Influence of Pavement Surface Type on Tire/Pavement Generated Noise

ABSTRACT: Pavement noise evaluations were conducted on 42 pavement surfaces in New Jersey using the Close Proximity Method (CPX) via the NCAT Noise Trailer. The CPX Method is a current ISO Standard that measures sound levels of the tire/pavement interface, thereby providing a method to evaluate solely the influence of pavement surface on traffic noise. The surfaces were comprised of both hot mix asphalt (HMA) and Portland cement concrete (PCC) surfaces. The HMA surfaces consisted of dense-graded asphalt mixes (DGA), open-graded friction course (OGFC) with and without crumb rubber, stone-mastic asphalt (SMA), NovaChip®, and a microsurfacing slurry mix. The PCC surfaces, pavements and bridge decks, had varying surface treatments consisting of transverse tining, saw-cut tining, diamond grinding, and broom finish. The main focus of the research was to: 1) Evaluate how different pavement surfaces influence the generation of tire/pavement noise, 2) Evaluate the effect of vehicle speed on the tire/pavement generated noise, and 3) Provide guidance as to the repeatability of the CPX method and optimal test distance on the roadway to aid in maximizing testing efficiency.

Results of the testing indicated that the asphalt based surfaces provided the lowest tire/pavement noise levels. Of the HMA surfaces tested, the OGFC mixes modified with crumb rubber provided the lowest noise levels (96.5 dB(A) at 60 mph (96.5 km/h)). However, not only were these mixes modified with crumb rubber, but they also had the finest aggregate gradation. The loudest HMA surface was a 12.5mm SMA mix (100.5 dB(A) at 60 mph (96.5 km/h)). The PCC surfaces had the highest noise levels. Of all PCC surfaces tested, the transverse tined surface obtained the loudest noise levels (106.1 dB(A) at 60 mph (96.5 km/h)). It was found that if the PCC surface was diamond ground, the noise levels could be comparable, and sometimes lower, than typical HMA pavement surfaces. Typical noise levels of the diamond ground PCC surfaces were approximately 98.7 dB(A) at 60 mph (96.5 km/h). To evaluate the effect of vehicle speed, noise measurements were conducted at 55, 60, and 65 mph (88.5, 96.5, and 104.6 km/h). Test results within this range indicate that on average, the tire/pavement noise increases linearly and at a rate of approximately 0.18 dB(A) for every 1.0 mph (1.6 km/h). The NovaChip® mixes were less susceptible to the increase in vehicle speed (0.15 dB(A) increase for every 1.0 mph (1.6 km/h) increase), while the PCC broom finish (no treatment) surfaces were affected the greatest by vehicle speed (0.29 dB(A) increase for every 1.0 mph (1.6 km/h) increase). The CPX method was found to be repeatable, with an average standard deviation of approximately 0.13 dB(A), as long as the test distance was greater than 0.2 miles (0.32 km). This is most likely due to the sensitivity of the test method being influenced by the ability to track the identical wheel-path in successive test runs.

KEYWORDS: close proximity method (CPX), tire/pavement noise, pavement surface
Introduction

Traffic noise has become epidemic in the United States. Along with engine, exhaust, and aerodynamic (power train) noise, pavement/tire noise is a major contributor to the overall traffic noise problem [1, 2]. On-going research in both Europe and the United States has indicated that it is possible to build pavement surfaces that will provide low-noise roadways. Therefore, pavement engineers need to be made aware of how different pavement surface types influence the noise generated from the tire/pavement interface.

