Tire/Pavement Noise and Wearing Course Surface Characteristics of Experimental Canadian Road Pavement Sections

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Tire–pavement noise and wearing course surface characteristics of experimental Canadian road pavement sections

F. Irali, A. Kivi, S.L. Tighe, and C. Sangiorgi

Abstract: An evaluation of the acoustic and surface characteristics of different Canadian pavement types was carried out in 2013 at the test track of the Centre for Pavement and Transportation Technology at the University of Waterloo. Noise testing was performed to determine the coefficient of noise absorption on cored samples and noise emissions in the field using the close proximity and the on-board sound intensity methods. Wearing course characteristics were evaluated with field testing, including visual condition surveys, evaluation of frictional properties with the British Pendulum tester, mean texture depth measurements, and surface profile and roughness evaluation with a walking profiler. As of the time of testing, the noise testing results indicate comparable acoustic properties in both flexible and rigid pavement sections, despite differences in the initial pavement materials, mixes, and surface finishing. With increasing pavement age, the amount of noise emissions increases as the pavement surface is worn down. Comparable friction values are also observed in all pavement sections, in line with the noise testing results. However, this is largely based on the initial construction values. Surface distresses are also not uniformly distributed: they are more severe in the oldest sections and more frequent in the loaded lane, which carries the heaviest traffic loads.

Key words: tire–pavement noise, wearing course characteristics, pavement age, surface texture, surface roughness.

Résumé : Une évaluation de la surface et des caractéristiques acoustiques de différents types de revêtements utilisés au Canada a été réalisée en 2013 sur la piste d'essai du Centre for Pavement and Transportation Technology, à l'Université de Waterloo. Des essais acoustiques ont été effectués afin de déterminer le coefficient d'absorption du bruit d'échantillons carottés et les émissions sonores sur le terrain à l'aide des méthodes CPX (close proximity) et OBSI (on-board sound intensity). Les caractéristiques de la couche d'usure ont été évaluées au moyen d'essais réalisés sur le terrain, comprenant des inspections visuelles de l'état du revêtement, l'évaluation des propriétés de frottement à l'aide d'un pendule de frottement, des mesures de la profondeur moyenne de texture et l'évaluation du profil de surface et de la rugosité à l'aide d'un profilomètre portatif. À ce jour, les résultats des essais acoustiques montrent que les propriétés acoustiques des sections de revêtement dur sont comparables à celles des sections de revêtement souple, bien que les matériaux composant le revêtement d'origine, les mélanges d'asphalte utilisés et la méthode de surfaçage diffèrent selon le type de revêtement. En vieillissant et à mesure que sa surface s'use, le revêtement génère de plus en plus d'émissions sonores. Par ailleurs, on observe des valeurs de frottement similaires, quelle que soit la section de revêtement étudiée, ce qui corrobore les résultats des essais acoustiques. Cependant, ces résultats s'appuient largement sur les valeurs initiales relevées au moment de la construction des revêtements. En outre, les contraintes superficielles ne sont pas uniformément réparties : elles sont plus élevées dans les sections les plus anciennes et plus fréquentes dans la partie du revêtement soumise à des charges importantes, c'est-à-dire celle qui supporte le volume de trafic le plus élevé. [Traduit par la Rédaction]

Mots-clés : bruit de pneus et du revêtement, caractéristiques de la couche d'usure, âge du revêtement, texture de surface, rugosité de surface.

1. Introduction

The stresses induced by vehicle loadings and harsh climatic conditions can have a detrimental effect on the surface texture (Suo and Wong 2009) and wearing course characteristics of pavements. Environmental conditions, changes in temperature and moisture can greatly affect the properties of paving materials (Mills et al. 2009; Ech et al. 2012) and cause the deterioration of the pavement surface, which is progressively worn down and further affected by traffic effects and pavement age (Mills et al. 2006), leading to unfavourable changes to the surface texture.

Surface texture modifications affect friction, ride quality, safety, and acoustic performance (Bitelli et al. 2012). In fact, in flexible pavements, the noise generated by tire–pavement interaction is greatly influenced by pavement surface characteristics such as aggregate gradation, macrotexture, age, and presence of distresses (Sandberg and Ejsmont 2004). Shape, homogeneity, spacing and orientation of aggregates, in fact, can affect tire–pavement noise mechanisms (Sandberg and Descornet 1980).

Pavement materials can also influence tire–pavement noise, due to variations in vibration attenuation and damping capacities

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(Biligiri 2013). From the data gathered in the United States to date, the absolute noise levels of Portland cement concrete (PCC) are usually higher than the levels measured in asphalt concrete (AC) pavements. However, PCC surface textures can be modified to achieve large reductions in tire–pavement noise, qualifying them as a legitimate tool to mitigate traffic noise (Donovan et al. 2012).

The acoustic characteristics of pavements are known to evolve with time. Age, presence of distresses, and increasing macrotexture augment the overall noise levels (Weiguo 2009). Previous studies have determined that, as the pavement gets older, noise levels from asphalt pavements usually increase even before significant pavement deterioration begins to occur (Bendtsen et al. 2009).

Presently, there is not yet an effective predictive model to forecast the surface texture evolution in a given environment, nor the changes in noise due to tire–pavement interaction. Research in these areas is in progress and field testing is important to provide additional data to the scientific literature. A current common approach to evaluate these characteristics consists of the on-site evaluation of in-service pavements (Ech et al. 2012).

