Ministry of Transportation of Ontario Quiet Pavement Studies

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ABSTRACT

In 2009, Ministry of Transportation of Ontario (MTO) initiated a study on the effectiveness of using different asphalt mix types in reducing noise arising from the tire-pavement interaction at the source. Five trial asphalt sections were constructed in October 2009 on Highway 405 in the Niagara Region.

In 2015, MTO Eastern Region also conducted a quiet concrete pavement study to compare NGCS (Next Generation Concrete Surface) pavement with several conventional transversely tined concrete pavements. On Board Sound Intensity (OBSI) measurements were conducted according to AASHTO TP76-12 on a total of nine (9) sections of Highways 115, 417, 401 and 410.

In 2022, MTO Pavements Section undertook another OBSI noise study on seven (7) test sections along Highways 401, 402 and 404 located in Western and Central Regions. These studies generally used asphalt mix sections as controls, consisting of Superpave 12.5 FC2 or SMA 12.5 (Stone Mastic Asphalt) asphalt surface mixes. The remaining sections were concrete sections of varying ages with different surface texture treatments such as grooving, tining or a combination thereof.

From the studies conducted by the ministry, the development of quiet pavement alternatives can provide a more cost-effective solution to address noise pollution in urban areas than use of noise barriers. The studies have shown that pavements with different textures provide different noise reduction effects and open graded asphalt mixes and longitudinally grooved concrete pavements have shown the best long-term performance in sound mitigation. This paper presents the findings from the above noted pavement noise studies conducted by MTO between 2009 and 2022. Longitudinal grooved concrete pavement and open graded asphalt pavement textures are found to provide the best tire-pavement noise mitigation at the source for the flexible and rigid pavement, respectively. It is recommended to upgrade the traffic noise model (TNM) developed by Federal Highway Administration (FHWA) that MTO is currently using to account for new pavement textures, which is essential for accurate environmental screening of road projects.

1. INTRODUCTION

The Ministry of Transportation Ontario (MTO) is responsible for the design, construction, maintenance, and preservation of Ontario's highway network, which includes about 40,000 lane-km of highways [1]. One of the challenges that transportation agencies face is reducing vehicle-pavement noise, especially on high speed and high-volume highways near urban areas. The noise generated by vehicles is mainly due to the interaction between the tires and the pavement.

To address this issue, MTO has investigated and promoted the use of quiet pavements, which can help reduce the noise at the source. Two types of noise measures are commonly used in roadway studies, The Statistical Pass-By Index (SPBI) and the On-Board Sound Intensity (OBSI). The OBSI method allows for the relative comparison of the noise generation potential of the different roadway surfaces and has been selected for initial 2009 quiet asphalt pavements study and subsequent 2015 and 2022 quiet concrete pavement studies.

The Next Generation Concrete Surface (NGCS) technology has been shown to provide the quietest concrete texture, and more transportation agencies have shown interest in using it for noise mitigation [2,3,4]. MTO has conducted quiet pavement trials using different surface mixes and the NGCS technology on various highways since 2009. MTO has adopted a new hybrid concrete pavement specification requiring a burlap dragged and longitudinal groove texture with full NGCS texture as a permissible option. This has resulted in significant improvements in noise reduction and smoother ride compared to transversely tined concrete pavement and provide near equivalent performance to the best asphalt quiet pavement texture.

The current traffic noise model (TNM) developed by Federal Highway Administration (FHWA) that MTO is using for environmental screening of road project is found to be unable to model the noise reduction associated with longitudinal grooved concrete or NGCS pavements [5]. Overall, the MTO's efforts to promote and adopt quiet pavements on its highway network are aimed at providing a safe, reliable, efficient, and environmentally sustainable system for road users in Ontario.

2. BACKGROUND AND PURPOSE

Overall, the three studies presented in this paper aim to investigate the noise reduction performance of quiet asphalt and concrete pavements with different textures and ages compared to conventional asphalt pavements. The results of these studies can provide valuable insights into the effectiveness of quiet asphalt and concrete pavements as a noise mitigation measure, especially in areas adjacent to noise sensitive areas.

The findings can also contribute to the improvement of noise prediction models and methodologies used by the Ontario Ministry of Transportation (MTO) for traffic noise assessments. Additionally, the study results can provide a more cost-effective alternative solution to noise barriers, which have traditionally been used for noise mitigation in urban areas.

Overall, the studies can provide a better understanding of the noise reduction performance of new asphalt and concrete pavement texture technologies and their potential use in highway resurfacing projects in noise-sensitive areas.

3. 2009 QUIET ASPHALT PAVEMENT STUDY

In 2009, MTO carried out a quiet asphalt pavement study consisting of five 500 m sections on Hwy 405 near Niagara Falls. The five asphalt surface trial mixes consisted Open Friction Surface Course on Open Graded Binder Course, Open Graded Friction Course on conventional SP 19 Binder Course, Rubber Asphalt Open Graded Course on SP 19 Binder, SMA Surface Course on SP 19 Binder Course and 12.5FC2 Surface Course on SP 19 Binder Course (control section). The results and findings of this study was published in a 2019 Canadian Technical Asphalt Association (CTAA) paper [6].