Nature of Noise Measurement

Noise, like all other sounds, is a form of acoustic energy. The acoustic energy or sound pressure is measured in units of decibels. Since the human hearing covers a wide range of sounds, it does not lend itself to be measured on a linear scale. Instead, a logarithmic scale is used to measure sound pressure and the unit is called a decibel or dB. The decibel combines the magnitude of the sound pressure with the perception of how humans hear the sound. The “A-weighting”, which is used within the context of the dB scale, is used to “correct” sound pressure to more closely represent the response of the human ear to sound pressure. Thus, a noise pressure of 85 dB(A) from a noise source would be judged louder than a noise level of 82 dB(A) at the same distance from the source. The decibel scale ranges from 0 dB(A), the minimum threshold of human hearing, to 140 dB(A) where serious hearing damage can occur. Table 1 [3] represents this scale and some of the levels associated with various daily activities.

<table>
<thead>
<tr>
<th>Common Activity</th>
<th>Noise Level dB(A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lawnmower</td>
<td>95</td>
</tr>
<tr>
<td>Loud Shout</td>
<td>90</td>
</tr>
<tr>
<td>Motorcycle Passing 50 ft Away</td>
<td>85</td>
</tr>
<tr>
<td>Blender at 3 ft Away</td>
<td>85</td>
</tr>
<tr>
<td>Normal Conversation</td>
<td>60</td>
</tr>
<tr>
<td>Quiet Living Room</td>
<td>40</td>
</tr>
</tbody>
</table>

In addition to sound levels, people hear over a wide range of frequencies. This is the main reason for the “A-weighting” of noise pressure as described earlier. A person with good hearing typically can hear frequencies between 20 Hz and 20,000 Hz, while the range from the lowest to highest note of a piano is 27.5 Hz to 4,186 Hz.

Field Measurement of Road Noise

A standardized method for the measurement of noise is necessary to allow the pavement engineer to characterize the level of noise from different pavement surface courses. Considerable work has been done to develop such techniques. Three methods commonly used for measuring pavement noise levels in the field are:
2. The single vehicle by-pass method; and
3. Near-field techniques such as the close proximity method (CPX) that was developed in Europe and defined by ISO Standard 11819-2 [6].

Both the statistical by-pass and the single vehicle by-pass provide noise measurements that accompanying the entire vehicle/pavement system (i.e. engine, exhaust, etc.) and may be biased as to the different vehicles. Therefore, to provide only noise measurements solely associated with the tire/pavement interaction, the close proximity method (CPX) was used.

Close Proximity Method (CPX)

The CPX method consists of measuring the sound levels at or near the tire/pavement interface. In the CPX method, sound pressure is measured using microphones located near the road surface. The testing requirements for CPX testing are described in ISO Standard 11819-2 [6]. This method consists of placing microphones 8 inches (20.3 cm) from the center of the tire and 4 inches (10.2 cm) above the surface of the pavement. 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. Figure 1 shows the mounting of the microphones in the acoustical chamber and Figure 2 shows the acoustical chamber used in the study.

One concern with the CPX method is that the measured roadway noise is related only to the tire/pavement interface [7]. The standard method used by the FHWA’s Volpe Laboratories for measuring traffic noise for use with the FHWA’s traffic noise model is the statistical by-pass. This method was selected because it includes both the power train and tire/pavement noise. However, both the power train and tire/pavement noise are strongly related to vehicle speed. At low speeds, the power train noise dominates while at high speeds the tire/pavement noise dominates. Work conducted in Europe has found that there is a cross-over speed for roadway noise domination [7]. This cross-over speed is approximately 25 to 30 mph (32.2 to 48.3 km/h) for cars and 35 to 45 mph (56.3 to 72.4 km/h) for trucks. At speeds less than the cross-over, the power train noise dominates. Consequently, at speeds higher than the cross-over speed, the tire/pavement noise is dominant. 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 (72.4 km/h). Similar conclusions were drawn from Billera et al. [8].

Testing Program

A field testing program was established to evaluate noise levels on a wide range of pavement surface types and materials. A total of 42 pavement sections were evaluated. Both hot mix asphalt (HMA) and Portland cement concrete (PCC) pavements were represented. The HMA pavements were represented by a wide variety of mixes that included; open-graded friction course (OGFC) with and without crumb rubber, dense-graded asphalt (DGA), stone-mastic asphalt (SMA), Novachip®, and microsurfacing slurry mix. The PCC pavements and bridge
decks evaluated had different surface treatments that included; broom finishing, diamond grinding, transverse tining and transverse saw-cutting.