The Centre for Pavement and Transportation Technology (CPATT) at the University of Waterloo operates an experimental test road with the objective of quantifying environmental and load effects on several different pavement structures in the Canadian environment. The CPATT Test Track consists of over 12 different types of pavements, including flexible, rigid and interlocking pavers, of varying ages. These experimental sections are subjected to frequent heavy truck loadings and harsh, wide-ranging climatic conditions throughout the year.

2. Objective and scope

Research was undertaken in 2013 to assess the acoustic properties and the wearing course characteristics of each experimental pavement section of the CPATT Test Track. The objectives of the evaluation were the following ones:

- make a relative comparison between the medium- to long-term acoustic characteristics of each pavement section;
- determine whether the differences in the acoustic properties of the tested pavements are due to the characteristics of noise absorption or to difference in the noise emission properties, and evaluate a possible relation between the two;
- make a relative comparison between the surface characteristics of the different pavement sections based on age;
- evaluate whether there is a relation between the acoustic properties and the surface characteristics of the tested sections;
- provide a qualitative evaluation of the effect of age on noise and surface characteristics of the different pavement sections.

The unique aspects of this analysis were the following ones:

- all experimental pavement sections evaluated were exposed to the same external conditions, especially load and climate;
- the noise testing was carried out at a single facility, providing excellent consistency of the ambient test conditions;
- noise emission testing was carried out with a special frame owned by the CPATT, that allows measuring in parallel both sound pressure and sound intensity levels;
- the pavement sections were designed with experimental pavement materials and, in the case of the rigid sections, with different surface finishing methods, providing innovative data for acoustic and surface evaluation, especially on the long term.

3. CPATT test track description and location

The CPATT test track is located in the Region of Waterloo Waste Management Site and it is a full-scale accelerated research facility, 1294 m long and 8 m wide. The test road is composed of different sections paved with various asphalt concrete and Portland cement concrete mixes to allow researchers to monitor the performance of each section in the Canadian environment under heavy truck loadings. The first section of the test track was constructed in 2002 and consisted of six sections surfaced with five different asphalt mixes, including two control hot-laid 3 (HL3) sections, a polymer modified asphalt HL3 (PMA) section, a stone mastic asphalt (SMA) section and a SuperPave (SUP) asphalt section. In 2007, four conventional jointed plain concrete pavement (JPCP) sections were added, each with a different percentage of recycled concrete aggregate (RCA): 0%, 15%, 30% and 50%, respectively. In 2008, four interlocking concrete pavement sections were added. A fourth section was constructed in 2009, consisting of a HL3 mix containing recycled asphalt shingles (RAS). A plan layout of the CPATT test track is presented in Fig. 1.

The traffic travelling on the test track pavements is mainly composed of heavy vehicles, including approximately 33 500 garbage trucks annually on each way, corresponding to 149 000 equivalent single axle loads (80 kN ESALs) in the loaded direction each year or 4 265 000 ESALs over the pavements 20-year design life (Smith and Tighe 2010). In the flexible sections, only the asphalt wearing surface varies. The underlying layers of each of the five sections are composed of the same materials of the same thicknesses.

The asphalt concrete was placed on a 150 mm thick compacted granular base (Granular A) layer and a 450 mm thick subbase (Granular B) layer.

The subbase and the subgrade, comprised of clayey to silty sand and gravel soils, are separated by a geotextile.

The asphalt layer is 90 mm thick in both HL3 sections, 85 mm thick in the PMA section, and 145 mm thick in the RAS section. The SMA and the SUP surface courses are, respectively, 55 mm and 50 mm thick, and they are both underlaid by a 50 mm thick binder lift of HL3.

The pavement structure in the rigid sections, instead, is composed of 250 mm of Portland cement concrete, 100 mm of asphalt stabilized open graded drainage layer (OGDL), and 450 mm of Granular B material. The flexible and rigid pavement structures have also been depicted in Fig. 1.

Three different texturization methods were applied to the rigid sections. Longitudinal tining was applied to all sections. Small sections of the RCA-30% and the RCA-15% sections were transversely tined. The RCA-0% control section and a small portion of the RCA-15% were also textured using a burlap drag.

In this study, only the flexible and rigid pavements are assessed, i.e., the interlocking pavement section is not evaluated. The concrete sections are assessed according to their pavement material, i.e., RCA percentage.

An additional analysis according to the texturization type, due to the limited length and continuity of the same-texture segments, was only possible for the longitudinal tining segment. Additional testing for tire–pavement noise was performed on this section.

4. Tire–pavement noise evaluation

Tire–pavement noise can be related to a complex set of mechanisms affecting noise generation and amplification phenomena. Generation mechanisms can depend on phenomena affecting mechanical vibrations of the tire, related to impact and adhesion mechanisms between the tire treads and the road surface, or aerodynamical phenomena generated at the tire–pavement interface, due to air displacement mechanisms when the tire is rolling on the road (Sandberg and Ejsmont 2004; FEHRL 2006; EAPA 2007).

Amplification mechanisms can enhance or reduce the noise generated at the tire–pavement interface and can be caused by the horn effect at tire longitudinal edges, the acoustical and mechanical impedance effects at the tire–pavement interface and the tire resonance (Bernhard et al. 2005).

Fig. 1. Plan view representation of the CPATT Test Track and its sections.

