Specification Improvement to Deliver Safe and Durable Concrete Pavement in Ontario

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Paper prepared for presentation at the
Innovation in Geotechnical and Materials Engineering Session

at the 2020 TAC Conference & Exhibition

ABSTRACT

The Ontario Ministry of Transportation strives to provide a safe, reliable and efficient transportation system to the travelling public. Constructing safe and durable pavement is critical to achieve this mandate.

Ontario has a significant amount of concrete pavement, which includes 849 lane-kms of exposed concrete pavement and 2,187 lane-kms of composite pavement. In 2018, a substantial update to the concrete pavement specification was completed. Significant changes were made to improve the durability of the concrete pavement joints in order to minimize the risk of premature joint deterioration, which can be a safety hazard if the deterioration is severe. Changes to address premature joint deterioration included improved concrete properties and changes to the joint design. The specification implemented the use of longitudinal grooving to replace transverse tinning, which promotes sustainability and safety by reducing hydroplaning and noise levels. Also, the concrete aggregate material specification was updated to increase the insoluble residue content to improve concrete pavement frictional resistance. Furthermore, to improve quality assurance efficiency, smoothness is measured using an Inertial Profiler replacing the use of the California Profilograph.

The changes to the concrete pavement specification are critical to ensure a quality product. To date, a few ministry contracts have been constructed using the updated specification. Details of the specification update and impact to the quality are documented in this paper.

1. INTRODUCTION

The Ministry of Transportation Ontario (MTO) is responsible for constructing durable pavement to ensure the safety, reliability, and efficiency of the transportation system. MTO has a significant amount of concrete pavement, which includes 849 lane-kms of exposed concrete pavement and 2,187 lane-kms of composite pavement.

MTO first observed a problem with premature joint deterioration of concrete pavement in one section of a highway (approximately 12 km long) in the eastern part of the province. Many of the joints in this section of the highway were exhibiting severe spalling and deterioration on both the transverse and longitudinal joints. The deterioration was occurring in the area surrounding the joint sawcut, starting at the bottom of the sawcut, and progressing outward and upward, eventually leading to spalling of the joint. The deteriorated zone was typically in the upper third of the thickness of the concrete pavement.

The severe deterioration that occurred in one section of highway, became visible at the surface of the pavement after 8 years of service. This section of highway was reconstructed due to the premature joint deterioration only 14 years after it was constructed. Thus, the concrete pavement life cycle was significantly impacted due to this type of premature joint deterioration.

Premature joint deterioration of concrete pavements, also known as "joint rot" is a problem reported to have occurred on several highways in cold weather climates. Research and a jurisdictional scan were carried out to identify solutions to address this problem. This has led to the changes to the concrete pavement specification in 2018.

2. FIELD OBSERVATIONS

Premature joint deterioration in concrete pavements was first observed 8 years after construction in a section of the westbound lanes (WBL) of Highway 417, between Ottawa and Montreal (Figure 1).

