EVALUATION OF ASPHALT PAVEMENT CRACK SEALING

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ABSTRACT

Crack sealing is one of the most commonly used routine maintenance treatments for road and airport asphalt pavements. Asphalt pavement performance monitoring shows that properly completed, timely crack sealing can significantly extend the service life of asphalt pavements.

Recent practical experience in Ontario (road and highway pavements) and Newfoundland (airport pavements) shows that crack sealant failures (debonding) can occur in asphalt pavements that incorporate aggregates that are hard, brittle, and prone to stripping.

This paper presents the results of extensive research on crack sealant performance in asphalt pavements, completed on several Canadian road and airport projects where poor crack sealant performance had been observed. It presents recommendations for changes in crack sealing methods to achieve improved pavement performance and more cost-effective asphalt pavement crack sealing.

RÉSUMÉ

Le scellement des fissures est un des traitements routiniers d'entretien le plus communément utilisé pour les revêtements bitumineux de routes et d'aéroports. Le suivi de la performance des revêtements bitumineux montre que bien complété, le scellement opportun des fissures peut prolonger significativement la vie en service des revêtements bitumineux.

Une expérience pratique récente en Ontario (revêtements de routes et autoroutes) et à Terre-Neuve (revêtements d'aéroports) montre que la rupture du scellant des fissures (bris du lien) peut se produire dans les revêtements bitumineux qui incorporent des granulats qui sont durs, fragiles et sujets au désenrobage.

Cet exposé présente les résultats d'une recherche approfondie sur la performance du scellement des fissures dans les revêtements bitumineux complété sur plusieurs projets Canadiens de routes et d'aéroports où une piètre performance du scellement de fissures a été observée. Il présente aussi des recommandations de modifications dans les méthodes de scellement des fissures afin d'obtenir une performance améliorée de la chaussée et une meilleure rentabilité du scellement des fissures des revêtements bitumineux.

1. INTRODUCTION

When properly completed, using quality construction methods and materials, crack sealing will prevent the ingress of water through the pavement and into the underlying granular base, subbase and subgrade. Asphalt pavement performance monitoring shows that properly completed, timely crack sealing can significantly extend the service life of asphalt pavements.

Proper asphalt concrete pavement crack sealing should last about 5 to 7 years. There are however known cases where crack sealants have failed quickly, sometimes within the first year of service or after the first prolonged period of wet, cold weather. Recent practical experience in Ontario (road and highway pavements) and Newfoundland (airport pavements) shows that crack sealant failures (debonding) can occur in asphalt pavements that incorporate aggregates that are hard, brittle, and prone to stripping. The problems appear to be related to the method used to form the reservoirs for the sealant with shattering of the hard, brittle aggregate during the routing operation causing bond failure between the hot-poured sealant and the surface course asphalt concrete. High mix air voids content and asphalt concrete permeability can exacerbate the problem. Water present in the pores is forced into the longitudinal joints/cracks by traffic action accelerating stripping and debonding of crack sealants from the asphalt concrete.

2. BACKGROUND

Problems with bonding of hot-poured rubberized crack sealant to the asphalt pavement occurred in Ontario in 1997 on Highway 69 near Estaire, Highway 60 in Bancroft in 1998, and on Highway 11 near Orillia in 1999. The Region of Peel also reported a loss of crack sealant on Highway 50 between Region Road 107 and Castlemore Road in 2001. Early failure of asphalt concrete crack sealing was also observed on two runways at Canadian Forces Base (CFB) Goose Bay, Labrador, in 2000.

2.1 Highway 11 South of Orillia and Highway 50 in the Region of Peel

Crack sealing was carried out on Highway 11 south of Orillia in the summer of 1998 during good weather. There was no apparent problems with the crack sealant product or its installation at the time of construction. The pavement cracks were routed to the specified configuration (40 by 10 mm) and the rout was conditioned with hot, compressed air. The crack sealant was then applied. Some loss of the sealant from the routed cracks was reported shortly after a period of rain in the fall of 1998. A further significant quantity of sealant came out over the subsequent first winter period. A site inspection completed in 1999 indicated that red meta-arkose/granitic aggregate was used as the coarse aggregate in the surface course asphalt mix. The crack sealing material was found to be bonded only to the asphalt concrete in the top 2 to 3 mm at the edge of the rout and to the fine aggregate matrix between the coarse aggregates in the bottom of the rout, as indicated in Figure 1.