Human perception of noise and sound can vary based on individual sensitivity and subjective factors. However, there are commonly used scales and metrics that help quantify and characterize noise and sound levels. Two widely recognized scales used to measure and describe noise and sound include the decibel (dB) scale and the A-weighting scale (dBA). The sound pressure level, historically called the decibel (dB), is the absolute amount of pressure change exerted in the air by a sound. The decibel scale is a logarithmic scale used to measure the intensity or level of sound. It compares the sound pressure level to a reference level. On the decibel scale, small increases in decibel values correspond to significant increases in sound intensity. The scale is often used to represent a wide range of sound levels, from the faintest audible sounds to extremely loud sounds. A-weighted decibel (dBA or dB(A)) is an expression of the relative loudness of sounds as perceived by the human ear. A-weighting is the standard for determining hearing damage and noise pollution. Generally, a change of 3 dB is accepted as the smallest difference in level that human being can hear, and a five-decibel change is clearly noticeable to the ear [7]. In this trial, the MTO's criteria for successful noise attenuation is a target of reducing the current noise level by 5 dB. The OBSI noise measurements in Figure 1 showed that the noise reduction performance of the various asphalt trials taken immediately after construction, 1,3 and 4 years after construction. From the noise measurements over time, it is noted the open graded surface mixes provide better initial noise reduction initially but lose their noise reduction effectiveness with time. Original asphalt surface mixes noise reduction effectiveness is not maintained over time but remain quieter than conventional pavements [8,9].

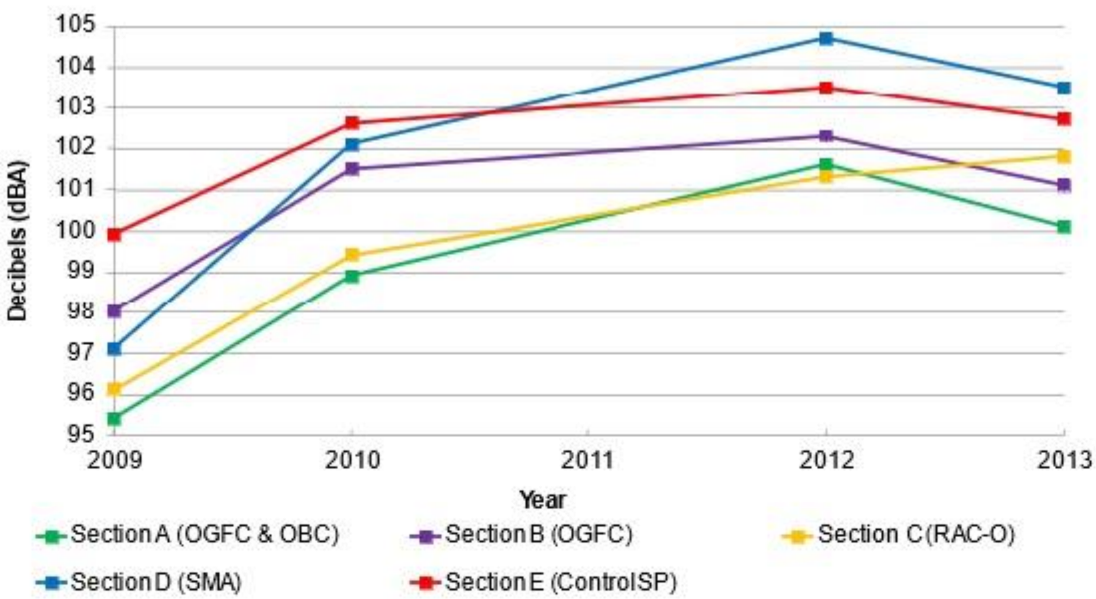

Figure 1. Noise Reduction Performance of Asphalt Surface Course Trials

4. <u>2015 MTO EASTERN REGION (ER) QUIET PAVEMENT STUDY</u>

4.1 Scope of Study

The 2015, a quiet pavement study conducted by MTO's Eastern Region aimed to compare the noise reduction performance of longitudinally grooved concrete pavement with several concrete pavements that had transverse, longitudinal tining and asphalt pavements. The study used OBSI measurements according to AASHTO TP76-12 method on nine sections of highways in Ontario. The study also included control sections with typical SP12.5 FC2 and SMA asphalt surfaces to better understand the noise reduction performance of the concrete pavement alternatives.

4.2 Description of Test Sections

The site descriptions and construction years for the nine test sections are shown in Table 1. Figures 2 and 3 highlight the newly grooved on Highway 115 and transversely tined concrete pavement along Highway 401 respectively.

Table 1. Site Descriptions of ER Quiet Concrete Pavement Study

Section	Highway	From	To	Pavement Type	Construction Year
1	115	EB 1.0km E of Hwy 35 IC	EB 200m E of County Rd 20 Boundary Rd	Concrete Longitudinal Grooving	2012
2	115	EB 100m East of Tapley Quarter Lline	EB 700m East of Hwy 7A	Concrete Longitudinal Grooving	1997
3	115	WB 1.1 km West of Hwy 7	WB 100m East of Hwy 7A	Concrete Longitudinal Grooving	1997
4	115	WB 1.5km East of Tapley Quarter Line	WB County Rd 20 Boundary Rd	Concrete Longitudinal Grooving	2011
5	115	WB Boundary Rd	WB 1.0km East of Hwy 35	Asphalt Surface SP12.5 FC2 (CONTROL SECTION)	1992
6	417	WB Hwy. 34 Exit 27	WB C.R. 23A Exit 35	Concrete Transverse tining	2003
7	417	EB Hwy. 34 Exit 27	EB C.R. 23A Exit 35	Concrete Transverse tining	2000
8	410	NB Bovaird Drive	NB Mayfield Rd.	Concrete Transverse tining	2007
9	401	EB Collector Lane Hurontario St Sta 19+000	EB Collector Lane Hurontario St Sta 20+000	Concrete Transverse tining	2013

Figure 2. Newly Longitudinally Grooved Concrete Pavement on Highway 115

Figure 3. Concrete Pavement with Transverse Tining on Highway 401

4.3 Test Method

A 500m long section of pavement was selected at each of the sites for On Board Sound Intensity (OBSI) measurement. Within each test section, OSBI measurements were recorded for five consecutive 100 m segments, and for the overall 500 m length. Three runs were done each time.

