

Challenges for Tire Noise Evaluation on Common Pavements

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ABSTRACT

Developing common methods of noise evaluation and facilities can present a number of challenges in the area of tire/pavement noise. Some of the issues involved include the design and construction of pavements globally, the change in pavement over time, and variation in the noise produced with standard test tires used as references. To help understand and address these issues for airborne tire/pavement noise, acoustic intensity measurement methods based on the On-board Sound Intensity (OBSI) technique have been used. Initial evaluations have included measurements conducted at several different proving grounds. Also included were measurements taken on a 3m diameter tire noise dynamometer with surfaces replicating test track pavements. Variation between facilities appears to be a function of both design/construction and pavement age. Consistent with trends in the literature, for smooth asphalt surfaces, the newest surface produced levels lower than older surfaces. For more aggressive, exposed aggregate concrete surfaces, the levels produced appear to depend more on the roughness built into the surface rather than aging effects. The tire noise dynamometer produced overall levels slightly higher than the actual pavements especially at higher frequencies. The long term stability and durability of the dynamometer surface make it a useful reference for evaluating the actual pavements over time.

INTRODUCTION

Vehicle road noise development in multiple locations is challenging from many perspectives. Driving conditions and pavement surfaces can vary greatly throughout the world. In order to establish a common framework for road and tire

noise development and define operating conditions to ensure the appropriate vehicle content to meet customer expectations, nominally common road test surfaces are required. An initial step in assessing the road surfaces is to consider the pavement characteristics. Once comprehended, further work can be undertaken to establish tire noise and vehicle level correction factors. This paper is focussed on the initial work to measure the pavement surface effects on tire-road noise.

The noise radiated by tires is an important factor for interior airborne noise and vehicle passby noise. Pavement characteristics that affect radiated tire noise are defined by pavement parameters such as surface texture, aggregate size and gradation, and design. Even with specification of these parameters, differences can still exist due to local construction practices, local materials, and pavement age. Experience in the United States has shown that for highway pavements, variations of 3 dB can occur in the noise produced by new sections of pavement over distances of several hundred meters when they are constructed at the same time by the same contractor¹. Even for more tightly controlled surface specifications, differences of 2 dB have been documented for ISO 10844 test surfaces built to the standard^{2,3}. Validating the performance of pavements is further complicated by the tires themselves. The noise generation is known to be dependent on air temperature with noise decreasing with increasing temperature^{4,5}. It is also a function of loading and applied torque for tires on drive axles^{3,6}. Aside from measurement variables, standard reference tires of the same design can vary by almost 1 dB from each other⁷ and tires tend to increase in noise

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generation with age as indicated by changes in rubber durometer hardness⁸.

For radiated tire noise, the measurement technique of choice was the on-board sound intensity (OBSI) method that had been used in previous comparisons^{2,3} and is currently in the process of being standardized by several organizations include SAE, ASTM International, and the American Association of State Highway Officials (AASHTO). OBSI was also selected as it has been shown to be highly correlated with passby noise under cruise and coast conditions^{5,6,9} as well as being correlated with airborne interior tire noise¹⁰. It can also be applied directly on test similar vehicles eliminating the need to ship specific cars or test trailers.

The purpose of this paper is to document these initial test programs and discuss findings regarding the differences in surfaces used for noise development. The results of comparative testing completed on a tire noise dynamometer equipped with surfaces replicating the vehicle development pavements are also presented and discussed.

TRACK-TO-TRACK COMPARISON

TEST DESCRIPTION

All of the tire/pavement noise measurements used in this program were conducted using the OBSI measurement method. To implement this method, two phased matched condenser microphones and associated preamplifiers are attached to a plastic probe holder at a spacing of 16mm in a side-by-side configuration and fitted with a spherical windscreen for each measurement location. A dual probe approach allows the leading and trailing edge positions to be measured simultaneously. The probes were positioned 75mm from the pavement surface and 100mm from the face of the tire, at locations opposite the leading and trailing contact patch of the tire, and oriented so that the sensitive axis was pointed toward the tire. A photograph of the OBSI fixture mounted on a test car is shown in [Figure 1](#). Leading and trailing edge measurements were acquired simultaneously, but separately, and then averaged together during post-analysis. The microphone signals were analyzed using a Brüel & Kjær Pulse system into 1/3 octave band levels using a 5-second averaging time as well as into narrow-band data with a resolution of 8 Hz. The microphones were calibrated using a Larson Davis Model CAL200 acoustic calibrator set for 94 dB at the beginning and end of the measurement period. Three passes were made for each test section, which were averaged together during post analysis. OBSI quality metrics of coherence between the two microphones comprising each probe and the difference between sound pressure and sound intensity level were monitored during data acquisition. During data acquisition, the actual time

signals of the four microphones were also viewed on the data acquisition laptop computer.