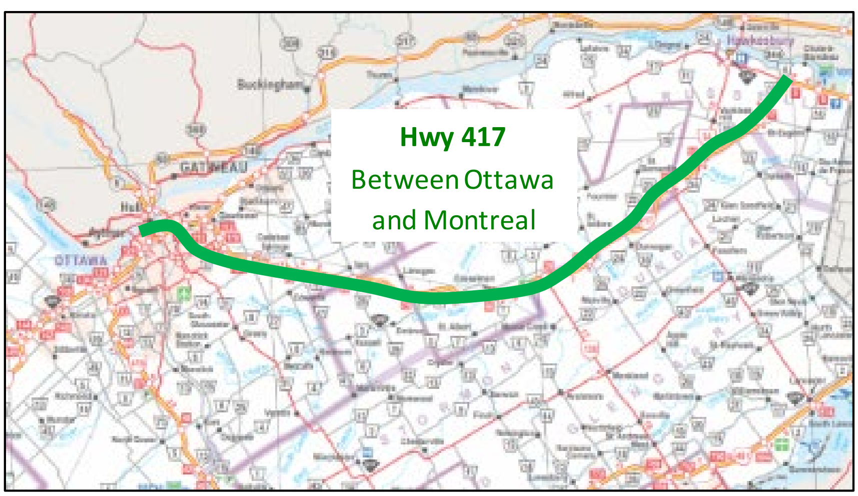

Figure 1: Highway 417 Between Ottawa and Montreal

Many joints in this section of concrete pavement, both longitudinal and transverse, were visibility deteriorated and spalled at the pavement surface (Figure 2). There were also joints in this section that appeared intact at the surface. An investigation was carried out by taking cores at the joints that appeared intact to examine the condition of the concrete below the sealant. Cores were also taken mid-panel to test the material properties of the concrete. In addition to the core samples taken from the deteriorated section of the highway, cores were taken from adjacent sections, constructed at approximately the same time, but which were not exhibiting signs of distress at the surface. Examination of these cores revealed significant deterioration in the sections of the highway not yet exhibiting surface distress. Examination of the cores and joints revealed that water entering the joints was not moving through to the underlying base. Some cores had very narrow, hairline cracks, which limited the flow of water through the joints and some joints remained uncracked.

Figure 2: Deteriorated Joints on Highway 417

A core taken at a joint on Hwy 417 that appeared to be intact, revealed significant deterioration of the joint below the sealant (Figure 3). This was typical of the joints from this contract of Hwy 417 where there was no significant deterioration at the surface.

Figure 3: Deterioration Below the Surface of a Visibly Intact Joint on Hwy 417

Based on the finding that even a visibly intact joint has underlying deterioration, an investigation was carried out to determine if the same problem was occurring in concrete pavement elsewhere in the province. Sections of concrete pavement were examined on Highway 401 near Windsor and Highway 410 near Brampton, where there were no signs of deterioration at the pavement surface. However, further investigations showed some freeze-thaw damage has been occurring at these joints (Figure 4), but at lower severity than Highway 417.

Figure 4: Premature Joint Deterioration (core taken from Highway 410)

From observations, the joint deterioration started in the area of the initial joint sawcut and reservoir cut, below the joint sealant. It appeared to have started in the lower half of the sawcut zone, and worked its way out and up, eventually popping off the surface of the concrete pavement. Deterioration was typically limited to the top third of the concrete in the joint area. Concrete below the joint sawcut was not affected, and adjacent concrete outside of the joints was not affected.

Field investigations, literature review, and discussions with other agencies, technical organizations and experts were carried out in order to determine the cause of the problem and potential solutions. Freeze-thaw damage of critically saturated joints, together with paste deterioration due to chemical attack were identified as the primary factors causing the premature joint deterioration (1). Concrete material properties and joint design were identified as the two main factors to address the premature joint deterioration (2). The concrete pavement specification was updated with changes to the specified material properties, the joint design, along with other changes including replacing contractor quality control with owner quality assurance testing for smoothness and dowel bar alignment for acceptances, and changes to aggregate specification to improve friction properties.

3. OVERVIEW OF SPECIFICATION UPDATES 2018

Addressing premature joint deterioration in concrete pavements was the catalyst for the significant update to the concrete specification in 2018. The Ontario provincial standard for concrete pavement construction (OPSS 350) was deleted and replaced with a non-standard special provision PVMT 0007. Revisions to this special provision were made in 2019, and again in 2020.

3.1 Concrete Material Properties

One of the changes made to address the issue of premature joint deterioration was to strengthen the material property requirements in the special provision. Changes were made to concrete strength, permeability, air void system, and the maximum allowable slag content.

The 28-day compressive strength, tested on cores, was increased from 30 MPa to 35 MPa. The update also introduced a requirement for a maximum permeability of 2,500 coulombs using the rapid chloride permeability (RCP) test, tested on cores. A requirement for a minimum hardened air system (AVS) of 3% air content and a maximum spacing factor of 0.230 mm for tested cores, was also added to the specification.

Based on recommendations from technical experts, the maximum allowable slag content was increased from 25% to 30%. The higher allowable slag content can improve the resistance of concrete to de-icer attack in a saturated freeze-thaw environment (3). A 3-year scaling warranty was also added to the special provision.

These changes to the material properties were made to improve the durability of the concrete in the joint.

3.2 Joint Design

One of the major changes in the new special provision is the joint design. The joint design was changed from one which included a 25 mm wide reservoir cut with backer rod to a 6 mm wide joint filled with a low-modulus joint sealant (Figure 5).

