similar and better than the low-stiffness modulus Hydrotech 6165, which conforms to ASTM D-3405 (see Figure 2).

This evidence appears to contradict the previous assumption that the low-modulus materials will perform better in a harsher climate than the standard D-1190 formulation. However, it should be noted that overall performance for all three sealant materials is exceptionally good because after three winters of service life, less than 10 percent of the sealant suffered a bond failure rating of "extensive."

Material/Rout Configuration Performance

All three sealant materials are matched with rout configurations of 12 × 12 mm and 40 × 10 mm for the southern part of the province and 19 × 19 mm and 40 × 10 mm for central, eastern, and northern areas.

Performance based on the criteria of bond failures indicates that regardless of materials, rout configuration of 19 × 19 mm is the poorest performer. There is virtually no difference in performance between 12 × 12 mm and 40 × 10 mm in southern Ontario, where the climatic condition is considered milder (see Figures 3–6).

The results definitely reinforce the previous assumption that rout configuration of 19 × 19 mm for asphalt concrete pavement is the least desirable and should be discarded. For uniformity, rout configuration of 40 × 10 mm should be the standard province-wide. For southern Districts 1, 2, 3, 4, and 6, rout size of 12 × 12 mm can be used as the optional standard, especially for urban expresssways.

Extension of Pavement Service Life

Crack Development

Evaluation of crack development during the pavement service life, on the basis of the criteria of crack factor, shows that cracking increases from the 1st to the 6th year, when it becomes more or less static until the 10th year. From the

11th year onward, crack development appears to accelerate (see Figure 7).

The most interesting aspect is that transverse cracking developed almost immediately from Year 1 to its full potential and thereafter remained fairly static until the Year 10. From the 11th year onward, transverse cracking appears to again accelerate. In addition, cracks other than transverse appear to begin their development in the 2nd year of pavement service life and reach a peak in the 6th year, which accounts for the trend of increasing crack factor from Year 1 to Year 6 (see Figure 8).

Rout and seal treatment of cracks does not appear to have a great deal of influence on crack development, because there is no discernible trend in crack development between the sealed test sections and the unsealed control sections.

Crack Deterioration

The criterion used to determine crack deterioration is the degree of deformation at the transverse crack, commonly known as either lipping or cupping. Treatment is considered to be effective when it either retards or stops the deformation process, thus extending pavement service life. An increase in deformation results in increased roughness in the pavement surface and reduced serviceability.

Figure 9 shows the static condition of the rout and seal test sections after three winters of the treatment's service life. The unsealed control sections indicate a marked increase in the severity of lipping and cupping distress.

Timing

The data on crack development indicates that rout and seal treatment should be applied between the 3rd and 5th year for maximum cost benefit (see Figures 7 and 8). For pavement with low crack factor less than 2.0 by the 4th year, there is no benefit to rout and seal cracks as the crack factor will remain static and low (see Figures 7 and 8).

A second rout and seal treatment can also be cost effective in prolonging or extending pavement surface life if it is carried out at the 8th or 9th year, before crack development begins to accelerate.

MINIEXPERIMENTAL STUDY

In 1981, a small-scale study was launched by the Pavements and Roadway Office and the Ottawa District Maintenance Office to look into the consequence of sealing pavement cracks with rout and seal treatment versus deferred maintenance (*2,4,5*).

A second of Highway 17 near Ottawa was selected that was originally constructed in 1965 with 115 mm (4½ in.) of hot-mix asphalt, and rehabilitated in 1979 because of extensive cracking with 65 mm (2½ in.) of hot-mix asphalt. In 1981, 2 years after resurfacing, extensive transverse cracks reappeared and the pavement was routed and sealed as a preventive maintenance measure. Part of this pavement was used for the miniexperimental study.

In 1985, an investigation was made of the deferred maintenance control section and the rout and seal test sections. Results proved that rout and seal treatment prevented secondary crack development on the sealed cracks and also stopped or retarded internal deterioration, which was reflected on the surface as cupping deformation (*5*).

In 1989, as part of the winter monitoring program, a performance evaluation was made of the experimental test sections. The performance data are presented in Table 1.

Material Performance

Hydrotech 6160 and Meadow 164R had been approved as sealant materials at the same time. The third material, which had just been placed in the marketplace, was the Shell Cariphalte, a low stiffness modulus polymer material that Shell Canada hoped would be accepted by the Ministry on the Designated Sources List. (Shell Canada has now discontinued the manufacturing and sale of this product.)

