

Noise Impacts of Pavement Surface Characteristics

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PROJECT TITLE

Noise Impacts of Pavement Surface
Characteristics

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Introduction

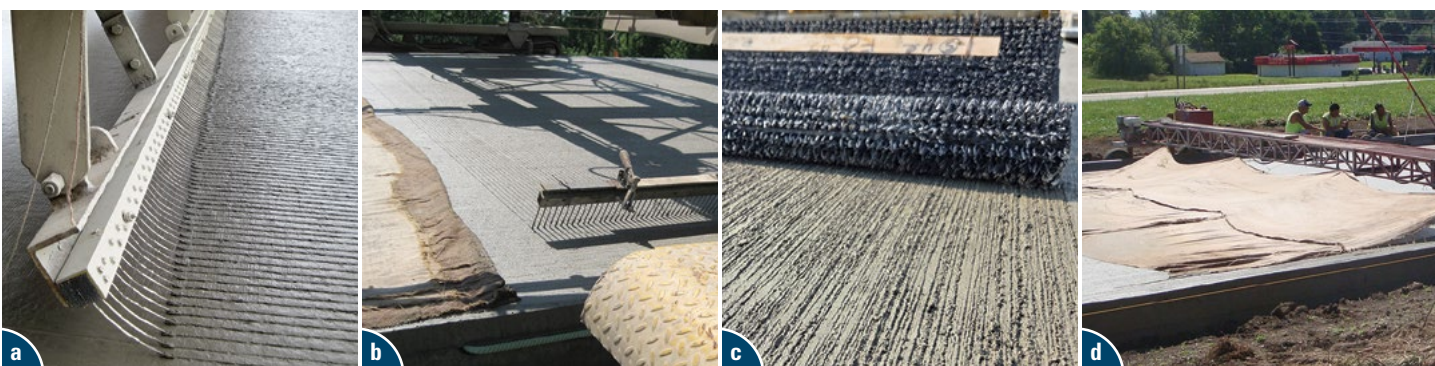
This Moving Advancements into Practice (MAP) brief is part one of a two-part series addressing the impacts of concrete pavement surface characteristics. Part one focuses on noise impacts, and part two will focus on ride quality impacts, including textures, equipment, friction, and safety.

Concrete Surface Types

Up until the late 1960s, many of the concrete roadways constructed in the United States used a burlap drag texture. This type of texture provided a quiet pavement and proved useful when speeds and traffic volumes were low. However, as highway speeds and traffic volumes increased, friction became a growing concern. In 1979, the Federal Highway Administration (FHWA) began requiring transverse tining for roadways posted above 40 mph with Technical Advisory T 5140.10. This decision led to the widespread adoption of uniform transverse tining on concrete pavements in the United States, which persisted as the primary texture until the 2000s, when communities began experiencing noise issues due to increased traffic volumes. Regularly spaced transverse grooves can produce tonal spikes at frequencies around 1,000 Hz. This tonal property is referred to as tire whine and is an artifact of the transverse groove geometry, not the concrete itself.

Nevertheless, tire whine at excessive levels constitutes a particularly annoying component of pavement noise that can lead to dissatisfaction among drivers and nearby residents and businesses.

In 2005, FHWA rescinded T 5140.10 and replaced it with T 5040.36, which allowed the use of many texture types. Refer to Figure 1 for types of concrete surface textures. Since the late 1990s, many states had already begun switching from transverse tining to longitudinal tining for higher speed roadways, as a longitudinally tined surface does not possess the tonal aspects of a transversely tined surface. Longitudinal tining is currently the most prevalent texture for new concrete pavement construction, while three state departments of transportation (DOTs) currently use astroturf drag texture as their final riding surface: Minnesota Department of Transportation (MnDOT), Colorado Department of Transportation (CDOT), and Wyoming Department of Transportation (WYDOT). MnDOT has successfully used this texture for 28 years, and CDOT and WYDOT have used it for approximately 15 and 3 years, respectively.



The Transtec Group, Inc., used with permission (a); Robert Rasmussen, used with permission (b); Dan Labo, used with permission (c); Jerod Gross, used with permission (d)

Figure 1. Concrete surface textures created through (a) longitudinal tining, (b) transverse tining, (c) artificial turf drag, and (d) burlap drag

Transportation Noise

Historical Perspective

Managing traffic noise has been integral to the development of transportation systems since the beginning of civilization. In fact, the first documented noise ordinance was issued by Julius Caesar in 44 BC, when he dictated the time at which wagons could enter Rome to prevent the clanking of wagon wheels on cobblestone streets during business hours (Sandberg and Ejsmont 2002). A more modern historical example can be seen in the United States during the late 1800s, when wooden blocks were sometimes used instead of cobblestones in high-density urban areas to help reduce the clank of wagon wheels (Sandberg and Ejsmont 2002).

With the introduction of the automobile in the early 1900s, however, transportation noise would forever be changed. The source of noise changed from horses' hooves and wagon wheel clanking to engine and exhaust noises. It wasn't until the 1950s that auto manufacturers voluntarily agreed to limit exhaust noise. Noise regulation in the United States first occurred at the state level, with California leading the way with legislation in 1967. The first federal attempt at noise regulation occurred in 1972, when Congress passed the Noise Control Act.

Many changes in technology and population have occurred in the 54 years since the first federal regulation. Today, noise is a quality-of-life issue in many urban areas and represents one of the many competing factors in urban design and living. When constructing highways, owners and agencies must contend with tradeoffs related to safety, pavement smoothness, highway capacity, and noise.