The asphalt pavement on Highway 50 in the Region of Peel incorporated a similar type of red meta-arkose coarse aggregate. A very significant loss of crack sealant installed in 2000 was reported in 2001. In some areas, losses as high as 70 to 90 percent were observed. Strips of crack sealant that had pulled out of the cracks were observed on the pavement surface, as indicated in Figure 2 and on the shoulders.

Figure 1. Crack Sealant Debonding on Highway 11, Southbound, Oro Road to Orillia, Summer 1999

Figure 2. Failing Crack Sealant on Highway 50, Region of Peel, 2001

2.2 Highway 401 Westbound between Mississauga Road and Winston Churchill Boulevard

Hot-poured rubberized crack sealant was used on an Ontario Ministry of Transportation (MTO) Central Region crack sealing contract on Highway 401 Westbound through Mississauga (between Mississauga Road and Winston Churchill Boulevard) in the summer of 2000. The pavement cracks were routed to the specified configuration (approximately 40 by 10 mm) and the rout was conditioned with a hot pulse jet type lance. Crack sealant material was then installed in conformance with the project specification requirements. Some loss of sealant from the routed longitudinal grooves was first reported in the fall of 2000 after a period of cold, wet weather. A significant loss of sealant was also reported in the spring of 2001. Very poor bond was observed between the remaining crack sealant and the asphalt concrete pavement, as indicated in Figure 3. Note the shattered aggregate particles at the bottom of the rout where the sealant was removed. The sealant was bonded only to the top edges of the rout and to the asphalt concrete fine aggregate/asphalt cement matrix between the coarse aggregate.

Figure 3. Sealed Longitudinal cracks on Highway 401, Westbound in Mississauga

2.3 CFB Goose Bay, Labrador

The crack sealing work on Runway 08-26 consisted of removing the existing sealant by routing, routing new cracks, and then sealing the cracks with a low modulus crack sealant. Prior to placing the sealant, the routed cracks were blown clean with compressed air and then heated with a hot, compressed air lance to remove moisture. The work was completed in August and September of 1999. The surface course asphalt concrete incorporated a red granitic aggregate.

It was observed during the spring of 2000 that the pavement crack sealant from the previous summer's contract was becoming dislodged within the touchdown area of Runway 08-26, as indicated in Figures 4 and 5. It was observed (Figure 5) that particles of shattered aggregate had stuck to the bottom of the sealant giving it a sandpaper like texture.

Examination of the Runway 08-26 crack sealing revealed that most of the missing sealant was within the area at both ends of the runway where aircraft were landing (tire rubber marks on the pavement). The bond of the sealant was poor throughout these areas (except at the west end of the runway where the sealant was found to be well adhered).

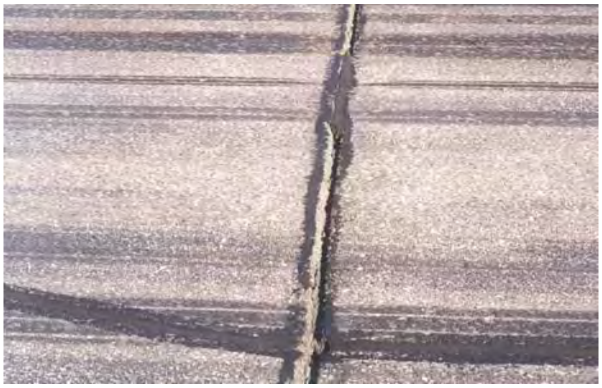

Figure 4. Crack Sealant Debonded in Transverse Crack on Runway 08-26 at Canadian Forces Base Goose Bay

Figure 5. Debonded Crack Sealant in a Transverse Crack on Runway 08-26 at Canadian Forces Base Goose Bay

3. METHODOLOGY

The evaluation of asphalt pavement crack sealant performance consisted of:

- Literature review of Canadian and American publications on crack sealing materials, installation, performance, and failure mechanisms
- Site visits and field performance monitoring of asphalt concrete pavement crack sealing
- Laboratory examination of samples obtained from asphalt concrete pavements exhibiting crack sealing failures and
- Laboratory testing of samples obtained in the field in the Asphalt Pavement Analyzer (APA) and Instron Pull-Out Machine.