After eight winters of service life, the sealants are still effective in their designed function, which is waterproofing the pavement surface. This includes Meadow 164R, which has the worst performance record for bond failure and was subsequently withdrawn from the market by its manufacturer. Figure 10 shows a typical rout and seal crack using Hydrotech 6160, Figure 11, using Shell Cariphalte, and Figure 12, using Meadow 164R.

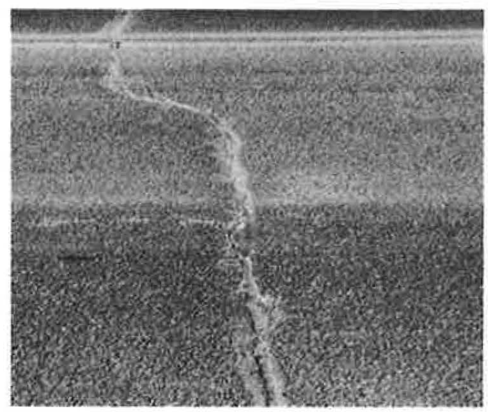


FIGURE 10 19- × 19-mm rout and seal with Hydrotech 6160 Test Section 1, 1981 (February, 1989).

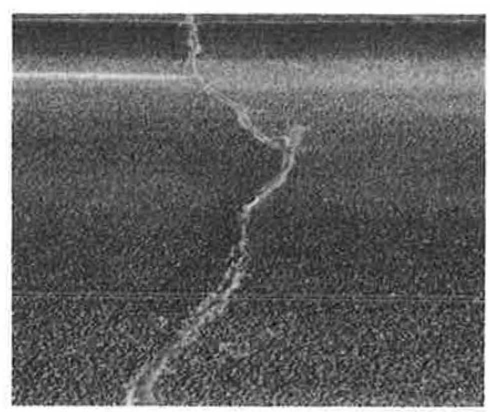


FIGURE 11 19- × 19-mm rout and seal with Shell Cariphalte Test Section 3, 1981 (February, 1989).

Pavement Performance

The sealed test sections, Meadow 164R included, were definitely in better condition than the control section (see Table 1). The sealed cracks remained sealed with little secondary crack development. New crack development for sealed sections was also less than in the control section, which in 1989 was estimated as approximately 30 percent more than in 1981.

There was no spalling with the sealed cracks, whereas spalling did occur in numerous unsealed cracks in the control section (see Figure 13).

The new crack development, after the sealing in 1981, has had no maintenance in the sealed test sections or in the control section. These unsealed cracks have now progressed to openings of as much as 19 to 25 mm. It will be beneficial to have a follow-up rout and seal treatment in the eighth or ninth year to extend the pavement service life before accelerated deterioration takes place.

FIGURE 12 19- × 19-mm rout and seal with Meadow 164R Test Section 7, 1981 (February, 1989).

TABLE 1 MINIEXPERIMENTAL STUDY—HIGHWAY 17, OTTAWA DISTRICT

SECTION NO.	CHAINAGE (km)	MATERIAL	ROUT	SEALANT BOND CONDITION
1	0 - 1.0	Hydrotech	19 mm	<10% bond failure, about 5 cm sealant missing from <10% of crack <15% new cracks developed, Average crack width 13-19 mm
2	1.0 - 2.0	Control		<30% new cracks developed Most transverse crack width 13-19 mm, some 19-25 mm Most longitudinal crack width 6-13 mm, some 13-19 mm
3	2.0 - 2.5	Shell	19 mm	No bond failure, no sealant missing <10% new cracks developed Average transverse crack width 6-13 mm, C\L crack >25 mm
4	2.5 - 3.0	Shell	10 mm	No bond failure, no sealant missing <10% new cracks developed Average crack width 6-13 mm, some longitudinal cracks 19-25 mm
5	3.0 - 4.0	Hydrotech	10 mm	<10% bond failure, no sealant missing <10% new cracks developed Average crack width 6-13 mm, some longitudinal cracks 19-25 mm
6	4.0 - 4.5	Meadows	10 mm	>50% bond failure, about 5 cm sealant missing from most cracks <15% new cracks developed Average crack width 6-13 mm, some longitudinal cracks 19-25 mm
7	4.5 - 5.0	Meadows	19 mm	>50% bond failure, about 5 cm sealant missing from 50% of cracks <15% new cracks developed Average crack width 6-13 mm, some longitudinal cracks >25 mm
8A	7.4 - 7.9	Meadows	Flat	>40% bond failure, about 5 cm sealant missing from 25% of cracks <15% new cracks developed Average crack width 6-13 mm, some longitudinal cracks >25 mm
8B	7.9 - 8.4	Meadows	Bead	>40% bond failure, about 5 cm sealant missing from 10% of cracks <15% new cracks developed Average crack width 6-13 mm, some longitudinal cracks >25 mm
8C	7.9 - 8.4	Hydrotech	Bead	<10% bond failure, no sealant missing <15% new cracks developed Average crack width 6-13 mm, some longitudinal cracks >25 mm
8D	7.4 - 7.9	Hydrotech	Flat	<10% bond failure, no sealant missing <15% new cracks developed Average crack width 6-13 mm, some longitudinal cracks >25 mm