Noise Basics

All sounds interact with the human ear by exerting pressure on the ear drum. The extent to which transportation noise causes annoyance can be due to its pitch or its loudness (Lodico and Donovan 2018). Pitch is the subjective perception of the tone of a sound due to the frequency of its sound waves, allowing sounds to be classified as higher or lower. Humans can typically hear in a frequency range of 20 Hz to 20 kHz, but human hearing is particularly sensitive to the frequency range of 2 to

5 kHz (Snyder 2006). Loudness is the subjective perception of the volume of a sound due to the intensity of its sound waves.

Although there are different metrics for measuring sound, highway noise is typically measured in decibels (dB), a measurement unit used to describe the intensity of a sound. To better capture the way sound is perceived by the human auditory system, an A-weighted decibel (dBA) scale is used. The A-weighting method applies a filter to the measured sound that de-emphasizes the very low and very high frequency components to simulate the response of the human ear (Lodico and Donovan 2018). The decibel measurement scale is logarithmic, with 0 dBA based on the lowest level of sound that a healthy, unimpaired human ear can detect. Since the scale is logarithmic, each 10 dBA increase in sound level is perceived as approximately a doubling of the loudness over a wide range of intensities. Figure 2 provides a scale indicating how different dBA levels relate to typical sounds in the environment, while Table 1 relates sound change levels to perceived loudness and acoustic energy loss. It is generally assumed that in a noisy environment, a 3 dBA change in noise level is required before that change can be perceived, while a 10 dBA change would make the noise seem twice as loud.

Common Outdoor Activities	Noise Level (dBA)	Common Indoor Activities
Jet fly-over at 1,000 feet	— 110 —	Rock band
Gas lawn mower at 3 feet	— 100 —	
	— 90 —	
Diesel truck at 50 feet at 50 mph	— 80 —	Food blender at 3 feet Garbage disposal at 3 feet
Noisy urban area, daytime	— 70 —	Vacuum cleaner at 10 feet Normal speech at 3 feet
Gas lawn mower, 100 feet Commercial area	— 60 —	Large business office Dishwasher next room
Heavy traffic at 300 feet	— 50 —	
Quiet urban daytime	— 40 —	Theater, large conference room (background)
Quiet urban nighttime	— 30 —	Library
Quiet suburban nighttime	— 20 —	Bedroom at night, concert hall (background)
Quiet rural nighttime	— 10 —	Broadcast/recording studio
Lowest threshold of human hearing	— 0 —	Lowest threshold of human hearing

Source: California Department of Transportation 2013; dBA = A-weighted sound level

Recreated from Lodico and Donovan 2018

Figure 2. Typical A-weighted noise levels relative to typical sounds in the environment

Table 1. Relative loudness and acoustic energy loss for different sound change levels

Sound Level Change	Relative Loudness	Acoustic Energy Loss
0 dBA	Reference	0
-3 dBA	Barely perceptible change	50%
-5 dBA	Readily perceptible change	67%
-10 dBA	Half as loud	90%
-20 dBA	1/4 as loud	99%
-30 dBA	1/8 as loud	99.9%

Source: Courtesy of FHWA

Since traffic travels in consistent paths, it is assumed to be a line source in terms of sound propagation. Sound propagation from a line source decreases 3 dBA for every doubling of distance from the source (Lodico and Donovan 2018).

The impact of surface texture on pavement noise generation is indicated in Figure 3. The more positive the texture (upward pointing), the louder the noise generated, and the more negative the texture (downward pointing), the quieter the noise generated. Although conventional diamond grinding produces some positive texture, the Next Generation Concrete Surface, which combines flush grinding with longitudinal grooving, has the least amount of positive texture, which is why it is the quietest, nonporous, concrete texture yet developed.

How Infrastructure Affects Noise Propagation

Sound propagation from a traffic source to abutting properties (receptors) typically travels close to the ground. As such, the absorptive properties of the infrastructure between the noise source and receptors can reduce overall noise levels. For receptors within approximately 200 ft of the noise source, ground attenuation is not considered important (Lodico and Donovan 2018). At longer distances with hard ground surfaces such as concrete, attenuation is also not considered important. However, for soft ground surfaces like grass, soft dirt, and bushes, attenuation will reduce noise by an additional 1.5 dBA per each doubling of the distance from the source (Lodico and Donovan 2018). Pavement type

can also impact noise attenuation through sound absorption. For example, a porous concrete pavement can absorb noise.

Since sound reflects off hard surfaces, the built environment can play a major role in the success of noise mitigation. When sound walls are constructed on both sides of a freeway or tall buildings exist along the right of way, noise can be reflected from these structures, further contributing to the overall noise level. Additional discussion of this phenomenon can be found in the section on managing transportation noise.

How Weather Conditions Affect Noise Propagation

Weather can play a significant role in the success of noise mitigation under certain conditions, since it can negate the effects of walls or berms (but not pavements). This is because the effective speed of sound in air is a function of both air temperature and wind speed. Similarly to the way light bends at an air/water interface, sound waves are refracted, or bent, when sound speed varies because of wind and thermal gradients.