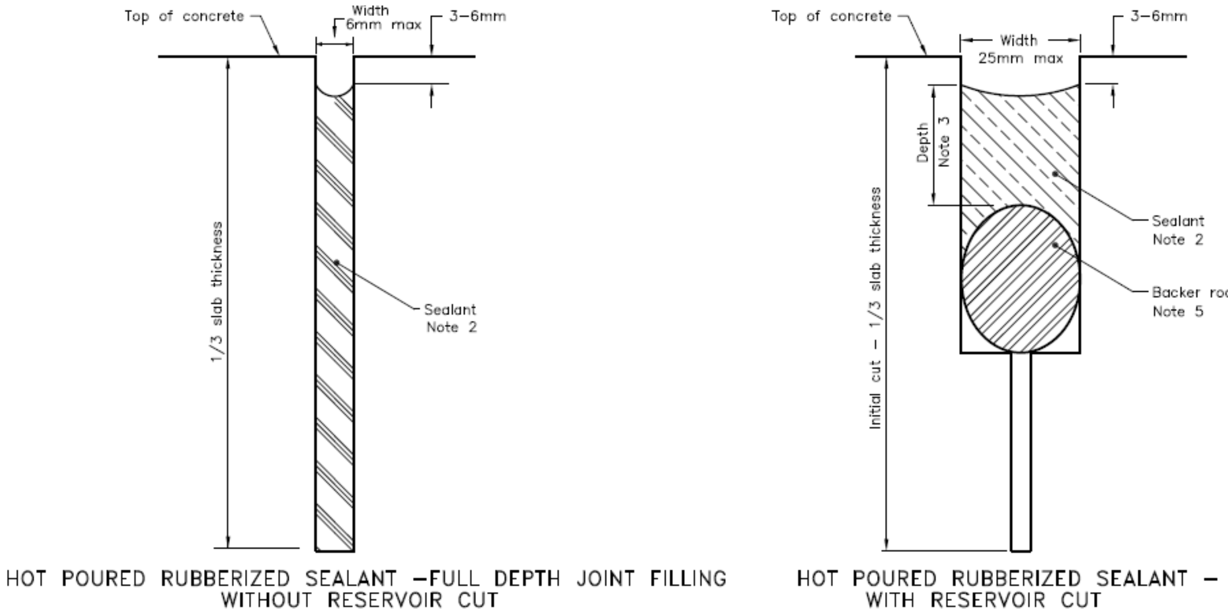

Figure 5: New and Old Joint Design Schematics

This change in joint design was made, because it was found that the joint deterioration started in the area below the joint sealant and backer rod, and above the bottom of the sawcut. Water, containing deicers, ponded in this area leading to the joint deterioration. The new joint design is narrower with a maximum width of 6 mm (Figure 6), and the joint is filled top to bottom with joint sealant.

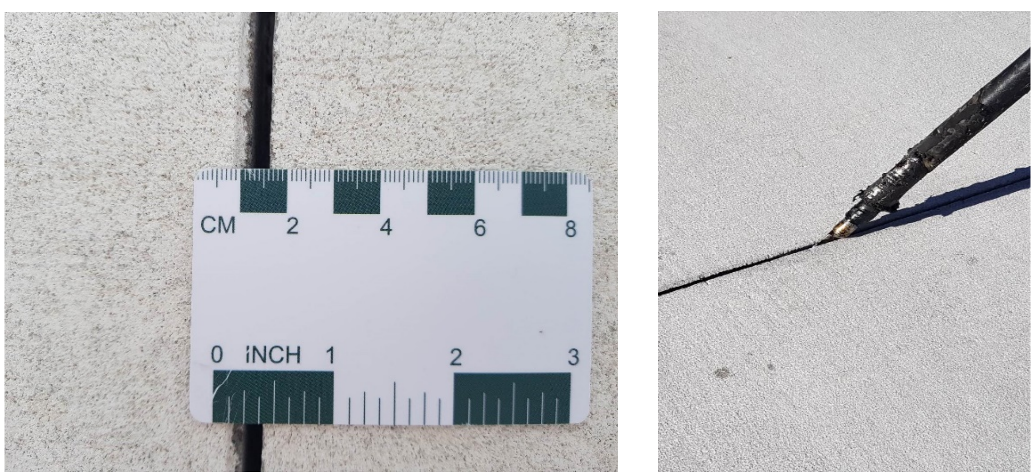

Figure 6: New Narrow Joint Design

The new joint design minimizes the volume of liquid that can be present in the joint. This approach of joint filling has been used successfully by other agencies such as New York Department of Transportation (NYDOT) and is recommended by experts in the field. This is also documented in the American Concrete Pavement Association (ACPA) Technical Bulletin (4).