The methodology developed for this evaluation was based on the authors' extensive experience in crack sealing materials, testing, installation, and performance as well as Canadian and U.S. practice [1 to 10].

The National Research Council (NRC) report by Masson [1] was of particular interest as it reported similar observations on the impact of the router on the asphalt concrete, methods of crack preparation and effect of aggregate type on crack sealant bonding.

4. LABORATORY TESTING

During the Highway 401 Westbound site inspection in Mississauga, four asphalt concrete slabs were dry cut from the asphalt pavement. The slabs were cut such that they straddled sealed cracks and a removed slab is shown in Figure 6. The rout was about 40 mm wide and 10 mm deep and no shattered particles were observed on the saw-cut vertical face of the slab. In the laboratory, each of the slabs was visually examined, photographed and logged. The hot-poured rubberized crack sealant was then pulled from the slabs manually to assess the bond between the sealant and asphalt concrete. The slabs were then separated along the cracks and both the vertical crack face and the rout were examined. The exposed aggregate in the slabs was examined petrographically. The slabs were also examined under a binocular microscope to assess the condition of the aggregate within the asphalt concrete and to assess potential damage done to the asphalt pavement by the router.

Figure 6. Cross Section of a Slab taken from Highway 401 Westbound in Mississauga

A total of 36 representative slabs were also obtained from CFB Goose Bay, 16 from Runway 16-34, 16 from Runway 08-26, and four from Taxiway Hotel/Kilo. The samples were cut in sets of four: one across a sealed crack or joint; and three from the adjacent area. Laboratory examination confirmed that the sealant was bonded only at the top 2 to 3 mm of the vertical face of the rout. When the sealant was removed, numerous small pieces of shattered aggregate were observed to be adhered to the sealant giving it a sandpaper like appearance. Some asphalt concrete stripping was also observed in the crack faces. The surface asphalt concrete included a red, hard aggregate that was considered to be brittle. Laboratory testing was completed on routed crack sealant reservoirs and saw-cut crack sealant reservoirs. Samples prepared in the laboratory used two different types of sealant material. The sealant bond development and moisture resistance were tested in the Asphalt Pavement Analyzer (APA) in the submerged flexural mode (a rubber wheel running over or across the sealant). In addition, a crack sealant pull-out test was completed on representative samples.

4.1 Asphalt Pavement Analyzer (APA) Testing

The laboratory testing was undertaken in two stages. In Stage 1, the testing was completed using asphalt concrete samples obtained from Highway 50 in the Region of Peel. The asphalt concrete pavement on Highway 50 incorporated brittle red meta-arkose aggregate and is known for its very poor crack sealant performance. For this testing program, crack sealant reservoirs 20 to 25 mm wide and 20 mm deep were cut using the routing and saw-cutting methods prior to obtaining asphalt pavement slabs for the laboratory testing. The Stage 1 testing was completed to confirm the testing procedures and to provide further information on the comparative behaviour of brittle aggregate asphalt concretes. In Stage 2, slabs obtained from CFB Goose Bay were tested.

The Stage 1 testing in the APA demonstrated that a 25 mm wide reservoir was too wide as the APA rubber wheel was often observed to cut through the sealant instead of running on the surface on the sample. Consequently, in Stage 2, the size of the reservoir was reduced to 20 by 20 mm (note that the width of the rout is not consistent and was hard to control).

The slabs obtained on site were trimmed to 300 mm long by 125 mm wide by 75 mm deep. Crack sealant reservoirs 20 by 20 mm were then cut using both routing and saw-cutting methods, as indicated in Figure 7. The reservoirs were then carefully cleaned but not brushed with a steel wire brush. The router caused some damage to the edges of the reservoir and many coarse particles were shattered during the routing operation. The reservoirs were then filled with hot-poured rubberized crack sealant, as indicated in Figure 8. The APA moisture sensitivity testing was completed on samples in both dry and wet conditions. Detailed information on the APA was provided in a previous paper [11]. Wet APA conditioning included a 24 hour saturation period with the testing then run on samples submerged in water, as indicated in Figure 9. Control samples were conditioned in air and tested dry. In order to prevent the sealant from sticking to the test wheel during the testing, the surface of the sample was covered with a layer of polyethylene.