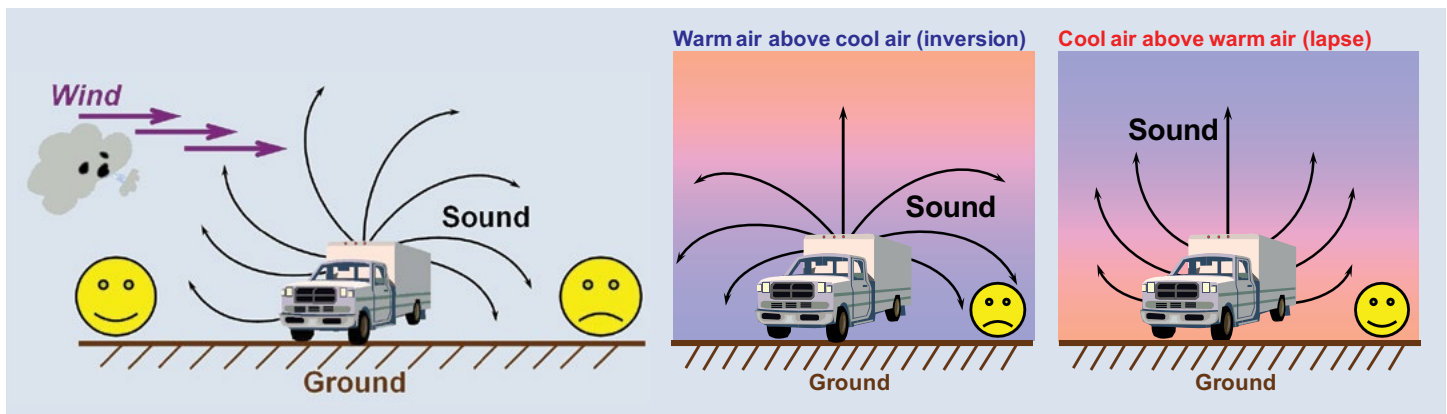
Figure 4 illustrates the effects of three weather-related conditions on noise (Rasmussen et al. 2010). In a neutral weather condition, which rarely exists, there is almost no wind, and the atmospheric temperature decreases with altitude. In this situation, sound propagates equally in all directions through a uniform atmosphere, where atmospheric absorption of the sound occurs. This absorption increases dramatically at frequencies greater than 1,000 Hz, with the higher frequencies disappearing by 1,200 ft from the source (Saurenman et al. 2005). Atmospheric absorption is greatest with high temperatures and low humidities. For highway noise, atmospheric absorption typically only accounts for 1 to 3 dBA (Saurenman et al. 2005).

The rightmost image in Figure 4 indicates a high temperature lapse rate, which refers to the rate at which air temperature decreases with an increase in altitude. Under high lapse rate conditions, sound waves tend to bend upward, causing sound levels to be lower than they would be under neutral atmospheric conditions (Saurenman et al. 2005). A cooler layer of air over a warmer layer of air increases the lapse rate.



Robert Rasmussen, used with permission

Figure 3. Idealized texture for loud and quiet pavements



Robert Rasmussen, used with permission

Figure 4. Sound propagation as affected by wind and temperature

The middle image in Figure 4 indicates a temperature inversion. This is a meteorological phenomenon where a layer of warmer air traps cooler air near the ground. This situation is the opposite of normal atmospheric behavior, where temperature typically decreases with altitude. Temperature inversions can lead to stable atmospheric conditions and are often observed in valleys during clear nights. In a study conducted in Phoenix, Arizona, nighttime thermal inversion conditions caused sound level increases of 5 to 8 dB at distances greater than a quarter of a mile from freeways, making sound walls ineffective at mitigating noise. Unfortunately, this increase in noise usually occurred around sunrise, when high traffic volumes coincided with strong inversion conditions. Quiet pavements control noise at the source, minimizing the effects of this weather phenomenon.

The leftmost image in Figure 4 indicates the impact of constant wind in one direction. This can amplify noise on the downwind side while decreasing noise on the upwind side, creating a shadow condition due to the bending of the sound waves.

How Transportation Noise is Measured

There are two types of noise measurements, often referred to as near-field and far-field. Near-field measurements refer to measurements taken at the tire-pavement interface, such as measurements taken using the on-board sound intensity (OBSI) procedure. Far-field measurements involve setting up stationary microphones at prescribed distances and locations from the travel lane at specified heights. Each method has its advantages and disadvantages.

Near-Field Measurements

OBSI measurements can be collected at highway speeds continuously throughout a project. They better quantify the variability of a pavement's acoustic properties than far-field measurements and are the only reliable way to evaluate a pavement's acoustic longevity. The OBSI procedure only provides data on tire-pavement noise; it cannot determine total traffic noise.

In the United States, OBSI is the standard method for conducting near-field measurements and is specified in AASHTO T 360-16. The AASHTO T 360-16 test method uses a single standard reference test tire (SRTT), the P225/60R16 97S radial tire specified in ASTM F2493, to conduct testing. The procedure's use of a single tire to represent the multitude of tires that drive over roadways creates some limitations to this approach.

The development of OBSI systems over time is indicated in Figure 5. Figure 5a shows the original General Motors (GM) OBSI system developed in the early 1980s. Figure 5b shows this system as adopted in 2002 by the California Department of Transportation (Caltrans), which was the first OBSI system used in the highway industry. The GM system (Figures 4a and 4b) had two horizontally mounted microphones and required two passes of the test vehicle to complete a test. The first pass was to evaluate the leading edge of the tire, and the second pass was to evaluate the trailing edge of the tire. While this worked well for test track research, it was time consuming and inefficient when used in practice on highways with interchanges separated by many miles.

In 2003, the Arizona Department of Transportation developed the first vertical dual-probe OBSI system, which was enclosed (Figure 5c). Shortly thereafter, the American Concrete Pavement Association (ACPA) developed the first vertical dual-probe OBSI system with an exposed flow in 2005 (Figure 5d) based upon a concept provided by Dr. Paul Donovan. In 2008, the latter system was standardized in AASHTO TP76, which evolved into the current AASHTO T 360-16 specification for OBSI testing. The vertical dual-probe OBSI system uses four microphones to collect both leading edge and trailing edge results in the same pass. Since the two results are collected simultaneously, they capture noise from the exact same location. When two passes are made to collect data, in contrast, it is unlikely that the second pass will fall within the exact same wheel path location as the first. OBSI measurements are typically collected in the right wheel path of any tested lane.



