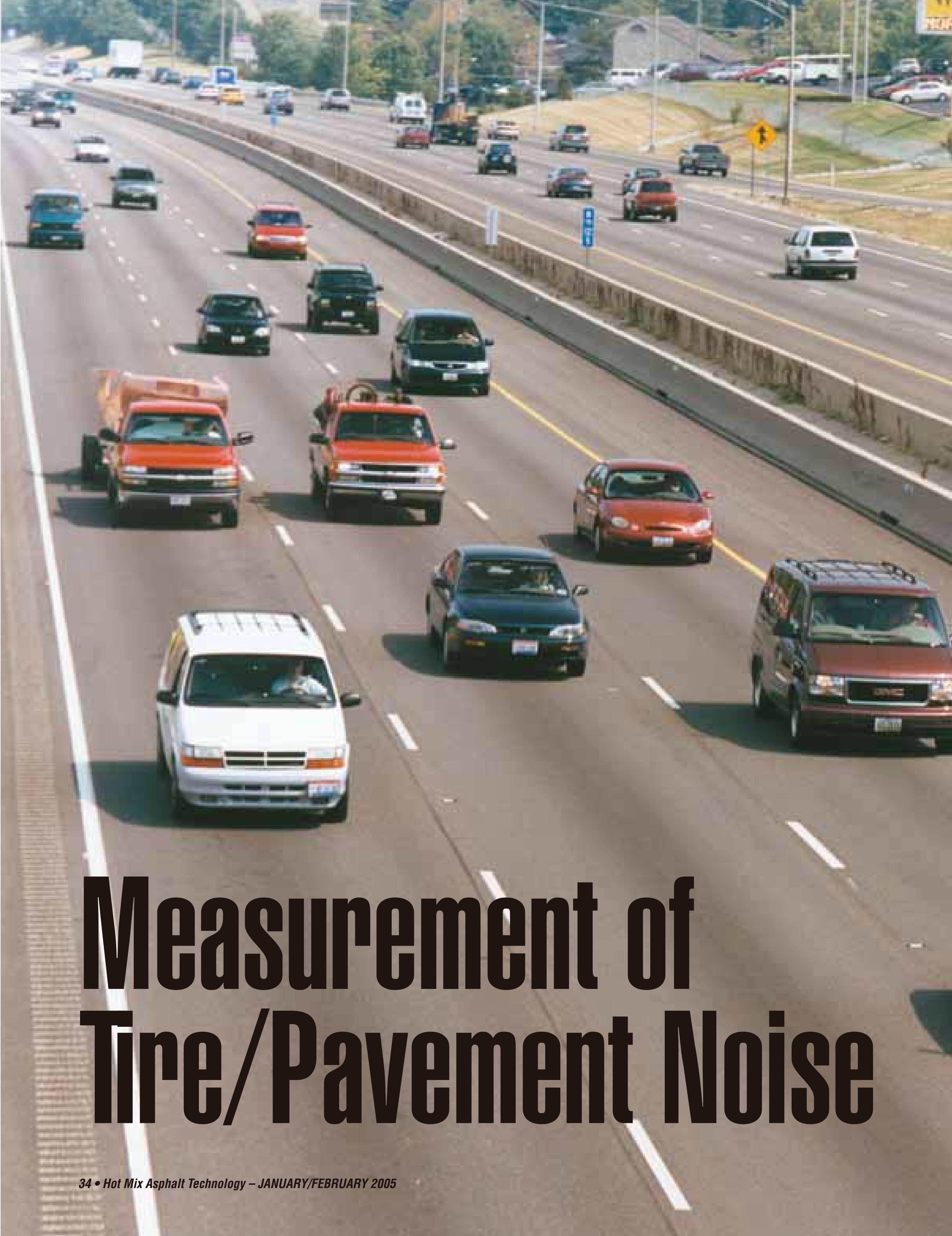

Measurement of Tire/Pavement Noise

Figure 1 – Wayside measurements

Sound caused by transportation systems is the number one noise complaint.

Research in Europe and in the United States has indicated that it is possible to build pavement surfaces that will provide low-noise roadways. The National Center for Asphalt Technology (NCAT) has initiated a study to develop a pavement selection guide or design manual for use by the DOTs and others to design low-noise Hot Mix Asphalt (HMA) pavement wearing courses.

Throughout the world, sound caused by transportation systems is the number one noise complaint. Highway noise is one of the prime offenders. Engine (power train), exhaust, aerodynamic, and pavement/tire noise all contribute to traffic noise.

It has been shown that modification of pavement surface type and/or texture can result in significant tire/pavement noise reductions. European highway agencies have found that the proper selection of the pavement surface can be an appropriate noise abatement procedure. Specifically, they have identified that a low-noise road surface can be built at the same time considering safety, durability and cost using one of the following approaches:

1. A surface with a smooth surface texture using small maximum-size aggregate.
2. A porous surface, such as an open graded friction course (OGFC) with a high air void content.
3. A wearing surface with an inherently low stiffness at the tire/pavement interface.

