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Quieting of Portland Cement Concrete Highway Surfaces with Texture Modifications

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ABSTRACT

In recent years, various types of asphalt concrete (AC) surfaces have become identified as “quiet pavements” due to their ability to reduce tire/pavement noise and ultimately, traffic noise. Often lost in this perception is the fact that substantial reductions in tire/pavement noise can also be made by texture modifications to existing Portland Cement Concrete (PCC) or by novel constructions. PCC surfaces have been found to span a range of as much as 16 dB. As a result, there is the potential to achieve large noise reductions depending on the existing and final surfaces. In California, grinding of bridge decks and elevated structures has been found to reduce tire/pavement source levels 3 to 10 dB with comparable reductions in wayside measurements. In Arizona, grinding of PCC has reduced source levels up to 9 dB relative to some transversely tined surfaces. Measurements conducted in Europe using the same measurement methodology indicated a range of 11 dB including more novel porous PCC surfaces. In this paper, measurement results and case histories are reviewed for situations where PCC modifications were successful and unsuccessful in producing quieter pavement.

1. INTRODUCTION

Originating in the early 1980's for tire noise research (1), the sound intensity method of measuring tire/pavement noise was developed for the application of quantifying the performance of different pavements for their noise performance in 2002 (2). Since that time, a database of the performance of almost 200 pavements has been established using a single tire design and a consistent measurement methodology for test vehicle speed of 97 km/h. This database has been used to estimate the expected tire noise benefit due to pavement overlays and pavement texturing as well as to assess the performance of different pavement groupings. Sound intensity measurements have also been used to document the reductions produced by pavement modifications and to support pavement research work. Initially, the investigations were more focused on “quiet pavements” which were either open graded asphalt concrete (OGAC) or rubberized asphalt concrete (RAC) or both. As the database expanded to include more pavement types, it was noted that a large range in the noise performance of PCC surfaces existed also. In the extreme cases, this difference could be as great as 13 dB. With this realization, texturing of PCC surfaces became a viable option for reducing tire/pavement noise and related traffic noise depending on the initial performance of the surface and type of final texturing used. This option has been exercised in several circumstances to produce noticeable reduction in tire/pavement and traffic noise. Further, data taken in Europe indicates that even further improvement in PCC performance is possible if porous pavements are considered.

2. CALIFORNIA/ARIZONA DATABASE

In California, the predominate PCC surface texture is longitudinal tining. This is used for most at grade highways. Skyways, viaducts and bridge decks, however are typically random transversely tined. In some instances, ground or even grooved PCC surfaces are found in the state. In Arizona, the standard for PCC texturing has been uniformly spaced transverse tining. On an experimental basis, random transversely and longitudinally tined PCC has been investigated, as has “whisper” grinding (3). Based on this work, Arizona recently adopted longitudinally tining as the preferred texture for new PCC surfaces in situations where additional overlays are not used. Photographs of the four more common textures, ground, longitudinally tined, uniform and random transverse tined are provided in the Fig. 1.

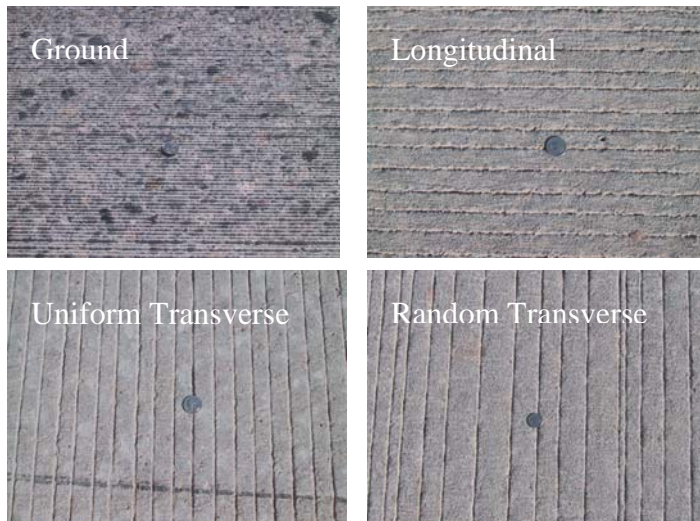


Fig. 1: Primary types of PCC surface texturing – vehicle travel from left to right