The measurement of the tire/pavement interface noise levels with the CPX method was used to:

1. Provide an evaluation of the influence of pavement surface materials on tire/pavement generated noise levels;
2. Measure the effect of vehicle speed on measured tire/pavement noise levels; and
3. Provide guidance as to the repeatability of the CPX method and optimal test distance on the roadway to aid in maximizing testing efficiency

Test Results – Pavement Type

For comparison purposes, all test sections were evaluated at 60 mph (96.5 km/h). This vehicle speed was chosen as a moderate traffic speed for most of the roadways tested in New Jersey.

HMA Test Sections

Open-Graded Friction Course (OGFC)

A total of eight test sections of OGFC were evaluated. The results are illustrated in Figure 3. The lowest tire/pavement noise level was obtained by the OGFC that was modified with crumb rubber using the Rouse procedure. The Rouse procedure used a -80 mesh crumb rubber particle size, while the McDonald procedure used a -40 mesh crumb rubber particle size. The New Jersey Department of Transportation (NJDOT) MOGFC-1 and MOGFC-2 have different gradation specifications, with the MOGFC-1 coarser than the MOGFC-2 mix. The results from Figure 3 also show that there is some variability in the noise measurements within the same roadway, as indicated by the I-195 East section. The NJDOT MOGFC-2 was placed along a 5 mile (8 km) section. The CPX test results indicated that depending on the exact location within this test section, the noise levels can vary by as much as 0.3 dB(A). The variability can also be seen from the Rt. 24 East and West test sections where the job mix formula and source material were used and placed at almost identical times, yet there is a 1.0 dB(A) difference in noise level. The difference may be attributed to in-place air voids or a change in the material’s gradation. Further analysis on this section is being conducted.

The total range of noise levels between all OGFC sections tested was 2 dB(A). As shown in Figure 3, the asphalt rubber modified (AR-HMA) OGFC sections obtained the lowest noise levels. Recent work by the Arizona Department of Transportation (AZDOT) has indicated that the addition of crumb rubber to OGFC reduces noise more than OGFC without crumb rubber [9]. However, a further look into the gradation of the different OGFC mixes, illustrated in Figure 4, illustrates that the two AR-OGFC mixes also had the finest gradation.

Figure 4 indicates that the two AR-OGFC mixes were nearly identical in gradation, which may explain why the measured noise levels were comparable; 96.2 and 96.8 dB(A) for the I-195 and Rt. 9, respectively. The NJDOT MOGFC-1 and MOGFC-2, which had louder noise levels than the AR-OGFC mixes, were also coarser in gradation. Therefore, although the addition of crumb rubber may aid in reducing some of the tire/pavement generated noise, it may also be concluded that the finer gradation may also play a significant role.
Dense-Graded Asphalt (DGA)

The DGA mixes tested had nominal aggregate sizes that ranged from 9.5 mm to 19 mm, however, not all of the pavement surfaces were designed using Superpave. A few of the mixes were designed using the Marshall Design procedure. These are indicated as NJDOT I-4 MABC (Medium Aggregate Bituminous Concrete) and NJDOT FABC (Fine Aggregate Bituminous Concrete). The NJDOT I-4 is essentially a 12.5 mm Superpave mix, while the NJDOT FABC is somewhat analogous to the 9.5 mm Superpave mix. These mixes are located on I-195 West-bound at New Jersey’s SHRP test area. The results for the 8 sections of the DGA mixes are shown in Figure 5. Instead of showing the milepost location, the sections include the age of the surface course, as it was anticipated that this might influence the tire/pavement noise generation.