On Board Sound Intensity (OBSI) measurements were conducted according to AASHTO TP76-12 using a Uniroyal “Tigerpaw” AS65 tire (P225/R16). The measurements were taken at a speed of 100 km/h. The testing commenced on October 15 and was completed on November 4, 2015.

4.4 Summary of Test Results

The data presented in Table 2 and Figure 4 show that there is a marked difference in the noise levels generated by different textures of concrete pavement. Specifically, the transversely tined concrete pavement produces noise levels as high as 110 dBA, which is significantly louder than the noise levels produced by concrete pavement with longitudinal grooving (around 104 dBA). This difference in noise levels exceeds 5 dBA, which is noticeable to the human ear.

In contrast, the normalized OBSI measurement of PCC longitudinal grooving (ranging from 103.2 to 103.9 with an average of 103.6) is comparable to the control section composed of Hot Mix Asphalt (HMA). The normalized OBSI measurement of SP12.5 FC2 is 103.9.

Table 2. Overall Sound Intensity (dBA) Measurement

	Section	Measured Overall dBA	Normalized dBA	Number of Runs
1	Hwy 115 PCC Longitudinal Grooving	104.2	103.9	6
2	Hwy 115 PCC Longitudinal Grooving	103.4	103.2	6
3	Hwy 115 PCC Longitudinal Grooving	104.3	103.9	6
4	Hwy 115 PCC Longitudinal Grooving	103.6	103.4	6
5	Hwy 115 HMA SP 12.5 FC2 (Control Section)	104.2	103.9	6
6	Hwy 417 PCC Transverse Tining	109.0	108.9	6
7	Hwy 417 PCC Transverse Tining	110.4	110.3	7
8	Hwy 410 PCC Transverse Tining	108.0	107.6	6
9	Hwy 401 PCC Transverse Tining	106.6	106.7	3

Overall, these observations suggest that longitudinal grooving is a more effective method for reducing noise levels on concrete pavements compared to transverse tining. Figure 4 provides a clear visual representation of this difference in noise reduction performance between the two pavement textures.

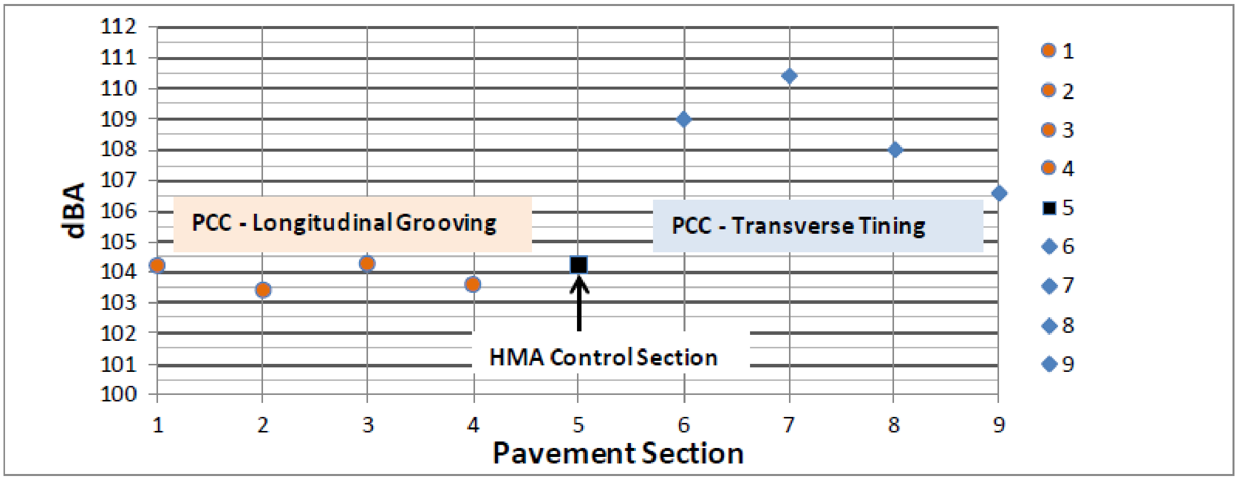

Figure 4. Longitudinal Grooved and Transverse Tined Noise Level

5. 2022 MTO WESTERN AND CENTRAL REGIONS (WR/CR) QUIET PAVEMENT STUDY

5.1 Introduction and Purpose

In 2022, the Ontario Ministry of Transportation (MTO) conducted On-board Sound Intensity (OBSI) noise measurements on seven test roadway sections located along Highways 401, 402, and 404 in the Western and Central Regions by SLR Consulting Ltd. These sections consisted of different pavement types, including two control sections composed of Superpave 12.5 FC 2 and SMA 12.5 (Stone Mastic Asphalt), as well as sections composed of concrete with varying ages and treatments such as grooving and tining [10].