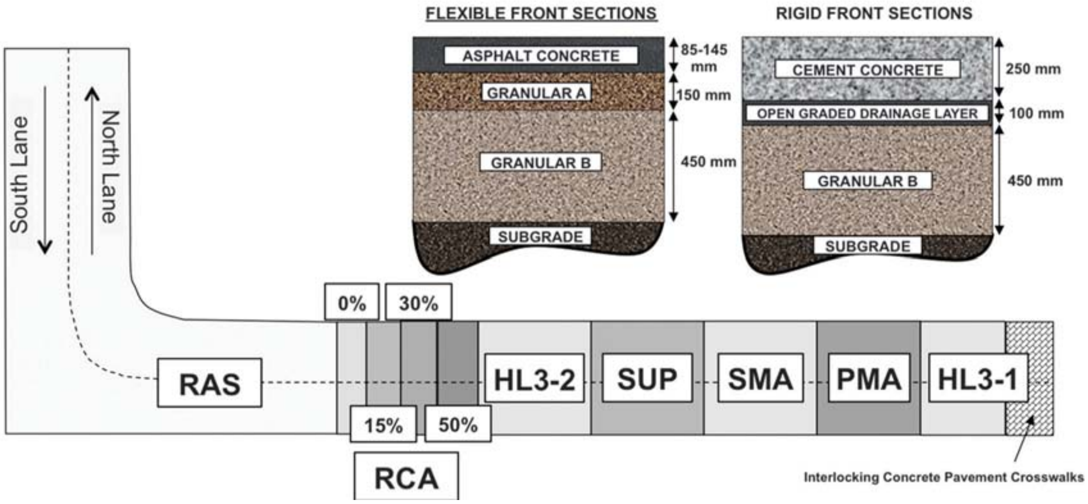


Fig. 2. Core samples selected for sound absorption testing.

Therefore, as both road surface characteristics and acoustic impedance affect tire–pavement noise, tests have been carried out to measure both aspects.

The coefficient of sound absorption was measured by means of the Impedance Tube method: the objective of this test was to provide information about the acoustic impedance of each pavement section, a characteristic that depends mostly on pavement materials and not on surface characteristics, such as texture.

Noise emissions characteristics were evaluated by means of the close proximity (CPX) and on-board sound intensity (OBSI) methods: the aim of these tests was to provide information about the noise emitted at the tire–pavement interface, which mostly depends on surface characteristics.

4.1. Evaluation of noise absorption characteristics

The coefficient of noise absorption has been measured on core samples, removed from the test track pavements, using the Impedance Tube method, in accordance with the ISO 10534-2 standard.

According to the standard, the frequency range for this test is limited to 1200 Hz due to the diameter of the tube, equal to 150 mm.

Three samples were cored from each pavement section for noise absorption testing: the core samples can be observed in Fig. 2, ordered according to the CPATT test track map, seen in Fig. 1. To be representative, the samples were cored in the wheelpath and in areas with no specific distresses.

The results are displayed in Fig. 3. The coefficient of sound absorption is lower than 0.1 at every measured frequency and for every sample type: therefore, the intrinsic sound absorption characteristics of these pavement materials can be considered to be very low, with an almost negligible impact on tire–pavement noise reduction.

With such low values of noise absorption, potential differences in the following noise emission tests can be mostly related to surface characteristics.

4.2. Evaluation of noise emission characteristics

Sound pressure and intensity levels at the tire–pavement interface have been measured in parallel using the CPX method, in accordance with the ISO standard 11819-2 and the OBSI method, in accordance with the AASHTO TP 76-09 standard.

The tests were carried out using a suitable frame installed on the CPATT vehicle to allow simultaneous testing. Figure 4 displays the setup for noise testing.

The following exceptions to the standards were made:

- since the CPX and OBSI Standards require different types of tire, the regular tire of the vehicle was used for the measurements. This exception had to be made to perform the two tests at the same time;
- the measurements were performed at the reference speed of 56 km/h, according to the OBSI Standard. The nominated reference speed of the CPX was slightly lower, equal to 50 km/h.

The selected speed allows direct comparison between CPX and OBSI test results.

Although not using the specified reference speed for the CPX, the main purpose of this research is to compare different pavement sections under the same conditions and relative comparisons can still be made regardless of the selected reference speed.

Since test sections should be essentially straight, only the tangential segment of the RAS section, parallel to the other test sections, has been measured. The section located after the curve was not tested.

Fig. 3. Coefficient of sound absorption for each pavement type.

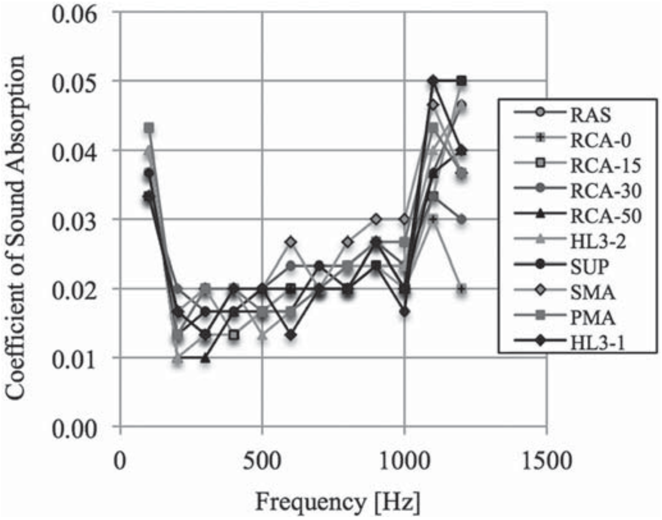


Fig. 4. Layout of the CPX and OBSI noise testing setup.