The results from Figure 5 indicate that the 12.5 mm Superpave mixes tended to have the lowest noise levels. The recently placed 12.5 mm mix on I-78 East obtained the lowest noise levels of the DGA mixes at 97.1 dB(A). However, the testing does show that up to a 2.0 dB(A) difference can be expected between the 12.5 mm Superpave mixes. The loudest noise level measured was a 19 mm Superpave mix placed on US 22 West at 100.1 dB(A). There appears to be a trend of the tire/pavement generated noise increasing with increasing nominal aggregate size. There is also a trend of increasing noise levels with increasing pavement age when only considering the 12.5 mm Superpave and NJDOT I-4 mixes, which have similar nominal aggregate sizes. This is consistent with the findings of McNerney et al. [2]. The NJDOT FABC, which has been in service for almost 30 years, has a nominal aggregate size of 9.5 mm.

Stone-Mastic Asphalt (SMA)

SMA was placed on only two roadways in New Jersey, US-1 North and South and I-78 East. The material placed on US-1 had a nominal aggregate size of 12.5 mm, while the SMA placed on I-78 had a 9.5 mm nominal aggregate size. The results for the testing are shown in Figure 6. The SMA placed on I-78 were located on bridge decks, therefore, the milepost number associated with the section references the beginning of the bridge deck.

It is evident that the nominal aggregate size has a dramatic effect on the tire/pavement generated noise on SMA pavement surfaces. The average noise level for the I-78 section was 98 dB(A). Whereas, the average noise level for the US-1 test section was 101 dB(A), a 3.0 dB(A) increase in tire/pavement generated noise simply due to an increase in nominal aggregate size.

Ultra Thin HMA Surfaces – NovaChip® and Micro-surfacing

Two additional HMA surface course treatments were also evaluated; NovaChip® and microsurfacing (total of five test sections). The NovaChip® is a proprietary surface treatment and paving process, similar in structure to an SMA mix, developed by Koch Materials. The NovaChip® has been used in the past in New Jersey as an ultra thin surfacing technique to aid in minimizing pavement noise on the New Jersey Garden State Parkway. The microsurfacing is a slurry of quick setting polymer-modified asphalt binder, aggregate, water and mineral filler. The slurry is then sprayed onto the existing pavement surface to create an ultra-thin surface. The noise measurement results for the two ultra thin materials are shown in Figure 7.

The results indicate a minimal difference between the two ultra thin surface materials, with noise levels slightly increasing with age.
PCC Test Sections

A total of twelve test sections of PCC materials were evaluated using the CPX method. The PCC sections differed in the following surface treatments: diamond grinding, transverse tining, transverse tining via sawcutting, and broom finish (no treatment). The results of the tire/pavement noise testing are shown in Figure 8.

From Figure 8, it is evident that diamond grinding reduces the tire/pavement significantly. The average noise levels for the different PCC surface treatments are shown in Table 2. On average, diamond grinding reduces the tire/pavement noise by 5.1 dB(A) when comparing it to a PCC pavement with no surface treatment (Broom Finish). Similar findings on the diamond ground PCC surfaces were also found in Michigan [10]. On average, the transverse tining via sawcutting reduced the noise levels by 1.1 dB(A), while the traditional transverse tining increased the noise levels by 2.7 dB(A) when compared to the PCC surfaces with no surface treatment.

TABLE 2 – Average Noise Levels for PCC Surface Treatments

<table>
<thead>
<tr>
<th>Surface Treatment Method</th>
<th>Number of Test Sections</th>
<th>Tire/Pavement Noise (dB(A))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diamond Ground</td>
<td>2</td>
<td>98.4</td>
</tr>
<tr>
<td>Transverse Tined via Sawcut</td>
<td>5</td>
<td>102.4</td>
</tr>
<tr>
<td>Transverse Tined</td>
<td>2</td>
<td>106.2</td>
</tr>
<tr>
<td>Broom Finish (No Treatment)</td>
<td>3</td>
<td>103.5</td>
</tr>
</tbody>
</table>

Test Results – Effect of Vehicle Speed

Three different vehicle speeds were used to evaluate the influence of vehicle speed on tire/pavement generated noise. A total of 39 of the previous 42 pavement sections were tested at 55, 60, and 65 mph (88.5, 96.5, and 104.6 km/h). Typical data from the vehicle speed analysis is shown as Figure 9. Figure 9, although not a comprehensive illustration of all sections tested, indicates that the PCC with diamond grinding surface treatment acts similar to most of the HMA test sections.