3.3 Smoothness and Dowel Bar Alignment

In recent years, MTO has transitioned from contractor quality control (QC) testing to owner quality assurance (QA) testing for acceptance. As a result, the revision of this special provision also replaced QC testing with QA acceptance testing including adding a referee processes for the measurement of pavement smoothness and dowel alignment.

Dowel bar alignment is critical to ensure there are no locked-up joints preventing slab movement for expansion and contraction. An MIT Scan is employed to measure dowel alignment in a non-destructive manner. The payment factor is calculated using percent within limits (PWL), where PWL lower than 50% is rejectable, and PWL greater than 90% is acceptable. Between PWL of 50% and 90% a payment adjustment is applied.

Smoothness measured using a high-speed inertial profiler replaced measurement using a California Profilograph. The inertial profiler service providers must successfully complete the MTO inertial profiler correlation program. The smoothness measurement is an average of the right and left wheel path to determine the mean roughness index (MRI). The maximum acceptable MRI is 1.0 m/km, and sublots with MRI greater than 1.25 m/km are rejectable. Localized areas of roughness shall not exceed an MRI of 3.5 m/km. The MRI smoothness requirements for concrete pavement are now the same as asphalt pavement.

QA acceptance testing of smoothness and dowel bar alignment ensures that acceptable pavement smoothness and dowel alignment are achieved.

3.4 Improved Friction

Fine aggregate quality has a significant influence on the concrete pavement long term friction performance. High carbonate content of fine aggregate is prone to premature polishing and friction loss. To achieve adequate long-term friction, specifying a higher non-carbonate content is vital. A requirement was added to the special provision to have a minimum of 60% insoluble (non-carbonate/siliceous) residue content in the fine aggregate, when tested according to MTO LS-613 (5).

MTO has examined the use of alternative solutions to replace the transverse tining in concrete pavement, to address the tonal noise and friction considerations. Numerous neighbourhood noise complaints about a recently constructed transverse tined concrete highway, led the ministry to construct a noise barrier along a stretch of that highway. This has raised concerns at the design stage that a separate environmental assessment should be warranted for alternatives to conventional asphalt pavement projects that have a projected noise level of more than 3dB above conventional asphalt pavement. Based on literature review and testing done by the ministry, it was found that longitudinal grooved concrete pavement without transverse tining has a noise level similar to asphalt pavement. Also, significantly less wheel spray during rain were observed on longitudinal grooved concrete pavements compared to transversely tined concrete pavements. This MTO special provision was amended to include burlap drag and longitudinal grooving as the final texture. Diamond grinding is permitted to correct smoothness deficiencies (Figure 7).

Figure 7: Final Diamond Grinding and Grooving Texture

The specification revision improved the overall friction of the concrete pavement by specifying fine aggregates with higher insoluble residue and the adoption of diamond grooving to achieve the final texture.

4. CONTRACT RESULTS AND CHALLENGES

A few major changes were implemented in the 2018 special provision, including changes to the specified material properties, a new joint design, and increased smoothness requirements. A summary of the contract results and challenges encountered are presented in this section.

4.1 Contract Results

Average acceptance results for all contracts carried out to date under the new specification are presented in Table 1. Results show that the specified material acceptance requirements can be met. (Table 1).

Table 1: Summary of Contracts Results

Criteria	Average Results	Requirement
28-day Compressive Strength (MPa)	50.2	35 (minimum)
Hardened air content (%)	4.6	3.0 (minimum)
Spacing Factor (mm)	0.156	0.230 (maximum)
RCP (coulombs)	1377	2500 (maximum)
MRI Smoothness (m/km)	0.698*	1.000 (maximum)

*Note: Some sections were diamond ground.

On average, results met the 2018 concrete pavement specification requirements for compressive strength, air void system, spacing factor, permeability, thickness, and smoothness.