In the APA crack sealant moisture sensitivity test, a 30 mm wide solid rubber wheel was run on a sample resting in the mould. A contact pressure of 1,725 kPa was applied. The test was run at a constant temperature of 20°C. Generally, 8000 cycles were applied, unless a total bond failure occurred earlier, at which time the test was terminated. The APA was stopped at 500 cycle intervals so the bond between the sealant and the asphalt concrete could be examined and photographs taken.

The results of the Stage 2 testing are summarized in Table 1. Figure 10 shows a sample with a routed reservoir that exhibited a failure after only 2000 cycles. The sealant was observed to be fully debonded from the asphalt concrete in the reservoir. Figure 11 shows a sample with a saw-cut reservoir that exhibited only partial failure after 8000 cycles. There was still some bond between the sealant and the asphalt concrete in the reservoir.

Figure 7. Samples taken from Runway 08-26 at Canadian Forces Base Goose Bay Ready for Crack Sealant Application

Figure 8. Sample with Routed Reservoir Filled with Crack Sealing

Figure 9. Crack Sealed Sample Ready for Wet Testing in the Asphalt Pavement Analyzer

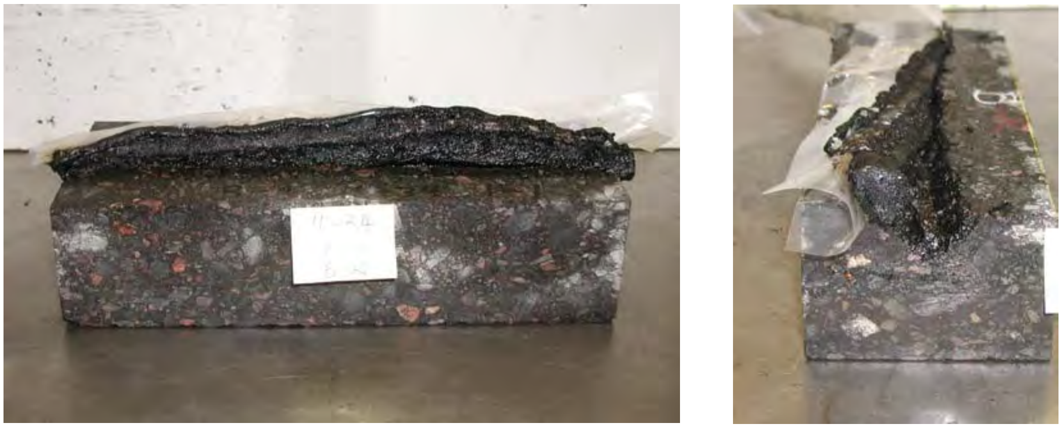

Figure 10. Sealant Debonded from Routed Reservoir after 2000 cycles
in the Asphalt Pavement Analyzer

Figure 11. Sealant Bonded in Saw-Cut Reservoir After 8000 Cycles in the Asphalt Pavement Analyzer

4.2 Pull-Out Testing

Pull-out testing was completed in the laboratory using an Instron machine. Asphalt concrete cores (150 mm diameter) and 150 by 150 mm slabs, having both routed and saw-cut reservoirs were used for this testing. After the reservoirs were filled with crack sealant, the samples were conditioned in water in accordance with American Society for Testing and Materials (ASTM) D 4867. Control samples were conditioned in air.

The load, applied at a constant rate and the time to failure were monitored using the Instron data acquisition system. The maximum load applied during the pull-out test and de-bonding time was recorded for each sample. The maximum peak load ratio was used for the performance assessment. The time to failure is also an indication of the sealant performance and the longer the time to failure, the better the performance. The results are summarized in Table 2.

Figure 12 and 13 show samples after wet testing with routed and saw-cut reservoirs, respectively. The sealant in the wet test, routed sample (Figure 12) failed in adhesion to the asphalt concrete. Particles of shattered aggregate adhered to the sealant and gave the bottom of the sealant a sandpaper like texture. The sealant in a saw-cut sample (Figure 13) failed in the wet test in both adhesion and cohesion but there was still some sealant adhering to the asphalt concrete. Figure 14 shows a cohesion failure of the sealant in the dry pull-out test with a saw-cut reservoir.