A weighted maximum and equivalent sound pressure and intensity levels were measured at different frequencies in the 25–10000 Hz range for each microphone; arithmetic averages of the signals were subsequently calculated.

The peculiar characteristics of the rigid sections were taken into consideration for the test. Since they are made with different materials, consisting of different percentage of RCA, and with different surface finishing, they were tested twice:

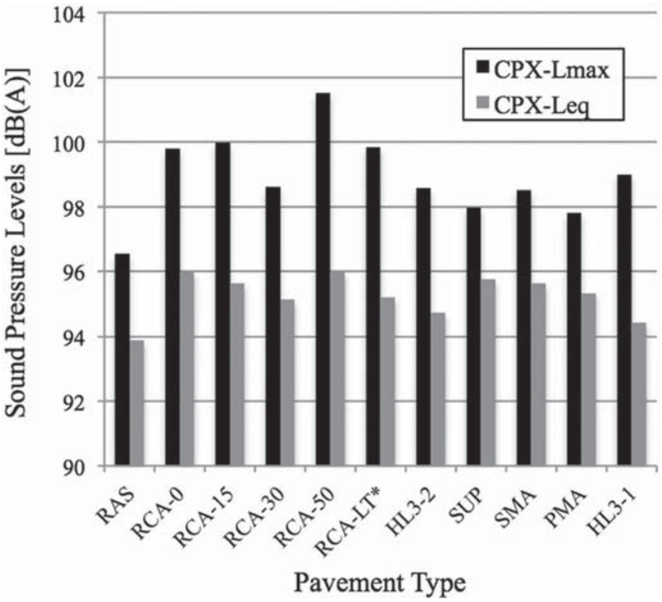
- a first time according to the pavement materials, regardless of the surface finishing: RCA-0%, RCA-15%, RCA-30%, RCA-50%;
- a second time according to the different surface finishing: due to the standard requirements related to the minimum length of each section for testing, the evaluation of only one longitudinal tining segment (RCA-LT) was possible. This segment includes a portion of the RCA-50% section and a portion of the RCA-30% section.

4.2.1. Close-proximity method (CPX) evaluation

In Fig. 5, the overall maximum and equivalent sound pressure levels are reported for every pavement section. The noise range of overall maximum noise levels is approximately 5–6 decibels and as a general trend, rigid sections are noisier than the flexible sections.

Slighter variation can be observed in the equivalent sound pressure levels, compared to the maximum ones. In fact, noise range is approximately 2 dB(A) and comparable noise performance can be observed between rigid sections and some flexible ones, such as PMA, SMA, and Superpave sections.

Fig. 5. Overall CPX maximum and equivalent sound pressure levels for each pavement section.



To better understand these values, it can be noted that a 3 dB(A) difference corresponds to doubling or halving the number of sources emitting a sound of equal sound pressure level. From the human ear perspective, 3 dB(A) is above the threshold of the perceivable difference in noise, but it is still considered a just-noticeable change (Brüel and Kjær 1986; Ahammed 2009).

The RAS section is the quietest, whereas SMA, usually considered a quiet pavement type, has provided a high sound pressure value, as loud as the rigid section ones.

An interesting observation can be made about the rigid sections. Additional measurements taken on a segment textured with longitudinal tining, indicated in Fig. 5 as “RCA-LT*”, provided the quietest results for concrete pavements. The longitudinally tined section is composed of both RCA-30% and RCA-50% mixes. Assuming that the 20% difference in RCA content does not affect the general properties of the material, it can be surmised that the difference in sound pressure levels can be related to the surface texture finishing, as observed in previous studies. The longitudinally tined section at the CPATT test track has the lowest noise emission levels among all the other rigid sections and it was quieter than other flexible sections, such as PMA, SMA, and Superpave ones.

4.2.2. On-board sound intensity (OBSI) evaluation

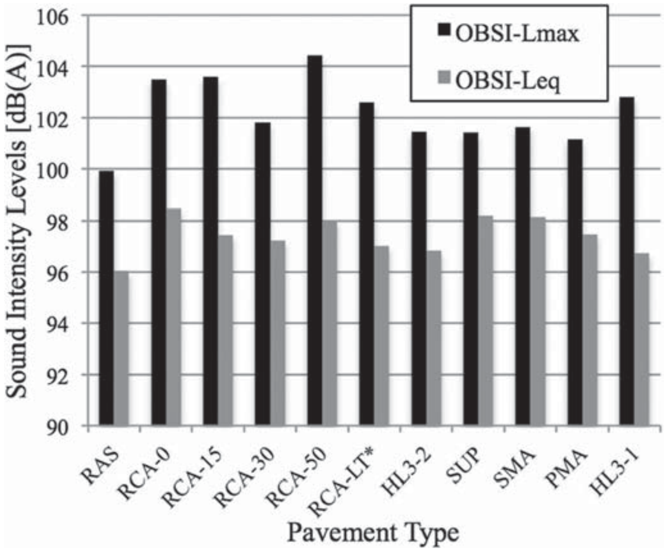
The test setup is composed of a probe, consisting of two parallel microphones placed in the same direction of the motion and it enables measuring the sound intensity.