Field measurement of road noise

To be able to study traffic noise it is necessary to have a scientifically reliable method for measuring the acoustical characteristics of pavement surfaces in the field. Two concepts are currently being used for the measurement of roadway noise:

1. Far-field or wayside measurements where the noise level is measured by microphones that are placed along the side of the roadway.
2. Near-field or close-proximity techniques (CPX) where the noise level is measured by microphones placed near the tire/pavement interface.

Far-field or wayside measurement procedures

Far-field or wayside studies use three approaches: statistical by-pass, controlled by-pass and time-averaged procedures. All of these procedures consist of placing microphones at a defined distance from the vehicle path at the side of the roadway. For research purposes the statistical by-pass and the controlled by-pass procedures are the most commonly used. The time-averaged procedure is the most commonly used for doing traffic noise studies associated with the design or major widening of a highway project. Figure 1 shows a typical set up for wayside measurements.

The statistical by-pass procedure calls for placing microphones a specified distance from the roadway and height above the roadway. In Europe the standard is 25 feet from the center of the vehicle lane at a height of 4 feet above the pavement *(2)*. In the United States the standard as defined by the Federal Highway Administration *(3)* is

50 feet away and five feet above the roadway. Both procedures call for the measurement of the noise characteristics of a specified number of vehicles. In Europe the requirement is for 180 vehicles to be measured for noise (100 automobiles and 80 dual-axle and multi-axle trucks). The FHWA procedure does not specifically state the number of vehicles required for a valid sample. It states that the number of samples is somewhat arbitrary and is often a function of budgetary limitations. But, the procedure does provide some guidance. For example, if the traffic speed is 51 to 60 mph, the minimum number of samples recommended is 200.

Strict rules exist for both the European and US procedures at a test site. The section of highway being tested must be essentially straight and level. There is a limit on the background noise and no acoustically reflective surfaces can be within 30 feet of the microphone measuring the noise levels. There are also strict requirements on the weather conditions – especially wind speed and direction. The vehicles must be traveling at a constant speed through the testing zone. The procedure requires that the noise from only one vehicle is measured at a time. The noise level from all of the vehicles is acoustically summed to provide a Statistical By-Pass Index (SBPI). These vehicle restrictions limit the use of this procedure on high volume multilane highways. Even if the same mix of vehicles is used the results may vary due to differences in vehicle tires. Thus, this procedure has limited usage for comparing different pavement types.

In the single vehicle pass-by method, noise from cars and light trucks is typically measured at a specially designed test site. There is no standardized test procedure for

Figure 2 – Finnish CPX Noise Trailer
The NCAT trailer is being used to measure road noise close to its source.

Figure 3 – NCAT close proximity trailer
Measuring road noise at a standard distance.

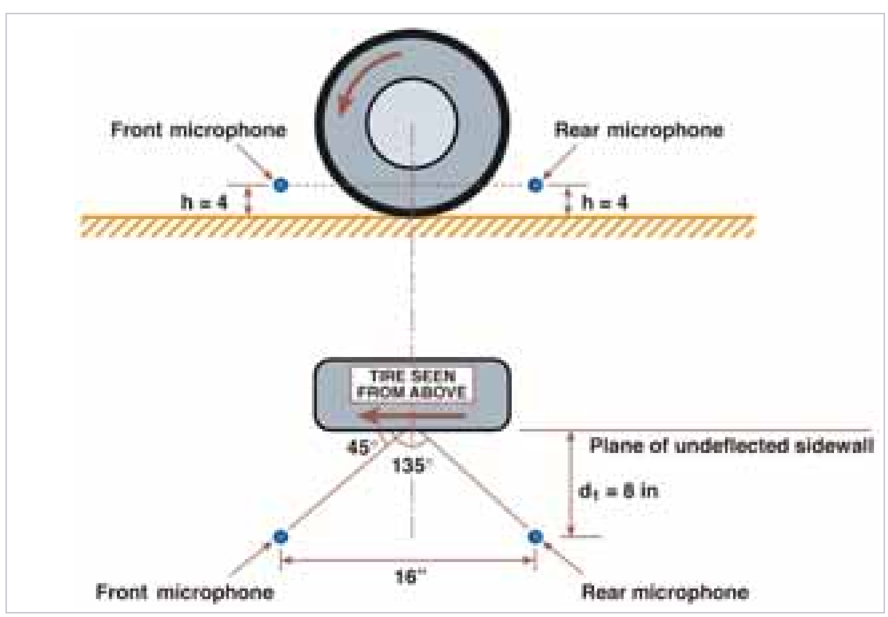

Figure 4 – Diagram showing microphone locations in NCAT CPX Trailer

Type of Surface	No. Sites Tested	Average Noise Level (dB(A)	Maximum Noise Level Measured (dB(A))	Lowest Noise Level Measured (dB(A)
Transverse-tined PCC	25	103.6	106.5	100.6
Longitudinally tined PCC	15	99.8	103.6	98.1
Diamond-ground PCC	12	98.9	101.0	97.0
Dense-graded HMA	76	97.1	101.0	93.0
Stone Matrix Asphalt	22	98.0	101.0	95.0
Coarse-graded OGFC (5/8 inch minus)	29	97.0	99.1	92.6
Fine-graded OGFC (3/8 inch minus)	10	92.6	93.9	90.9