The purpose of these measurements was to evaluate the noise performance of different concrete pavement types and treatments. Results of these noise measurements may also be used to compare to Traffic Noise Model (TNM) noise values used for environmental noise screening of proposed highway project. The data collected from these measurements can be used to inform future pavement design and construction practices and to improve the overall noise performance of Ontario's highways.

The measurement program was designed to evaluate the noise generation of five test concrete sections using the On-Board Sound Intensity (OBSI) method outlined in the AASHTO TP-76-12 test method.

This study focuses on examining variability in measured sound intensity, overall sound intensity levels, and comparison to control sections. They provide valuable information on the noise generation of different pavement types and treatments, which can be used to inform future pavement design and construction practices aimed at reducing highway noise levels. AASHTO TNM model will require update to model concrete pavement with different surface texture (currently default to transversely tined concrete output values) based on the results.

5.2 Descriptions of Test Sections

Table 3 provides details on the pavement types used in each test section. Section 2, SP12.5 FC2, represents a "typical" asphalt pavement control section, while Section 6 is also a "typical" reference section of asphalt. Sections 1, 3, and 5 are longitudinally grooved concrete with varying ages and mitigation/remedial actions.

Table 3. Pavement Types and Test Sections of WR/CR Quiet Pavement Study

Test Section	Type and Construction Year	Section Location
1	Longitudinal Grooved Concrete - 2020	WBL 2.9 km East Old Heritage Road
2	Asphalt SP 12.5 FC2 - 2019	EBL 2.9 km East Old Heritage Road (Control)
3	Longitudinal Grooved Concrete - 2018	EBL 2.0 km West of Charing Cross Road
4	Longitudinal Tinned Concrete - 2017	EBL 1.9 km West Victoria Road
5	Longitudinal Grooved and existing Tinned - 2018/19	WBL 1.0 km East Creditview Road
6	Asphalt SMA 12.5 - 2020	WBL Guelph Line (Control)
7	Transverse Tinned Concrete - 2014	NBL 0.9 km South Green Lane

Section 2 and Section 6 represent “typical" asphalt pavement control section. Sections 1, 3, and 5 are longitudinally grooved concrete with varying ages and mitigation/remedial actions.

Figure 5 shows the different types of pavement surfaces with different textures that are included in the test sections. These include longitudinally grooved concrete, longitudinally tined concrete, transversely tined concrete, as well as the asphalt pavement surface

Overall, the information presented in Table 3 and Figure 5 provides a detailed description of the test sections and the different pavement types and treatments used in the study. This information is important for understanding the results of the On-board Sound Intensity (OBSI) noise measurements and for formulating future pavement design and construction practices aimed at reducing highway noise levels.

Concrete – Longitudinally grooved

Superpave 12.5 FC 2

Concrete – Longitudinally tined

Concrete – Transverse Tined

Figure 5. Different Type of Pavement Surface Textures

The assessment of pavement noise generation was conducted using the procedures outlined in the American Association of State Highway and Transportation Officials (AASHTO) Standard TP 76-12, which provides a standard method of test for the measurement of tire and pavement noise using the On-board Sound Intensity (OBSI) method. Additional guidance was obtained from the National Cooperative Highway Research Program Report 630.

Pavement noise was measured at a test road speed of 100 km/h, as per the AASHTO Standard TP 76-12. The speed variation was kept within +/- 1.6 km/h over the test section. The speed of the vehicle was monitored using GPS-based instrumentation. This ensures that the measurements were consistent and any variations in noise levels were not due to variations in vehicle speed

The AASHTO method recommends the use of an ASTM Standard Test Tire for conducting the measurements, but since these tires are not generally available, a Uniroyal Tiger Paw AS65 tire (P225/ R16) was used instead. This tire is considered acceptable according to the NCHRP Report 630.

A test rig was constructed and mounted onto the hub of the test tire per Figure 6, ensuring that the microphones remain at a constant position with respect to the pavement, tire, and contact patch. The microphones were held at 102 mm from the side wall of the tire and 76 mm from the pavement. The leading edge and trailing edge microphones were positioned 209 mm apart and centered on the contact patch per Figure 7. The microphones were equipped with windscreens to reduce wind noise during the tests.

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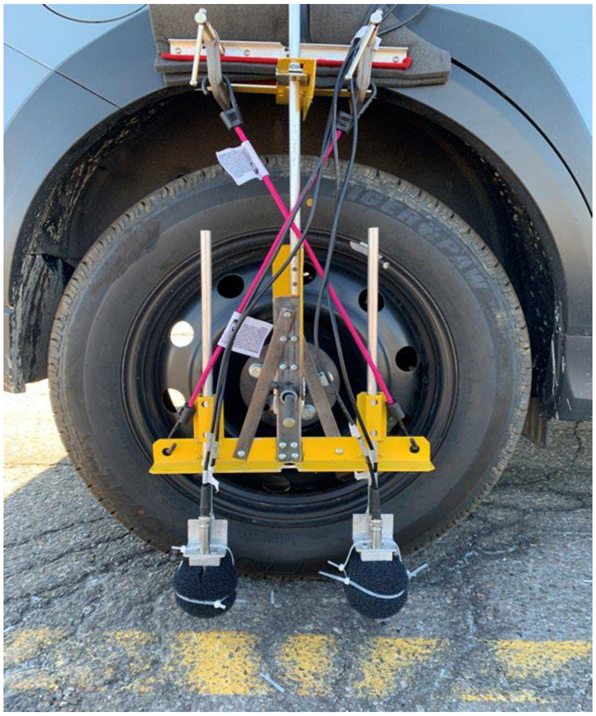