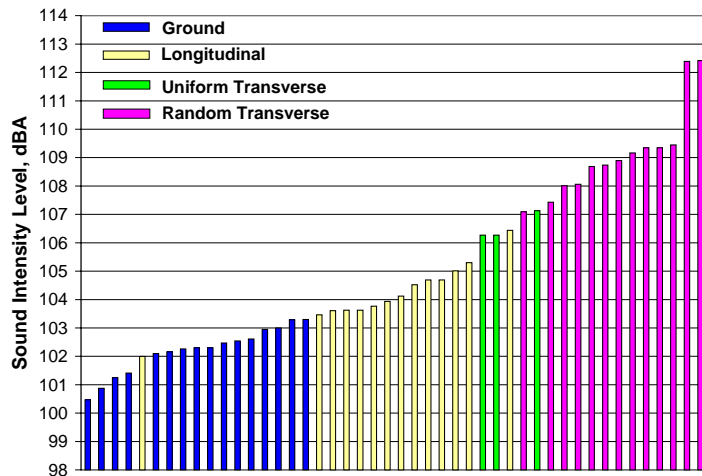


Fig. 2: Overall A-weighted sound intensity levels of tire/pavement noise for PCC surfaces - CA/AZ database with indicated groupings

The tire/pavement noise performance of PCC surfaces in the groupings represented in Fig. 1 is provided in Fig. 2. As maybe expected, the ground surfaces are typically the quietest followed by longitudinally tined and finally transversely tined. With only a few exceptions, these groupings do not overlap. Further, the uniform transverse tined surfaces are quieter than the random, however, it will be noted that only a very few of the uniform transverse surfaces are included in the database. Typically new PCC surfaces are not initially ground. As a result, longitudinally tined texture would be preferred as the initial texturing for obtaining the quietest noise performance. Within this category, however, a range of more than 4 dB has been measured implying that with a better understanding of the controlling parameters, designing and building quieter longitudinal tined may be possible. Not shown in Fig. 2 are two textures that are not commonly used in California or Arizona. These are a burlap drag and a broomed texture applied in the longitudinal direction. These surfaces produced levels of 101.5 and 101.8 dBA respectively (4). This is slightly below that of the quietest longitudinally tined surfaces and could be considered as options if

other important pavement criteria, such as pavement skid number, are met by these textures. It was also found that grooving of these base textures only very slightly increased the tire/pavement noise while possibly improving other criteria (4).

3. APPLICATIONS

Modifications to existing PCC highways typically take the form of grinding a portion of the surface away producing texture in a longitudinal direction. This often produces two benefits; less noise generated by the surface texture itself and the reduction of “joint slap” between adjacent PCC sections particularly if faulting has occurred (4). For discussion purposes, applications of quieting PCC pavements with these texture modifications are divided into two categories: at grade road surfaces and bridge decks or other elevated structures. Examples in both categories are provided below.

A. At Grade Highways

As would be expected from Fig. 2, the largest improvements due to surface grinding occur when the original surface has transverse tining. With the prevalence of transverse tining in Arizona,