Figure 12. Adhesion Failure of Sealant in a Wet, Pull-out Test with a Routed Reservoir

Figure 13. Partial Adhesion and Partial Cohesion Sealant Failure in a Wet, Pull-out Test with a Saw-Cut Reservoir

Figure 14. Cohesion Failure of Sealant in a Dry, Pull-out Test with a Saw-Cut Reservoir

5. FINDINGS

5.1 Site Visit Observations

A meta-arkose/granitic aggregate was used as both the coarse and fine aggregate in the Highway 401 Dense Friction Course (DFC) surface course mix. The DFC mix generally had an open texture and non-uniform appearance with considerable ravelling, particularly in wheel paths. Most of the crack sealant debonding was observed to have occurred in longitudinal routs throughout the section. The crack sealing of transverse cracks appeared to be intact.

When the crack sealant material was pulled away to expose the face of the routed reservoir, it was observed that there was little or no bond of the crack sealant to the coarse aggregate. The hot-poured rubberized crack sealant was found generally to be bonded to the asphalt concrete fine aggregate/asphalt cement matrix between the coarse aggregate particles and to the edges of the rout. After the sealant was pulled away for laboratory examination, it was observed, in numerous locations, that the coarse aggregate was completely shattered at the bottom and sides of the rout. Small fragments of the shattered aggregate were bonded to the crack sealant and readily pulled away from the hot-mix asphalt. The bottom surface of the crack sealant often had a sandpaper like texture as a result of this fine aggregate adhering to the crack sealant, with little or no asphalt cement present on the aggregate. During the dry cutting and removal of the pavement slab samples straddling the cracks, free water was observed to be present between the surface course and the underlying binder course hot-mix asphalt.

It is surmised that the localized failures of the longitudinal cracks may be exacerbated by pumping associated with tire action of moving vehicles. Relatively short sections of the crack sealant were observed to have failed due to de-bonding of the sealant from the shattered aggregate and then lifted by the hydraulic action of the water trapped between the pavement layers. The shattered aggregates in the rout sides enabled water to penetrate into the reservoir and become trapped between the sealant and the asphalt pavement. Water is forced into the asphalt mix and along the longitudinal joints/cracks by vehicle tire action, contributing to accelerated de-bonding and stripping of the crack sealant. Ultimately, the bond between the sealant and the asphalt concrete is broken (moisture accelerated damage). Additionally, pieces or entire aggregate particles may be pulled out of the asphalt concrete by the sealant. Although the top surface of the sealant was largely flush with (and sometimes slightly below) the surface of the adjacent pavement, there was a significant loss of the sealant from the longitudinal cracks.

In Ontario trials, the same crack sealant material used on Runway 08-26 at CFB Goose Bay was found to be resistant to stripping in pavements where competing ‘equivalent’ products had been observed to strip badly. However, it appears from visual examination of the Runway 08-26 pavement that stripping was a factor in the poor sealant bond. Water/dampness observed under the sealant was considered to contribute to a stripping problem. Examination of the Airfield Pavement History records revealed that the runway is a composite pavement consisting of Hot Mix Asphalt Concrete (HMAC) over Portland cement concrete (PCC) except for the west end of the runway where it is HMAC over granular base material. The sealant was only well-bonded at the west end of the runway. It appears that the underlying Portland cement concrete (PCC) prevents water, which has percolated through the hot-mix asphalt concrete (HMAC) to the HMAC/PCC interface, from draining, keeping the asphalt concrete ‘wet’ and susceptible to moisture damage. At the west end of the runway where there is no underlying PCC, the sealant is performing satisfactorily.

Typically, the sealant was only bonded to the adjacent pavement at the top 2 to 3 mm of the rout and could be easily pulled from the rout. When the sealant was removed from the rout, the underlying pavement was observed to be damp to wet (except at the west end of the runway where the sealant was found to be well adhered and the rout was dry). The pavement surface adjacent to cracks was observed to be sound. The sealant had numerous blisters up to about 50 mm in diameter. When intact blisters were pressed down, water was often forced to the pavement surface at the edge of the seal, as shown in Figure 15. When blisters were opened up, free water was also often observed.

The Contractor used a hot-air lance of the type that blows hot compressed air into the rout (in conformance with the specification). This hot air has the potential to oxidize the asphalt within the rout, which may also inhibit the bonding of the sealant.

