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Quieter Pavement Research: Concrete Pavement Tire Noise

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Abstract: This research report presents the results of tire/pavement noise measurements performed on concrete pavements as a part of the California Department of Transportation (Caltrans) Quieter Pavement Research (QPR) study to investigate tire/pavement noise characteristics on concrete pavements and bridge decks.

The study included a total of 120 pavement sections at 47 different sites on various state highways throughout California. Most of the sites (36) were divided into three sections each for measurement and evaluation of tire/pavement noise using the On-board Sound Intensity (OBSI) method, while the other sites had one or two test sections. The evaluation included visual observation of pavement surface condition and texture type, some of which was performed from a moving vehicle, as no traffic closures were used for this research. The following five texture types were evaluated, with the number of sections shown in parentheses: burlap drag (37), diamond ground (33), diamond grooved (19), longitudinally broomed (10), and longitudinally tined (21). The report explains the data collection and data reduction procedures, data analysis, and discussion of the results.

Overall, the longitudinally broomed texture type was found to be the quietest, although this texture had a small data sample, followed by diamond grooved and diamond ground. Burlap drag was as quiet as diamond ground, and longitudinally tined was the loudest. Differences in mean OBSI levels were small between all types, while differences of up to 5 dB(A) were measured within a given texture type. The range of OBSI levels across all sections during the two years was 99.4 to 107.3 dB(A). In addition to texture, the measured OBSI levels include the effects of joint slap, faulting and sealant, if they were present.

Keywords: tire noise, OBSI, concrete pavements, texture types

Proposals for Implementation: No single texture type was found to be particularly quieter than the others across the set of sections for each type, which precludes the authors of this study from making a strong recommendation about their use for accomplishing noise reduction. A preliminary recommendation, based on the limited number of measurements over the short time period included in this study, is that longitudinal brooming may provide the quietest surfaces, although this is based on a small data sample. Diamond grinding and diamond grooving appear to provide noise advantages, but longitudinally broomed or burlap drag surfaces can also be quiet.

Related Documents:

- Ongel, A., J. T. Harvey, E. Kohler, Q. Lu, and B. D. Steven. (2008). Investigation of Noise, Durability, Permeability, and Friction Performance Trends for Asphaltic Pavement Surface Types: First- and Second-Year Results. (UCPRC-RR-2007-03)
- Ongel, A., J. T. Harvey, E. Kohler, Q. Lu, B. D. Steven, and C. L. Monismith. (2008). Summary Report: Investigation of Noise, Durability, Permeability, and Friction Performance Trends for Asphalt Pavement Surface Types: First- and Second-Year Results. (UCPRC-SR-2008-01)
- Ongel, A. E. Kohler, and J. Nelson. (2007). Acoustical Absorption of Open-Graded, Gap-Graded, and Dense-Graded Asphalt Pavements. (UCPRC-RR-2007-12)
- Ongel, A., J. T. Harvey, and E. Kohler. (2007). State of the Practice in 2006 for Open-Graded Asphalt Mix Design. (UCPRC-TM-2008-07)
- Ongel, A., N. Santero, and J. Harvey. (2005). Report of Field Site Visit District 3, Sacramento Interstate 5, PM 17.2-17.9 RAC-O Overlay. (UCPRC-TM-2005-07)
- Lu, Q., E. Kohler, J. T. Harvey, and A. Ongel. (2009). Investigation of Noise and Durability Performance Trends for Asphaltic Pavement Surface Types: Three-Year Results. (UCPRC-RR-2009-01)
- Q. Lu, P.C. Fu, and J. T. Harvey. (2009). Laboratory Evaluation of the Noise and Durability Properties of Asphalt Surface Mixes. (UCPRC-RR-2009-07)
- Lu, Q., J. T. Harvey, and R. Wu. (2010). Investigation of Noise and Durability Performance Trends for Asphaltic Pavement Surface Types: Four-Year Results. (UCPRC-RR-2010-05)

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DISCLAIMER

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PROJECT OBJECTIVES

This project evaluated tire/pavement noise on rigid pavements and bridge decks in California. The work involved the identification and monitoring of field sections in a study similar to the Quieter Pavement Research (QPR) investigation performed by the University of California Pavement Research Center (UCPRC) on asphalt pavements. The project has three objectives:

1. To identify relationships between the design variables in concrete pavements and bridge decks and tire/pavement noise, covering the majority of concrete surface textures used in California,
2. To determine trends in noise levels versus age for concrete pavement and bridge decks, and
3. To develop recommendations for concrete surface textures that minimize tire/pavement noise.

This report addresses all three objectives for concrete pavements. Tire/pavement noise evaluations for bridge decks are covered in a separate report.

EXECUTIVE SUMMARY

In the early 2000s, the California Department of Transportation (Caltrans) identified a need for research into the acoustics, friction, durability, and related performance properties of the state highway system pavement surfaces. Previous studies have evaluated the Department's asphalt open-graded mixes and selected experimental asphalt surfaces. The primary objectives of Quieter Pavement Research (QPR) on asphalt surfaces were to evaluate the comparative effectiveness of various types of mixes in reducing tire/pavement noise without sacrificing durability and safety, to determine the pavement characteristics that affect the tire/pavement noise, and to develop correlations between laboratory sound absorption and tire/pavement sound intensity in the field for different frequencies.

The study presented in this report is also part of the Caltrans QPR program and is intended to determine which concrete pavement surface textures reduce tire/pavement noise. This study was initiated by the Caltrans QPR Task Group in May 2008. The project has three objectives:

1. To identify relationships between the design variables of concrete pavement surface textures used in California and tire/pavement noise characteristics,
2. To determine trends in tire/pavement noise levels versus age for concrete pavements, and
3. To develop recommendations for surface textures that minimize tire/pavement noise.

The field measurement part of the study involved the identification and monitoring for two years of 120 concrete pavement test sections at 47 sites distributed throughout the state. All sections are on state highways. Thirty-six sites had three consecutive test sections each, while one site had two test sections and ten sites had one test section each. Measurements were made twice over a two-year period.

The mechanisms of tire/pavement noise are affected by pavement surface texture, and five different texture types were investigated in this project. Surface textures change after construction under the actions of traffic and the environment and the interaction of the two, which is sometimes referred to as the *aging* of the textures. For this reason, either the year of construction or of the last retexturing was investigated for all test sections in this study.

The project began in September 2008 with the identification of candidate sections that would provide a range of surface textures and ages representative of concrete pavements typically found on California highways. The final list of test locations was selected from the candidate sections after a range of climate regions and traffic levels were also considered. The experiment was not designed as a factorial experiment because it was intended as an initial study to assess existing pavements, and therefore it is not balanced with respect to the age of the sections, traffic levels, or climate regions.

The tire/pavement noise from each of the different surface texture types was evaluated using the On-board Sound Intensity (OBSI) method, which measures the noise level at the tire/pavement interface. (OBSI is the same method used for the asphalt surface tire/pavement noise studies.)

Test sections were grouped into five surface texture types based on their construction texturing process: burlap drag (BD), diamond ground (DG), diamond grooved (Gr), longitudinally broomed (LB), and longitudinally tined (LT). The number of sections for each group tested in Year 1 and Year 2 are shown in the report. There were fewer sections in the second year because some of them were taken out of service, and there were occasional logistical problems. The sample sizes for the diamond grooved and particularly the longitudinally broomed textures were smaller than the samples for the other textures.

