Tech Brief

Concrete Solutions for Quieter Pavements on Existing Roadways

by Paul Wiegand, P.E.

Overview

One of the most pressing issues facing state departments of transportation (DOTs) is highway noise, particularly in urban areas. On high-speed facilities where autos are the predominant vehicles, nearly 70% of the noise is generated at the tire-pavement interface. The impact of tire-pavement noise lessens as the percentage of trucks increase and other elements of highway noise—vehicle drive trains and vehicle exhaust systems—become more predominant. DOTs are facing increasingly significant public concern over highway noise. Currently, many urban projects involve the construction of noise walls to mitigate the problem.

Prior to the current research activities that are underway, it was difficult to determine the surface characteristics that result in low tire-pavement noise. With research managed by the National Concrete Pavement Technology Center (CP Tech Center), patterns that relate concrete surface texture to noise levels are beginning to become apparent. In 2005 and 2006, the surface characteristics of over 547 pavement sections representing a variety of conventional surface textures and totaling more than 27 miles of pavement were measured (see figure 1). The information collected includes on-board sound intensity (OBSI) measurements at the tire-pavement interface, wayside noise, in-vehicle noise, texture, friction, and smoothness. Further work is required to verify the initial data trends.

Because of their durability, long service life, and ability to be maintained, concrete pavements often remain in use in less than ideal situations. Concrete pavements that exhibit some deterioration, such as cracked or patched areas with faulted joints, can and do continue to serve the traveling public. Although noise and smoothness are impacted by this deterioration, such concrete pavements are generally structurally sound and thus are left in service by the state, county, or city agency. However, by leaving these pavements in service, the perception is created that concrete pavements are not smooth and quiet.

Although not universally true, many of the noisiest concrete pavements are transversely tined pavements. This surface-texturing technique was used for a long period of time, because it was thought to develop the greatest level of safety through its friction characteristics. Transverse tining has in fact met friction needs, particularly in wet-weather areas. In recent years, however, higher noise levels and citizen complaints have led DOTs to consider covering those noisy transverse-tined pavements with asphalt surfaces. In many cases, this may not represent the best long-term, cost-effective solution.

The OBSI data in figure 1 are divided into three noise zones that can be used to better understand the relationship between texture and noise, and thus facilitate informed decisions related to desired surface characteristics. Zone 1 is the innovation zone. It represents the best solutions for those conditions that merit high-quality noise solutions. New concrete textures will need to be developed to meet the low noise levels of this zone. Zone 2 is the quality zone that includes many conventionally textured concrete pavements, which are cost effective and provide a balance between noise, friction, and smoothness. Zone 3 includes pavements that exhibit the highest noise levels. These pavements are

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characterized by highly variable, very aggressive transverse textures and often serious joint deterioration.

Covering concrete pavements with asphalt is generally not the best method to develop quieter, long-serving pavements. Existing concrete pavements can be diamond ground or a concrete overlay with a different texture can be placed, and a quieter pavement will result. Evaluation of options to address tire-pavement noise should include the expected life of the treatment and the maintenance and rehabilitation required to achieve that potential service life. Another very important factor to consider is the impact on highway users who experience the safety and time-lost impacts that result from the frequent construction activities of short-lived alternatives such as asphalt resurfacing. This impact is especially critical on heavily traveled urban freeways that are frequently at or over their carrying capacity.

Diamond Grinding

Diamond grinding of concrete pavements to address noise concerns has proven very successful. In Arizona, grinding of concrete surfaces has reduced noise levels by up to 9 dB relative to some transversely tined surfaces. The level of noise reduction is dependent on the number of trucks, since the percentage of noise related to the tire-pavement interface is reduced when there are more trucks in the traffic stream. Current diamond grinding processes produce relatively quiet pavements. Even so, Purdue University is undertaking research to identify additional diamond grinding alternatives for even quieter pavements. Diamond grinding also eliminates the tonal problems sometimes experienced with transverse tining. Since only a very thin layer (about 1/16 inch) is removed, no adverse structural impact is noted after the diamond grinding process.

The cost of diamond grinding varies due to aggregate hardness, depth of removal, and operational restrictions at the worksite. The extreme range involves a low-end cost estimate of $1.50 per square yard in softer limestone and a high-end cost of $10 per square yard in very hard aggregates with significant work restrictions. Typical average costs are between $2 and $4 per square yard. (Note that these are 2006 prices.)

Depending on the structural integrity of the pavement that is diamond ground, the extended life of the pavement will reach 15 to 17 years, based on research in California. Diamond grinding means longer-lasting, quieter pavements that retain features such as sound qualities (acoustic durability) and skid resistance for many years. In addition, as the fins left during the grinding process are worn off, the actual sound levels decrease over time. The diamond grinding process is a very durable, cost-effective solution to address pavements exhibiting high noise levels.