FIGURE 13 No maintenance, test section 2, control, 1981 (February, 1989).

SUMMARY

Rout and seal treatment is designed to seal asphalt concrete pavement cracks to prevent water from entering and damaging the pavement structure. It is important for pavements in cold areas because of the combination of low-temperature-induced crack opening and the winter maintenance practice of snow and ice removal with salt.

This experimental study, evaluating the effectiveness of rout and seal treatment and its cost benefit, has achieved good results, which lead to the following conclusions:

1. The equipment and methodology presently used by the ministry are efficient and highly successful and should be the specified standard.
2. All three approved materials on the Ministry Designated Sources List perform satisfactorily whether they are formulated to meet ASTM D-1190 or D-3405.
3. Standard rout configuration for the province of Ontario should be 40 × 10 mm.
4. Rout configuration for southern Ontario (Districts 1, 2, 3, 4, and 6) should have 12 × 12 mm as the optional choice. The 12 × 12 mm will present a neater appearance, less material usage than 40 × 10 mm, and will be especially suitable for urban expressway systems.
5. Rout and seal treatment will either stop or retard the deformation commonly known as lipping and cupping, which is detrimental to pavement serviceability and, therefore, pavement service life.
6. The initial rout and seal treatment must be performed between the third and fifth year of the pavement service life to achieve maximum cost effectiveness.
7. The second rout and seal treatment, which is a follow-up operation, should be performed between the eighth and ninth years of the pavement service life to extract the maximum benefit of the initial treatment in extending pavement service life.
8. For pavement with an initial low crack factor (2.0 or less) at the 4th year of pavement service life, rout and seal treatment has doubtful benefit.
9. Deferred maintenance, particularly on transverse cracks, is not an acceptable engineering or economical option.

RECOMMENDATIONS

Three winters of monitoring have been completed. Monitoring must continue until the sealant reaches extensive failure or, at minimum, for an additional 2 years. The Pavement Design and Evaluation Section of the Highway Design Office should be the agency designated to continue further monitoring of this project.

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REFERENCES

1. *Maintenance Operation Instruction: M-1005-A Crack Sealing Flexible Pavements.* Ontario Ministry of Transportation and Communications, Ottawa, Sept. 1981, Interim Revision, May 1984.
2. G. J. Chong. Sealing Cracks in Flexible Pavements in Cold Areas. In *Proc. Ontario Ministry of Transportation and Communications, PICA Mini-Workshop*, Vancouver, Oct. 1982.
3. G. J. Chong and W. A. Phang. *Sealing Cracks in Flexible Pavements in Cold Areas—An Audio-Visual Script.* Report PAV-83-01. Ontario Ministry of Transportation and Communications, Ottawa, Jan. 1983.
4. G. J. Chong. Consequences of Deferred Maintenance on Transverse Cracks in Cold Areas. In *Proc. Ontario Ministry of Transportation and Communications, PICA Workshop III*, Ottawa, July 1987.
5. G. J. Chong and W. A. Phang. *Improved Preventive Maintenance: Sealing Cracks in Flexible Pavements in Cold Regions.* Report PAV-87-01, Ontario Ministry of Transportation, Ottawa, Jan. 1988.

The author wishes to state clearly that the views expressed herein are not necessarily the position of the Ministry of Transportation.

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