To provide a method for comparing the effect of traffic speed on the tire/pavement related noise, the noise gradient parameter was used. The noise gradient parameter in this study was defined as the change in noise versus the change in speed with units of dB(A) per mph. The noise gradient was calculated using the 65 and 55 mph (104.6 and 88.5 km/h) noise level measurements, respectively. Pavement surfaces with lower noise gradients would be less prone to have an increase in the tire/pavement related noise due to an increase in the traffic speed. This parameter may be important to state agencies who are deciding whether or not to raise traffic speed limits along residential areas.

The results for the calculated noise gradient are shown in Table 3. Table 3 indicates that the NovaChip® achieved the lowest noise gradient for the HMA based sections, while the transverse tined PCC surface treatment achieved the lowest noise gradient for the PCC based sections.
However, it should be noted that both surface types had limited data (one section for the NovaChip® and two sections for the transverse tined PCC). Based on a weighted average for each test section surface type, the HMA materials had a noise gradient equal to 0.19 dB(A) per mph, while the PCC sections had a noise gradient of 0.17 dB(A) per mph. This is in good agreement with the previous testing conducted for the Michigan Department of Transportation where the average noise gradient found was 0.2 dB(A) for all materials (HMA and PCC). The vehicle speeds used in the Michigan DOT study were 45, 60, and 75 mph (72.4, 96.5, and 120.7 km/h) [10]. The noise gradient trendlines shown in Figure 9 indicate that the gradient may also be assumed to be linear. This was again in good agreement with the Michigan DOT study [9].

### TABLE 3 – Average Tire/Pavement Noise Gradients from Variable Vehicle Speed Testing

<table>
<thead>
<tr>
<th>Pavement Surface Type</th>
<th>Number of Sections</th>
<th>Noise Gradient (dB(A) per mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OGFC</td>
<td>8</td>
<td>0.16</td>
</tr>
<tr>
<td>DGA</td>
<td>13</td>
<td>0.20</td>
</tr>
<tr>
<td>SMA</td>
<td>7</td>
<td>0.17</td>
</tr>
<tr>
<td>NovaChip®</td>
<td>1</td>
<td>0.15</td>
</tr>
<tr>
<td>Microsurfacing</td>
<td>2</td>
<td>0.28</td>
</tr>
<tr>
<td>PCC – Diamond Grind</td>
<td>1</td>
<td>0.15</td>
</tr>
<tr>
<td>PCC – Transverse Tining (Sawcut)</td>
<td>4</td>
<td>0.16</td>
</tr>
<tr>
<td>PCC – Transverse Tining</td>
<td>2</td>
<td>0.13</td>
</tr>
<tr>
<td>PCC – No Treatment</td>
<td>1</td>
<td>0.29</td>
</tr>
</tbody>
</table>

1.0 mph = 1.6 km/h

**Test Results – Repeatability of Noise Measurements**

When conducting the CPX measurements, the trailer needs to be driven over a particular test section at the given test speed. Normal procedures used by NCAT when conducting CPX testing suggest that each test section is tested three times to provide an average over that test length. However, this can be quite time consuming, especially if there are roadways that do not permit easy accessibility for the noise trailer exiting, turning around, and repositioning itself for another test run. An example of this in New Jersey is the New Jersey Turnpike, where the distance between some exits is 20 miles (32.2 km). Therefore, if the test section could be run only once with confidence, many more sections could be tested within a given time frame.