Paul Donovan, used with permission

Figure 5. Development of the OBSI test fixture over time

One significant advantage of the OBSI method is that the measurement device is installed with special lug nuts on the host vehicle. As such, any standard passenger-type automobile that meets the requirements of AASHTO T 360-16 can be used. Simply mount the SRTT on the vehicle and attach the OBSI fixture to the lug nuts. Once the SRTT and supporting lug nuts have been installed, the host vehicle is typically driven to the test area, where the fixture can be installed in minutes and made ready for testing. This allows the host vehicle to travel hundreds of miles to different locations without exposing the test equipment to damage.

One additional advantage of the OBSI method is that it can be used to approximate far-field measurement results 25 ft from the center of the travel lane. Simply subtract 23.8 dBA from the OBSI reading (Lodico and Donovan 2018). Both the overall level and frequency content are representative of the far-field measurement at that location. Since the OBSI method produces a continuous measurement, this allows approximation anywhere along the corridor, which is otherwise extremely difficult and expensive to do with far-field measurements.

Far-Field Measurements

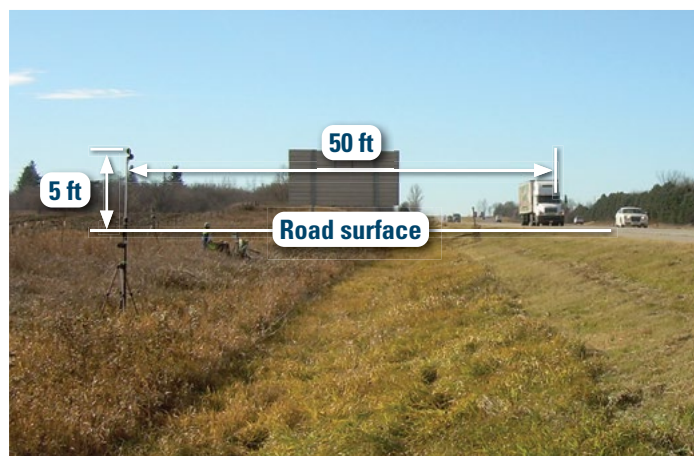
Far-field measurements are the traditional approach to measuring transportation noise in the United States. As previously mentioned, these measurements consist of static measurements taken along a corridor, either within the roadway prism or within abutting communities (receptors). Far-field measurements are still the basis for transportation noise design and compliance for federally funded projects. Far-field measurements provide the total noise from a roadway and are not limited to only noise generated by tire-pavement interaction. However, since the resulting value is the sum of all transportation noise, it is difficult to specifically evaluate tire-pavement noise. This is particularly true when determining the acoustic longevity of pavement surfaces, since traffic levels, speed, and composition may vary over time. Far-field measurements are only applicable to traffic noise at the time of measurement.

Figure 6 provides an example of a far-field measurement approach called the statistical isolated pass-by (SIP) method. In this example, a microphone placed 50 ft from the center of the travel lane records the noise generated by each individual vehicle as it passes by.

An alternative far-field measurement approach is the continuous-flow traffic time-integrated method (CTIM). CTIM is used when measuring single-vehicle pass-by events would be difficult, such as when measuring continuously flowing or relatively dense traffic. Measurements taken at a specified distance capture noise generated by all vehicles on all roadway lanes. Like the pass-by method, this method is not useful for determining the noise from tire-pavement interaction.

Managing Transportation Noise

Highway noise is the result of vehicular travel along a roadway. It is mainly a function of traffic volume, composition, and speed and consists of all noise produced by each vehicle's drivetrain, exhaust, tires, air turbulence, and other design features, such as horns and brake operations. All of these noises act together to produce traffic noise at adjacent properties.



Paul Donovan (with modification), used with permission

Figure 6. Far-field noise measurement

For typical highway applications, the noise contribution from cars and large trucks is quite different. Passenger cars generate about 70% to 90% of their total noise through tire-pavement interaction. This fact implies that modification of the roadway surface and/or tire type can meaningfully impact overall tire-pavement noise. The total noise from passenger cars can also be represented by a noise source at or near the roadway surface.

Large trucks contribute to noise in a much different way than passenger cars, and this difference should always be considered in the design stage of roadway projects. Although the types of noise sources for both passenger cars and large trucks are similar, the magnitudes and locations of these sources are different. The drivetrain of a truck is positioned much higher than that of a passenger car, and the exhaust stacks are approximately 11 to 12 ft above the roadway surface. These higher locations create the potential for truck noise to be heard over longer distances. Additionally, truck tires interact with pavement differently than car tires, and pavement surface texture generally does not have a significant effect on truck noise levels. This suggests that on roadways where truck traffic percentages are higher, little can be gained through changes to pavement surface type or texture.

Typical Strategies for Managing Noise

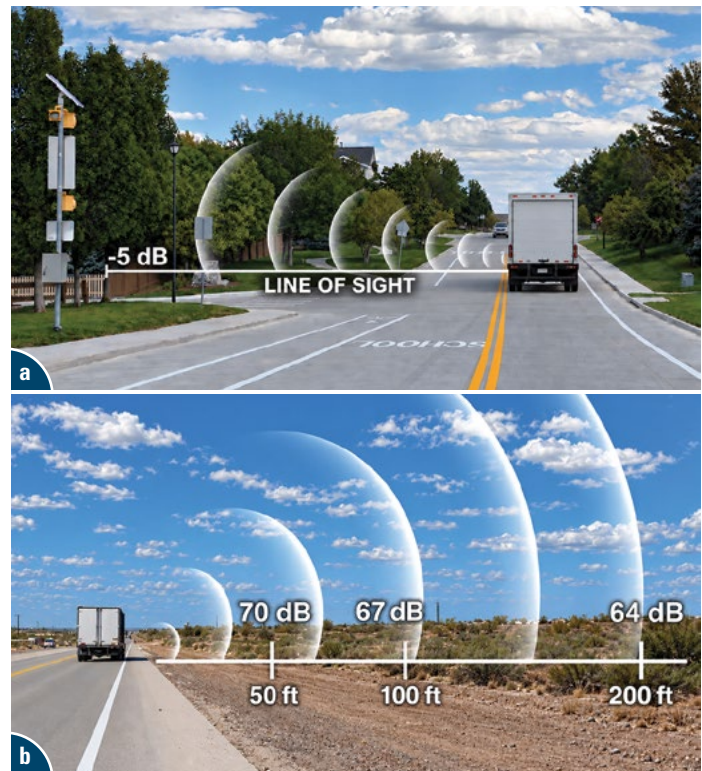
Noise mitigation is generally accomplished through the following strategies:

