Cold 2014 Winter and Early Asphalt Pavement Cracking Observed in Ontario

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ABSTRACT

Properly designed and constructed new asphalt pavements should provide good service for about 20 years they need major rehabilitation. The life of pavement that went through major rehabilitation should be about 15 years. In Zone 3 in Southeastern Ontario the standard asphalt cement grade is PG 58-28. It is typically bumped to PG 64-28 for heavier or slow moving traffic. The asphalt mixes incorporating these asphalt cement grades should be able to withstand the winter temperature down to - 28°C.

The 2014 winter was considered to be very cold in Ontario with the temperature often dropping to -25°C or even lower. There was premature pavement cracking observed recently on number of roads in Southwestern Ontario. Some agencies believe that this was mainly due to the very cold winter. Properly designed and constructed pavements exhibited cracking after 2 to 3 years, and sometimes even 6 months. It has also been observed that this cracking occurred mainly in pavements where PG 64-28 asphalt cement was used. This focused the attention of the road agencies on the quality of asphalt cement used in Ontario. Extensive field and laboratory investigation was carried out. This paper describes three municipal roads that incorporated PG 64-28 asphalt cement and exhibited very early cracking. It presents some of the test results. It comments on methods of asphalt cement modification and present and example of updated specification requirements.

1.0 INTRODUCTION

Properly designed and constructed asphalt pavements incorporating good quality materials are typically anticipated to require major rehabilitation after about 20 or more years of service. The life of pavement that went through major rehabilitation should be about 15 years without the need of any major intervention. It is common belief that this should be true if weather conditions are not extreme. In Southeastern Ontario the standard asphalt cement grade is PG 58-28; it is often bumped to PG 64-28 for heavier traffic and even to PG 70-28 for very heavy traffic. The asphalt mixes incorporating these asphalt cement grades should be able to withstand the winter temperature down to - 28°C. The 2014 winter was considered to be very cold in Ontario with the temperature sometimes dropping to - 25°C or even lower.

There was early pavement cracking observed recently on number of roads in Southwestern Ontario. It has been noted in the last few years and particularly after the 2014 winter. Pavements that were considered to be properly designed and had good quality control/quality assurance (QC/QA) results exhibited cracking after 2 to 3 years or sometimes even after less that a year or even six months. It has been also noticed in some municipalities that mainly the pavements that incorporated PG 64-28 grade have cracked. Investigations are carried out to determine if the cracking is related to very low winter temperatures and particularly if it is related to asphalt cement quality and what testing should be used to screen poorly performing materials.

This paper describes the case studies of three municipal roads that incorporated PG 64-28 asphalt cement and exhibited very early cracking. The investigation included pavement visual condition inspections, QC/QA results review and pavement coring and slab cutting investigation to evaluate the depth of cracking and obtain materials for laboratory testing. The recovered asphalt cement testing included conventional PG grade verification, Multiple Stress Recovery (MSCR), Extended Bending Beam Rheometer (eBBR) and Double Edge Notch Test (DENT). In addition, the recovered asphalt cements were tested for the presence of zinc and molybdenum considered by some researchers to be the indicators of the presence of recycled engine oil in asphalt cement. This paper presents the results for the cracked pavements and provides initial recommendations for updates for asphalt cement specifications.

2.0 PREMATURE PAVEMENT CRACKING OBSERVED IN 2010

Premature asphalt pavement cracking starting with a midlane crack was for the first time observed in the Region of Waterloo in 2010. Photograph 1 shows the centerline cracking observed on Bleams Road after only about 6 months after construction (one winter). Since that time this type of failure was still unique it was not clear how to investigate the failures and to determine the causes of the failure, and develop recommendations for failure prevention.

Extensive field and laboratory investigation was carried out that included Falling Weight Deflectometer (FWD) testing. The investigation was described in a CTAA paper [1]. The conclusions from the investigation were not clear. Based on the FWD testing the structural condition of the pavement was good. The asphalt layers, the foamed asphalt and the granular layers met the specification requirements. The cracking was observed only in the HMA wearing course. The cracked pavement was covered with a single layer of bonded wearing course in 2013. Although the pavement condition in 2014 could be considered to be relatively good, the cracks reflected through the bonded wearing course very quickly. Only recently, after more similar failures were observed by number of municipalities and Ontario Ministry of Transportation (MTO), the attention of the investigation included the checking the quality of the incorporated asphalt cements.

Photograph 1 Midlane cracking of a 6 months old pavement on Bleams Road constructed in 2009 [LU, 2010]

3.0 EXTENSIVE PREMATURE PAVEMENT CRACKING OBSERVED IN 2014

In 2014, an ‘avalanche’ of pavement premature cracking was reported. Initial thought was that such common pavement premature cracking was related to a very cold 2013/2014 winter when the temperature dropped to - 25°C and even less and the periods of cold temperature were relatively long. After more information became available this was then verified. The cracking was generally observed almost exclusively on asphalt pavements that incorporated Performance Graded asphalt cement PG 64-28. The base grade in Zone 3 in Ontario is PG 58-28. For heavy and slow moving traffic the PG grade in this part of Ontario is commonly bumped to PG 64-28 by modification of the base PG 58-28 grade. Region of Niagara and City of Hamilton reported that no premature cracking was observed on projects where the base grade PG 58-28 was used. Therefore, it was concluded that the method(s) of asphalt cement modification to bump it from 58-28 to 64-28 had a drastic negative impact on asphalt pavement performance. While it is obvious that other aspects such as the percentage of added Reclaimed Asphalt Pavement (RAP) or asphalt cement content in the HMA mixes could also had an impact on pavement performance, it became obvious that the main focus should be on the quality of the asphalt cement.

