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The effects of pavement surface characteristics on tire/pavement noise

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ABSTRACT

Pavement surface characteristics are major attributes to tire/pavement interactions and are considered as cost-effective options to mitigate traffic noise. The objective of this paper is to evaluate the effects of single and multiple pavement surface characteristics on tire/pavement noise levels. During the period from August 2009 to August 2011, noise levels and pavement surface characteristics are measured quarterly on impervious and open-graded asphalt pavements at 2009 NCAT test track. The linear regression analysis method and dominance analysis method are used to evaluate the effects of single and multiple pavement surface characteristics on noise levels, respectively. The results show that surface texture increases noise levels at lower frequencies (below 1600 Hz) especially on impervious asphalt pavements. Porosity decreases noise levels at every frequency (except at 2500 Hz) on open-graded asphalt pavements. These findings will help to design future low-noise asphalt pavements.

1. Introduction

Tire/pavement noise is a major source of traffic noise at high speeds. The noise exposure not only impairs human hearing capacity (hearing loss), but also causes some mental diseases [1]. Sound wall or sound barrier is a common measure to mitigate traffic noises, but their construction and maintenance costs are high.

Originally, Porous Asphalt (PA) and Open-Graded Friction Course (OGFC) were developed in Europe and US to improve frictional resistance of asphalt pavements [2]. The spray and splash were significantly reduced and surprisingly noise levels were also mitigated. It was believed that pavement surface characteristics (such as porosity, texture, and stiffness) might be major attributes to tire/pavement interaction and they might lead to cost-effective options to mitigate traffic noises. Since then, poro-elastic material and asphalt rubber material are also reported to reduce noise levels [3–5].

With regard to the effects of pavement surface characteristics on noise levels, previous researches show that macrotexture and International Roughness Index (IRI) increase noise levels at lower frequencies and higher air-void content reduces noise levels at higher frequencies [6–8]. However, until now, the question about the relative significance of pavement surface characteristics on noise levels is still not well known [6]. This paper will help to understand tire/pavement noise generation mechanisms and to design new generation of low-noise asphalt pavements.

2. Methodology

2.1. 2009 NCAT test track

Forty-six asphalt pavement sections are included in the 2009 NCAT oval-shaped test track (Fig. 1), 40 of them are impervious asphalt pavements (including 27 fine-graded Superpaves, eight coarse-graded Superpaves [9], five Stone Mastic Asphalt (SMAs)), and the other ones (six sections) are open-graded asphalt pavements (OGFCs). Among them, 10 fine-graded and eight coarse-graded Superpave pavement sections (all constructed in 2009 except for E4 section in 2000), five SMA and five OGFC pavement sections are selected and analyzed in this paper (Table 1).

2.2. Data collection

Tire/pavement noise was measured by On-board Sound Intensity (OBSI) method (AASHTO TP 76-08) [10]. Two sound intensity probes were used in OBSI measurements, one at the leading edge and another at the trailing edge of the tire/pavement contact patch. All measurements were conducted at 45 mph (72 km/h) using a Chevrolet Uplander minivan with SRTTs (Uniroyal tires). Three consecutive runs were taken for each measurement. During the period from August 2009 to August 2011, noise was measured nine times. The results of OBSI measurements are called as Sound Intensity Levels (SILs) and given in terms of spectral contents in one-third octave bands from 315 Hz through 4000 Hz. In this paper, the frequencies of interest only include lower frequencies (315, 500, 1000 Hz) and higher frequencies (1600, 2000 and 2500 Hz).