In Fig. 6, the overall maximum and equivalent intensity levels are reported for every pavement section. The maximum level noise range is approximately 4–5 decibels and in general, the rigid sections are noisier than the flexible ones.

Some little variations can be observed in the equivalent levels, compared to the trend of the maximum values. In fact, noise range is approximately 2 dB(A) and comparable noise levels can be observed in both the rigid sections and flexible sections, with the exception of the RAS section, which is the quietest.

The same consideration can be made for the concrete longitudinal tined section as made for the CPX testing: this section provided the

Fig. 6. Overall OBSI maximum and equivalent sound intensity levels for each pavement section.



lowest sound intensity levels of all the rigid sections, it was quieter than other flexible sections, and was one of the quietest sections overall, with respect to the sound intensity levels.

4.2.3. Frequency analysis

A frequency analysis has been carried out to determine whether there is a relation between variations of the coefficient of sound absorption and the CPX and OBSI results with respect to specific noise frequencies. Therefore, the frequency range has been limited to the range available for the noise absorption test. Results are represented in Fig. 7.

In the graph, it can be observed that the peak frequencies for CPX and OBSI values occur at 1000 Hz, within the interval of frequencies at which the human ear is most sensitive, i.e., between 1000 and 5000 Hz (FEHRL 2006).

Furthermore, no specific specular trend can be observed between α and CPX and OBSI values.

At the frequencies between 1000 and 1200 Hz, a decrease in sound CPX and OBSI values seems to correspond to an increase in the coefficient of sound absorption, suggesting that the sound absorptive characteristics may contribute to a decrease in sound pressure and intensity levels at those specific frequencies. However, since α values are generally close to zero, an influence on the CPX and OBSI values is unlikely.

5. Wearing course characteristics evaluation

Various surface characteristics of the different pavement types were assessed: roughness, skid resistance, and surface texture using the volumetric method. Surface distress manifestation was also assessed using visual condition surveys amongst the different sections.

5.1. Roughness and smoothness evaluation

Roughness and smoothness characteristics of the experimental pavement sections have been evaluated by means of the SurPRO profiler, a rolling surface profiler intended for roads and other structures, such as floors and runways.

Measurements have been taken in every section in a wheelpath of both the northbound (loaded) lane and the southbound (unloaded) lane. Data was processed and analyzed with the ProVAL (Profile Viewer and Analyzer) software to calculate the International Roughness Index (IRI), as defined in ASTM standard E-1926-08, for every different section.

The results obtained are displayed in Fig. 8. In the graph, the roughness data are separated by section and lane. It can be readily observed that the IRI values are typically higher in the loaded lane than in the unloaded lane.

The IRI data ranges between 1.59 m/km, measured in the HL3-2 unloaded lane, and 4.02 m/km, measured in the PMA loaded lane. If one considers the overall value of every pavement section (both lanes), IRI ranges from 1.74 m/km in the HL3-2 section, up to 3.70 m/km for the PMA section.

According to the ASTM standard, the measured values indicate that all the pavement sections can be considered to have acceptable smoothness, especially by taking into account their age, the loads they are subjected to and the actual use of the facility, where the speed limit is of 40 km/h. The profile test results do not show an evident difference between asphalt and concrete sections.

Apart from the RCA-0% section, the Portland cement concrete sections account for some of the lowest IRI values amongst all the test track sections.

5.2. Macrotexture and skid resistance evaluation

Testing to evaluate surface texture and friction was also completed on all the CPATT test track sections. The mean texture depth (MTD), according to ASTM Standard E 965 and the British Pendulum Number (BPN), according to ASTM standard E303-93 were determined in a systematic manner throughout all experimental sections.

To maintain consistency with the noise testing program, the four points in the RAS section were all located in the tangential segment parallel to the other test sections.

The texture depth and friction results are depicted in Fig. 9. Slightly higher MTD values have been measured in the asphalt pavements, compared to the concrete pavements. On the other hand, comparable BPN results can be observed in the flexible and rigid sections.

Some observations can be made from this data. The peak value for both BPN and MTD values was obtained in the SMA section, confirming the high-quality surface characteristics that are expected from this material, even 10 years since paving. The relatively high values of MTD seen in the SMA are expected if one takes into consideration the peculiar characteristics of this kind of asphalt mix, characterized by a high coarse aggregate content.

The rigid sections all displayed similar results in MTD, but the BPN results were slightly more variable. This observation can be related to the texturing methods applied during paving, since three different texturization methods were applied, as described in section 1.

From a volumetric point of view, the type of tining, i.e., longitudinal or transverse, does not seem to have a great impact on MTD values, judging from the consistent and expected results. On the contrary, the differences in BPN are likely related to the different surface finishing methods used on these sections.

5.3. Visual evaluation

A visual condition survey was carried out to evaluate the severity, extent, and distribution of surface distresses. The condition surveys were performed using the methods outlined in the Ministry of Transportation of Ontario (MTO) pavement evaluation manuals. The results are summarized in Table 1.

In general, distresses are consummate with the age of the pavement. The newest RAS section exhibits the fewest distresses, whereas distresses are generally more frequent and more severe in the older asphalt sections. It is also noted that the northbound lane, carrying loaded traffic is generally found to be in slightly worse condition, suggesting that the action of heavier traffic contributes to the increased distress manifestation and propagation.

Fig. 7. CPX, OBSI, and coefficient of sound absorption values at the respective sound frequency.