Another potential improvement to NCAT’s current testing is the required test length. Typical test lengths that have been used for the CPX testing are approximately one mile (1.6 km). Unfortunately, the required one mile (1.6 km) test length would not allow for testing on test sections like bridge decks or even the SHRP test sections in New Jersey. Therefore, the repeatability of the noise measurements with respect to the material type and section distance was important to evaluate.
A total of 33 test sections was used to evaluate the repeatability of the CPX method. Each surface type was represented with test section lengths ranging from 0.012 miles (0.2 km) to 1.0 miles (1.6 km). The repeatability, as determined by the standard deviation, of the CPX test results is shown in Figure 10. The standard deviation of the CPX measurements is strongly correlated to the length of the test section. For the test sections that were less than 0.2 miles (0.32 km), which included all bridge decks in the study, the average standard deviation was 0.65 dB(A), while for the test sections greater than 0.2 miles (0.32 km), the average standard deviation was 0.13 dB(A).

The level of repeatability may be attributed to the CPX test method’s sensitivity. When the test section is of considerable length, the effect of not following the identical wheel-path from the previous test run may be nullified by the natural variation of the test section itself. Figure 11 shows the variability of the measured tire/pavement noise with distance for the 12.5 mm Superpave HMA material on I-78. As can be seen from the figure, the range of tire/pavement generated noise is as high as 2.3 dB(A), with the average from the mean equaling 0.52 dB(A). This is most likely due to macro-texture changes on the pavement surface. However, when the test section is considerably shorter, the sensitivity of the test method is more influenced by the noise trailer’s ability to track the identical wheel-path in successive test than macro-texture changes on the pavement surface.

Conclusions

A total of 42 pavement sections, varying from HMA to PCC, were tested using the Close Proximity Method (CPX) to evaluate the effect of pavement surface type on the tire/pavement generated noise. Comparisons for all of the pavement sections were conducted at 60 mph (96.5 km/h). Test was also conducted at 55 and 65 mph (88.5 and 104.6 km/h) to evaluate the effect of vehicle speed on the generated noise. Multiple runs within the same test section were also conducted to provide evidence of the repeatability of the device. Based on this testing, the following conclusions can be drawn:

- On a whole, the HMA based surfaces generated lower noise levels than the PCC surfaces. However, if the PCC surface was diamond ground, noise levels of the PCC was comparable to the HMA materials. The average tire/pavement noise level for the HMA materials was 98.5 dB(A) ($n = 30$). Meanwhile, the average tire/pavement noise level for the PCC materials was 102.6 dB(A) ($n = 12$).
- The nominal aggregate size of the HMA materials had an effect on the generated noise. Comparisons between the different dense-graded asphalt (DGA) mixes showed that the 12.5 mm Superpave mixes produced less noise than the 19 mm Superpave mixes. Meanwhile, the 9.5 mm nominal aggregate size stone-mastic asphalt (SMA) mix had lower generated noise values than the 12.5 mm nominal aggregate size SMA mix.
- A comparison of the open-graded friction course (OGFC) HMA surface courses, typically used to aid in reducing tire/pavement related noise, found that the OGFC mixes modified with crumb rubber attained the lowest noise levels. However, the crumb rubber modified OGFC mixes also had finer aggregate gradations than the traditionally used OGFC mixes in New Jersey.
- Measured noise levels at 55, 60, and 65 mph (88.5, 96.5, and 104.6 km/h) showed that, on average, the tire/pavement generated noise increases by 0.18 dB(A) for every one mph
(1.6 km/h) increase. These results compare well with a previous study conducted for the Michigan DOT where the average noise gradient was 0.2 dB(A) per mph (1.6 km/h). When broken down by surface material type, the HMA materials had a noise gradient of 0.19 dB(A) per mph (1.6 km/h), while the PCC surfaces had a noise gradient of 0.17 dB(A) per mph (1.6 km/h). Although based on a limited number of tests, the PCC with no surface treatment was affected the greatest by vehicle speed, with a resulting noise gradient of 0.29 dB(A) per mph (1.6 km/h). The pavement surface that was least affected by vehicle speed was the transverse tined PCC, with a noise gradient of 0.13 dB(A) per mph (1.6 km/h).