Besides the typical air density correction that takes into account the effect of air density on the speed of sound, two additional adjustments were considered necessary to normalize results and to make them consistent with other OBSI databases. Results were converted to a particular test tire (the first Standard Reference Test Tires used by the UCPRC) and to a particular sound analyzer (the newer Sinus Harmonie 4-channel analyzer).

The quietest texture type, when considering the mean of the OBSI results of sections with the same nominal surface type and combining Year 1 and Year 2 data, was found to be the longitudinally broomed. The longitudinally broomed group presented a mean OBSI level of 102.3 dB(A), although this is based on a small sample. If sections with surfaces that had the texture worn out or essentially erased are excluded, then the mean OBSI value for this group is 102.0 dB(A). The diamond grooved and the diamond ground texture types produced similar mean OBSI levels, and are therefore ranked next at 103.6 and 103.8 dB(A) on average, respectively. Burlap drag and longitudinally tined surfaces resulted in mean OBSI levels of 104.5 and 104.8 dB(A), respectively. Again, if worn surfaces are excluded, then the mean OBSI value for these two groups are 103.8 and 104.7 dB(A), respectively. It should be remembered that human hearing can generally only perceive differences in sound intensity of at least 2 to 3 dB(A).

In general, the differences in OBSI observed between the various texture types are fairly small. A simple two-tailed t-test, which is presented in the report, was used to determine if the difference is significant or not for each pair.

The report also presents the OBSI level results against surface age for each texture type. The vast majority of the burlap drag sections were built in the 1960s and 1970s. There is only one “young” section, which was at the Mojave Bypass and about six years old at the time of testing, while the oldest sections were 62 years old. The burlap drag sections show a general trend of increased noise for the older sections, from 102 dB(A) for the younger sections (under 10 years) to about 107 dB(A) for the older sections (over 40 years). The oldest diamond-ground sections evaluated were 11 years old at the time of testing. There was a general trend that the older sections have higher OBSI levels. The diamond-grooved sections have ages of three and about 12 years old since they were last textured with no sections of intermediate age. It is not possible to observe a trend in OBSI level over time with the available data for the diamond-grooved sections because of the limited ranges of age in the data set for that texture. The longitudinally broomed sections were 6 to 34 years old. From the limited available data, it seems that OBSI levels on this type of surface texture do not increase much over time. For the longitudinally tined sections it was observed that the OBSI levels remain mostly between 104 and 106 dB(A) regardless of age.

The first set of conclusions pertains to the first objective of this study: To identify relationships between the design variables of concrete pavement surface textures and tire/pavement noise, covering the majority of surface textures used in California. The primary design variable investigated in this study was texture type, and the secondary one was texture condition (*new, aged, worn out*). Taking into account all sections, regardless of texture type, the OBSI levels on existing concrete pavements in California range from about 99 dB(A) to about 107 dB(A). The range does not change when the sections where the texture has been *worn out* (meaning that the constructed texture has been worn off by traffic) were removed. It is understood that the range was unchanged because of two cases introduced by the loss of texture: on texture types that lacked a significant amount of positive texture at construction the wearing of traffic could produce a positive texture and increased OBSI, and alternately texture types that had positive texture at construction could have that texture worn off by traffic, resulting in decreased OBSI. An example of the former case could be loss of paste around large aggregates, and an example of the latter case could be wearing off of fins from diamond grinding. These results indicate that a more in-depth investigation to characterize the textures should be included in the next years of this study. This will require texture measurements within traffic closures.

There is a large variation in tire/pavement noise level for each of the five texture types evaluated. The difference between the lowest and highest OBSI levels for the same nominal texture type could exceed 5 dB(A) without considering texture conditions, pavement age, and traffic and climatic conditions. Given that the average OBSI levels for the different texture types are similar to each other, this means that there is a large overlap in the OBSI levels for the different types of surface textures that are found on the state highway network.

The comparison of the network results with those from the Mojave sections that have the same concrete mix and other variables showed that the burlap drag, diamond ground, diamond grooved, and longitudinally tined textures at Mojave are generally similar to or quieter than the same textures on the rest of the state highway network, while the longitudinally broomed (LB) texture at Mojave is noisier than nearly all of the LB sections measured on the rest of the network. This conclusion from the Mojave sections again indicates that a more in-depth characterization of the pavement textures—besides their nominal type and condition *(new, aged, worn* *out)*—is necessary to explain differences within texture type, such as the fact that the longitudinally broomed (LB) sections at Mojave are louder than other texture types at the same location, while other LB sections are generally quieter than other texture types.

The overall conclusion with regard to design variables is that texture type is not sufficient as a design variable to predict tire/pavement noise across the design life.

The second set of conclusions pertains to the second objective of this study: To determine trends in noise levels versus age for concrete pavements. It is clear from this study that the two years of data collected in this experiment is insufficient to develop equations for the rate of change of tire/pavement noise. The data presented in this report does not present clear trends for change in OBSI versus time. Better characterization of texture in conjunction with collection of OBSI over longer periods of time is necessary to develop better understanding of the effects of time and traffic on tire/pavement noise, and the changes in texture parameters that explain it.

The third set of conclusions pertains to the third objective of this study: To develop recommendations for concrete pavement surface textures that minimize tire/pavement noise. The ranking of texture types from quietest to loudest for the sections evaluated in this research project is shown below, without considering differences in age, traffic, or climate. Shown in parentheses are the average overall OBSI excluding worn out texture conditions, and shown in italic is the range of overall OBSI excluding sections with worn out textures:

1. Longitudinally broomed (small sample size, 102.0, *101.9 to 105.5)*
2. Diamond grooved (103.6, *101.7 to 106.3)*
3. Diamond ground (103.8, *99.4 to 107.3)*
4. Burlap drag (103.8, *101.1 to 103.0)*
5. Longitudinally tined (104.8, *102.7 to 106.8)*

Although OBSI measurements on the diamond ground surfaces included the quietest in the entire sample (99.4 dB[A]), they also yielded a wide range of noise levels whose average exceeded that of the limited sample of longitudinally broomed sections. Out of the five textures evaluated, longitudinal tining was the loudest, regardless of age, and cannot be the recommended texture when the only concern is tire/pavement interaction noise. Longitudinally broomed textures appear to be adequate because they are quieter on average than the other textures and tire/pavement noise from them seems to have little increase over time, although only a very limited number of sections of this texture type could be included in this study. Burlap drag and longitudinally broomed textures may not be good options in some places because of their possible lack of capacity to evacuate water from under tires, which is an issue outside the scope of this study. Longitudinal tining could be an option but since it was found to produce higher OBSI levels than diamond grooving, the latter should probably be preferred between the two. From a cost point of view (which was not evaluated in the study), longitudinal tining might be preferred over diamond grooving.

The measured OBSI levels include the effects of joint slap, faulting and sealant providing positive texture (referred to as *overbanding)*, all of which would increase the OBSI level if they are present. These effects were not separated from the tire/pavement noise associated with the surface texture of the concrete. Faulting and overbanded sealant could not be considered because a method of measuring faulting and overbanding using the high-speed profilometer was not established at the time the project scope and budget were determined, and traffic closures to manually measure faulting, joint width, and overbanding were not included in the project budget. Some initial analysis was performed regarding the effects of joints on overall OBSI measurements, without separating the separate effects of slap caused by the joint groove, faulting, and overbanded sealant. That initial analysis showed the spike in noise caused by the joint (faulting, groove, and any sealant combined). However, the project had insufficient funding to fully analyze and consider these effects in the results. A method for estimating the effect of joint slap based on the cross-sectional area of the joint groove has become available since the data collection and analysis for this report were completed. There is laboratory data and some field validation data relating fault height and sealant condition to overall measured tire/pavement noise.