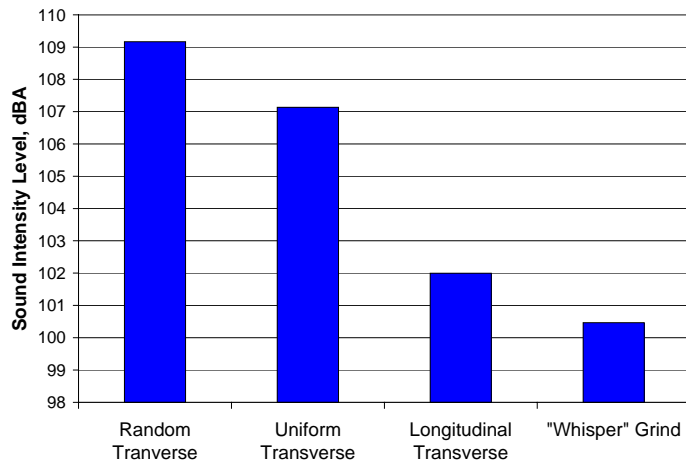


Fig 3: Sound intensity levels for different PCC textures in Arizona

this effect has been documented quite well in Arizona Department of Transportation (ADOT) studies. In previous papers, the comparison of different tining methods was investigated in some detail (3). Afterwards, a joint demonstration project between ADOT, International Grooving and Grinding Association, the American Concrete Pavement Association, and the local cement industry was undertaken on four newly constructed test sections. Four grinding techniques were used in constructing these sections with the parameters of spacing between grinding blades, amount of head pressure, and beam length. The overall sound intensity levels produced by the tined sections and quietest ground section are compared in Fig. 3. From the worst-case random transverse tined surface to the ground section, the reduction is almost 9 dB. The one-third octave band spectra for the four surfaces (Fig. 4) show that most of the improvement between the tined and ground surfaces occurs at frequencies below about 1600 Hertz. In this region, reductions of 10 to 12 dB occur.

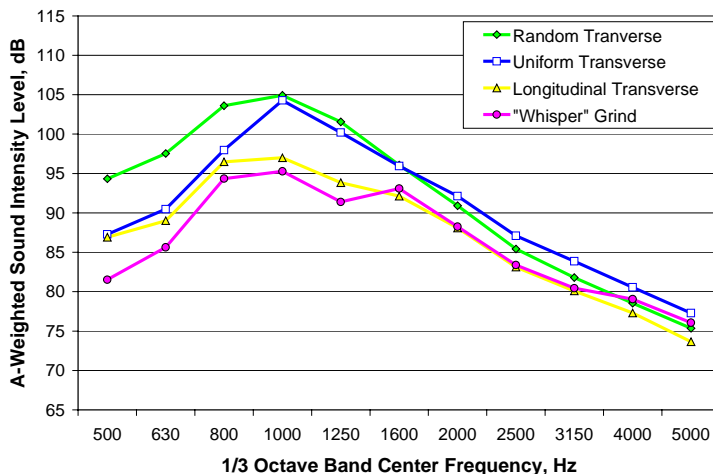


Fig. 4: 1/3 octave band spectra for different PCC textures in Arizona

In California with its absence of transverse tining on at grade highways,

the reductions with grinding are not as dramatic. However, in some cases, the reduction is significant enough to be recognized by the surrounding community. In Santa Clara County, a new freeway (SCL 85) alignment was constructed through an established residential area. The roadway was PCC pavement with standard longitudinal tined texture. Although noisier truck traffic is restricted from operating on this segment of freeway, and much of the freeway is depressed below grade, and a very elaborate and extensive sound wall system lines this corridor, neighborhood noise complaints started soon after the freeway was opened. Motivated by public outcry, the local transportation commission funded a short, experimental grooving and grinding test section in the city of Saratoga to determine if modifying the pavement surface could lower overall traffic noise levels (Fig. 5). Initial reaction from the community was quite favorable after the texturing. To quantify this effect, sound intensity measurements were made comparing the ground pavement to that of the original tining. The results produced two observations. First, although the overall average difference between the two surface types was only slightly more than 2 dB, the grinding produced more uniform noise levels with variations of 1 dB or less for ground different sections (Fig 6). The original tined surface had variations ranging from 1 to more than 2 dB. As a result, the worst to best reduction was more than 4 dB with a number of individual sections producing reductions on the order of 3 dB. The second observation was that the largest reductions on a one-third octave band basis were found in bands around 1600 Hertz (Fig. 7). These frequencies are thought to be responsible for a higher frequency “presence”, or sizzle sound, which can be noticeable in the community.



