

PAVEMENT NOISE RESEARCH

The Minnesota Department of Transportation (Mn/DOT) Office of Materials and Road Research advances the state of the practice of pavement design, construction, and maintenance by conducting and participating in pavement and materials research projects, implementation of research results, and supporting practitioners. One of the many research strategies is the study of tire-pavement noise using MnROAD test cells.

MnROAD is a unique cold region pavement research test track that is part of the Road Research program. As the world's largest and most comprehensive outdoor laboratory for cold weather road research, MnROAD is a research and data resource for Pavements and cold weather issues. Researchers from all over the world have collaborated on research projects and are using MnROAD data and research to improve roads in cold weather climates, as well as quiet, safe and durable pavements.

Why We Care About Noise

Noise from highway traffic is an environmental problem in both metropolitan and rural areas. The most significant impact of traffic noise is the annoyance it causes to people and the associated negative effects this annoyance has on the quality of life. In addition to annoyance, traffic noise may also impact health, create difficulty with speech communication, suppress real estate values, and cause the stagnation of economic expansion due to public resistance to expanded highway capacity.¹

To solve the problem of increased urban highway noise, Mn/DOT researchers have set out to find cost-effective pavement types that can reduce the sound at its sources: where the rubber meets the road.

Role of Tire-Pavement Interaction in Overall Noise

Highway traffic noise is generated by four sub-sources of highway vehicles: engine/drive train noise, exhaust noise, aerodynamic noise, and tire/pavement interaction noise. For properly maintained automobiles, tire/pavement interaction is the dominant sub-source at speeds above approximately 30 mph. Pavements that produce less noise for the tire/pavement interface sub-source are an important strategic solution necessary to address future highway noise problems.²

Tires are often engineered for a specific application; summer tires are optimized for handling and noise, while mud and snow tires help move water and improve friction. The tire tread pattern and rubber components are what typically affect most of the properties of interest to the tire companies as well as tire-pavement noise. The more complex a tire pattern is, the louder it will typically be. Harder tires will also typically be louder than softer components.

¹ An Introduction to Tire-Pavement Noise of Asphalt Pavement, Bernhard and Wayson

² An Introduction to Tire-Pavement Noise of Asphalt Pavement, Bernhard and Wayson



The influence of a pavement on tire-pavement noise is as equally important as the tire. Texture type and configuration affect noise and other surface parameters. To a lesser degree, pavements that are “softer” will also typically be quieter. Pavements, like tires, must not be built just for noise, however. Of paramount concern is safety, with additional considerations for cost and durability. Fortunately, we know that quieter pavements do not have to compromise these other characteristics of interest.³

Pavement texture is an important parameter in tire-pavement-interaction-noise (TPIN). As pavements carry traffic load over the years measurable degradation occurs in texture. As the pavement is exposed to environmental and traffic elements, changes occur in ride quality measured by the International Roughness index (IRI) as well as the Surface Rating (SR). Changes in surface features affect acoustic durability. The ability to predict these changes require development of new survival algorithms.

Ride Quality, Friction, and Texture

Growing concerns about road traffic noise and skid resistance has generated increased awareness and interest in the interaction of pavement surface and automobile tires. It has also resulted in increased experimentation and field performance observations of texture, noise, friction ride, and hydroplaning potential. Current research reveals that equal mean texture depth does not imply similar noise and friction response and ride influence. Other important parameters include texture orientation, configuration, and positive or negative characterization. Minnesota’s innovative low water-cement ratio, well-graded aggregate, and quality control facilitate drag-type texturing techniques, which have resulted in quieter pavements.

Texture is not the governing parameter in tire-pavement interaction noise for flexible pavements. Viscoelastic properties, time dependent elastic behavior, surface distresses determine the acoustic properties of flexible pavements.

What Things Make a Quieter Pavement

Quieter pavements are generally quieter for three reasons, in decreasing order of importance (FHWA-IF-08-004, July 2007):

- Texture – provides a set of active frequencies that interact with the tire to produce noise.
- Porosity – Porosity can help absorb noise and reduce contact area, especially when in excess of 20 percent. However, since additional air voids can affect durability of any paving material, this tradeoff must be balanced. Inclusions (i.e. rubber, polymers, and fibers) in lieu of air voids continue to be looked at as a viable alternative.
- Stiffness – While the most difficult to control for practical purposes, it is known that pavements that have stiffness characteristics approaching that of a tire can be quieter than those that are more typical of asphalt and concrete in use today. The target of very low stiffness will be the most difficult one to meet, as durability of such soft pavements will likely be highly compromised.

³ The Little Book of Quieter Pavements, Rasmussen, Bernhard, Sandberg, and Mun, July 2007.