Figure 6. AASHTO-Compliant OBSI Test Rig Used in Measurements

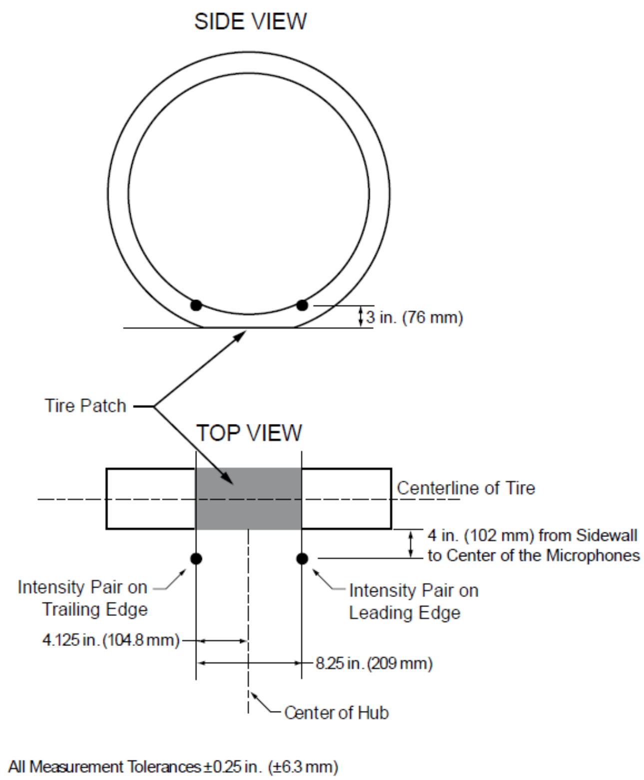

Figure 7. Microphone Locations (From AASHTO TP 76-09)

5.4 OBSI Measurements

Measurements were conducted in June and July 2022. Conditions were mainly clear and dry, with wind speeds up to 25 km/h. Air temperature, humidity and pressure data were used to correct the sound intensity measurements to account for air density, in accordance with the AASHTO standard.

5.5 OBSI Testing Results

5.5.1 Variability Within Test Sections

The variability in measured sound intensity is important because it provides insight into the consistency of the pavement's noise generation across the length of the test section. A high degree of variability could indicate potential issues with the pavement's design or construction. The variability in measured sound intensity level within each test section was evaluated in the study. Specifically, the measured sound intensity for each 100 m segment (out of the total length of 500 m) was compared, as well as the total section length of 500 m. The results showed remarkable consistency between the segments, with no significant differences observed between the individual segments or the overall average of the entire 500 m test section per Figure 8.

The measured sound intensity values were calculated according to the AASHTO standard and were the energy average of the leading edge and trailing edge intensity measurement results.

Based on the results, the overall sound intensity of the complete 500 m section was used for all subsequent analysis and comparisons. Generally, the measurement values are limited to the frequency range that are covered by the 400 to 5000 one-third octave bands; therefore, it is common to report one-third octave bands from 400 to 5000 Hz [11].

Overall, these details provide important information about the variability in measured sound intensity within each test section and the methodology used for calculating the sound intensity values