Fig. 5: Photograph of textured section of SCL 85 indicating both grooving and grinding and original

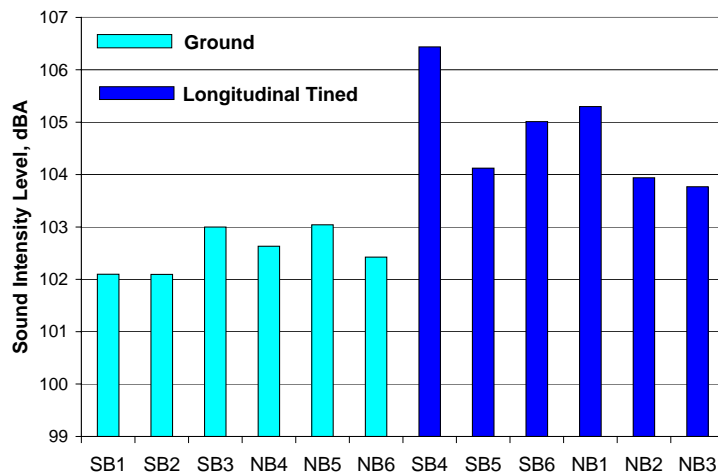


Fig. 6: Comparison of overall sound intensity levels for different northbound (NB) and southbound (SB) sections of SCL 85 with new surface texture and original longitudinally tined PCC

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Between June and November of 2002, Caltrans completed a pavement rehabilitation project on a portion of Interstate 280 in San Mateo County, California. The pre-project pavement was older Portland Cement Concrete (PCC) with some slab faulting. Faulting occurs when the concrete slabs become misaligned and disjointed due to heavy truck loads, failing foundations, and/or temperature differentials. Under the

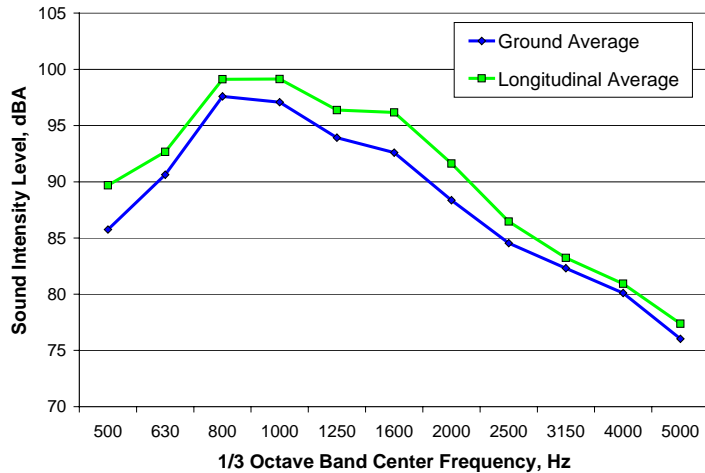


Fig. 7: Comparison of 1/3 octave band spectra for ground & grooved sections of SCL 85 and the original longitudinally tined sections