In summary, where quieter pavement is needed, the data collected to date indicate that each of the textures evaluated can produce pavements with OBSI less than 102 dB(A). All of the textures evaluated were generally quieter than the longitudinally tined sections. However, the factors that control tire/pavement noise for a given texture type, and which produce the wide range of tire/pavement noise measured for each texture, could not be measured as part of this study.

It is therefore recommended that diamond-grooving, diamond-grinding, and longitudinal-tining techniques be further investigated to better understand the wide range of noise values, so that best practice can be identified to consistently reduce their noise levels. It is recommended that the next steps in the Caltrans QPR study of concrete pavements include better characterization of the textures on the sections, expansion of the experiment to better consider age, climate, and traffic levels, and inclusion of new generation concrete textures that are currently being constructed in the state. It is also recommended that future surveys of concrete pavement noise consider the effects of faulting, overbanding of sealant, and joint slap separately from the effects of texture. As part of that effort, data should be collected to develop a model (theoretical if possible, empirical if not) that will permit calculation of the effects of joint faulting and sealant overbanding on the total measured tire/pavement noise.

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1 INTRODUCTION

In the early 2000s, the California Department of Transportation (Caltrans) identified a need for research into the acoustics, friction, durability, and related performance properties of pavement surfaces on the state highway network. Consequently, in November 2006, the Caltrans Pavement Standards Team (PST) approved a research project to investigate the tire/pavement noise characteristics and performance properties of existing flexible pavements, including the Department's current open-graded mixes, dense- and gap-graded mixes, and selected experimental mixes.

The flexible pavement Quieter Pavement Research (QPR) study had as its objectives evaluation of the asphalt mixes' durability and their comparative effectiveness in enhancing safety and reducing noise, determination of the pavement characteristics that affect the tire/pavement noise, and evaluation of the correlation between laboratory sound absorption and tire/pavement sound intensity in the field. The research study's design included measurement of the material properties of asphalt mixes and measurement of the field performance characteristics (durability, noise, ride quality, macrotexture, and permeability) of four asphalt surface types located throughout the state in different climate and traffic conditions. A similar research study for rigid pavements, which is the subject of this report, was initiated by the Caltrans Quieter Pavement Research Task Group in May 2008.

The quieter concrete pavement research study presented in this report was undertaken to determine the acoustic characteristics of the noise generated by tire/pavement interaction on concrete pavement surfaces, and to identify the types and properties of concrete surface textures that would effectively reduce tire/pavement noise. This study has three objectives:

1. To identify relationships between the design variables of concrete pavement surface textures and tire/pavement noise, covering the majority of surface textures used in California,
2. To determine trends in noise levels versus age for concrete pavements, and
3. To develop recommendations for concrete pavement surface textures that minimize tire/pavement noise.

The field measurements conducted as part of this study involved the identification and monitoring for two years of 120 concrete pavement sections throughout the state. Measurements were made once each year over a two-year period on most of these sections.

The mechanisms of tire/pavement noise are affected by pavement surface texture, and five different texture types—burlap drag (BD), diamond ground (DG), diamond grooved (Gr), longitudinally broomed (LB) and longitudinally tined (LT)—were investigated in this project. The five surface textures and the number of pavement sections for each are presented in Table 2.1.

After construction, pavement surface textures change under the actions of traffic, the environment, and the interaction of the two; this change is sometimes referred to as the *aging* of the textures. For this reason, the year of construction or of the last retexturing was investigated for all test sections. The project began in September 2008 with the identification of candidate pavement sections with a range of surface textures and surface ages representative of concrete pavements typically found on California highways. The final list of sections was selected from those candidates based on their texture type and age, and a range of climate regions and traffic levels. Information about the concrete material in each section was unavailable. This is unfortunate since cement content, aggregate gradation, and other mix design variables affect the initial texturing and how it changes over time. As concrete surfaces are degraded by years of traffic and climate, the original texture is eventually worn away and the surface can no longer be considered representative of that texture. Sections included in this study were classified as having *new*, *aged*, or *worn out* textures based on visual observation. The experiment was not designed as a factorial experiment because it was intended as an initial study to assess existing pavements, and therefore it is not balanced with respect to the age of the sections, traffic levels, or climate regions.

Tire/pavement noise was measured on these sections using the On-board Sound Intensity (OBSI) method, the same method used for the flexible surface tire/pavement noise studies. The results were analyzed to determine overall OBSI levels and OBSI levels for different frequencies at one-third octave bands.

Chapter 2 of this report describes the data collection and data reduction procedures. Chapter 3 presents the various results relating the measured OBSI levels to each texture type and then to pavement surface age, and the effects of IRI and MPD. Chapter 4 includes an analysis and discussion of the results. Chapter 5 presents the conclusions.

Four appendices are included with this report. Appendix A presents example pictures of texture types and Appendix B shows bar charts with results of overall OBSI obtained on both testing years. Appendix C presents the case of a longitudinally tined section that rapidly lost its texture due to traffic. Finally, Appendix D contains pictures and the OBSI spectra of each section in the study.

2 DATA COLLECTION AND REDUCTION METHODS AND TEST SECTION SELECTION

2.1 Data Collection

In this study, concrete pavements with different surface texture types were evaluated using the On-board Sound Intensity (OBSI) method, which measures the noise level at the tire/pavement interface.

As specified in AASHTO TP-76-09 *(1)*, data was gathered on each section during three passes of five-second duration at 60 mph (96 km/hr), the typical OBSI procedure that was also followed in an earlier part of the California QPR studies on the tire/pavement noise of asphalt pavements. The data quality checks incorporated in the AASHTO protocol were verified at the beginning of the study rather than for every section, which represents a deviation from the AASHTO procedure.

In the testing on asphalt-surfaced pavements, each section resulted in approximately five seconds of data collection. For the concrete pavement testing in this report, the sound analyzer was programmed to collect three five-second periods of data in succession, creating three subsections at each test location. In addition to the three five-second interval passes, one more pass was conducted with an experimental fifteen millisecond (0.015-second) interval. This additional procedure and its analysis were carried out to try to identify the effects of joints and non-homogeneity along each section. This 15-millisecond pass was only conducted during the measurements performed in the first year of the two-year study. Some initial analysis was performed regarding the effects of joint slap, as well as faulting and sealing of the joints, on overall OBSI measurements. However, there was insufficient funding in the project to fully analyze and consider these effects in the results.

The collection of data on three successive 440-foot (134 m) sections—resulting from five seconds of travel at 60 mph (97 km/h), the time and distance typically specified for sound analysis—resulted in a total three-section length of 1,320 feet (402 m).

Consecutive subsections were distinguished from each other with a unique identifying number added to the end of the site's ID number. For example, Section QP-100.1 corresponds to the first 440 feet (134 m) of test site QP-100. Section QP-100.2 immediately followed this section, with no gap between them, and then Section QP-100.3.

In addition to the use of the OBSI method to measure tire/pavement noise, an inertial profilometer was used to measure International Roughness Index (IRI) and Mean Profile Depth (MPD), and visual observations were made of the surface texture type and condition of each test section. The measured IRI values and texture observations were collected at the same fixed short intervals used for OBSI measurement. The instrumented vehicle used in this project is shown in Figure 2.1.