Figure 15. Water Forced out of a Sealed Transverse Crack on Runway 08-26 at Canadian Forces Base Goose Bay

5.2 Laboratory Testing

The majority of coarse aggregate particles in the vertical faces and bottom of the rout were observed to be shattered at the rout/sealant interface. Figure 16 shows a microscopic photograph of a sample from the Highway 401 project highlighting the typical shattering of a coarse aggregate particle at the bottom of the rout. The red meta-arkose/granitic aggregate is known to be very hard/brittle and it is likely that the shattering occurred as the result of the routing operation. No shattering of the coarse aggregate was observed where the pavement slabs were saw-cut. This suggests that the saw-cutting operation causes significantly less damage to the hard/brittle meta-arkose/granitic coarse aggregate than the impact routing operation.

The results of the APA crack sealant moisture damage testing and pull-out testing completed on the samples obtained from CFB Goose Bay show that the bond of both crack sealant materials was reduced in the presence of moisture. This reduction was most drastic when the crack sealant reservoirs were formed by routing. Neither sealant material showed any serious de-bonding in the dry test. The samples with saw-cut reservoirs exhibited bond failure after 6,000 to 8,000 cycles in the APA but some sealant material was still observed to adhere to the asphalt concrete in the reservoir. The sealant failed partially in adhesion to the asphalt concrete and partially in cohesion in the pull-out test. The samples with routed reservoirs typically exhibited a total bond failure after about 2,000 cycles in the APA. The sealant failed in adhesion to the asphalt concrete in the pull-out test.

6. DISCUSSION

Field observations and laboratory testing confirm that the loss of sealant appears to be mainly the result of the impact damage to the brittle red meta-arkose/granitic coarse aggregate caused by the routing equipment shown in Figure 17. In order to mitigate potential shattering of such aggregates during routing, the use of a random-crack saw with diamond blades, as indicated in (Figure 18 should be considered for cutting the crack sealant reservoirs in asphalt pavements containing brittle aggregates. This equipment/method will cause less damage (particularly aggregate shattering) to the pavement than conventional routers.

Figure 16. Microscope Photograph of Shattered Aggregate at the Bottom of the Rout in a Slab Cut from Highway 401 Westbound in Mississauga.

A National Research Council (NRC) study completed in Canada [1] indicates that crack routing, cleaning and heating operations create defects in the surface course asphalt concrete, which in turn weaken the asphalt concrete-sealant interface. Routing can cause micro-cracking of asphalt concrete. The bond between the asphalt concrete and the sealant subsequently fails when the sealant pulls out the fines and shattered aggregate out of the asphalt concrete. This is exacerbated by moisture/water that penetrated into the shattered zone. The rotary-impact routers commonly used in Ontario can cause considerable damage to the asphalt concrete. Eaton and Ashcraft [2] confirmed that routing of any configuration is detrimental to pavements, and can even cause the surrounding pavement to crack. It is obvious that the damage can be much more severe if the asphalt concrete mix incorporates brittle aggregates (the red meta-arkose/granitic aggregates are considered to be very hard and brittle). The Federal Highway Administration (FHWA) [12] recommends the use of a random-crack saw with diamond blades, which causes less damage to the asphalt concrete and provides a more rectangular reservoir with smoother walls.