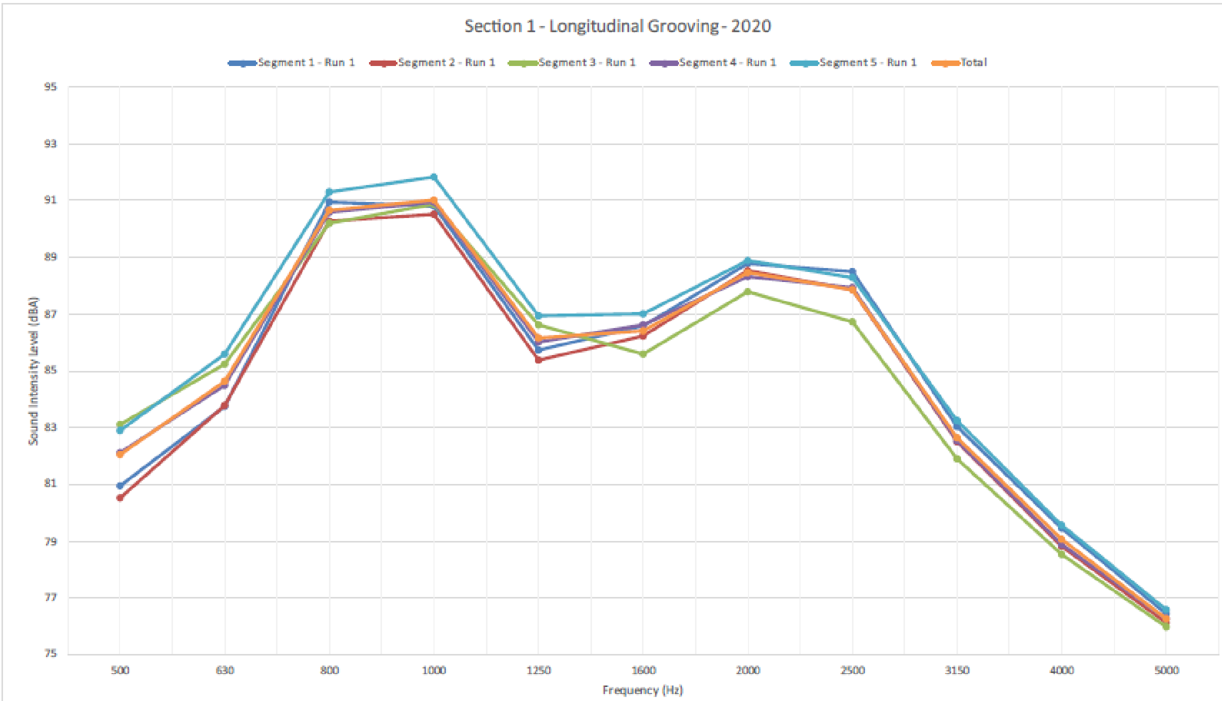

Figure 8. Variability in Measured Sound Intensity Within the Test Sections

5.5.2 Overall Sound Intensity

The overall sound intensity levels for each 500 m test section were presented at each speed and lead/trail tire edges. This data allows for a direct comparison between the noise levels generated by each pavement section. The lead/trail tire edges were also evaluated separately because the noise generated by each edge can vary depending on factors such as pavement texture and traffic flow.

All the OBSI test results apply the temperature corrections recommended in the AASHTO standard. The overall reported sound intensity is shown in Table 4.

Table 4. Overall Measured Sound Intensity Levels

Section	Highway	Type	Age (year)	OBSI (dBA)
1	Highway 402 – Sarnia	Concrete - Longitudinal grooving	2 (2020)	97.7
2	Highway 402 (control) – Sarnia	SP 12.5 FC 2	3 (2019)	97.6
3	Highway 401 – Chatham	Concrete - Longitudinal grooving	4 (2018)	97.3
4	Highway 401 – Chatham	Concrete - Longitudinal tining	5 (2017)	98.7
5	Highway 401 – Mississauga	Concrete - Longitudinal grooving - Remediation	3 (2019)	100.6
6	Highway 401 (control) – Cambellville	SMA 12.5	2 (2020)	98.3
7	Highway 404 - Sharon	Concrete - Transverse tining	8 (2014)	101.9

5.5.3 Comparison Versus Control Section 2 and Section 6 (12.5FC2 and SMA)

The results for the various concrete sections were compared to the asphalt control sections. This comparison allows for an assessment of the noise reduction performance of each pavement section relative to the control sections. The results of this comparison can be used to identify the most effective pavement types and treatments for reducing noise levels on highways.

Table 5 presents the sound intensity levels for different concrete pavement textures and compares them to two reference asphalt pavements (SP12.5 FC2 and SMA), which are designated as control sections (Section 2 and Section 6). The results show that Section 3 is the quietest pavement among all the concrete pavements tested, with a sound intensity level that is 0.3 dB lower than the control Section 2 and 1.0 dB lower than the control Section 6.

The rankings of the concrete pavements, from quietest to loudest, are as follows: Section 3, Section 1, Section 4, Section 5, and Section 7. When compared to the control Section 2, Section 1 has a slightly higher sound intensity level (0.1 dB), while Section 4, Section 5, and Section 7 have significantly higher sound intensity levels (1.1 dB, 3.0 dB, and 4.3 dB, respectively). When compared to the control Section 6, Section 1 has a slightly lower sound intensity level (0.6 dB), while Section 4, Section 5, and Section 7 have higher sound intensity levels (0.4 dB, 2.3 dB, and 3.6 dB, respectively).

The study finds that longitudinal grooving and longitudinal tining are comparable to the control sections in terms of sound intensity levels, with a difference of within 1 dB. In Section 5, it is noted that transverse tining texture is still present, in addition to the longitudinal grooving remediation. Section 7, which uses transverse tining, is noticeably louder than the two control sections.

The graphical comparisons in Figures 9, 10, and 11 provide visual representations of the sound intensity levels of the different pavement types relative to the two asphalt control sections.

Table 5. Overall OBSI Levels and Difference Relative to Control Sections 2 and 6

Section #	Type	Sound Intensity Level (dBA)		
		Average	Relative to Section 2 (SP 12.5)	Relative to Section 6 (SMA 12.5)
1	Concrete - Longitudinal grooving	97.7	+0.1	-0.6
3	Concrete - Longitudinal grooving	97.3	-0.3	-1.0
4	Concrete - Longitudinal tining	98.7	+1.1	+0.4
5	Concrete - Longitudinal grooving (Remediation)	100.6	+3.0	+2.3
7	Concrete - Transverse tining	101.9	+4.3	+3.6