Figure 1. OBSI fixture installed on a test vehicle

All testing was performed with an ASTM Standard Reference Test Tire (SRTT) sized at P225/60R16 adjusted to a 'cold' tire inflation pressure of 207 kPa (30 psi). The testing was carried out over an extended time period at the different track locations, and on similar mid-sized front wheel drive sedan vehicles with the test tire mounted in the right rear tire position. For Track 1 measurements, the ambient temperature was 16° C (61° F), for Track 2, 26° C (79° F), and Track 3 it ranged from 17.2° C (63° F) to 20.6° C (69° F). Based on previous reported research¹¹, the temperature range between the measurements could amount to about a 0.5 dB difference in OBSI level with the results from Track 2 being lower. The difference in test tire loading between the three vehicles is sufficiently small so that there should be little effect on the OBSI levels¹¹.

At each of the three tracks, two common noise development surfaces were tested that included a smooth hot mix asphalt (HMA) pavement and an exposed aggregate portland cement concrete (PCC) pavement.

PCC NOISE DEVELOPMENT PAVEMENTS



Figure 2. Photographs of coarse road pavements at Track 1 (top), Track 2 (middle), and Track 3 (bottom)

Each track had a PCC pavement of exposed aggregate (coarse road). As a result of these exposed stones, the coarse road surface typically produces high noise levels below 1000 Hz and is often used to generate higher levels of interior structure-borne noise. Photographs of the coarse road surface at the three test tracks are shown in [Figure 2](#). The overall A-weighted sound intensity levels are shown in [Figure 3](#) for the 60 and 97 km/h test speeds. As part of the Track 3 testing, three SRTT tires were included producing a range of about 1 dB. Of the three surfaces, the Track 3 pavement produced

highest levels, particularly at 97 km/h where the levels were 3 to 5 dB higher than the other two. The levels for Track 1 were similar to those from Track 2 with a difference of less than 1 dB. At 60 km/h, the differences between the Track 1 and Track 3 measurements were reduced to about 2 dB compared to 3 dB for the same tire pairing at 97 km/h. The one-third octave band levels for the three surfaces are compared in [Figure 4](#) for the 97 km/h test speed. For the Track 1 and Track 2 pavements, the spectra are nearly the same, especially at 800 Hz and above. Below 800 Hz, the levels for the Track 1 measurements are about 2 dB higher. Typically, the noise in this frequency range is controlled by surface roughness, however differences in roughness are not very apparent from [Figure 2](#) although the Track 1 aggregate may be slightly larger. The spectrum for the Track 3 measurement is uniformly about 3 dB higher than the other two surfaces. In the lower frequencies, higher levels would be expected based on the photographs of [Figure 2](#), as the stone in the pavement appears to be more exposed than for the other tracks creating added roughness. In the mid to high frequencies, typical noise mechanisms include air-pumping from the tread pattern and friction related “scrubbing” of the tread on the pavement. However, neither of these mechanisms appears to be a factor in comparing these pavements. Given the unusually high amount of the displacement input generated by the Track 3 surface, tread band and tread element vibration may be extending into the higher frequencies to a greater extent than is normally the case on more conventional pavements.

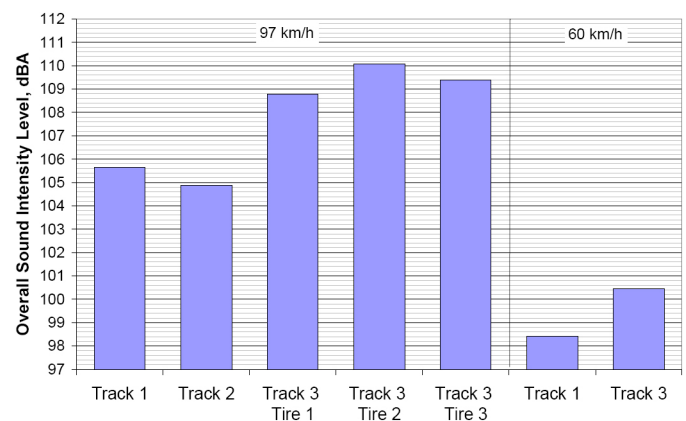


Figure 3. Overall A-weighted OBSI levels for coarse road pavements at 60 and 97 km/h