Quite often there is more than one mechanism that contributes significantly to the overall sound level. As a result, reducing one mechanism will lead to an overall reduction in noise that is less than expected. For example, one might think that a very smooth pavement would be the quietest. However, that is not the case, due in part to the air pumping, stick-slip, and possibly stick-snap mechanisms that will remain as significant noise generating mechanisms.

How is Noise Measured

Various approaches exist for measuring tire pavement noise. Included among these are the on-board sound intensity (OBSI) method, controlled pass by (CPB) method, and the statistical pass by (SPB) method. CPB uses stationary microphones positioned near a roadway to measure sound. The traffic mix and volume passing the microphones is controlled to reduce error in the monitoring data. Sometimes vehicles turn off their engines as they approach the microphones to facilitate a tire-pavement noise measurement. SPB obtains sound measurements in the same manner as the CPB method, however traffic is free-flowing (not controlled).



OBSI Setup. The front end is connected to these intensity probes via cables.

The Impedance Tube Methods (Kundt Tube) for Sound Absorption is used to measure the portion of the total sound energy absorbed by a material when a sound wave is reflected by its surface. This is a stationary method, and is not used on moving vehicles or to measure noise from passing traffic. An increased interest in measuring tire-pavement noise at the source has occurred parallel to the recent interest in quiet pavements. As a result, OBSI testing is becoming much more popular, and the figure below shows a sample OBSI instrumentation rig installed on an automobile for use in measuring tire-pavement noise.

Mn/DOT Office of Materials commenced OBSI testing in 2007, making the department one of only five states that has adopted this technology. OBSI captures the tire-pavement interaction noise using a set of sophisticated microphones mounted near the contact patch. Freeway speeds are typically above the cross-over speeds (where the dominant noise source shifts from engine to tire-pavement noise) for all vehicle types. Above the cross-over speeds, tire pavement noise is the dominant traffic noise source, being much higher than the aerodynamic source and the stack source. Mitigation of noise by surface treatment is therefore useful in freeways. In the Decibel scale used in OBSI a reduction of 3 dB(A) is tantamount to a 50 percent reduction in noise sources assuming the traffic distribution is maintained. A doubling of distance from a point source results in a 6dB(A) change.

The OBSI method differs from the statistical-pass by method in the sense that it isolates other noise sources and repeatedly measures the tire pavement noise. The OBSI scale is therefore different from the SPB.



Summary of MnROAD Pavement Surface Characteristic Studies

Three pavement surface characteristics studies are currently in progress at MnROAD, as follows.

Project Goals – PCC Pavement Surface Characteristics (MnROAD Studies)

Rehabilitation TPF 5-134

The objective of this effort is to analyze the surface characteristics for noise, ride, safety and durability on diamond ground PCC pavements at MnROAD. The surfaces include standard grinding, the Innovative Grind developed at the National Center for Quiet, Safe and Durable Highways, and the Ultimate Grind or the improved Innovative Grind. The pooled fund study includes FHWA, Mn/DOT, TxDOT, American Concrete Paving Association and the International Grinding and Grooving Association.

The MnROAD cells will be monitored for five years to evaluate how the surfaces perform over time. The data will also be used to create mathematical models that can be used to predict tire-pavement noise from different types of rehabilitated Portland Cement Concrete (PCC) pavements. The research team



Ground PCC Pavement Surfaces

will also work with FHWA to write a Technical Report that summarizes all of the construction, monitoring, data analysis efforts, and other aspects of the project.

Project Goals – PCC Pavement Surface Characteristics (MnROAD Studies) New Construction MPR 6-(012)

The project team will study how pavement characteristics change in cold weather climates and freeway traffic over a five-year period and determine how to characterize the observed changes. The project will also determine the interaction of various pavement characteristics to gain a better understanding of tire-pavement interaction and the performance (durability and potential for use) of quieter pavements. The project team's ultimate goal is to implement quieter, safe, and sustainable pavements into practice. This will also provide information on various PCC surfaces that can be incorporated into the FHWA Traffic Noise Model (TNM). This project is jointly funded by Mn/DOT and FHWA.



Project Goals – HMA Pavement Surface Characteristics MPR 6-(029)



Porous Asphalt

Research already shows that porous pavements absorb more traffic noise than normal pavements. It also shows that as asphalt pavements age, they tend to become noisier. There is an optimal porosity for durability and sound attenuation characteristics. In general, pavements with smaller aggregates and more open surface textures provide more noise reduction than a typical dense-graded HMA mixture. The goal of this research project is to measure the degree of noise attenuation provided by various HMA pavements, and their acoustic durability with respect to time and traffic.