- The repeatability of the CPX method, as represented by the standard deviation of three consecutive test runs, was found to be dependent on the distance of the test run. If the test section was less than 0.2 miles, the average standard deviation was found to be 0.65 dB(A) (n = 19). However, when the test section was greater than 0.2 miles, the average standard deviation was 0.13 dB(A) (n = 14).

References


FIG. 1 – Schematic Showing Microphone Locations for CPX Test Method

From ISO STANDARD 11819-2
FIG. 2 – National Center for Asphalt Technology’s Noise Trailer
FIG. 3 – Tire/Pavement Noise Measurements for the OGFC Test Sections

Vehicle Speed = 60 mph

Sound Pressure (dB(A))

Crumb Rubber Modified
(McDonald)

NJDOT MOGFC-1

NJDOT MOGFC-2

96.2
96.8
97.0
97.1
98.1
98.3
98.6
98.6

Rt 195
West
(SHRP Section)

Rt 9 N MP
60-61
(10 yrs)

Rt. 78 W
MP 30
(1 yrs)

Rt 24 E
MP 7.7-8.7
(4 yrs)

Rt 24 W
MP 8.6-7.6
(4 yrs)

Rt 195 E
MP 6-6.4
(2 yrs)

Rt 195 E
MP 3-4
(2 yrs)

Rt 195 E
MP 5-5.5
(2 yrs)

60 mph = 96.5 km/h
FIG. 4 – Gradation of the Different OGFC Mixes in Study
FIG. 5 – Tire/Pavement Noise Measurements for the DGA Test Sections

Vehicle Speed = 60 mph

Sound Pressure (dB(A))

<table>
<thead>
<tr>
<th>Location</th>
<th>Sound Pressure (dB(A))</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-78 E (12.5mm Superp.) 0 yrs</td>
<td>97.1</td>
</tr>
<tr>
<td>US-22 W (12.5mm Superp.) 4 yrs</td>
<td>98.5</td>
</tr>
<tr>
<td>NJDOT FABC 30 yrs</td>
<td>98.6</td>
</tr>
<tr>
<td>I-78 W (12.5mm Superp.) 4 yrs</td>
<td>99.3</td>
</tr>
<tr>
<td>NJDOT I-4 with 30% RAP 10 yrs</td>
<td>99.5</td>
</tr>
<tr>
<td>NJDOT I-4 Mix 10 yrs</td>
<td>99.6</td>
</tr>
<tr>
<td>NJDOT I-4 with 10% RAP 10 yrs</td>
<td>99.7</td>
</tr>
<tr>
<td>US-22 W (19mm Superp.) 4 yrs</td>
<td>100.1</td>
</tr>
</tbody>
</table>

60 mph = 96.5 km/h
FIG. 6 – Tire/Pavement Noise Measurements for SMA Test Sections

Vehicle Speed = 60 mph

Sound Pressure (dB(A))

60 mph = 96.5 km/h
FIG. 7 – Tire/Pavement Noise Measurements for the Ultra-Thin Resurfacing Materials

60 mph = 96.5 km/h
FIG. 8 – Tire/Pavement Noise Measurements for the PCC Test Sections

60 mph = 96.5 km/h
FIG. 9 – Typical Data to Illustrate the Effect of Vehicle Speed on Tire/Pavement Noise

1.0 mph = 1.6 km/h
FIG. 10 – Repeatability of CPX Test Measurements

1.0 miles = 1.6 km
FIG. 11 – Measured Tire/Pavement Noise for 12.5 mm Superpave HMA on I-78

- Average: 97.1 dB(A)
- Range: 2.3 dB(A)
- Average from Mean: 0.52 dB(A)

1.0 miles = 1.6 km