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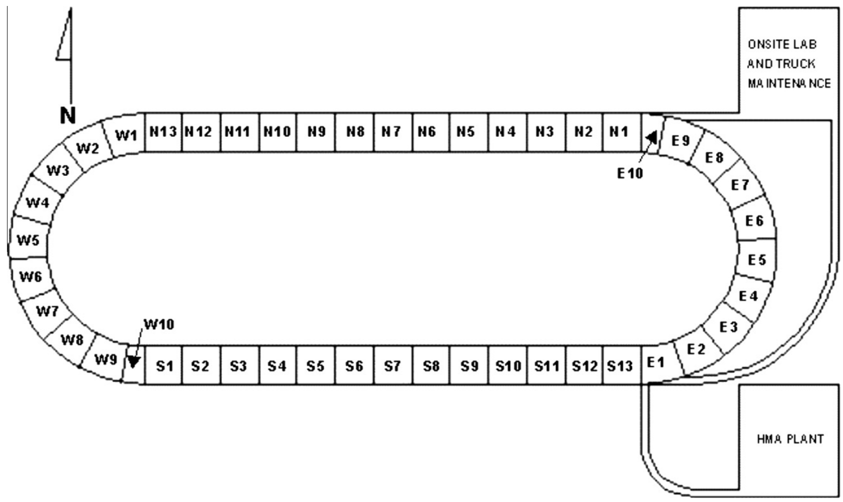

Fig. 1. 2009 NCAT test track.

Table 1
Pavement sections of 2009 NCAT test track included in this paper.

Pavement surface type		No. of sections	Test track sections	Construction year
Impervious pavement	Fine-graded Superpave [a]	10	N5, N6, N7, N8, N10, N11, S9, S10, S11, S12	2009
	Coarse-graded Superpave [a]	8	E4	2000
			E8, E9, W2, W7, S2, S6, S7	2009
	Stone Mastic Asphalt (SMA)	5	E1, N9, N12, W1, S1	2003, 2006, 2009, 2000, 2003
Open-graded pavement	Open-Graded Friction Course (OGFC)	5	N1, N2, S8	2009
			N13, S3	2006

[a] The Superpave mixture can be categorized into fine-graded and coarse-graded mixtures by magnitude of % passing of primary control sieve (PCS) of the mixture. For example, it is a fine-graded Superpave mixture if % passing of aggregate at 2.36 mm (PCS) is greater than 39% for a 12.5-mm (nominal maximum aggregate size, NMAS) mixture. Otherwise it is a coarse-graded Superpave mixture.

Table 2
Number of measurements of noise and pavement surface characteristics.

Pavement surface type		No. of sections	Noise (SIL)	Texture (MPD)	Porosity (V_A)	Stiffness (E^*)	Roughness (IRI)	Aggregate size (NMAS)
Impervious pavement	Fine-graded Superpave	10	9	8	1	9(3)[a]	8	1
	Coarse-graded Superpave	8	9	8	1	9(3)[a]	8	1
	SMA	5	9	8	1	9(2)[a]	8	1
Open-graded pavement	OGFC	5	9	8	1	0	8	1

[a] The numbers in the parentheses refer to the numbers of surface materials on the test track sections measured.

In addition to noise measurements, pavement surface characteristics which have been reported to affect tire/pavement noise were collected during the same period. Surface texture was measured by circular texture meter (CTM) and recorded in terms of Mean Profile Depth (MPD) [11,12]. Pavement roughness was measured with inertial laser profiler (mounted on a NCAT ARAN van) and reported as International Roughness Index (IRI). Stiffness (reported as Dynamic Elasticity, E^*) was obtained according to the master curve of E^* of surface asphalt mixtures at different temperatures. Porosity and aggregate size were determined using Quality Control (QC) documents during the initial constructions and recorded as air void (V_A) and nominal maximum aggregate size (NMAS), respectively.

Table 2 summarizes number of measurements of noise and related pavement surface characteristics. Porosity (air void, V_A) of each surface material was only measured during its initial construction. Also, the stiffness (dynamic modulus, E^*) of OGFC materials were not measured yet. In addition, the aggregate sizes of pavement surface materials stay the same values during their lifetimes.

3. Single surface characteristic analysis

Like those done in many previous researches, the linear regression analysis method is used to evaluate the effects of single pavement characteristic on noise levels.

3.1. Texture

Fig. 2 plots the correlations of noise levels at one-third octave frequency bands with surface textures of different asphalt pavements.

At lower frequencies (315, 500 and 1000 Hz), pavement surface textures of fine- and coarse-grade Superpave asphalt pavements (Superpaves) influence noise levels. As expected, noise levels at