1. Eliminating noise at the source (pavement type)
2. Constructing barriers such as berms and walls
3. Creating distance from the source of the noise

Line of Sight

One important aspect of noise mitigation involves breaking the line of sight to the noise source. This is important to reduce both the psychological perception of noise and the noise itself. Once the line of sight is broken, as shown in Figure 7, the noise level is reduced by approximately 5 dBA. Each additional 1 to 2 ft of wall or berm height reduces the noise level by another 1 dBA. Note that it is much more difficult to break the line of sight for a heavy truck than for a car, since the noise sources for trucks are higher above the roadway surface. Trucks therefore require taller sound walls or barrier solutions. In recent years, trucks' exhaust locations have begun to change to exit below the cab, similar to passenger cars. This change in design could impact future noise mitigation strategies.

Table 2 provides guidance on the difficulty of achieving different attenuation levels using barriers such as berms or walls, while Figure 8 illustrates the limits of barriers' effectiveness.



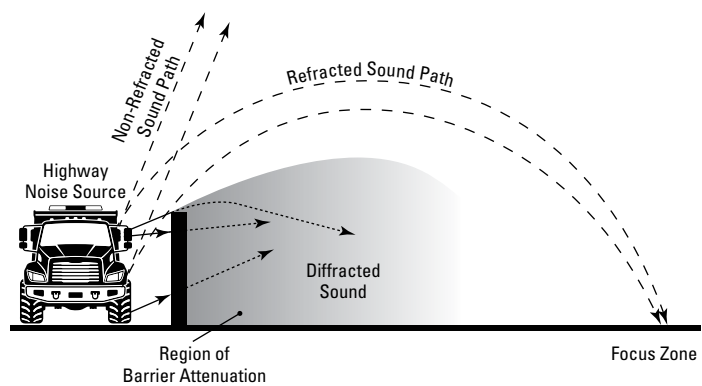
Angela James Folkestad, ACPA, CO/WY Chapter, used with permission (a)

Figure 7. Sound propagation rules of thumb: (a) effect of breaking the line of sight and (b) effect of doubling the distance from the noise source

Table 2. Barrier attenuation

Reduction in Sound Level	Reduction in Acoustic Energy	Difficulty to Obtain Reduction
5 dB(A)	70%	Simple
10 dB(A)	90%	Attainable
15 dB(A)	97%	Very difficult
20 dB(A)	99%	Nearly impossible

Source: FHWA 2011



Recreated from Saurenman et al. 2005

Figure 8. Sound refracted by atmosphere "skipping" over a barrier

Effects of Traffic Volume and Speed

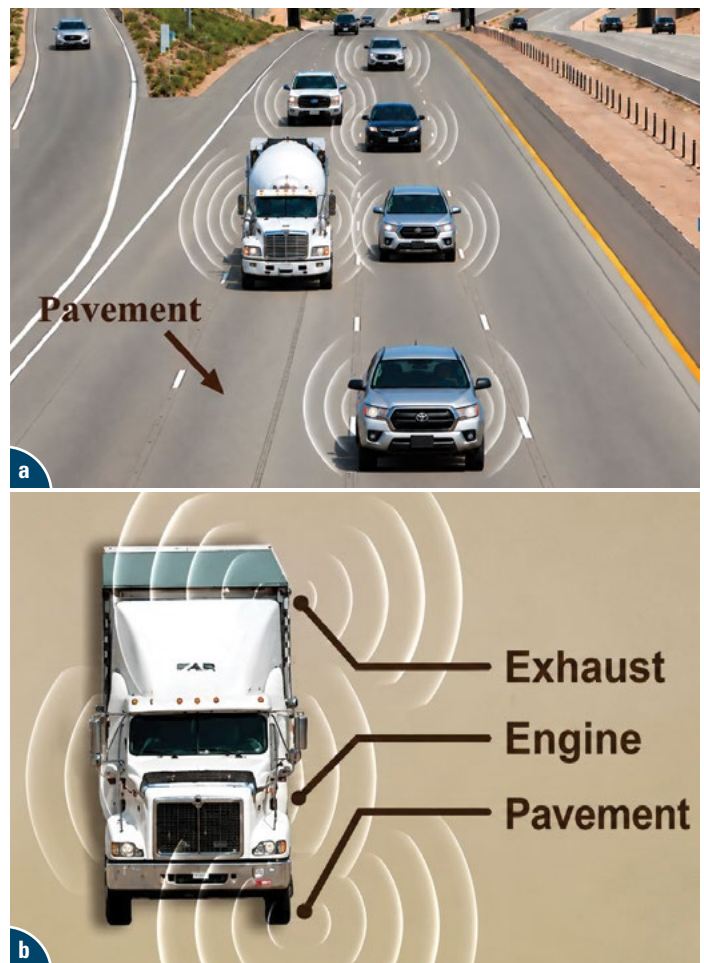
When the traffic volume on a roadway doubles, the overall noise level increases by 3 dBA. If the existing traffic had produced a noise level of 65 dBA within the surrounding neighborhood, for example, doubling the traffic would increase that level to 68 dBA. Conversely, reducing the traffic volume by half would reduce total noise by 3 dBA.