By 2015, Region of Waterloo observed premature cracking of pavements that were 2 to 4 years old on total of 33 km long sections. Region of Waterloo commonly uses PG 64-28 on its roads. Fever premature cracking failures were observed at Region of Niagara likely because the Region commonly uses PG 58-28 asphalt cement and bumps the grade to 64-28 on few roads. However, the premature cracking on Portage Road that was full depth rehabilitated (pulverizing the existing HMA and mixing with underlying granular layer material, placement of additional 150mm if new granular layer followed by the placement of 100mm of new HMA in two lifts) and the pavement cracked after only 6 months raised the alarm. The Region used PG 64-28 asphalt cement on this road.

Photographs 2 to 7 show examples of premature cracking on Katherine Street, Trussler Road, Swan Street and Moser Young Road in Region of Waterloo. Photographs 8 and 9 are from Portage Road in Region of Niagara. The similarity in the cracking pattern is obvious. The most visible is the medium severity midlane cracking. Low severity random cracking was also observed. Careful pavement inspection also revealed extensive pavement microcracking.

Photograph 2 Multiple midlane cracks on Katherine Street [VH, 2014]

Photograph 3 Midlane and longitudinal cracking on Katherine Street [VH, 2014]

Photograph 4 Midlane cracking on Trussler Road [VH, 2014]

Photograph 5 Midlane, longitudinal and check cracking on Swan Street [VH, 2014]

Photograph 6 Midlane cracking on Moser Young Road [VH, 2014]

Photograph 7 Check cracking on Moser Young Road [VH, 2014]

Photograph 8 Cracking on Portage Road constructed in 2013 [VH, 2014]

Photograph 9 Cracking on Portage Road constructed in 2013 [VH, 2014]

4.0 QC/QA DOCUMENTATION REVIEW AND PAVEMENT FIELD INVESTIGATIONS

Extensive pavement failure investigations were carried out on Katherine Street and Trussler Road in Region of Waterloo and Portage Road in Region of Niagara. The available Quality Control (QC) and Quality Assurance (QA) documentation was carefully reviewed. It revealed that the mix designs and the field and laboratory testing results generally met the specified requirements. A program of field and laboratory investigation was developed. It included pavement visual condition inspection, checking the pavement for permanent deformation (rutting), slab cutting in order to determine the depth and type of cracking and obtaining material samples for laboratory testing. The program also included checking of the depth and quality of the underlying granular layers.

Photographs 10 to 13 were taken during the investigation of a pavement in Region of Waterloo. None of the failed pavement exhibited permanent deformation (Photograph 10). Asphalt layers cuts were typically carried out across medium severity cracks (Photograph 11). One cut was done at a good location (with no cracks) for comparison purposes. The premature cracks in the investigated pavements were mainly observed only in the surface course. The underlying binder course was intact (Photograph 12). This clearly indicated that the cracks were not of the fatigue bottom up type. Photograph 13 shows the reinstatement of the granular base after checking its quality of obtaining granular material samples for laboratory testing. On all investigated pavements the quality of the granular layers was good to very good. The granular material was dry and met the specified requirements.

Photograph 10 No rutting was observed on the 2 years old cracked pavement [LU, 2014]

Photograph 11 Cutting asphalt slab as part of the failure investigation on 2 year old pavement [LU, 2014]

Photograph12 The crack in the investigated pavement was observed only in the surface course [LU, 2014]

Photograph 13 Reinstatement of the granular base layer after checking its quality and obtaining samples for laboratory testing [LU, 2014]

The documentation review and field investigation clearly showed that the pavement as constructed was of good quality in terms of meeting the specified requirements. The asphalt pavements did not exhibit any rutting and there were no signs of any fatigue cracking.

5.0 ASPHALT LAYERS LABORATORY TESTING

The obtained samples were to the laboratory for asphalt mix and asphalt cement testing. There were Superpave mixes from Region of Waterloo and Marshall mixes from Region of Niagara. The testing of the HMA mixes revealed that all of them met the Superpave or Marshall properties requirements and construction requirements as covered in Ontario Provincial Standard Specifications OPSS.MUNI 1151

“Material Specification for Superpave and Stone Mastic Asphalt Mixtures”, OPSS 1150 “Material Specification for Hot Mix Asphalt” and OPSS 310 “Construction Specification for Hot Mix Asphalt”.