Table 1 – Typical Noise Levels for different pavement types

Figure 5 – Noise propagation

this testing. The vehicle approaches the site at a specified speed in a specified gear. An example of this type of testing is a study conducted by Marquette University for the Wisconsin DOT (*4*). In this study, they used a 1996 Ford Taurus that was operated at 60, 65 and 70 mph in the right lane. They conducted their testing by placing two microphones five feet above the pavement and positioned at 25 feet from the center of the traffic lane. The microphones were placed 200 feet apart. Three runs were made to collect enough data for each speed.

The time-averaged or community noise level methods are defined by the FHWA Manual **Measurement of Highway Noise** *(3)*. This manual details procedures for conducting this type of noise survey. For example, the data are used to determine the community-noise exposure level (L_{den}) and the day-night average sound level (L_{dn}). In this method, the noise level of an existing traffic stream is determined over a time period (for example, 15 minutes, 30 minutes, or an hour). The time period and the location of the microphones will vary depending on the objectives of the study being conducted. Traffic counts, categories of vehicles, and speeds of the vehicles along with meteorological data must be captured.

Near-field measurements or close-proximity methods

Near-field tire/pavement noise or close-proximity (CPX) methods consist of measuring the sound levels at or near the tire/pavement interface. In the CPX method, sound pressure or sound intensity is measured using microphones located near the road surface. This technique is being routinely used in Europe. See Figure 2 for a picture of the CPX device being used in Finland for conducting noise studies.

The requirements for the CPX trailer are described in ISO Standard 11819-2 (*5*). This method consists of placing microphones near the tire/pavement interface to directly measure tire/pavement noise levels. In 2002, NCAT built two CPX trailers, one for the Arizona Department of Transportation and one for use by NCAT. A picture of the NCAT trailer is shown in Figure 3.

The standard method used by the FHWA's Volpe Laboratories is the statistical pass-by method. This method was selected because it includes both the power train and tire/pavement noise.

The ISO Standard calls for the measurement of sound pressure. The microphones are mounted eight inches from the center of the tire and four inches above the surface of the pavement (see Figure 4). The microphones are mounted inside an acoustical chamber to isolate the sound from passing traffic. The acoustical chamber is required because sound pressure microphones will measure the sound from all directions and thus, there is a need to isolate the sound from other traffic and sound reflective surfaces.

A concern with regard to the use of near-field measurements is that they measure only the tire/pavement noise component of traffic-related noise (*1*).

The standard method recommended by the FHWA is the statistical pass by method or the time-averaged procedures. These methods were selected because they measure both the power train and tire/pavement noise. Both the power train and tire/pavement noise are strongly related to vehicle speed. Work done in Europe has indicated that there is a crossover speed for constant-speed driving of about 25 to 30 mph for cars and about 35 to 45 mph for trucks (*2*). At speeds less than 25 to 30 mph for cars or 35 to 45 mph for trucks, the power train noise dominates; however, at higher speeds the tire/pavement noise is more prevalent. Therefore, it appears that the concept of measuring the noise level of roadways at the tire/pavement interface is valid for roadways having speed limits above 45 mph.

The near-field test or close-proximity procedures offer many advantages:

1. The ability to determine the noise characteristics of the road surface at almost any arbitrary site.
2. The ability to check the state of maintenance, i.e. the wear or damage to the surface, as well as clogging of porous surfaces and the effect of cleaning clogged pores.
3. It is much more portable than the pass-by methods, requiring little setup prior to use.
4. The testing can be done on the

run at any selected speed (testing has been done at speeds that range from 30 mph to 70 mph).

Comparison of techniques

There is a concern about whether traffic noise can be predicted based on the measurements at the tire/pavement interface. Preliminary studies that have been conducted by NCAT and the Arizona Department of Transportation have shown that there is a difference of about 23 dB(A) between the close-proximity measurements and roadside noise levels measured at 25 feet from the edge of the traffic lane. Thus, if the noise level for the CPX trailer is 95 dB(A) at the tire/pavement interface then the noise level at 25 feet from the road will be about 72 db(A). The noise level drops off at the rate of 3 dB(A) for each doubling of the distance. See Figure 5. Thus, at 50 feet the noise level would be 69 dB(A) and at 100 feet would be 66 dB(A).

Test results from NCAT noise trailer

NCAT has tested more than 200 pavement surfaces in 16 states. The following table presents the average noise value for each of the pavement types tested. In addition to the sites listed, testing has been done on a number of miscellaneous surfaces such as bridge decks, microsurfacing, NovaChip, etc. For the HMA pavements, researchers found that the smaller the top size for the aggregate, the lower the noise level. HMAT

Doug Hanson is Assistant Director of the National Center for Asphalt Technology.

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