As mentioned previously, speed also affects the total noise level produced by a roadway. A good rule of thumb for passenger cars is that the overall noise level increases by 3 dBA for each 10 mph increase in speed. The converse is also true. This rule of thumb does not apply to trucks, for which tire noise is not as significant a factor in the total noise generated. As speeds decrease, however, the contribution of tire-pavement noise becomes less important for all vehicles, and eventually the drivetrain and exhaust noise dominates. The cross-over condition (that is, the speed at which tire noise is less important than drivetrain and exhaust noise) is probably in the range of 20 to 35 mph depending on traffic composition, with different cross-over speeds for cars and trucks. Once the cross-over threshold has been achieved, then noise mitigation by surface type is not practical. Low-speed urban areas are examples of the type of situation where drivetrain noise dominates.

Quieter Pavements

Another aspect of noise management is how human annoyance is evaluated. The current procedures gauge annoyance based on measuring the overall level (i.e., volume) of sound using a filtering technique (i.e., A-weighting) that attempts to simulate how a human ear perceives sound. This technique was developed over 50 years ago and is the basis for all current noise-related regulations. Although these procedures have served the industry well, they may underemphasize certain tonal attributes common to textures such as uniformly transversely tined concrete pavements.

Since the early 2000s, there has been increasing interest in controlling noise at the source by selecting quieter pavements. As mentioned previously, this can only be effective when passenger cars comprise most of the traffic stream and travel at highway speeds. Heavy trucks need only comprise between 4% and 20% of the traffic stream to become the dominant noise source and hence render pavement solutions less effective. Similarly, if speeds are low, then selecting a quiet pavement surface is not an effective solution because drivetrain and exhaust rather than tire-pavement interface becomes the major noise source. The effectiveness of quieter pavements is thus highly dependent upon the mix of trucks and cars in the traffic composition and the types of trucks in the traffic stream. The dominant noise sources for cars and trucks are indicated in Figure 9.

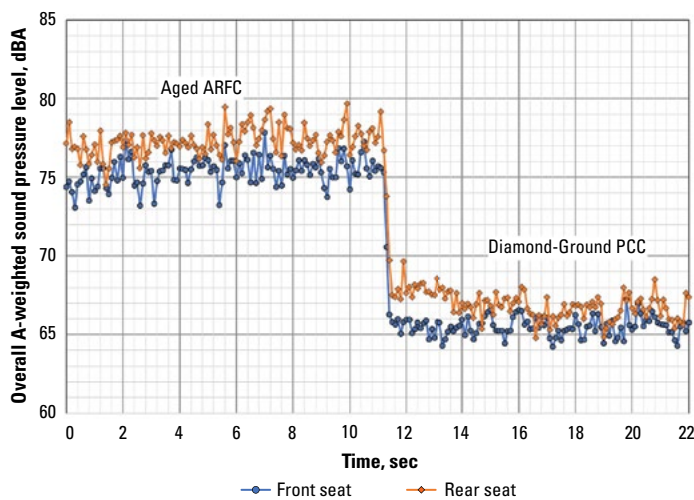


Larry Scofield (with modification), used with permission

Figure 9. Traffic noise sources from (a) passenger cars and (b) trucks

Interior Vehicle Noise

Noise regulation is concerned with the amount of noise that impacts surrounding neighborhoods rather than interior vehicle noise. However, consumers' perception of roadway noise is often developed from their driving experience and not from their experience living alongside a highway. For a given urban corridor, the affected neighborhoods could include hundreds to thousands of consumers, whereas the drivers traveling along the same corridor represent several hundreds of thousands of trips each day. This makes driver perception, even though not of concern from a regulatory standpoint, an important reality in consumer satisfaction with highway surfaces. Figure 10 provides an example of the interior noise produced by two surface types when driven over at highway speeds in a 2022 Toyota Camry. The asphalt rubber friction course (ARFC) surface is approximately 10 dBA louder than the diamond-ground surface (Donavan 2022). It is also apparent that the noise is always 1½ to 2 dBA louder in the backseat position than in the front seat position. This is typical for most passenger cars, though interior noise levels differ among vehicle types.



Recreated from Paul Donovan, used with permission

Figure 10. Interior noise measurements for two pavement types

How Do Agencies Design for Noise Mitigation?

Noise mitigation is typically begun in the design phase of a project and is intended to limit the maximum noise level in adjacent neighborhoods. To help designers mitigate noise, FHWA developed Traffic Noise Model (TNM), a computer program for predicting highway traffic noise levels and analyzing noise abatement measures, primarily for compliance with federal regulations like 23 CFR 772. The use of TNM is required on all federally funded projects. As of 2026, TNM 3.2 is the current version.

Using this model, it is possible to predict the total noise level that would occur at a given location away from the roadway for a specified traffic volume, traffic mix, and set of design conditions, such as the presence of berms or noise walls and the prevailing topography. This information provides the designer with the ability to ensure that future noise levels will comply with regulations prior to construction.

TNM computes source emissions that are then propagated to receivers, incorporating factors like distance, barriers, ground effects, and atmospheric conditions. To accomplish this, the software uses reference mean emissions levels (REMELs). REMELs are statistically derived reference noise emission levels for different vehicle types under controlled conditions. They represent the energy-averaged maximum A-weighted sound pressure levels (and corresponding 1/3-octave band spectra) from individual vehicle pass-bys. Levels are typically measured or corrected to a reference distance of 50 ft from the center of the traffic lane, at a height of 5 ft above the road surface (see Figure 6 for a field test example).