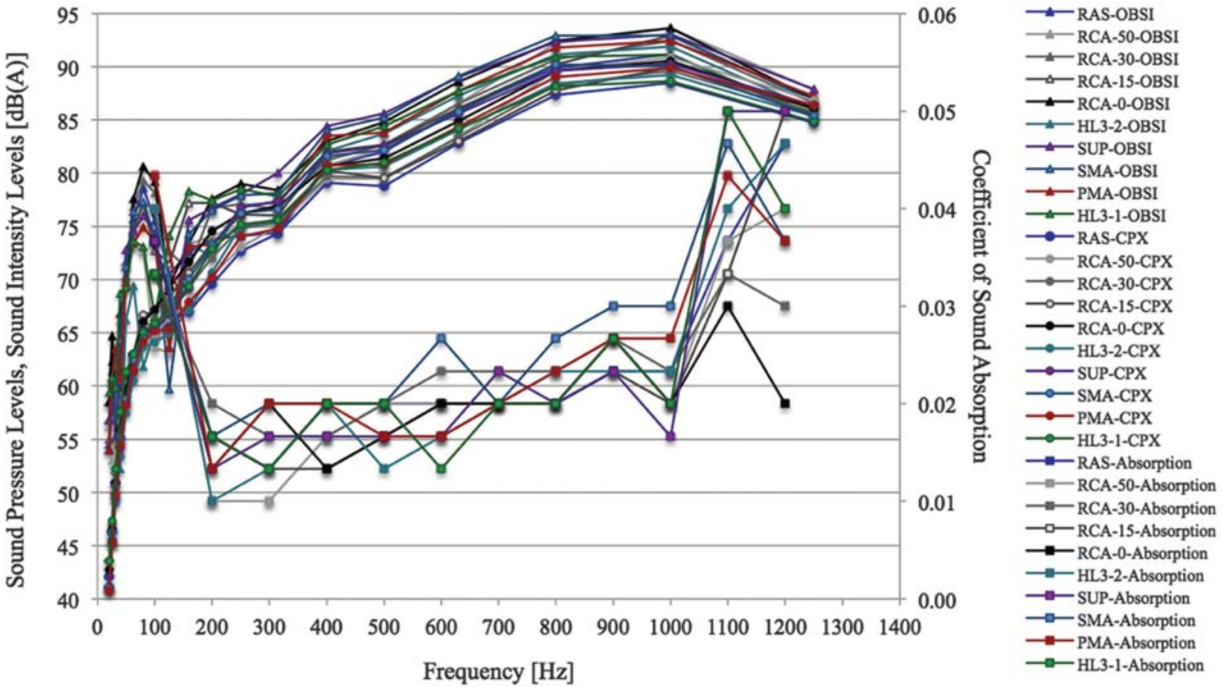


Fig. 8. Values of IRI for every test section and lane.

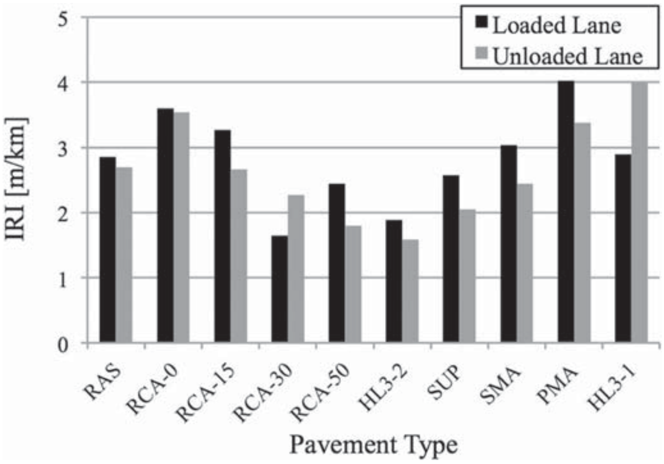


Fig. 9. Values of MTD and BPN for test sections.

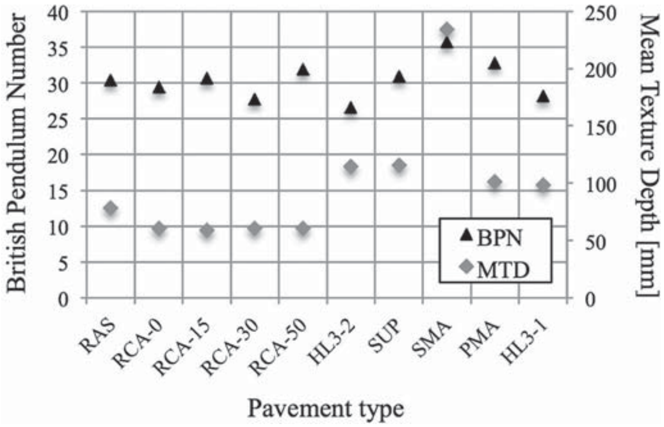


Table 1. Summary of visual condition survey.

