

Parameters Affecting the Noise Performance of ASTM Standard Reference Test Tires

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ABSTRACT

Currently, the ASTM P225/60R 97S Radial Standard Reference Test Tire (SRTT) is used as a control test tire for calibrating test track surfaces over time and for rank ordering the noise performance of different pavement designs. As a result, variation from one SRTT to another and the effects of tire aging are important to quantify. Measurements of tire noise sound intensity on eight asphalt and two concrete test sections were conducted for eleven new and six older SRTT tires. The range in level for the new tires on each of the ten pavements was determined and was found to be 1.1 dB when averaged over all pavements compared to 0.7 dB for a single tire tested multiple times. As a group, the older tires produced levels 0.5 dB higher than the new tires when averaged for all pavements. The older tires had higher tread rubber durometer hardness values than the new tires, however, within the old and new groupings, no consistent trends could be identified. After nine months, the original 11 new tires were retested with some tires being subjected to mileage accumulation, accelerated aging, and wheel width changes. It was found that the effect of tire aging variables including hardness, tread depth, time since construction, and mileage, were not necessarily consistent from tire-to-tire. However, considering the extremes of durometer hardness, reduced tread depth, accumulated mileage, and in-service years, a strategy for deciding when test tires should be retired was developed based on a combination of these factors. Due to the varying temperatures at which the measurements were made, an adjustment of tire noise level for temperature was developed as part of this research.

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INTRODUCTION

The identification and use of a reference tire for noise is critical in many automotive applications. For a single vehicle manufacturer, a reference tire is needed for comparing different test track pavements globally and developing common vehicle noise performance specifications [1]. For vehicle pass-by noise on ISO 108441 test tracks [2], a reference tire is desirable for comparing one track to another, assessing changes in noise performance over time, and even for examining variability within a single test track [3]. For isolating differences in noise produced by different pavements for application to highway design, a standardized, reference test tire is also needed. A reference tire should be available for purchase over time and have well documented specifications. Its noise performance should also be representative of tires currently in use by the public. To satisfy these requirements, the P215/R16 ASTM International

Standard Reference Test Tire (SRTT) [4] has become a popular choice for standardized noise testing of test track and roadway surfaces [5,6]. From previous research, the SRTT has been found to produce noise levels that are on the lower end of the distribution of noise produced by light passenger vehicles, however, it rank orders pavements in a manner consistent with tires of noisier and more aggressive tread pattern design [7]. With respect to longer-term availability, although there cannot be any specific assurances, the tire is used for standard measurement of other performance issues such as traction and pavement characteristics.

Two issues for using the SRTT as a reference tire is the variation in noise produced from one tire to another and the variation in noise for one tire over time. There has been some limited data reported in the literature on variation of the noise produced by SRTTs. In one study, on-road evaluation of six tires on four asphalt and three concrete pavements produced

an average difference in on-board sound intensity level (OBSI) level of 0.8 dB for tires of varying age and usage [7]. In another study, testing conducted on a road-wheel simulator with a smooth asphalt replica surface found that new SRTT tires with minimal break in were 0.5 dB higher in level on average than one-year old tires with about 300 miles accumulated [6]. In these studies, however, the results were not well linked to variables such as tire durometer hardness, tread depth, usage, and age. Typically, these variables are linked to increased noise levels [8,9], but not specifically for the SRTT.

Variation between SRTT test tires was examined in a systematic manner in the recently completed National Cooperative Highway Research Program (NCHRP) Project 1-44 (1) [10]. This research dealt with all aspects of measurement precision and bias in the American Association of the State Highway Transportation Officials (AASHTO) OBSI procedure [5]. A portion of this work included examining the variation between nominally identical new tires as well as those that had been in-service or had been subjected to various aging techniques. The testing, measurement results, and recommendations of this portion of the research are provided in this paper.

MEASUREMENT PROGRAM

The tire/pavement noise measurements were conducted at the Hyundai-Kia (H-K) Motors California Proving Grounds (HATCHI), near Mojave, California. It was decided to conduct the research at test track facility to minimize any influence of pavement aging that may occur over the 10 months of the study, for time savings in conducting the testing, and for safety reasons. The H-K facility was ideal for this use as it has a variety of specifically designed pavement types. Previous testing had shown that the SRTT OBSI levels range from 92.6 to 104.6 dBA for 15 of the H-K surfaces [11]. These surfaces included both asphalt concrete (AC) and portland cement concrete (PCC) pavements. Testing related to tire variation and aging was conducted in February, March, and December of 2010. Additional testing was also conducted in September to include more high temperature data on several test tires. Including all test sessions, the air temperature ranged from 4° to 38° C. The overall project consisted of a total of 750 combinations of pavements, tires, vehicles, and temperatures.