According to 23 CFR 772.9(b), “Average pavement type shall be used in the FHWA TNM for future noise level prediction unless a highway agency substantiates the use of a

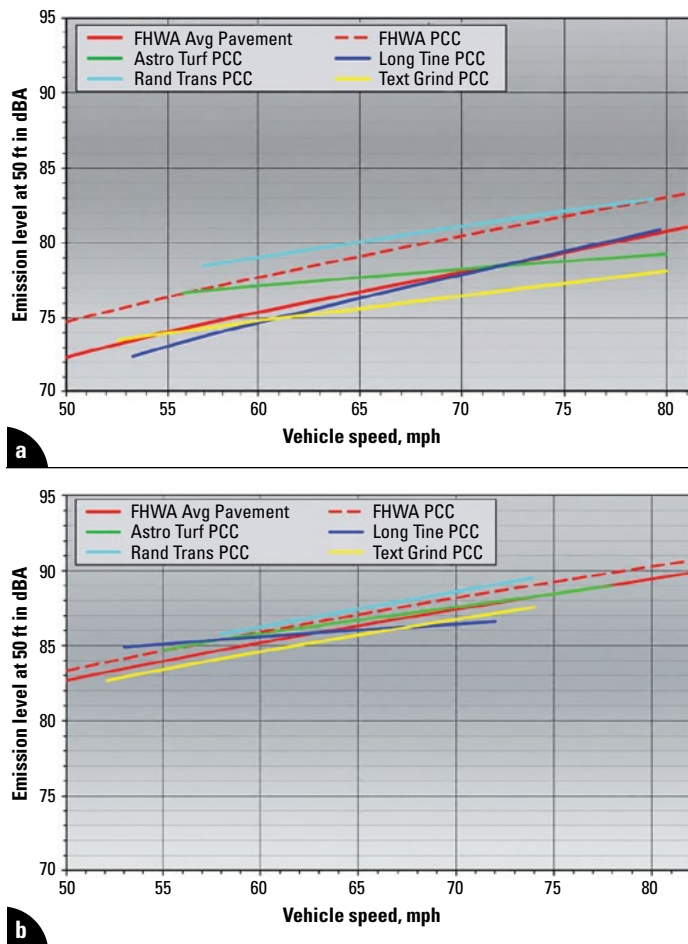
different pavement type for approval by the FHWA.” TNM combines REMEL data from dense-graded asphalt concrete (DGAC) and portland cement concrete (PCC) pavements to simulate the “average” pavement type that is required for use. While TNM offers built-in options like DGAC, open-graded asphalt concrete (OGAC), and PCC, their use (or the use of custom textures/REMELs) for making predictions on federal aid projects is restricted. They are mainly allowed only for validation studies or with project-specific FHWA approval.

The original REMEL database used within TNM is from the 1990s and reflects older vehicle fleets, pavements, and measurement techniques. There have been calls for updates due to changes in vehicle technology (e.g., quieter tires, electric vehicles), the introduction of new pavements, and improvements in measurement methods like beamforming, OBSI or CTIM.

FHWA’s issue with using pavement surface as a noise mitigation strategy is that, unlike with barriers or walls, the benefits may not be permanent, particularly for asphalt concrete (AC) pavements. Pavement acoustic properties change with time, which is why FHWA has not historically allowed pavement surfaces to serve as noise abatement strategies. However, the most efficient method for controlling noise, both interior vehicle noise and far-field noise, is by controlling it at the source, that is, with quiet pavements. This minimizes the impacts of environmental factors such as wind, temperature inversions, and so on. The cost of pavement surfaces is also significantly less than the cost of berms or sound walls, the latter of which can be negated by environmental factors.

Figure 11 indicates TNM REMELs for both light vehicles and heavy vehicles on selected pavement types based on testing conducted for ACPA (Reyff and Donovan 2006). Field measurements were collected on three longitudinally tined sections (Iowa US 30), one diamond-ground section (California SR58), one randomly transversely tined section (Minnesota I-35), and two astroturf sections (Minnesota I-35).

In addition to showing the field test results from different pavements surfaces, the graphs in Figure 11 include the TNM average pavement and the FHWA PCC pavement. For light vehicles (Figure 11a), pavement surface texture has a significant impact on traffic noise levels based on TNM modeling. Randomly transversely tined pavement, promoted as a quiet concrete pavement by FHWA, was the noisiest of the surfaces, followed by the FHWA PCC pavement. Diamond grinding produced the quietest surface at speeds above 60 mph, followed by longitudinal tining and astroturf. The FHWA average pavement (developed by averaging both AC and PCC results) was quieter at some speeds than most of the tested concrete textures.



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Figure 11. TNM-predicted noise levels for selected textures under (a) light vehicles and (b) heavy vehicles

It should be noted that there is a significant range in the noise levels produced by light vehicles for different textures. This indicates that certain textures provide distinct advantages when used for noise mitigation. It should also be noted that only external noise is represented in this discussion, as no regulation exists for interior noise. Regardless, the advantage of mitigating noise at the texture level is that it reduces noise at the source before transmission. If noise is not created, it cannot be propagated. This is an effective strategy for both interior noise and wayside noise mitigation.

As Figure 11b shows, the range in values across all textures is considerably narrower for heavy trucks than for light vehicles. This indicates that texture type does not have as significant an effect on truck noise.