It should be noted that, although IRI and macrotexture were collected as part of this project, the lasers used on the profilometer are now generally considered to be inadequate for IRI and macrotexture measurement on directionally textured surfaces. The lasers used for this project have very small contact areas which pop up and down on tined or grooved textures as the vehicle travels on the pavement, producing IRI values that are thought to be too high compared to the longitudinal profile elevation changes experienced by a tire much wider than the laser. Various organizations are investigating alternative lasers with wider footprints. There are some similar issues with MPD depending on the wander of the vehicle and how straight the tines or grooves are in the longitudinal direction. Therefore, the visual observations were necessary to determine the texture type.

Figure 2.1: Instrumented vehicle with on-board sound intensity probes and an inertial profilometer.

2.2 Data Reduction

A large effort went into data reduction for this project. The OBSI method requires the measurement of sound intensity levels in one-third octave bands, from the one centered at 400 Hz to the one centered at 5,000 Hz. These values are obtained at the leading and the trailing edges of the tire contact patch. Three repeated passes are conducted at each test section to account for lateral variability and for measurement inaccuracies due to deviations from the 60 mph (97 km/hr) specification. Measurements from the three passes at the two probe locations are used to obtain noise spectra, which are in turn used to calculate the overall sound intensity level, the single value that summarizes the overall tire/pavement noise.

The sound intensity levels at the leading and trailing edges are averaged through the energy method. The energy average is obtained using the following equation:

$$Energy\ average = 10 * \log_{10}\left[\frac{1}{n} \times \sum_{i=1}^{n} 10^{\frac{x_i}{10}}\right]$$

where x_i are the sound intensity values to be averaged, in this case the one-third octave results at the two probe locations, and n is the number of samples, in this case two.

An air density correction was applied that takes into account the effect of air density on the speed of sound, which is calculated from atmospheric variables collected during testing, including the air temperature, barometric pressure, and relative humidity, as well as the altitude of the section.

There have been improvements to the process of OBSI data collection that have affected every consultant and organization conducting this type of testing over the years. For this research, adjustments were considered necessary to normalize results and make them consistent with other OBSI databases delivered to Caltrans by the UCPRC. These adjustments include the following:

a. Test tire: Although the tires used in both years of data collection were Standard Reference Test Tires (SRTT), the actual test tire was replaced in early November 2009, when the tire was considered to be "young," to prevent problems associated with testing using an aged tire. Through comparisons performed later, linear transformation equations were developed to adjust the results of the Year 1 and Year 2 tires back to the first SRTT used by the UCPRC research team. The conversion made by the UCPRC adjusted the SRTT#2 tire (used in 2008) and SRTT#3 tire (used in 2009), back to the SRTT#1 tire, which was the SRTT first used in the asphalt study. The conversions were applied frequency by frequency, and the overall sound intensity was calculated from its own linear transformation as well, not from summation of the adjusted spectra values. The tire correction equations used for the data in this report were developed using data from concrete pavements only.
b. Sound analyzer: A frequency-by-frequency correction was applied to account for the fact that a new sound analyzer was used for the second year of this study. Year 1 OBSI data were measured using two Larson Davis two-channel analyzers, while a Sinus Harmonie 4-channel analyzer was used in Year 2. Linear transformation equations were determined using results from field sections tested with both analyzers, and the results that had previously been measured with the Larson Davis analyzers were converted to equivalent Sinus Harmonie analyzer results. The analyzer correction equations were developed using data from both asphalt and concrete pavements. Despite discussions with the manufacturers and Dr. Paul Donavan of Illingworth and Rodkin, it could not be determined why the 400 Hz frequency had a low correlation coefficient between the two analyzers. The 400 Hz frequency data was included in the overall OBSI correlation because it did show an expected trend, although there was more variance around that trend than for the other frequencies. Removing the 400 Hz frequency could possibly introduce bias into the overall OBSI correlation, despite that frequency having a low weighting in the dB(A) system.

These adjustments are presented in Table 2.2, where A is the intercept and B is the slope of the linear transformation. Also shown is the coefficient of determination R^2.

The decision to change tires between the two years of data collection was made in the summer of 2009 based on an observation that the large number of sections tested by the UCPRC each year was producing observable wear on the tread. There were no guidelines at the time for when to change tires. In early 2012, Donavan and Lodico *(9)* presented a paper at the Transportation Research Board conference based on measurements performed as part of NCHRP Project 1-41 *(1 10)* that included preliminary suggested guidelines for when to change tires. That paper states that "potential criteria for retiring a test tire are: 1) being in-service for more than 4 years, 2) having more than 11,000 miles, 3) having hardness number of greater than 68, and/or 4) having tread depth less than 7.2 mm." The paper also states that "These could be applied singly or concurrently such that if two or more are violated, the tire replacement should be considered."

In early February 2012, UCPRC examined the ages, miles put on each tire per year, hardness values recorded over time (UCPRC measures hardness on all tires in inventory several times each year), and tread depths measured over time (also recorded several times each year). It was found that the tire used in Year 1 of this study met criteria 2, 3, and 4: therefore, more than two of the criteria. Based on Donavan and Lodico's proposed guidelines, the UCPRC decision to change the tire between the two years of the study, and each year subsequently, was justified.

The paper by Donavan and Lodico also makes the following recommendation: "However, further research with a larger sample of older and newer tires should be considered to better statistically isolate these parameters and determine if and how such criteria could be implemented." The annual calibration of the new UCPRC tire to previously used tires will provide data to better understand the relationships between different tires and the physical mechanisms causing differences. The annual calibrations and other UCPRC practices include measuring hardness and tread depth, tracking accumulated miles, and development of frequency-by-frequency as well as overall OBSI statistical correlations between tires.

To help understand the effects of changing the tire between the two years of data collection, the uncorrected data and the corrected data are included in the same table in Appendix E: Summary Table and Selected Figures with Uncorrected OBSI Data, along with plots of selected figures from the main body of the report that have been replotted with uncorrected data. All results in the main body of the report are with corrected OBSI values.

It should be noted that no temperature correction has been applied to the data in this report. UCPRC has previously developed corrections for air temperature based on UCPRC testing at two sites *(11)*, but has not included them in reports.

2.3 Description of the Test Sections

A total of 120 pavement sections at 47 sites were included in this study. Section selection was based on the process explained in Section 2.1, with 108 pavement sections at 36 sites (i.e., three sections per site). In addition, one site had two sections and ten sites had only one section each. Data collection spanned two years. The Year 1 sections were selected and immediately evaluated between September 2008 and February 2009. For Year 2, the Year 1 sections were visited and evaluated again between September and December 2009.

The 120 pavement sections investigated for this concrete pavement study are all located on state highways distributed across California. The counties in which study sections are located are presented in Figure 2.2 to show the geographic diversity of the sections (the numbers in blue represent Caltrans districts).

The complete list of test sections is shown sorted by texture type in Table 2.1.