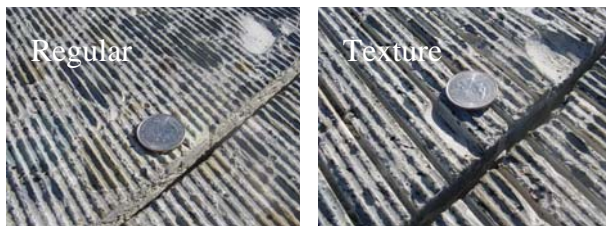


Fig. 8: Ground surface textures on I-280

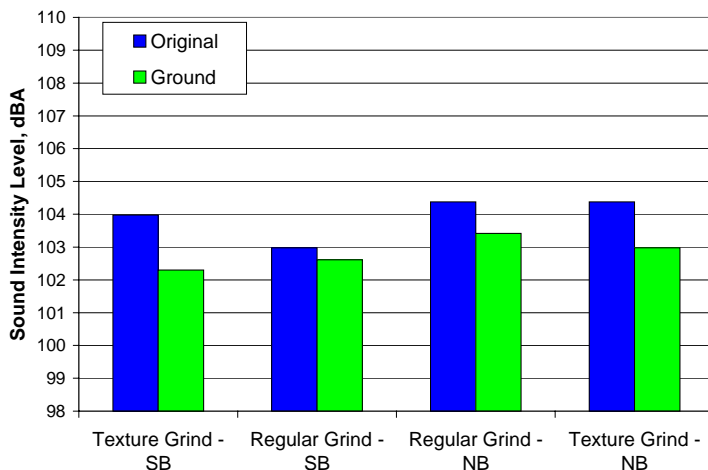


Fig. 9: Comparison of overall sound intensity levels for sections with the original and two types of newly ground PCC surfaces on I-280

project, faulting was repaired as required and new surface treatments applied. All of the project area was to be ground using a “regular” (diamond) grinding process with a vertical variation of 19mm/0.1km. Afterwards, one section was ground a second time to achieve a “texture” grind finish with a vertical variation of 8mm/0.1km. All three surfaces are shown in Fig. 8. In order to capture the change in pavement/tire noise with these new surfaces, pre- and post-project sound intensity measurements were conducted. In this case, there was very little positive community response after the grinding. Relative to the SCL 85 case, the change in sound intensity was small, ranging from less than 1/2 dB to less than 2 dB with an average of 1.1 dB (Fig.9). The reason for this smaller improvement was that the pre-grind levels were typically lower than those for SCL 85. On the other hand, the levels of the post-grind pavement were quite similar to those on I-280. The results of Fig. 9 also indicate virtually no difference for the regular and texture grinds.

B. Bridge Decks

In California, the most dramatic effects of modifying surface texture through grinding have been documented for bridge decks and other elevated structures. One such application has involved a newly resurfaced bridge deck in Northern California on Interstate I-5 near Redding. In this case, the new bridge surface in the northbound direction was generating complaints relative to the old surface and the existing southbound surface. From sound intensity measurements made on both the north- and southbound deck

surfaces it was found that new northbound surface defined the upper end of tire/pavement noise as shown in Fig. 2 at a level of 112.4 dBA while the southbound deck was more than 5 dB lower.



Fig. 10: Photograph of the northbound bridge deck on I-5 showing the ground travel lane and original texture shoulder

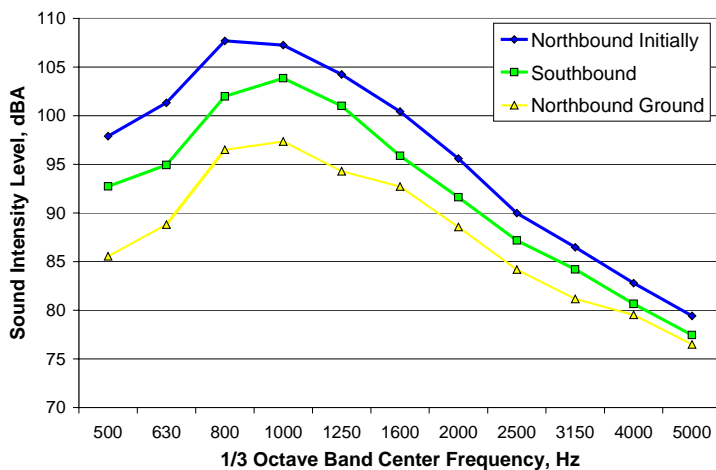


Fig 11: Comparison of 1/3 octave band spectra for both lane directions of the I-5 bridge deck



Fig. 12: Photograph of expansion joint on the new span of the Carquinez Bridge – AC bridge to the right, transversely tined PCC viaduct surface to the left

In an effort to mitigate the noise, the northbound surface was ground to eliminate much of the rough transverse texture on the deck (Fig. 10). The grinding reduced the sound intensity levels to 102.3 dBA producing a 10 dB reduction in overall level and resulting change in third octave band spectral content as illustrated in Fig. 11. Relative the existing southbound deck, the level for the newly ground northbound deck was 5 dB lower. As would be expected, this modification was well received by the residents neighboring to the east of the bridge.