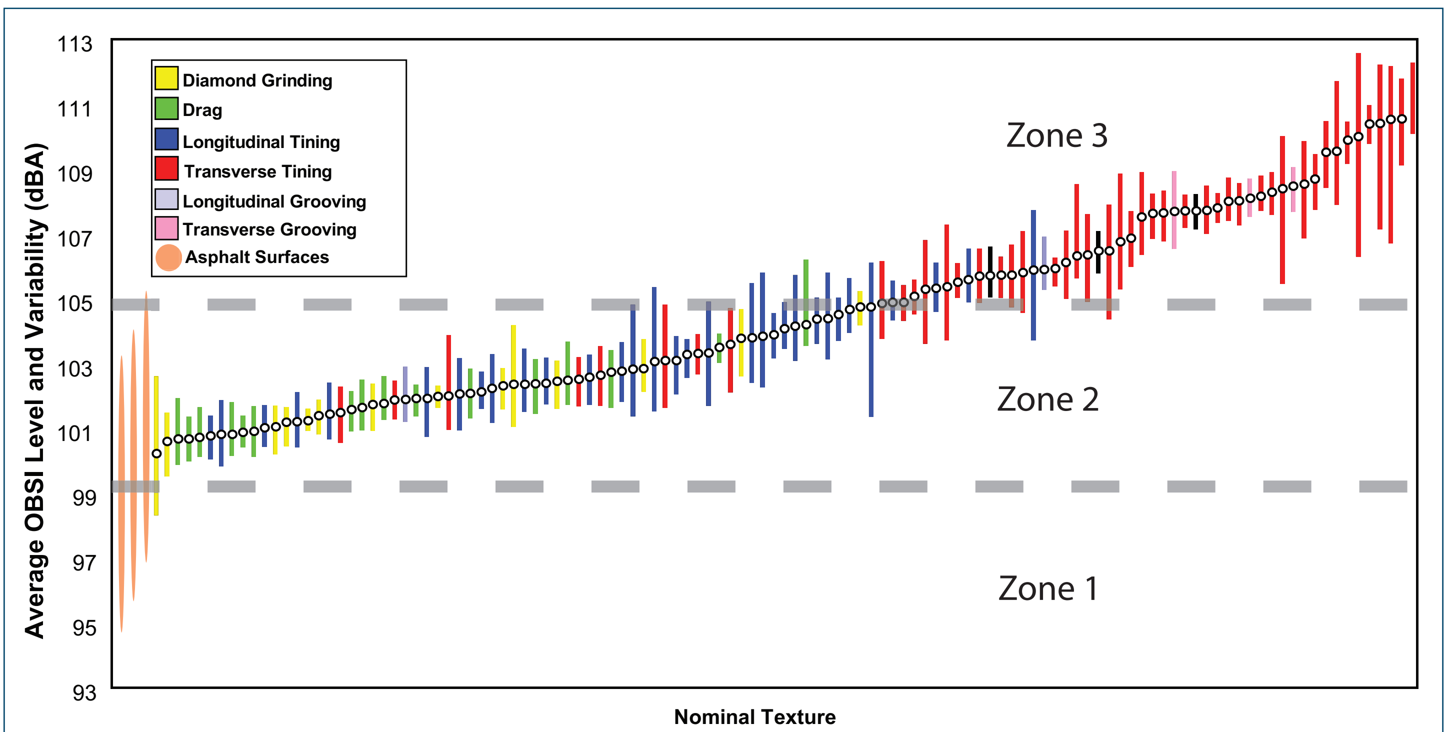

Figure 1. Tire-pavement interface noise by texture type

Overlays

Concrete Overlays

If a pavement is in need of structural enhancement and it is in a critical noise area, a concrete overlay may be the ideal choice. The noise characteristics can be addressed at the same time as the structural elements. As the overlay is being designed, the new surface texture should be chosen to address the noise concerns. The appropriate texture could be drag (turf or heavy burlap) or longitudinally tined. The quality of the small aggregate (hard sand) affects the friction characteristics of drag textures and must be considered in the design. With the use of these conventional textures, the noise level can be brought into the lower end of Zone 2, and potential exists to reduce the noise level of some transversely tined pavements by 6 to 8 dB. In the future, it will likely also be possible to use innovative textures in combination with an overlay to further reduce the noise levels into Zone 1.

Because pavement friction is one of the concerns raised in the shift from transverse texture to more quiet textures, CP Tech Center research examined that characteristic. The research indicates that good friction numbers can be obtained with drag textures, and the friction achieved with longitudinal tining is comparable to that of transverse tining (see figure 2).

Concrete overlays can be constructed of varying thicknesses, starting as thin as two inches. They can be bonded to the underlying pavement or separated from the original pavement by a bond breaker. Generally, the thinner overlays are bonded and the thicker ones are unbonded. The decision to use a bonded or unbonded overlay generally relates to the extent to which the underlying pavement will contribute structurally to the pavement system. Bonded overlays rely on the structural characteristics of the underlying pavement to a larger extent than unbonded overlays.