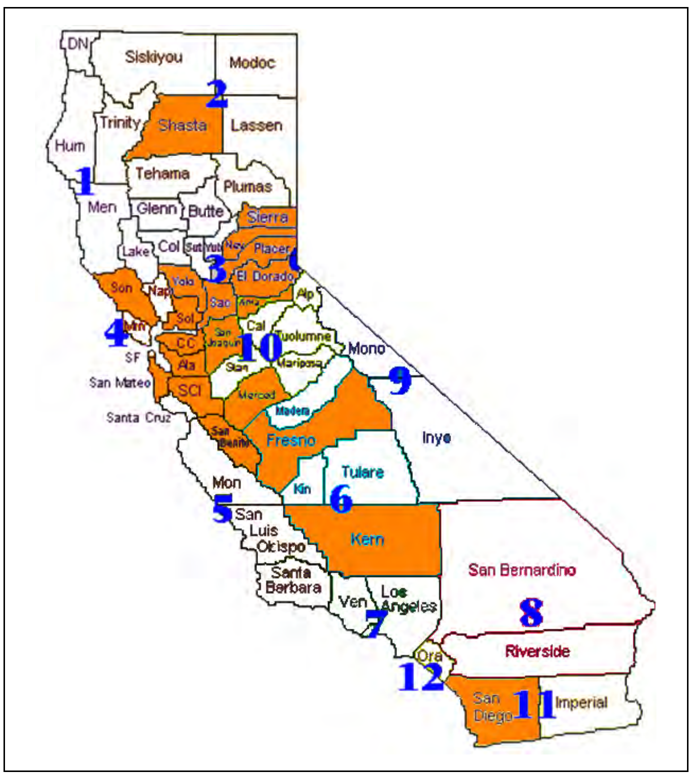

Figure 2.2: Map showing counties in which study sections are located.

Table 2.1: List of Locations, Texture Types and Conditions, and Construction and Resurfacing Years of Field Evaluation Sections (OBSI values corrected for analyzer and tire)

Section ID	Location: Dist-Cnty-Rte-Dir-PM	Lane[1]	Texture Type[2]	Construction Year	Surfacing Year	Texture Condition[3]	Date/Time of Collection in Year 1	Date/Time of Collection in Year 2	OBSI Level Year 1	OBSI Level Year 2
QP-117.1	04CC80W10.3	4 of 4	LT	2007	2007	New	10/28/2008 14:14	10/29/2009 14:57	103.1	106.3
QP-117.2	04CC80W10.2	4 of 4	LT	2007	2007	New	10/28/2008 14:45	10/29/2009 15:03	102.7	106.3
QP-117.3	04CC80W10.1	4 of 4	LT	2007	2007	New	10/28/2008 14:54	10/29/2009 15:12	102.9	106.4
QP-142.1	03NEV80W1.0	2 of 2	LT	2008	2008	New	11/24/2008 15:10	9/17/2009 12:31	104.9	111.4
QP-142.2	03NEV80W0.9	2 of 2	LT	2008	2008	New	11/24/2008 15:16	9/17/2009 12:49	104.5	111.2
QP-142.3	03NEV80W0.8	2 of 2	LT	2008	2008	New	11/24/2008 15:19	9/17/2009 12:52	103.9	112.6
QP-100.1	03Yol113N3.0	2 of 2	LT	1976	1976	Aged	9/3/2008 15:09	9/4/2009 14:07	103.1	105.3
QP-100.2	03Yol113N3.1	2 of 2	LT	1976	1976	Aged	9/3/2008 15:59	9/4/2009 14:24	104.7	106.8
QP-100.3	03Yol113N3.2	2 of 2	LT	1976	1976	Aged	9/3/2008 16:10	9/4/2009 14:40	103.7	105.6
QP-101.1	03Yol113N6.0	2 of 2	LT	1990	1990	Aged	9/23/2008 10:42	9/4/2009 14:16	105.2	106.7
QP-101.2	03Yol113N6.1	2 of 2	LT	1990	1990	Aged	9/23/2008 11:00	9/4/2009 14:29	105.5	106.7
QP-101.3	03Yol113N6.2	2 of 2	LT	1990	1990	Aged	9/23/2008 11:09	9/4/2009 14:46	105.2	106.8
QP-127.1	04SCL85S21.5L1	1 of 3	LT	1965	1965	Aged	11/7/2008 12:51	11/18/2009 13:03	103.2	104.6
QP-127.2	04SCL85S21.4L1	1 of 3	LT	1965	1965	Aged	11/7/2008 13:18	11/18/2009 13:09	103.7	105.1
QP-127.3	04SCL85S21.3L1	1 of 3	LT	1965	1965	Aged	11/7/2008 13:24	11/18/2009 13:16	103.1	104.5
QP-129.1	06FRE180W55.7	3 of 3	LT	2008	2008	Aged	11/10/2008 17:02	11/13/2009 15:03	103.6	105
QP-129.2	06FRE180W55.6	3 of 3	LT	2008	2008	Aged	11/10/2008 17:09	11/13/2009 15:13	103.7	104.8
QP-158.1	06Ker58E109.5	2 of 2	LT	2003	2003	Aged	1/9/2009 9:58	12/2/2009 11:39	103.6	104.4
QP-108.1	03Pla80E45.0	1 of 2	LT	1961	2004	Worn out	10/21/2008 11:24	9/16/2009 12:26	104.5	105.8
QP-108.2	03Pla80E45.1	1 of 2	LT	1961	2004	Worn out	10/21/2008 11:42	9/16/2009 12:35	104.7	105.7
QP-108.3	03Pla80E45.2	1 of 2	LT	1961	2004	Worn out	10/21/2008 11:48	9/16/2009 12:45	103.9	105.5
QP-162.1	06Ker58E111.5	2 of 2	LB	2003	2003	Aged	2/24/2009 16:53	12/3/2009 10:41	102.5	103
QP-146.1	04SM280N10.6	1 of 4	LB	1974	1974	Aged	12/2/2008 14:05	11/16/2009 11:28	101.4	102.7
QP-146.2	04SM280N10.7	1 of 4	LB	1974	1974	Aged	12/2/2008 14:11	11/16/2009 12:32	101.2	102.2
QP-146.3	04SM280N10.8	1 of 4	LB	1974	1974	Aged	12/2/2008 14:31	11/16/2009 12:41	101.1	102.1
QP-109.1	03Nev80E22.6	1 of 2	LB	1989	1989	Worn out	10/21/2008 17:02	Not tested	102.2	
QP-109.2	03Nev80E22.6	1 of 2	LB	1989	1989	Worn out	10/21/2008 17:24	Not tested	102.7	
QP-109.3	03Nev80E22.6	1 of 2	LB	1989	1989	Worn out	10/21/2008 17:35	Not tested	101.9	
QP-112.1	03Nev80W23.0	1 of 2	LB	1989	1989	Worn out	10/21/2008 17:21	Not tested	102.1	
QP-112.2	03Nev80W22.9	1 of 2	LB	1989	1989	Worn out	10/21/2008 17:33	Not tested	102.7	
QP-112.3	03Nev80W22.8	1 of 2	LB	1989	1989	Worn out	10/21/2008 17:45	Not tested	104.1	
QP-115.1	03Yol505S13.1	2 of 2	BD	1977	1977	Aged	10/27/2008 10:33	9/8/2009 11:33	104	105
QP-115.2	03Yol505S13.0	2 of 2	BD	1977	1977	Aged	10/27/2008 10:56	9/8/2009 11:46	103.3	105
QP-115.3	03Yol505S12.9	2 of 2	BD	1977	1977	Aged	10/27/2008 11:21	9/8/2009 12:05	103.3	105
QP-123.1	04ALA580E37.1	4 of 4	BD	1965	1965	Aged	11/5/2008 15:30	11/12/2009 14:14	104.2	105.5
QP-123.2	04ALA580E37.2	4 of 4	BD	1965	1965	Aged	11/5/2008 15:51	11/12/2009 14:20	104	104.6
QP-123.3	04ALA580E37.3	4 of 4	BD	1965	1965	Aged	11/5/2008 15:52	11/12/2009 14:26	103.9	105.1