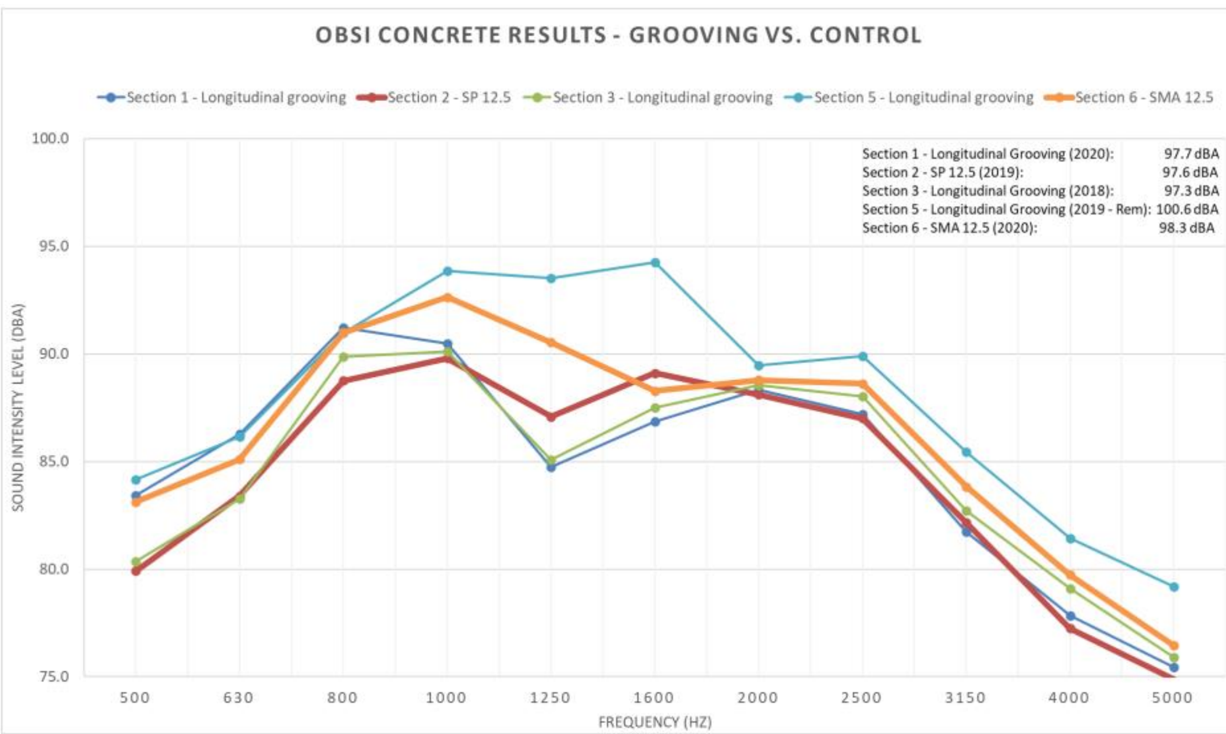

Figure 9. Concrete Longitudinal Grooving versus Asphalt Control Section

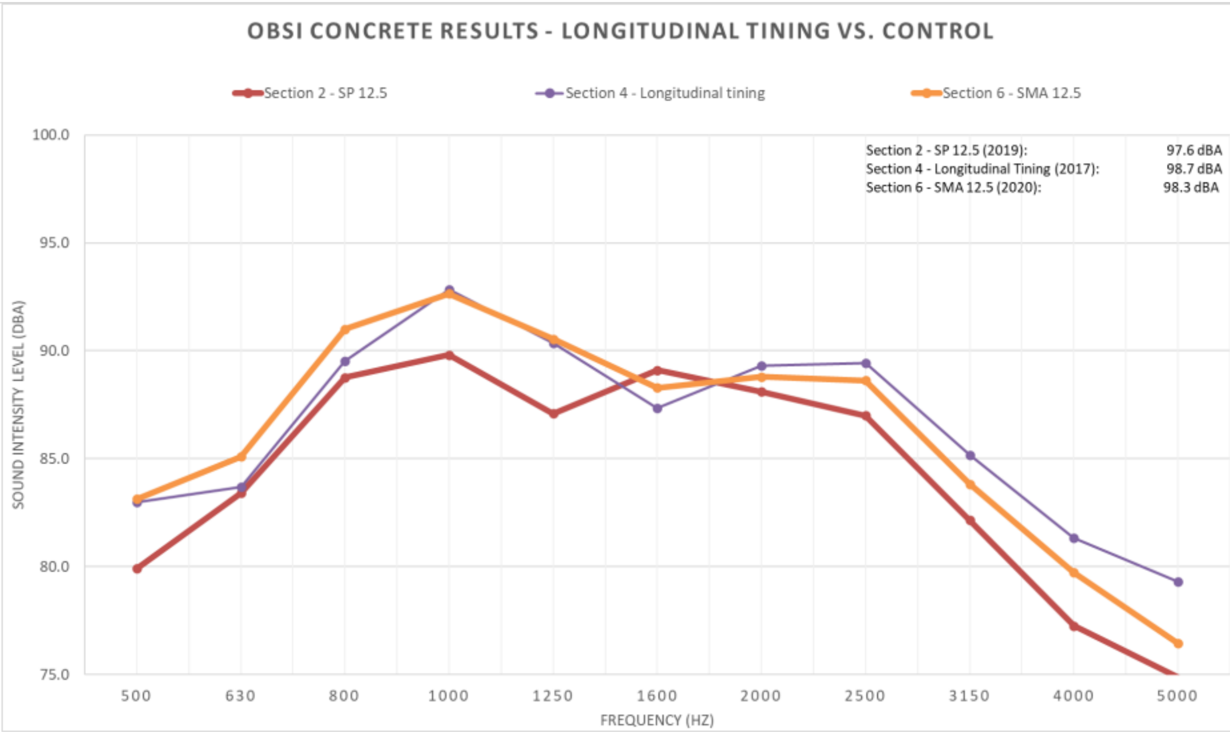

Figure 10. Comparison Between Concrete Longitudinal Tining and Asphalt Control Section