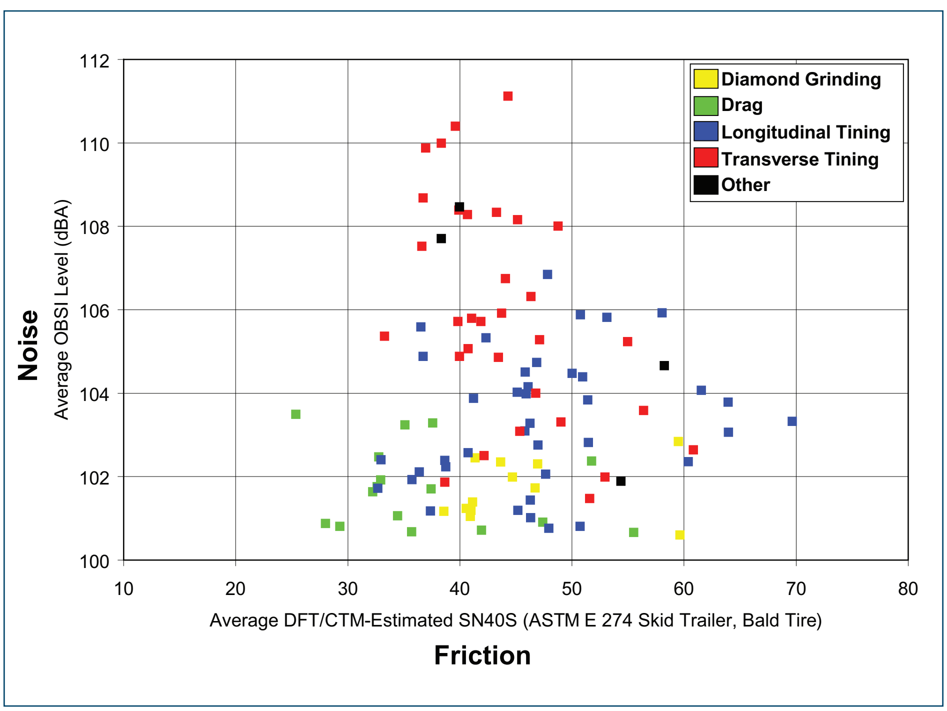

Figure 2. Noise vs. friction, categorized by texture type

Concrete overlays provide at least 20% more years of service than an asphalt overlay of comparable structural strength. The increase in service life is much greater on stretches of roadway where traffic volumes are high. This extended service life both conserves resources and ensures less user impact.

At the present time, concrete overlays are a little more expensive in first cost than dense-graded asphalt overlays, but when the proven longevity of concrete overlays is considered, concrete is competitive. This is becoming even more so with the recent (2006) increases in the price of oil, which impacts the price of asphalt overlays.

Asphalt Overlays

Asphalt overlays can be dense-graded or open-graded friction courses. Dense-graded overlays are usually two inches in thickness or greater. Their noise characteristics generally place them in Zone 2, as shown in figure 1. The quietest asphalt overlays are asphalt rubber friction courses (ARFCs). These ARFC overlays are very thin overlays placed on structurally sound pavements, usually concrete. ARFCs have an expected life of approximately eight years.

The Phoenix metropolitan area has implemented a program of constructing one-inch ARFC overlays on 12 to 14 inches of concrete pavement. Immediately after placement, noise is reduced by an average of 4 dB according to information provided by the Arizona DOT. As time goes on and traffic wears the surface, the amount of noise reduction lessens. Maintenance of the ARFC is difficult because of the reduced thickness and the characteristics of the material. Because of the rubber material in the mix, temperatures have to be above 85°F to place the ARFC. This constraint would be problematic in locations with cooler environments.

Data from the Phoenix project, as of August 2005, indicate that the average cost for ARFCs had been $9.14 per square yard. This average represents the cost in about two-thirds of the project area. Future projects were estimated to cost $14.30 per square yard in 2005. Recent figures indicate that asphalt prices have increased over 40% in the last year.

Summary

Concrete pavements have historically out-performed other pavement types on a length-of-service-life basis. With growing public concern about highway noise, existing concrete pavements must be made quieter. The concrete solutions for addressing highway noise provide cost-effective, long-life answers for highway designers.

By maintaining the concrete surface either with diamond grinding or a concrete overlay, the designer can address noise concerns and also improve safety by increasing skid resistance and offering light reflectivity values four to five times greater than asphalt surfaces. In addition, urban heat impact is also reduced, since concrete is 10 to 20 degrees cooler than asphalt.

When comparing diamond grinding and ARFCs as methods of addressing highway noise, diamond grinding provides twice the expected life at approximately one-third the cost. In addition, diamond grinding improves friction and safety. If cost per square yard is weighed with regard to the life of the improvement and the noise reduction in decibels, diamond grinding is over five times more effective than an ARFC.

When structural improvements are desired for pavements, concrete overlays can be placed and will also improve noise, safety, and smoothness. The cost of a concrete overlay is higher than an ARFC, because a concrete overlay adds structural capacity and improves safety and noise levels, while an ARFC only addresses noise. When comparing concrete overlays to dense-graded asphalt overlays of comparable structural strength, concrete overlays are approaching the same cost and have the additional advantages of longer service life, less user impact, and greater safety.

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