Figure 17. Typical Pavement Crack Router and Router Blade

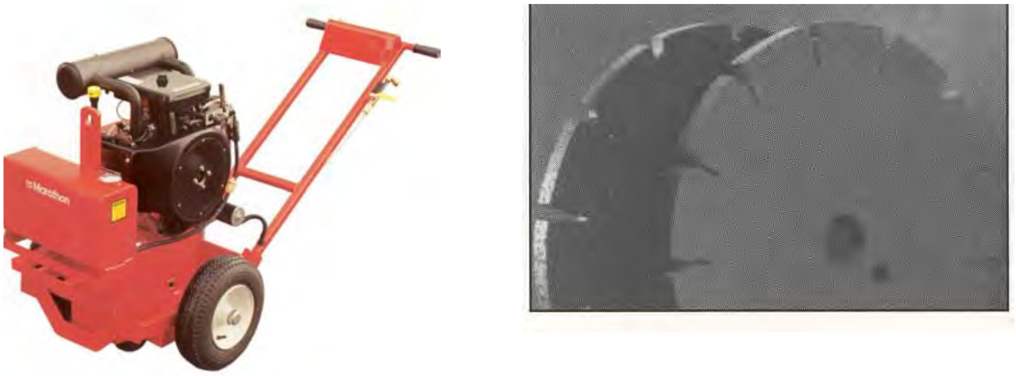

Figure 18. Typical Pavement Crack Saw and Saw Blades

The shape of the crack sealant reservoir should be reconsidered. The current 40 by 10 mm shape of the reservoir was adopted to reduce the strain on the sealant material, promote better bonding, allow the router to follow sharp directional changes in the pavement cracking, and produce less stress on the routing equipment and bits. Practical experience from a number of sites in Ontario does not support these expectations. NRC had also raised serious objections to the 40 by 10 mm rout configuration stating: "Although theoretically the performance of crack sealants improves as the width-to-depth ratio of the rout increases, in practice, their performance is at worst with 40 by 10 mm routs rather than with 12 by 12 or 19 by 19 mm routs… This is attributed to the vulnerability of wide sealant strips to tire damage."

The 40 by 10 mm rout configuration and application of a hot-poured sealant is the most commonly used method of crack treatment in Ontario. Unfortunately, this method is not always cost effective and in some cases the routing can cause severe damage to the asphalt concrete. As such, crack filling, without routing, should be considered for non-working cracks (movements less than 2.5 mm) particularly in pavements incorporating hard brittle aggregates. Non-working cracks typically include diagonal cracks, most longitudinal cracks, and some block cracks. Non-working cracks having moderate to no edge deterioration should be filled regularly to reduce the infiltration of water. Crack filling is considered to be a cost effective and quick operation. As no routing is performed, the crack filling will not cause any damage to the pavement. Crack filling should be done early in the life of the pavement, before the crack has the time to deteriorate to the extent that sealing (with routing) or repair is required. Harder, more resilient, low viscosity sealants are recommended for the crack filling operation. Only working cracks (movement greater or equal 2.5 mm) should be routed and sealed, but the procedure used should consider the damage that the routing operation can cause. For pavements incorporating hard, brittle aggregates saw-cutting is the preferred method to develop the sealant reservoir.

On a generic basis, consideration should also be given to potential stripping of the hot-poured rubberized asphalt crack sealant from these aggregate types. Even if anti-stripping additives are used in asphalt mixes, a fresh, untreated aggregate surface is exposed when the rout is made in the asphalt pavement. Although the incorporation of anti-stripping additives into the crack sealant material improves its stripping resistance, moisture damage can still be significant due to the severe hydraulic action of water forced into joints/cracks by tire action, and particularly if micro-cracks in aggregates and asphalt mix are induced by the routing operation. The Transportation Association of Canada (TAC) [13] gives comprehensive information on the stripping potential of aggregates and recommends methods of dealing with the stripping problem.

The type of hot, compressed air lance used on the CFB Goose Bay project may not have had sufficient capacity to remove unsound asphalt concrete within the rout, and may also have oxidized the surface of the asphalt concrete. It is recognized that this type of lance is widely used in crack sealing, but it may not be the most appropriate. A pulse-jet type hot lance expels combustion gases (low oxygen content) at a very high temperature and velocity. This high velocity gas stream quickly heats the treated surface and blows away any unsound materials. This is preferred over the use of hot, compressed air. However, the NRC study [1] indicates that using a hot lance does not enhance the adhesion of good sealants and can cause damage by burning the asphalt cement. It recommends cleaning and drying the rout with high-pressure, oil- and moisture-free, compressed air.

7. RECOMMENDATIONS FOR FUTURE TESTING

It is recommended that a wider wheel for the APA testing (70 mm wide) be used to evaluate the performance of the 40 by 10 mm crack sealant reservoirs. The effect of rout preconditioning on the crack sealant performance should also be evaluated. The preconditioning may include a single application of asphalt emulsion and an anti-stripping additive.

8. CONCLUSIONS

- Shattering of the very hard, brittle meta-arkose/granitic coarse aggregate during the routing operation appears, from the site observations and laboratory examination, to be the main cause of the bond failure between the hot-poured crack sealant and the surface course asphalt concrete.

- The developed method of laboratory testing is effective in accelerated crack sealant performance evaluation.

- Conventional crack sealing involving impact routing is not always cost effective and the routing operation can cause severe damage to the pavement. Simple filling of non-working cracks without routing, done early in the life of the pavement, should be considered.