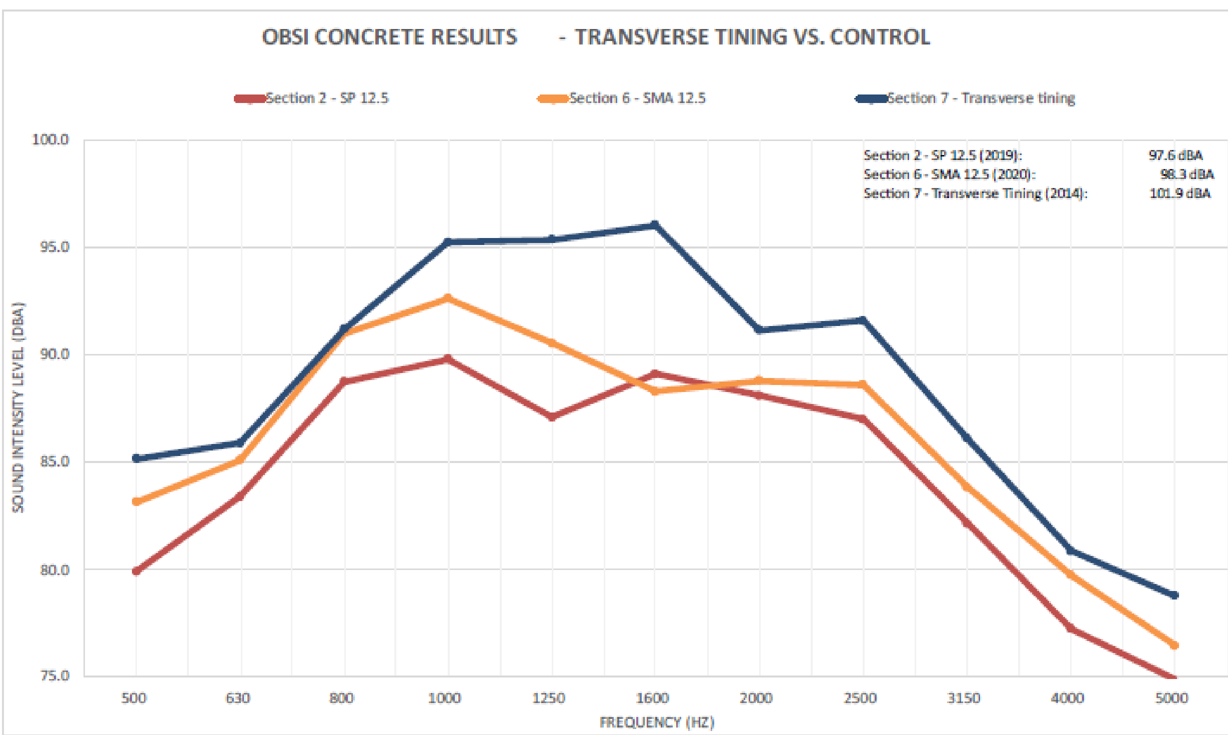

Figure 11. Comparison Between Concrete Transverse Tining and Asphalt Control Section

5.5.4 Comparison of Various Concrete Pavement Sections

Table 6 compares the OBSI measurement data of longitudinally grooved /tinned concrete sections against the concrete section with transverse tining. The results clearly show that the overall average sound intensity levels for longitudinally grooved concrete are much lower as compared to Section 7. Longitudinally tined concrete sections are quieter by a significant margin compared to transverse tined sections.

Table 6. Comparison of Longitudinal Grooving and Tining to Transverse Tining

Pavement Type	Sound Intensity Level (dBA)	
	Average	Relative to Section 7
Section 1 – Concrete – Longitudinal grooving – 2020	97.7	-4.3
Section 3 – Concrete – Longitudinal grooving – 2018	97.3	-4.6
Section 4 – Concrete – Longitudinal tining – 2017	98.7	-3.2
Section 5 – Concrete – Longitudinal grooving remediation - 2019	100.6	-1.4

Additionally, the noise reduction on Section 5, which had both the existing transverse texture and the new longitudinal grooved texture, is less than that of only longitudinally grooved sections without transverse tining (Sections 1 and 3).

5.6 Summary and Recommendation for MTO's WR/CR Quiet Concrete Pavements Study

5.6.1 Summary

Overall, the study highlights the potential benefits of using concrete pavements with longitudinal grooving or tining as a quieter and more durable alternative to traditional asphalt and transverse tined concrete pavements.

The major findings from the MTO's WR/CR quiet concrete pavements study can be summarized as follows:

- Relative to the asphalt control pavements (typical SMA and Superpave 12.5), concrete longitudinal grooving proved to be comparable in terms of sound intensity levels.
- Overall average sound intensity levels for longitudinally grooved concrete are significantly lower than those measured for transverse tined concrete sections.
- Longitudinal tining concrete section was comparable and within about 1dB of both asphalt control sections.
- Longitudinally tined concrete sections are quieter by a significant margin compared to transverse tined sections
- Concrete with transverse tining was noticeably louder than the two control asphalt sections.

5.6.2 Recommendation

Environmental screening is a critical process that helps to identify potential impacts of a project on the environment, including noise pollution. If the noise model used for environmental screening is not able to accurately predict noise levels for new pavement textures, the resulting screening process could be flawed, leading to inaccurate assessments of environmental impact. Based on the analysis of actual noise measurements on the different new concrete pavement textures in this study, it is recommended to upgrade the traffic noise model (TNM) developed by Federal Highway Administration (FHWA) that MTO is currently using to account for the new pavement textures. In addition, ongoing monitoring of the long-term performance of these quiet pavement alternatives is also recommended to be carried out, which will allow us to better understand how their noise properties perform over their life spans.

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