4.2 Contract Challenges

During the implementation of the 2018 concrete pavement specification, several challenges were identified. There were some feasibility concerns expressed by industry regarding the changes to the material property requirements. However, as outlined above, contract results demonstrate that the new requirements can be achieved (Table 1).

Another challenge was the construction of the new joint design. The contractor was required to produce a narrow joint cut with a maximum width of 6 mm, properly clean the joint to remove sawcut slurry and debris and then fill with a low modulus hot poured rubberized asphalt joint sealant to completely fill the joint. Cores were taken from joints to assess the joint cleaning and filling. Figure 8 shows an example of a well filled joint.

Figure 8: Core at the Joint Filled with Sealant

5. LESSONS LEARNED AND REVISIONS

5.1 Special Provision Changes in 2019

It was noted the total incentives applied to the concrete pavement item were too high. As such, a revision was made to the payment calculation to reduce the bonus. The maximum bonus for smoothness was reduced from 5% to 2%. The total maximum bonus for the concrete pavement item was changed to 5%, which includes 2% for smoothness, 2% for AVS, 0.5 % for strength, and 0.5% for thickness. The total maximum bonus for concrete base is 3%, which includes 2% for AVS, 0.5 % for strength, and 0.5% for thickness.

Some construction timing and procedures were changed in the 2019 special provision. Curing must be applied within 15 minutes of being formed by the paver (instead of 10 minutes, as was specified in the 2018 special provision). The Contractor can elect to complete the joint sealing prior to or after grooving, and any topping up of joint sealant must be completed within 8 hours of the first application. The 2019 special provision also included a clarification that the MIT scan data should be converted to absolute values prior to analysis.

5.2 Proposed Changes to the Special Provision

Proposed changes in the next update to the specification include taking an additional core per sublot for measurement of thickness. The current specification measures thickness on the cores used for compressive strength. Taking an additional core for thickness measurement allows the core to be taken after any repairs are carried out and is thereby representative of thickness of the pavement after repairs such as diamond grinding. It also allows referee testing, if invoked, to be done on the same core as was measured for acceptance, thereby minimizing variations that would results from re-sampling.

In terms of ensuring joint performance, another proposed change is to add a provision for samples to be taken at joints to determine if the joints have been cleaned and sealed according to the requirements. Also, a requirement for a double boiler, oil jacketed kettle for the melting the joint sealant will be added.

6. CONCLUSIONS

Premature joint deterioration is a serious problem in concrete pavements that directly reduces the service life, reliability, safety, and efficiency of the roads. Based on field investigations and research, MTO made significant changes to the concrete pavement specification (NSSP PVMT 0007) in 2018.

By implementing the 2018 specification, MTO was able to collect and compare concrete material properties and smoothness data.

In summary, the new concrete pavement special provision has improved concrete properties; adopted a new joint design that would mitigate the joint durability concerns; improved pavement smoothness and noise level by specifying longitudinal grooving as the final texture; and improved the long-term frictional properties by specifying high insoluble residue fine aggregate. MTO will continue to monitor and update the special provision as required to ensure concrete pavement sustainability is achieved.

7. REFERENCES

1. **Peter Taylor, Jiake Zhang, and Xin Wang.** *Conclusions from the Investigation of Deterioration of Joints in Concrete Pavements.* Iowa State University Institute for Transportation : National Concrete Pavement Technology Center, February 2016.

2. **Peter Taylor, Robert Otto Rasmussen, Helga Torres, Gary Fick, Dale Harrington, Tom Cackler.** *Interim Guide for Optimum Joint Performance of Concrete Pavement.* Iowa State University : National Concrete Pavement Technology Center, June 2012.

3. **R. Doug Hooton and Dimitre Vassilev.** *Deicer Scaling Resistance of Concrete Mixtures Containing Slag Cement, Phase 2: Evaluation of Different Laboratory Scaling Test Methods.* Iowa State University Institute for Transportation : National Concrete Pavement Technology Center, July 2012.

4. **American Concrete Pavement Association.** Concrete Pavement Joint Sealing/Filling. *Technical Bulletin.* TB010-2018, 2018.

5. **Ministry of Transportation Ontario, Laboratory Testing Manual.** *Method of Test for Determination of Acid Insoluble Residue of Aggregate.* Downsview : MTO. LS-613.