Section	Surface distresses observed
RAS	Slight centerline cracking throughout Small patch of severe raveling One pothole
SUP	Frequent, severe alligator cracking Frequent, severe longitudinal wheel track cracking Some potholes have begun to form in the alligator cracking areas
PMA	Intermittent, slight pavement edge cracking Few, slight longitudinal mid-lane cracks Few, very slight alligator cracking Few, very slight transverse cracks
HL3-1	Few, slight pavement edge cracks Intermittent slight alligator cracking
HL3-2	Slight pavement edge cracks Intermittent, slight alligator cracking Slight longitudinal wheel track cracking
SMA	Frequent, severe and moderate longitudinal wheel track cracking Intermittent, slight pavement edge cracks Intermittent transverse cracks
Concrete (all RCA sections)	Intermittent raveling Intermittent corner cracking Moderate joint spalling throughout

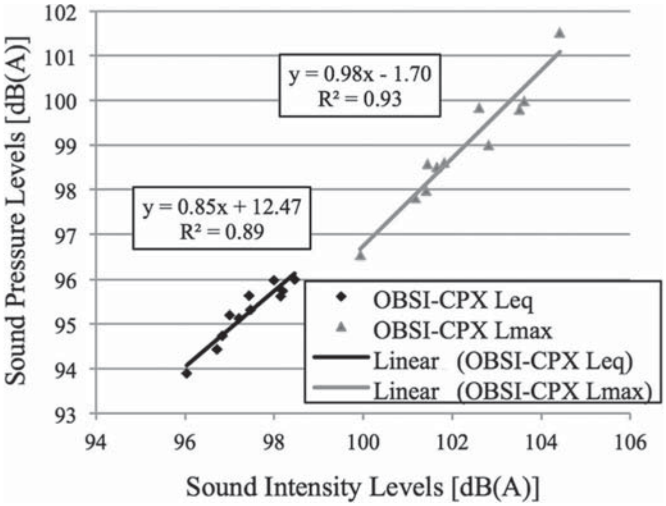
Note: RAS, recycled pavement shingles; SUP, Superpave; PMA, polymer modified asphalt; HL3, Hot-Laid 3; SMA, stone mastic asphalt; RCA, recycled concrete aggregate.

6. Age effect and data analysis

As described in section 4, due to the very low values of the coefficient of sound absorption of all the pavement sections, it can be assumed that the differences in the long-term tire–pavement noise emission values, measured with the CPX and OBSI methods, can be mostly related to differences in wearing course characteristics.

A linear regression model has been calculated for the CPX and OBSI test results, shown in Fig. 10. The high values of the coeffi-

Fig. 10. CPX and OBSI linear regression.



cient of correlation, especially for the equivalent noise levels, attest the high consistency of the measurements.

On this basis, the test results of noise and wearing course characteristics have been averaged over each pavement section's age to better consider time in service in the evaluation and to provide a general idea of the stability of the characteristics over time.

The OBSI and CPX equivalent sound levels, averaged over age, have been presented in Fig. 11. Maximum sound levels have not been considered since they are less representative than equivalent sound levels for the purpose of this analysis.

While this representation does not take into account the stability of the noise values in time, the trend observed in the graph suggests lower noise values for the HL3, SMA, Superpave, and PMA asphalt sections in the long term with respect to their higher age.

The IRI values are also presented in Fig. 12, averaged over their respective pavement section's age. While this representation does not take into account the differences in durability of the materials, it is interesting to observe that while the PMA and the HL3-1 sections provided higher values of IRI than newer sections, their averaged values are actually lower than some of them, suggesting a better behaviour for this pavement type over the longer term.

The BPN and MTD values are shown in Fig. 13, also averaged over age. BPN values of the RAS sections, averaged over the pavement age, are the highest, followed by the concrete sections, suggesting a greater influence on the friction in the long term, as compared to the remaining asphalt sections.

The SMA and the RAS sections have high values of mean texture depth averaged over age: while the high values of the SMA section were already visible in the regular graph, this representation also emphasizes the high averaged values of the RAS section, suggesting a similar behaviour for this pavement type in the long term. Comparable results can be observed in the remaining asphalt and concrete sections.

Additional data analysis has been carried out to study the correlation between noise results with IRI, with MTD and with BPN results. The correlation was very poor in all three of the following cases:

- CPX–IRI and OBSI–IRI: close to zero;
- CPX–MTD and OBSI–MTD: close to zero;
- CPX–BPN and OBSI–BPN: 0.10–0.25.

These results were in line with previous studies (Sandberg and Ejsmont 2004) and confirm that the effects of wearing course characteristics on tire–pavement noise cannot be predicted with these indicators.

Fig. 11. CPX and OBSI equivalent sound levels averaged over age.

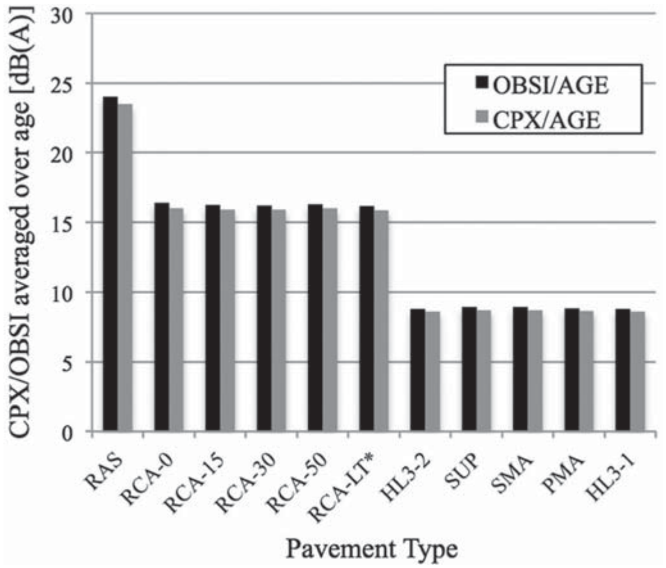
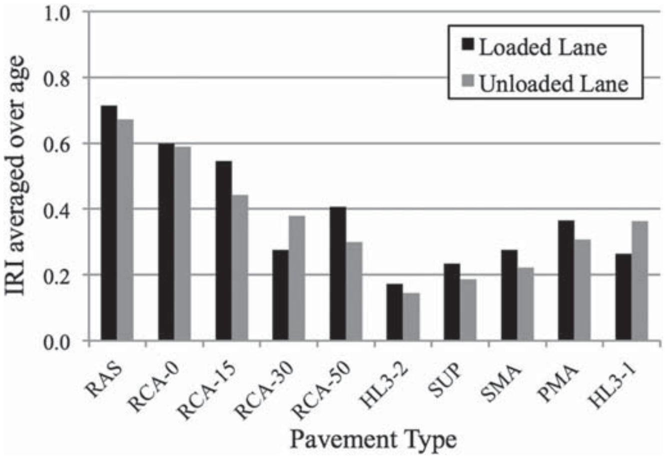