As a second example, shortly after the opening of a new westbound span of the Carquinez Bridge on I-80 in the San Francisco Bay Area, Caltrans began receiving noise complaints. Using sound intensity measurements, the problem area was identified as being the deck of a new viaduct connecting the bridge deck to the on-grade pavement. The bridge deck itself was constructed with a lightweight AC top surface, which produced sound intensity levels lower than the older, remaining bridge span. The surface treatment of viaduct, however, was transversely tined PCC and produced sound intensity levels 2 to 3 dB greater than either the old viaduct or the remaining eastbound viaduct. In addition, the new viaduct used a new style of expansion joint which featured transverse bars much like a “cattle guard” (Fig 12).

Using a 0.10 second averaging time, the impulses created by the joints could clearly be identified in the sound intensity measured transiting the bridge, viaduct and on-grade surfaces (Fig. 13). However, because of the very short duration of the impulses, they had no effect on the 5-second average time samples normally used for sampling tire/pavement noise. Similarly, they could not be isolated in wayside sound level measurements made in the surrounding community.

Although the impulsive noise of the joints would not be effected by grinding of

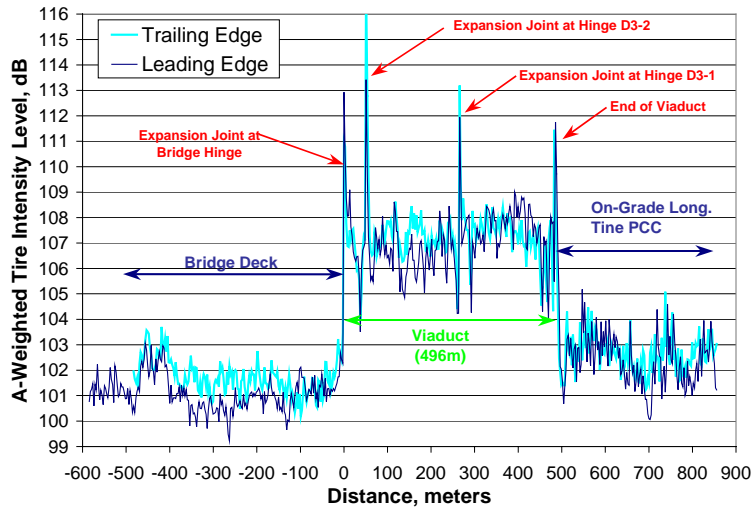


Fig. 13: Sound intensity measured with a 0.1 second averaging time spanning the Carquinez Bridge deck, viaduct, and at-grade PCC

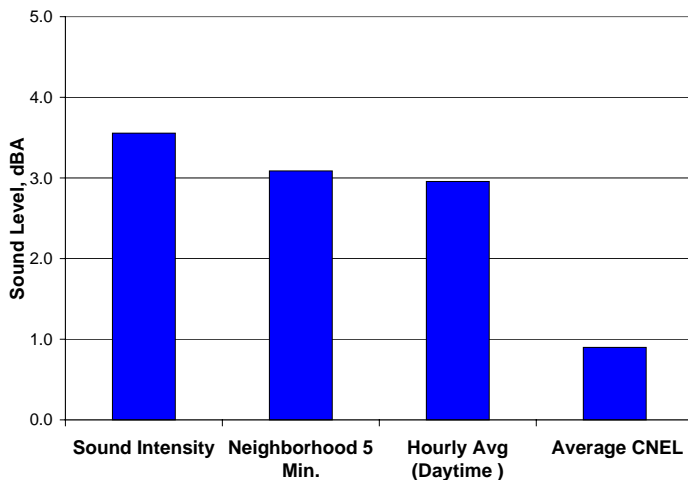


Fig. 14: Noise reductions produced by grinding of the Carquinez Bridge viaduct PCC surface