Section ID	Location: Dist-Cnty-Rte-Dir-PM	Lane[1]	Texture Type[2]	Construction Year	Surfacing Year	Texture Condition[3]	Date/Time of Collection in Year 1	Date/Time of Collection in Year 2	OBSI Level Year 1	OBSI Level Year 2
QP-137.1	04SON101N25.4L1	1 of 2	BD	1962	1962	Aged	11/17/2008 14:07	Not tested	102.2	
QP-137.2	04SON101N25.5L1	1 of 2	BD	1962	1962	Aged	11/17/2008 14:36	Not tested	103.1	
QP-137.3	04SON101N25.6L1	1 of 2	BD	1962	1962	Aged	11/17/2008 14:55	Not tested	102.8	
QP-159.1	06Ker58E110.3	2 of 2	BD	2003	2003	Aged	1/9/2009 10:38	12/3/2009 10:37	101.9	102.2
QP-102.1	03Yol113S5.5	2 of 2	BD	1976	1976	Worn out	9/23/2008 13:12	9/4/2009 14:20	101.1	103.3
QP-102.2	03Yol113S5.4	2 of 2	BD	1976	1976	Worn out	9/23/2008 13:46	9/4/2009 14:49	100.7	103
QP-102.3	03Yol113S5.3	2 of 2	BD	1976	1976	Worn out	9/23/2008 13:58	9/4/2009 14:49	100.8	103
QP-104.1	03Sac50E3.2	1 of 5	BD	1971	1971	Worn out	10/3/2008 13:56	9/11/2009 11:12	103.5	105
QP-104.2	03Sac50E3.2	1 of 5	BD	1971	1971	Worn out	10/3/2008 14:03	9/11/2009 11:47	104.1	105.4
QP-104.3	03Sac50E3.2	1 of 5	BD	1971	1971	Worn out	10/3/2008 14:25	9/11/2009 11:57	104.7	105.5
QP-105.1	03Sac50E4.0	1 of 4	BD	1971	1971	Worn out	10/3/2008 14:00	9/11/2009 11:43	102.9	104.8
QP-105.2	03Sac50E4.1	1 of 4	BD	1971	1971	Worn out	10/3/2008 14:11	9/11/2009 11:55	103.6	104.8
QP-105.3	03Sac50E4.2	1 of 4	BD	1971	1971	Worn out	10/3/2008 14:46	9/11/2009 12:06	103	104.7
QP-106.1	03Sac50E10.5	1 of 5	BD	1973	1973	Worn out	10/13/2008 14:48	9/11/2009 14:11	101.9	103.6
QP-106.2	03Sac50E10.6	1 of 5	BD	1973	1973	Worn out	10/13/2008 14:55	9/11/2009 14:36	102.4	104.1
QP-106.3	03Sac50E10.7	1 of 5	BD	1973	1973	Worn out	10/13/2008 15:14	9/11/2009 14:42	102.6	103.8
QP-107.1	03Sac80E13.6	5 of 5	BD	1973	1973	Worn out	10/16/2008 14:23	9/9/2009 13:03	103.2	104.9
QP-107.2	03Sac80E13.7	5 of 5	BD	1973	1973	Worn out	10/16/2008 14:29	9/9/2009 13:14	102.6	104.2
QP-107.3	03Sac80E13.8	5 of 5	BD	1973	1973	Worn out	10/16/2008 14:36	9/9/2009 13:18	101.7	103.7
QP-113.1	03Yol80W22.9	1 of 3	BD	1965	1965	Worn out	10/23/2008 12:37	Not tested	103.9	
QP-113.2	03Yol80W22.8	1 of 3	BD	1965	1965	Worn out	10/23/2008 12:45	Not tested	104.4	
QP-113.3	03Yol80W22.7	1 of 3	BD	1965	1965	Worn out	10/23/2008 12:54	Not tested	103.6	
QP-116.1	04Sol80E32.0	1 of 3	BD	1946	1946	Worn out	10/28/2008 10:35	9/10/2009 11:06	106.5	107.8
QP-116.2	04Sol80E32.1	1 of 3	BD	1946	1946	Worn out	10/28/2008 11:06	9/10/2009 11:20	106.3	107.3
QP-116.3	04Sol80E32.2	1 of 3	BD	1946	1946	Worn out	10/28/2008 11:06	9/10/2009 11:22	105.7	107
QP-126.1	04SCL85S21.5L3	3 of 3	BD	1965	1965	Worn out	11/7/2008 11:52	11/18/2009 12:38	107	107.4
QP-126.2	04SCL85S21.4L3	3 of 3	BD	1965	1965	Worn out	11/7/2008 11:57	11/18/2009 12:48	105.8	106.7
QP-126.3	04SCL85S21.3L3	3 of 3	BD	1965	1965	Worn out	11/7/2008 12:13	11/18/2009 12:53	106.9	107.4
QP-130.1	11SD5S39.7	4 of 4	BD	1964	1964	Worn out	11/11/2008 13:33	11/22/2009 13:20	106.9	107.3
QP-130.2	11SD5S39.6	4 of 4	BD	1964	1964	Worn out	11/11/2008 13:46	11/22/2009 13:28	106.6	107.1
QP-130.3	11SD5S39.5	4 of 4	BD	1964	1964	Worn out	11/11/2008 13:56	11/22/2009 13:33	106.8	107.1
QP-128.2	04SCL85N14.9	3 of 3	DG	1993	2006	New	11/7/2008 15:38	11/18/2009 15:06	102.9	104.1
QP-128.3	04SCL85N14.10	3 of 3	DG	1993	2006	New	11/7/2008 15:46	11/18/2009 15:15	101.6	103.1
QP-129.3	06FRE180W55.5	3 of 3	DG	2008	2008	New	11/10/2008 17:17	11/13/2009 15:19	103.3	104.6
QP-147.1	04SM280N11.6	1 of 3	DG	1973	2007	New	12/2/2008 15:46	11/16/2009 12:29	102.5	102.9
QP-147.2	04SM280N11.7	1 of 3	DG	1973	2007	New	12/2/2008 15:56	11/16/2009 12:39	102.8	103
QP-147.3	04SM280N11.8	1 of 3	DG	1973	2007	New	12/2/2008 16:09	11/16/2009 12:46	102.7	103.4
QP-103.1	03Yol50E0.2	1 of 4	DG	1969	2005	Aged	10/2/2008 10:35	Not tested	99.8	
QP-103.2	03Yol50E0.3	1 of 4	DG	1969	2005	Aged	10/2/2008 10:45	Not tested	99.6	