Traffic Composition's Impact on the Success of Surface Texture as a Mitigation Strategy

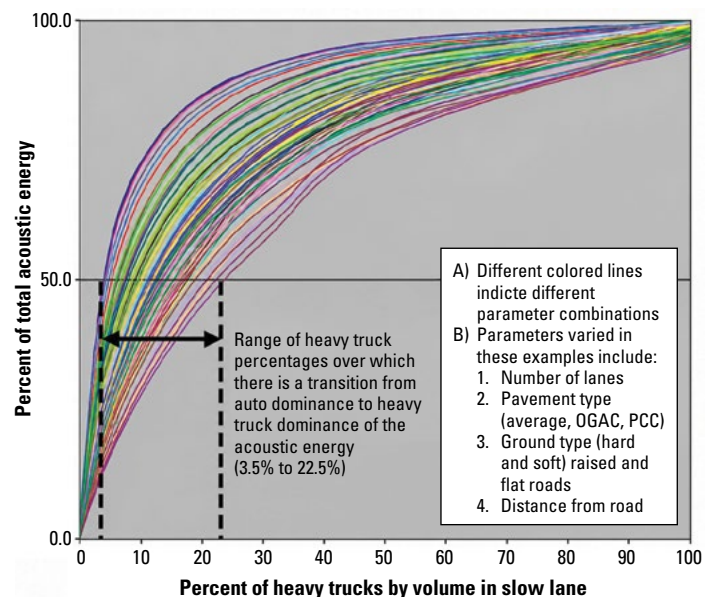
As previously indicated, the percentage of heavy trucks in the traffic flow impacts the ability of a pavement strategy to provide significant benefit to abutting properties (receptors).

This is because the noise sources for trucks are different than those for cars. However, pavements still provide benefits in terms of reducing interior vehicle noise for passenger cars.

Figure 12 indicates how the percentage of trucks in the traffic stream affects the total acoustic energy (far-field noise) produced by a roadway. Although each situation is somewhat different, the figure shows that trucks become the dominant source of noise (50%) when they constitute between 3.5% and 22.5% of the traffic stream (Hastings and Rochat 2007).

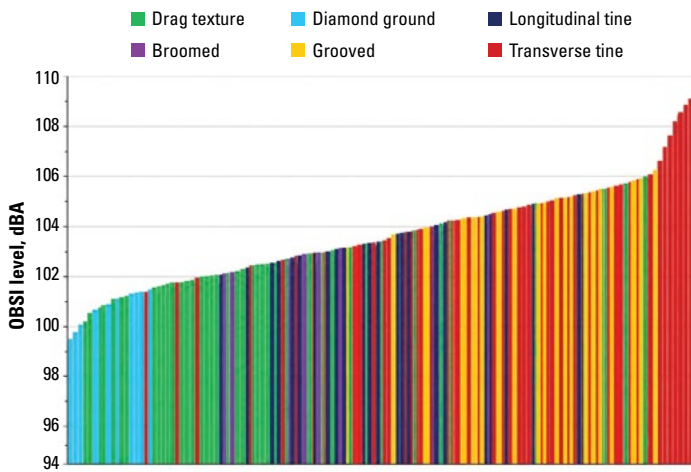
Acoustic Longevity of Pavement Surfaces

As previously stated, all pavements experience changes in acoustic properties over time, with concrete pavements experiencing less change than asphalt pavements. For this reason, FHWA does not consider pavement type or texture to be a viable noise mitigation strategy. However, surface texture can have a significant impact on the noise generated by a pavement. Figure 13 indicates the overall OBSI level for six different categories of concrete pavement textures. The graph indicates a 9.5 dBA range in the overall noise (99.5 to 109 dBA) for the various textures. The diamond-ground textures are the quietest and have the least variability. Drag textures are the next quietest and have low variability. Transverse tining is the noisiest texture and exhibits the greatest variability, while longitudinal tining performs better than transverse tining. It should be noted that for this graph, the range in pavement ages of the various textures is not considered, with each result a single snapshot in time.



Recreated from Judy Rochat, used with permission

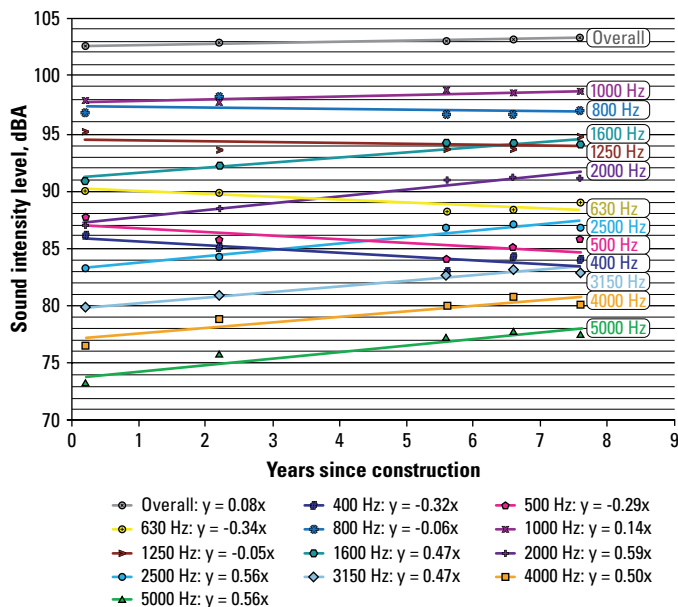
Figure 12. Impact of truck traffic percentage on overall transportation noise



Recreated from Paul Donovan, used with permission

Figure 13. Overall A-weighted OBSI levels of rigid pavements

However, longevity studies have been done, including a study by Donovan and Rymer (2010) that evaluated 11 different concrete textures over a 7½-year period. The pavements' initial textures included longitudinal tining, burlap drag, and longitudinal broom. Diamond grinding and grooving were applied to develop these 11 textures. Figure 14 shows the sound intensity level produced by one of these diamond-ground textures over time. It indicates that the overall sound intensity increased by only 0.08 dBA per year. As noted in the graph, however, different frequencies increased or decreased at different rates over time, which could impact the tonal perceptions. The increased noise in the higher frequencies suggests polishing of the surface aggregate.



After Donovan and Rymer 2010

Figure 14. Test results for a diamond-ground texture over a seven-year period

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