Test Procedures

All testing was conducted using on-board sound intensity in a vertical, two-probe configuration as shown in [Figure 1](#) mounted on the right rear (RR) wheel except for the left side mileage accumulation tires which were tested in the left rear (LR) position. Instrumentation consisted of phased-matched microphones and preamplifiers whose signals were acquired and processed into sound intensity with using a Brüel & Kjaer PULSE analyzer system. The PULSE analyzer produced $\frac{1}{3}$ octave band sound levels and narrow band, fast

Fourier transform (FFT) levels. The OBSI levels measured opposite the leading and trailing edges of the tire contact patch were averaged together to represent the total tire noise sound intensity. Three or more measurements were made for each tire/pavement combination and were averaged together to produce the reported level for the combination. The measurement protocol followed that of the AASHTO procedure [5]. Testing was conducted using a 2006 Chevrolet Malibu with two occupants and the OBSI instrumentation, providing a loading of about 770 lbs on the test tires. All measurements were at a test speed of 97 km/h (60 mph).



Figure 1. Photograph of dual OBSI probe fixture installed on a test vehicle

For the AC pavements, 5-second averages were made on each surface while, on the shorter PCC pavements, the averaging time was reduced to 4 seconds. This shorter averaging time was found not to increase the run-to-run variation over that experienced for the AC pavements. Vehicle speed was maintained to ± 1.6 km/h (± 1 mph) using the vehicle cruise control and monitored throughout each test run using a GPS unit with 0.16 km/h (0.1 mph) readouts of speed. The position of start point for acquiring data at each test section was signaled to the analyzer operator with an audible impulse produced by an optical sensor mounted on the OBSI fixture and triggered by reflective traffic cones. During the course of the measurements, the overall levels of the trailing edge probe were observed and recorded to monitor run-to-run consistency. The time signals from each microphone, the coherence, and Pressure/Intensity (PI) index were also monitored during data acquisition. Using these controls, run-to-run repeatability averaged 0.2 dB.

During the course of measuring the test tires, baseline measurements on a primary control test tire were repeated after three or less intermediate tire tests. This provided a moving reference such that the test tires always had a comparison tire measured under nearly identical conditions. These data were also used to develop a relationship between OBSI level and air temperature that was used to normalize

the data obtained under different conditions to a reference temperature of 14.4° C (58°F).

Test Tires

A total of seventeen SRTT tires were included in the test program. Eleven of these were newly purchased specifically for this project in order to evaluate the range in OBSI produced by new tires built at similar times. The new tires were identified as Test Tires TT#1 through TT#11 and all had a build date in November 2008 (i.e. week 46, year 08). All eleven of these new tires were measured in the initial test session in February. The hardness of the tires all fell within the range specified in the ASTM specification of 64 ± 2 when measured with an ambient temperature of 23.3 to 25°C, within the allowed range of $23.0 \pm 2.0^\circ\text{C}$. At the time final testing in December, the hardness of 7 of the 11 tires remained within the ASTM F 2493 range. The four tires that did not fall into this range were the tires that were used to assess the effects of accumulated mileage and remained on the test vehicle as it was used as a service vehicle between the February and December test sessions. With the mileage accumulated on these tires, the hardness numbers had increased and no longer fell within the ASTM F 2493 range. Of the other seven tires, two (TT#3 and #4) were subjected to accelerated aging by exposure to heat cycles during the course of the summer months. One tire, TT#5, was used as the primary test tire and was measured repeated as the control tire throughout all test sessions and was used to develop the relationship between tire noise and air temperature. TT#9 was used as a secondary test tire and was also measured during all test sessions, although not as extensively as TT#5. Two tires (TT#8 and #9) were tested only in February and December with the tires remounted on 165mm wheels after initial testing on 178mm wheels. The eleventh tire (TT#7) was used as a reference tire with very limited testing in the February and December sessions.

Six of the total seventeen test tires were not new tires and had been in-service for some time. These tires were 1 to 3 years older than the new tires and five out of six of these tires had higher hardness numbers (68 to 70) falling outside of the range of the new tires and the range specified in ASTM F 2493. Of these six older tires, four in-service tires were provided by Illingworth & Rodkin, Inc. designated as SRTT 1, SRTT 2, SRTT 3, and Passby RR, one in-service tire provided by the America Concrete Pavement Association designated as ACPA and one in-service tire provided by the Transtec Group, Inc. designated as Transtec. The actual accumulated mileage of these tires was not known.

Test Surfaces

Ten pavement surfaces were tested representing a variety of design categories and covering a range in the noise level of about 10 dB. The test sections included eight AC pavements and two PCC pavements. The AC pavements consisted of two dense-graded asphalt concrete (DGAC) pavements with maximum aggregate sizes of 9.5mm and 19mm ($\frac{3}{8}$ " DGAC

and $\frac{3}{4}$ " DGAC, respectively), an open-graded asphalt concrete (OGAC) pavement, an AC pavement that had been sand blasted and ground (Sand Blast), a slurry-sealed surface (Slurry Seal), a chip seal pavement (Chip Seal) with maximum 19mm aggregate, an AC of fine aggregate producing an "ultra smooth" surface (Ultra Smooth) and an AC pavement intended to be porous, but in fact, is not porous (Porous). The PCC surfaces included one longitudinal tine texture (Long. Tine PCC) and one diagonal broom texture (Broom PCC). For propriety reasons, further construction details of these pavements were not provided by H-K, however, photographs of each of the test pavements are shown in [Figure 2](#).



Figure 2. Test pavements at the Hyundai Kia Proving Ground (*Note: "Porous" is not actually porous)