Fig. 12. Values of IRI averaged over pavement age.



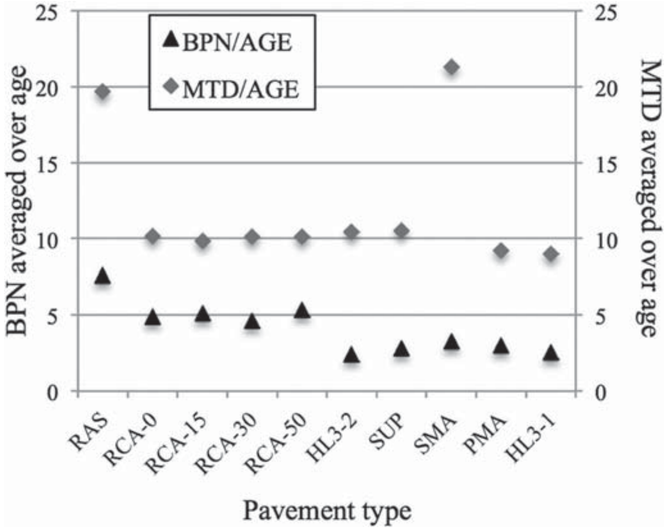
7. Conclusions and next steps

The test program carried out as part of this research has provided valuable data and information about the acoustic and surface characteristics of various pavement types subjected to the same loading and climatic conditions in Southern Ontario, especially beyond the short term. The location of the tested sections in the same test track improves the consistency of the results and assures a relative comparison between the sections is meaningful.

From the acoustic point of view, test results can lead to the following considerations:

- in the medium to long term, characteristics of noise absorption have provided negligible impact on tire–pavement noise results, suggesting that the difference in noise values can be mostly related to wearing course characteristics;
- in the medium to long term, comparable noise emission values (CPX & OBSI) have been observed in both rigid and flexible sections under the same external conditions, particularly load and climate;
- in the medium to long term, the longitudinally tined concrete section has proved lower noise results than some flexible asphalt sections, confirming the effectiveness of this texturization method in decreasing noise levels;

Fig. 13. BPN and MTD averaged over pavement age.



- the RAS section has proved to be the quietest, confirming that a smooth surface with uniform aggregate shape and distribution can reduce tire–pavement noise;
- the SMA section produced some of the highest levels of tire–pavement noise among the asphalt sections, defying expectations. SMA is usually considered a quiet pavement and is often selected to reduce road noise. However, its acoustic performance is inclined to decrease over time;
- as a general trend, the asphalt sections have proved to produce lower noise results than concrete pavements with respect to the pavement age.

From the wearing course characteristics point of view, the combination of harsh climatic conditions and severe freeze–thaw cycles, typical of the Canadian climate, and heavy loads, typical of the waste haulage vehicles travelling along the test track, has impacted some pavement sections more than others. Whereas some distresses can be observed in every test pavement, signs of structural distress can only be observed in few older sections and more frequently in the loaded lane. The following observations can be made:

- the RAS section is in the best condition, with negligible distress. It also produced average values of IRI, MTD, and BPN, compared to the other sections, confirming to be a relatively smooth pavement with adequate friction characteristics. Since it is the most recently constructed, to enable a fair comparison with other pavement type, a few more years of monitoring would be required;
- the stone mastic asphalt section has demonstrated good smoothness values and the highest values of friction and surface texture indicators. Despite that, it shows widespread distress;
- as a general trend, comparable results were observed in all asphalt sections, with average values of roughness, skid resistance and surface texture. Signs of distresses are usually present;
- all the rigid sections proved to have similar characteristics, even though the RCA content varied, providing very good ride quality and average skid resistance. Minor signs of distresses are present, but none of them appear to be structural in nature.

Taking into consideration the pavement age, comparable results can be observed between flexible and rigid sections: however, fair comparisons may require a few more years of monitoring, especially since concrete pavements are expected to provide significantly longer service life. This consideration is valid both for the acoustic and for the wearing course characteristics.

Continue monitoring is important to provide information on the long-term acoustic and wearing course characteristics of the tested pavement sections. To complete the evaluation, these tests should be repeated in 2018 and in 2020, when the concrete sections and the RAS section will be as old as the flexible sections at the time of this testing (2013) respectively.

This would allow direct comparison between the test results and would confirm or reject the considerations made about the age effect on the tested pavements.

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