Because of concerns about the quality of the incorporated asphalt cement it was decided that besides the conventional asphalt cement testing as covered by OPSS.MUNI 1101 “Material Specification for Performance Graded Asphalt Cement” more advanced testing was also needed. Based on the literature review like the ones presented in [2] it was decided to include, besides the conventional M320 verifying of asphalt cement continuous grade, (based on dynamic shear $G^*/\sin\delta$, $G^* \sin\delta$ and creep stiffness and m-value in BBR test) to include the ash test, Multiple Stress Creep Recovery (MSCR) test, Double-Edge-Notched Tension (DENT) test, and Extended Bending Beam Rheometer (Ex BBR) test. All laboratory testing of asphalt cement was carried on the binder recovered from the cut or cored samples. No virgin asphalt cement was available for testing. In addition the recovered asphalt cement was also tested at Queens University in Kingston for the presence of zinc and molybdenum and carbonyls in order to check the potential that the PG 64-26 was modified by blowing and addition of recycled engine oil.

Table 1 shows the results of the testing on Trussler Road and Portage Road.

Table 1 Summary of PG 64-28 testing results

Road	Test						
	Continuous Grade	MSCR		DENT (mm)	Ex BBR		Presence of Zinc and Molybdenum
		$J_{nr-3.2}$	% recovery		LTLG	Grade Loss	
Trussler Road	83-27	0.049; 0.051	49.0; 51.2	3.9; 3.2	-21.0; -20.9	6.1; 6.6	Yes
Portage Road	84-23	0.047	52.6	5.1	-17.9; -21.3	10.7; 8.1	Yes

6.0 MODIFICATION OF ASPHALT CEMENTS

As shown in the previous section, there was indication that the tested PG 64-28 asphalt cements obtained from the pavements that exhibited premature cracking contained carbonyls and some amount of zinc and molybdenum. This indicates that the PG 64-24 grade was likely obtained by blowing the base PG 58-28 asphalt cement and then adding recycled engine oil.

There are number of publications that suggest that the addition of the recycled asphalt cement does not harm to the asphalt cement. Some of those papers were presented in the past at Canadian Technical Asphalt Association (CTAA) conferences [3 to 6]. However, there were also papers presented at CTAA conferences that indicate that the addition of recycled engine oil is harmful particularly after the base asphalt is oxidized 2 and 7]. This method of asphalt cement modification causes physical hardening that is then reflected in asphalt mix brittleness and premature cracking.

In Ontario MTO is very concerned about the premature cracking and is carrying extensive studies and field trials in order to evaluate the causes and develop the testing method and limits to be included in the specifications. Ontario Hot Mix Producers Association (OHMPA) has formed a Task Force that looks at the causes of cracking and the ways of preventing it.

7.0 ASPHALT CEMENT SPECIFICATION

Some of municipalities have developed their own asphalt cement specifications or special provisions to address the premature cracking issue. Table 2 shows an example of the test and limits used in some of the specifications.

Table 2 Testing requirements and acceptance criteria for PGAC grades

PGAC Grade	Property and Attributes (Unit)	Test Method	Results Reported Rounded to the Nearest	Acceptance Criteria		Rejectable
All PGAC Grades	Ash Content, % by mass of residue (%)	LS-227	0.1	≤ 0.8		>0.8
All PGAC Grades except PG58-28 and PG52-34	Low temperature limiting grade (LTLG) (°C)	LS-308	0.5	-25		-25
	Grade Loss (°C)		0.5	≤ 6		>6
	Non-recoverable creep compliance at 3.2 kPa ($J_{nr-3.2}$) (kPa^{-1})	Multiple Stress Creep and Recovery (MSCR) testing according to AASHTO T 350 testing conducted at a temperature of 58 °C	0.01	< 4.5		≥ 4.5
	Average percent recovery at 3.2 kPa ($R_{3.2}$) (%)		0.1	> the lesser of [(29.371) $(J_{nr-3.2})^{-0.2633}$] or 55		≤ the lesser of [(29.371) $(J_{nr-3.2})^{-0.2633}$ -10] or 55
	Percent difference in non-recoverable creep compliance between 0.1 kPa and 3.2 kPa, J_{nrdiff} (%)		0.1	N/A Testing carried out only for information purpose		
	Average critical crack tip opening displacement (δt) (mm)	LS-299	0.1	≥ 8		<8

8.0 CONCLUSIONS

Premature cracking of asphalt pavements in Ontario is of very serious concerns to the owners and the industry. Although it is likely that the very cold winter temperatures speeded up the pavement cracking there is a concern that one of the main causes of the premature cracking is excessive physical hardening of asphalt cements, particularly PG 64-28, that is likely related to the way of asphalt cement modification. The agencies and the industry are putting a lot of effort now in determining the causes of cracking and proper ways of modifying the asphalt cement specifications, and setting the proper testing and acceptance limits.

Whatever the causes of the failures are and the final testing and acceptance limits, it is the authors' opinion that before any methods of asphalt cement modification are used, they should be investigated, trial sections should be constructed and monitored and it should be well proven that they do not compromise pavement performance. These testing methods and acceptance criteria should be clearly stated in the specifications.

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