the viaduct surface, Caltrans decided to grind the transversely tined surface in an effort to reduce complaints from the overall noise level. Prior to grinding, in order to document the effectiveness of the texturing, short and long term wayside, time-average noise levels were made in the community. This was considered to be of particular importance due to concern over the impulsive noise produced by the joints as well as the relatively high volume of trucks in the traffic flow. The reductions measured by the various techniques are provided in Fig. 14. As will be noted from these data, the reductions of about 3 dB were measured in both the tire/pavement noise source levels and the daytime, wayside levels. The CNEL values produced lower noise reductions due to the nighttime penalty in the metric and reduced contribution of traffic noise in those hours. After the grinding, the nearby residences noted improvement in the noise from the new span, although some concern still remained about the impulsive joint slaps.

4. EUROPEAN DATA BASE

In the fall of 2004, the sound intensity method as employed for use in California and Arizona was used to measure the performance various pavements in Europe for the standard test speed of 97 km/h (5). Although the main objective of this testing was to quantify the performance of “quiet” AC surfaces, measurements were also made on a number of PCC surfaces. With some exceptions, the performance of these surfaces covered about the same range as those contained in the California/Arizona database (Fig. 15). On the higher end, if the bridge decks surfaces were excluded from Fig. 2, the highest levels in both Europe and the United States (US) would be similar. On the lower end, one surface was found to be considerably quieter than any in the US. This was a porous and ground PCC surface on a roadway in Germany. This surface performed within 2 dB of very quietest AC pavement, which was of a double layer porous construction. From more limited testing done at 56 km/h, it was found that even unground porous PCC surfaces could perform similarly close to the quietest AC pavements.

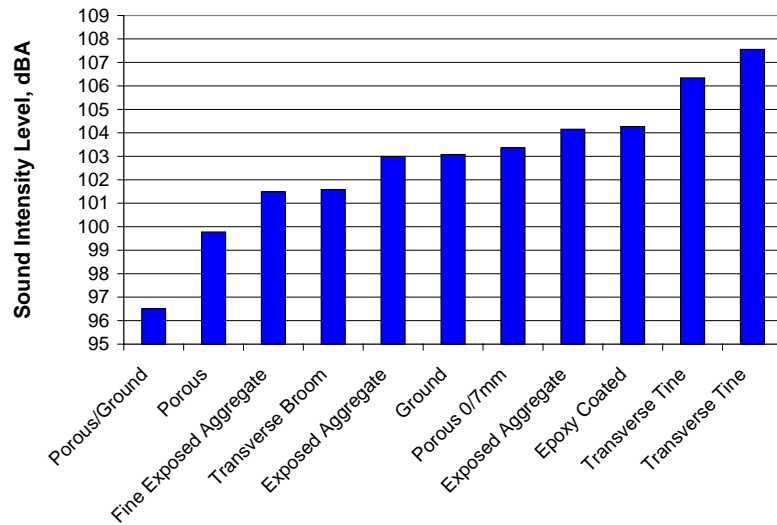


Fig. 15: Overall A-weighted sound intensity levels of tire/pavement noise for PCC surfaces measured in Europe

However, reductions as large as 10 dB in tire/pavement noise have been demonstrated which would certainly qualify PCC surface texture modification as a legitimate tool in mitigating traffic noise under the appropriate circumstances. To advance this notion, grinding techniques need to be optimized so that sound intensity levels in the range of 100 to 101 dBA, or lower, can be consistently produced. Further, the development and use of porous PCC designs should be explored in the US so that highway engineers have additional options for mitigating traffic noise through pavement selection.

ACKNOWLEDGEMENTS

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5. CONCLUDING COMMENTS

From the databases and examples of surface texture modifications, it is apparent that quieter PCC surfaces can be achieved. As with any evaluation of the effectiveness of any pavement change, the amount of reduction depends not only the end "quiet" pavement, but also on the initial pavement performance. From the data accumulated to date, at least in the US, the absolute level of quiet PCC does not approach that of quiet AC.