Section ID	Location: Dist-Cnty-Rte-Dir-PM	Lane[1]	Texture Type[2]	Construction Year	Surfacing Year	Texture Condition[3]	Date/Time of Collection in Year 1	Date/Time of Collection in Year 2	OBSI Level Year 1	OBSI Level Year 2
QP-103.3	03Yol50E0.4	1 of 4	DG	1969	2005	Aged	10/2/2008 10:56	Not tested	99.4	
QP-114.1	04Sol80W18.7	2 of 4	DG	1949	1999	Aged	10/23/2008 14:45	Not tested	102.3	
QP-114.2	04Sol80W18.6	2 of 4	DG	1949	1999	Aged	10/23/2008 15:11	Not tested	102	
QP-114.3	04Sol80W18.5	2 of 4	DG	1949	1999	Aged	10/23/2008 15:31	Not tested	102.6	
QP-128.1	04SCL85N14.8	3 of 3	DG	1993	2006	Aged	11/7/2008 14:59	11/18/2009 14:57	103	104.2
QP-131.1	11SD8W15.5	1 of 3	DG	1985	1997	Aged	11/11/2008 17:01	11/23/2009 9:33	105.3	103.7
QP-131.2	11SD8W15.6	1 of 3	DG	1985	1997	Aged	11/11/2008 17:11	11/23/2009 9:40	105.1	103.6
QP-131.3	11SD8W15.7	1 of 3	DG	1985	1997	Aged	11/11/2008 17:26	11/23/2009 9:49	105.2	103.6
QP-132.1	11SD805N2.1	5 of 5	DG	1975	1998	Aged	11/12/2008 12:39	11/24/2009 11:06	105.4	106.3
QP-132.2	11SD805N2.2	5 of 5	DG	1975	1998	Aged	11/12/2008 13:04	11/24/2009 11:24	106.6	107.2
QP-132.3	11SD805N2.3	5 of 5	DG	1975	1998	Aged	11/12/2008 13:16	11/24/2009 11:36	106	107.3
QP-133.1	11SD805N2.3	4 of 4	DG	1975	1998	Aged	11/12/2008 14:36	11/24/2009 11:50	106.5	106.4
QP-133.2	11SD805N2.4	4 of 4	DG	1975	1998	Aged	Not tested	11/24/2009 12:03		107.3
QP-134.1	11SD905W5.2	2 of 2	DG	1975	2000	Aged	11/12/2008 16:03	11/24/2009 12:21	105	106.4
QP-134.2	11SD905W5.1	2 of 2	DG	1975	2000	Aged	11/12/2008 16:35	11/24/2009 12:31	104.9	104.9
QP-134.3	11SD905W5.0	2 of 2	DG	1975	2000	Aged	11/12/2008 16:39	11/24/2009 12:35	106.2	106.4
QP-135.1	04SON101N25.4L2	2 of 2	DG	1962	2006	Aged	11/17/2008 12:27	Not tested	103.4	
QP-135.2	04SON101N25.5L2	2 of 2	DG	1962	2006	Aged	11/17/2008 12:50	Not tested	103.5	
QP-135.3	04SON101N25.6L2	2 of 2	DG	1962	2006	Aged	11/17/2008 12:57	Not tested	103.7	
QP-148.1	04SM280N1.6	1 of 4	DG	1969	2001	Aged	12/3/2008 13:07	11/16/2009 14:36	102.9	103.4
QP-148.2	04SM280N1.7	1 of 4	DG	1969	2001	Aged	12/3/2008 13:25	11/16/2009 14:51	103	103.6
QP-148.3	04SM280N1.8	1 of 4	DG	1969	2001	Aged	12/3/2008 13:34	11/16/2009 15:00	103.2	103.7
QP-155.1	06Ker58E110.6	2 of 2	DG	2003	2006	Aged	1/8/2009 14:54	12/2/2009 14:17	101.2	101.7
QP-160.1	06Ker58E110.0	2 of 2	DG	2003	2006	Aged	2/23/2009 17:08	12/2/2009 14:13	102.7	102.9
QP-166.1	06Ker58E111.7	2 of 2	DG	2003	2006	Aged	2/26/2009 9:13	12/2/2009 11:44	101.7	103
QP-110.1	03Nev80E24.0	1 of 3	Gr	1989	1996	Aged	10/21/2008 17:13	Not tested	102	
QP-110.2	03Nev80E24.1	1 of 3	Gr	1989	1996	Aged	10/21/2008 17:25	Not tested	102	
QP-110.3	03Nev80E24.2	1 of 3	Gr	1989	1996	Aged	10/21/2008 17:37	Not tested	101.9	
QP-111.1	03Nev80W24.2	1 of 2	Gr	1989	1996	Aged	10/21/2008 17:16	Not tested	103.2	
QP-111.2	03Nev80W24.1	1 of 2	Gr	1989	1996	Aged	10/21/2008 17:26	Not tested	103.1	
QP-111.3	03Nev80W24.0	1 of 2	Gr	1989	1996	Aged	10/21/2008 17:38	Not tested	102.7	
QP-136.1	04SON101S27.3L2	2 of 2	Gr	1962	2006	Aged	11/17/2008 12:40	Not tested	103.8	
QP-136.2	04SON101S27.2L2	2 of 2	Gr	1962	2006	Aged	11/17/2008 12:52	Not tested	103.6	
QP-136.3	04SON101S27.1L2	2 of 2	Gr	1962	2006	Aged	11/17/2008 13:00	Not tested	103.8	
QP-138.1	04SON101S27.3L1	1 of 2	Gr	1962	2006	Aged	11/17/2008 14:27	Not tested	103.1	
QP-138.2	04SON101S27.2L1	1 of 2	Gr	1962	2006	Aged	11/17/2008 14:41	Not tested	103	
QP-138.3	04SON101S27.1L1	1 of 2	Gr	1962	2006	Aged	11/17/2008 15:01	Not tested	101.7	
QP-153.1	10Mer99S17.5	1 of 2	Gr	1962	2006	Aged	12/17/2008 14:53	11/13/2009 13:03	105.1	106.1
QP-153.2	10Mer99S17.4	1 of 2	Gr	1962	2006	Aged	12/17/2008 15:21	11/13/2009 13:16	105.6	106.3

Section ID	Location: Dist-Cnty-Rte-Dir-PM	Lane[1]	Texture Type[2]	Construction Year	Surfacing Year	Texture Condition[3]	Date/Time of Collection in Year 1	Date/Time of Collection in Year 2	OBSI Level Year 1	OBSI Level Year 2
QP-153.3	10Mer99S17.3	1 of 2	Gr	1962	2006	Aged	12/17/2008 15:34	11/13/2009 13:28	105.1	105.9
QP-154.1	06Ker58E110.2	2 of 2	Gr	2003	2006	Aged	1/8/2009 14:27	12/2/2009 11:42	102.1	103.7
QP-156.1	06Ker58E111.2	2 of 2	Gr	2003	2006	Aged	1/9/2009 7:57	12/2/2009 11:43	103.7	104.7
QP-157.1	06Ker58E111.4	2 of 2	Gr	2003	2006	Aged	1/9/2009 8:40	12/2/2009 14:17	102.1	103.2
QP-161.1	06Ker58E110.4	2 of 2	Gr	2003	2006	Aged	2/23/2009 17:44	12/3/2009 10:58	103.2	103.2

Notes:

1. Lane # of total lanes (Lane #1 is next to the median.)
2. Texture Type:
   BD = burlap drag (37 sections)
   DG = diamond ground (33 sections)
   Gr = diamond grooved (19 sections)
   LB = longitudinally broomed (10 sections)
   LT = longitudinally tined (21 sections)
3. Texture Condition:
   New = Sections that had been open to traffic for less than a year at the time of the first measurements (12 sections)
   Aged = Sections where the texture could be observed in the wheelpaths (72 sections)
   Worn out = Sections where the texture had been worn out in the wheelpaths by traffic (36 sections)