Surfaces at the Site

MnROAD consists of two road segments that are divided into more than 60 test cells, which represent varying combinations of HMA and PCC road-building materials and designs. First is the mainline, a 3.5-mile long segment of Interstate-94 roadway from milepost 199 to mile post 196 west-bound. The mainline consists of a 3.5-mile two-lane interstate roadway carrying “live” traffic. The Mainline consists of both five-year and 10-year pavement designs.

The second is a low-volume 2.5-mile roadway loop that is used by a controlled five-axle semi-trailer. Parallel and adjacent to Interstate 94 and the Mainline is the Low Volume Road (LVR). The LVR is a two-lane, 2½-mile closed loop that contains 20 test cells. Traffic on the LVR is restricted to a MnROAD operated vehicle, which is an 18-wheel, 5-axle tractor/trailer. The pavement surface textures evaluated at MnROAD include the following:

- Dense Graded HMA;
- Novachip;
- 4.75mm HMA;

In addition to structural capacity and durability, pavements must be designed to meet noise, safety and ride requirements. The type of wearing course plays a major role in determining the surface characteristics of a pavement. This project will evaluate various new HMA pavements at MnROAD and analyze how they perform over a five year period. Surfaces include stone matrix asphalt, porous HMA, 4.75mm Superpave, and NovaChip.

Research already shows that porous pavements absorb more traffic noise



- Longitudinal and Transverse Tine PCC;
- Innovative Diamond Grind (PCC);
- Conventional Grind (PCC);
- Random Transverse tine PCC;
- Longitudinal and Transverse Broom Drag PCC;
- Pervious Concrete;
- Porous Asphalt, and;
- Astro-Turf Drag PCC.

Surface Characteristics Measurements

In addition to noise, MnROAD staff measure numerous pavement surface characteristics throughout the year. These are done in addition to the performance measures for strength and deterioration (rutting, cracking) that are taken. MnROAD maintains an extensive database of test section performance, traffic and environmental measures and makes this data available to researchers.

Surface Friction is a pavement characteristic measured at MnROAD. In the lab or in the field, MnROAD staff use a **British Pendulum Tester** to measure surface friction. A slider of known potential energy and slow slip speed makes contact with the pavement over a fixed distance. The loss of energy due to the contact with the surface is due to friction. Measurement results are considered representative of microtexture.

A popular method used by MnROAD staff to measure **Skid Resistance** is the **Locked Wheel Skid Trailer (LWST)**, using either the Ribbed Tire or the Smooth Tire. Both the LWST methods (ribbed or smooth tire) are identical. The locked wheel system simulates a 100% tire slip condition. The brake is applied to the testing wheel and the resulting constant force is measured for an average of 1 second after the wheel is locked. The test is performed a minimum of five times and the results are reported as a skid number, which is 100 times the friction value. The ribbed tire is primarily influenced by macrotexture and the smooth tire is primarily influenced by microtexture.

Another method to measure skid resistance is use of **Fixed Slip Devices** like the **Grip Tester**, which is more commonly used at airports. The grip tester produces continuous measurements of low-speed friction opposed to the LWST, which produces spot measurements corresponding to a distance traveled by a vehicle in one second. During low-speed fixed slip and skid force measurements, the effects of microtexture dominates – but at higher speeds the effects of macrotexture dominate. Correspondingly, these tests are often accompanied by measurements of macrotexture.

MnROAD staff measure **Macrotexture** using the **Sand Patch Test (ASTM E965-96)**. This test uses a uniformly graded patch of sand beads that is spread out to form a circle (of known diameter) on the pavement surface. The volume of the material divided by the area equals the **mean texture depth (MTD)** for a spot location on the pavement surface. Macrotexture, results from large aggregate particles, and has a relative wavelength between 0.5 mm and 50 mm, and amplitude of less than 10 mm. This allows for water drainage and improves tire-pavement contact.



The **Circular Track Meter** is similar to the sand patch test except it uses lasers to measure the surface profile of a circle around a circumference. The profile of this circle divided by the circumference yields a spot measurement of the MPD, and a root mean square (RMS) value of the macrotexture profile.

Ride is typically measured using a profile device that characterizes the amount of vertical rise over a horizontal distance. This can be measured using lasers and accelerometers with a van-mounted pavement management vehicle or with a light weight inertial surface analyzer device for short-distance, low-speed measurements. Mn/DOT's pavement management van uses 5 lasers to obtain profile. Mn/DOT Researchers also use the LISA Lightweight Profiler to monitor Ride quality of the test sections. The raw data is used to calculate the International Ride Index (IRI). IRI is highly dependant upon the length of the roadway section under analysis, and an extremely rough spot on a smooth road would produce little change in IRI for an analysis of a long pavement section.

For more information:

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