- The shape of the sealant reservoir should be reconsidered. The current 40 by 10 mm shape is considered by some researchers to be far from optimal due to the increased exposure of wide sealant strips to tire pushing/shear damage. The use of narrower routs with a width/height ratio ≥ 1 and low modulus sealants that provide for less internal strain at low temperatures is recommended.

- The use of random crack saw with diamond blades should be considered, particularly for pavements incorporating hard, brittle aggregates.

Table 1. Summary of Results of Crack Sealant Testing in the Asphalt Pavement Analyzer

LOCATION	SAMPLE CODE	CONDITION-ING	TYPE OF CRACK SEALANT	TYPE OF RESERVOIR	NUMBER OF CYCLES	BRIEF DESCRIPTION OF CRACK SEALANT PERFORMANCE
Runway 16-34	1-3	Dry	A	Saw-cut	8000	Good bond until the end of the test, some slight debonding at both ends of the slab.
	3-3	Dry	A	Routed	8000	Good bond until the end of the test, some slight debonding at both ends of the slab.
	1-1	Wet	A	Routed	2000	Total bond failure after 2000 cycles. Debonding started after 1000 cycles.
	1-2	Wet	A	Saw-cut	8000	Bond failure at 8000 cycles but still some adhesion visible, both ends failed, good bond after 4000 cycles, debonding started after 6000 cycles.
	2-1	Wet	A	Saw-cut	6000	Bond failure but still some adhesion visible, started to debond after 4000 cycles. Total debonding after 8000 cycles.
	2-2	Wet	A	Routed	2000	Bond failure after 2000 cycles but some adhesion still visible, debonding started after 1500 cycles at both ends.
	3-2	Wet	B	Saw-cut	8000	Bond failure but still some adhesion after 8000 cycles, both ends failed, good bond after 4000 cycles, started to debond after 6000 cycles.
Runway 08-26	5-1	Dry	A	Saw-cut	8000	Good bond until the end of the test.
Runway 08-26	8-3	Dry	A	Saw-cut	8000	Good bond until the end of the test, some slight debonding at both ends of the slab.
	5-2	Wet	A	Routed	4000	Bond failure after 4000 cycles but some adhesion still visible. Debonding started after 2000 cycles at both ends.
	7-3	Wet	A	Routed	3000	Total bond failure after 3000 cycles, debonding started after 2000 cycles at both ends.
	8-2	Wet	A	Routed	2000	Total bond failure after 2000 cycles, debonding started to speed up after 1500 cycles starting at both ends.
Taxiway Kilo	9-1	Wet	B	Routed	4000	Bond failure. Debonding started after 2000 cycles at both ends.
	9-3	Wet	A	Saw-cut	4000	The reservoir in the direction transverse to the direction of loading. Bond failure after 4000 cycles but the sealant still holds in place by the adjacent sealant.

Table 2. Summary of Crack Sealant Pull Out Test

FACILITY	SAMPLE CODE	CONDITION-ING	TYPE OF CRACK SEALANT	TYPE OF RESERVOIR	AREA UNDER THE CURVE (J)	MAXIMUM LOAD (N)	OBSERVATIONS		
							Type of Failure	**Edge Deterioration/ De-bonding**	**Edge Adhesion**
Runway 16-34	4-1 S2	Dry	A	Saw-cut	116.6	86.9	Shear/Adhesive	Moderate	Moderate
	4-1 S1	Wet	A	Saw-cut	109.5	86.9	Adhesive	Moderate	Moderate
	4-2 R2	Dry	A	Routed	146.6	97.6	Adhesive	High	Poor
	4-2 R1	Wet	A	Routed	<34	54.8	Adhesive	High	Poor
Runway 08-26	7-1 S2	Dry	A	Saw-cut	62.8	45.4	Shear	Low	High
	7-1 S1	Wet	A	Saw-cut	38.8	28.1	Shear	Low	High
	7-2 R2	Dry	A	Routed	44.8	41.9	Adhesive	High	Poor
	7-2 R1	Wet	A	Routed	<34	51.2	Adhesive	High	Poor
Taxiway Kilo	9-2 S2	Dry	B	Saw-cut	35.1	31.2	Shear	None	High
	9-2 S1	Wet	B	Saw-cut	37.5	28.1	Shear	Low	High

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