Table 2.2: Spectral and Overall Correction for Test Tire and Sound Analyzer

Parameter	Frequency												Overall
	400	500	630	800	1,000	1,250	1,600	2,000	2,500	3,150	4,000	5,000	
SRTT#2 to SRTT#1													
A	12.92	-4.83	-0.13	-3.61	12.85	2.34	-3.66	-6.17	2.15	-1.35	-0.46	0.97	-20.54
B	0.86	1.05	1	1.03	0.86	0.97	1.03	1.05	0.97	1.01	1	0.99	1.19
R^2	0.58	0.93	0.96	0.95	0.65	0.94	0.95	0.93	0.92	0.95	0.96	0.92	0.94
SRTT#3 to SRTT#1													
A	5.03	-33.53	-16.82	-16.27	-1.01	-1.04	9.1	1.15	0.74	10.46	7.62	2.03	-9.28
B	0.95	1.37	1.18	1.16	1.01	1.01	0.9	0.99	0.99	0.87	0.91	0.97	1.09
R^2	0.75	0.9	0.92	0.95	0.94	0.92	0.96	0.96	0.93	0.93	0.93	0.94	0.96
Larson-Davis to Harmonie Analyzer													
A	14.06	0.52	1.39	5.03	-0.28	3.6	2.27	1.7	1.34	1.91	2.33	4.34	2.19
B	0.83	0.99	0.98	0.95	1	0.96	0.97	0.98	0.98	0.98	0.97	0.94	0.98
R^2	0.67	0.95	0.95	0.95	0.97	0.95	0.97	0.96	0.95	0.92	0.92	0.89	0.97

2.4 Description of Texture Types and Texture Condition Categories

Five pavement surface texture types were identified for this study. Table 2.3 lists the surface texture types, the number of sections evaluated in each year of the study for each texture type, and the pavement sites in which the sections were located.

Table 2.3: Texture Types and Sections

Texture Type	Number of Sections	Sites (generally three sections per site)
Burlap drag (BD)	Year 1: 37 Year 2: 31	QP-102, QP-104, QP-105, QP-106, QP-107, QP-113, QP-115, QP-116, QP-123, QP-126, QP-130, QP-137, and QP-159. By Year 2, the six sections at Sites QP-113 and QP-137 had been overlaid.
Diamond ground (DG)	Year 1: 32 Year 2: 24	QP-103, QP-114, QP-128, QP-129.3, QP-131, QP-132, QP-133, QP-134, QP-135, QP-147, QP-148, QP-155, QP-160, and QP-166. In Year 2, the three sections at Site QP-103 could not be tested due to construction of a median concrete barrier that implied lane shift. Also the six sections at Sites QP-114 and QP-135 were overlaid by Year 2. Section QP-132.2 was not tested in Year 1 due to operator error, but it was tested in Year 2. QP-129.3 is DG, whereas the other two sections at this site are LT.
Diamond grooved (Gr)	Year 1: 19 Year 2: 7	QP-110, QP-111, QP-136, QP-138, QP-153, QP-154, QP-156, QP-157, and QP-161. The first four of these sites (with a total of 12 sections) were overlaid by Year 2.
Longitudinally broomed (LB)	Year 1: 10 Year 2: 4	QP-109, QP-112, QP-146, and QP-162. The first two of these sites (with a total of six sections) were overlaid by Year 2.
Longitudinally tined (LT)	Year 1: 21 Year 2: 21	QP-100, QP-101, QP-108, QP-117, QP-127, QP-129.1 and 2, QP-142, and QP-158.

It is important to note that this project did not have a sufficient budget for traffic closures, which would have allowed for a closer examination of the surface type. In most cases the assessment of surface type was done by observation from the shoulder, at highway speed in the field, and later from analysis of photographs. It was not possible either to obtain information on the mixes, such as aggregate gradation. It should be noted that all but one of the burlap drag (BD) sections were last surfaced before 1977. There is a possibility that these had some other type of texture previously which was completely worn off, leaving no evidence that it existed anywhere on the slabs, although this was considered unlikely.

Pavements were divided into three age categories:

- *New*, defined as a surface that had been open to traffic for less than a year at the time of the first measurements.
- *Aged*, defined as a surface where the texture could be observed in the wheelpaths.
- *Worn out*, defined as surface where the texture had been removed from the wheelpaths by traffic.

This classification is somewhat subjective and was derived from visual observation of the surface as well as comparison of the spectral content of OBSI with other sections of the same texture type. The number of sections in each texture type and condition category is shown in Table 2.4, summarized from the section-by-section information in Table 2.1. It can be seen in Table 2.4 that for some texture types there is no data for one or two of the three categories. These include longitudinally broomed in the *new* condition, burlap drag in the *new* condition, diamond ground in the *worn out* condition, and diamond grooved in the *new* and *worn out* conditions.

Table 2.4: Texture Types and Conditions

Texture Type	Texture Condition	Year 1		Year 2	
		Number of Locations	Number of Sections	Number of Locations	Number of Sections
LT	New	2	6	2	6
	Aged	5	12	5	12
	Worn out	1	3	1	3
LB	New	0	0	0	0
	Aged	2	4	2	4
	Worn out	2	6	0	0
BD	New	0	0	0	0
	Aged	4	10	3	7
	Worn out	9	27	8	24
DG	New	3	6	3	6
	Aged	10	26	7	18
	Worn out	0	0	0	0
Gr	New	0	0	0	0
	Aged	6	19	2	7
	Worn out	0	0	0	0

2.5 Lane Locations of Sections

Table 2.5 lists the locations of the test sections. All test sections at a site were in the same lane, however, the test lanes at the sites varied as follows: 60 of the 120 sections sites were on the outside lane, 57 were on the inside lane, and three were on the middle lane.

Table 2.5: Lane Locations of Sections

Test Lane and Total Number of Lanes		Number of Sections	
Outside	2 of 2	34	60
	3 of 3	9	
	4 of 4	11	
	5 of 5	6	
Inside	1 of 2	21	57
	1 of 3	18	
	1 of 4	12	
	1 of 5	6	
Middle	2 of 4	3	3

3 RESULTS

3.1 Results by Texture Type and Texture Condition

The OBSI spectral contents were plotted to compare the OBSI results among the different texture types. However, after examination of the changes of the spectra from Year 1 to Year 2, a decision was made to use each section's two-year average spectra. This approach was deemed a better one than trying to track the year-to-year changes over the two years because those were very small. To simplify the comparison even further, the spectra of sections from a given site were also averaged and depicted in graphs as one rather than three sections. Data for just one year was used in cases where that was all that were available. The legend in each graph shows whether a single line represents only one section or if the result comes from a site with three sections. The construction year for each surface is also included in the legend.

As mentioned in Section 2.4, an attempt was made to categorize the texture on each section into one of three texture condition categories: *new*, *aged,* or *worn out.*

3.1.1 Burlap Drag Sections

There were no sections with burlap drag texture in the *new* texture category. The texture *aged* and texture *worn out* sections are shown in Figure 3.1 and Figure 3.2 respectively. A comparison of the average spectral content for the conditions is shown in Figure 3.3. For one-third octave band frequencies below 1,600 Hz, the spectra for the sections with the texture *worn out* have greater sound intensity levels than for *aged* texture sections.

3.1.2 Diamond Ground Sections

There were no diamond ground sections in the texture *worn out* category. The *new* texture and *aged* texture sections are shown in Figure 3.4 and Figure 3.5 respectively. A comparison of the average spectral content for the two texture conditions is shown in Figure 3.6. The comparison shows almost no difference between the *new* and the *aged* textures, on average. Differences within each texture condition category are greater than differences between the average spectra for each category.

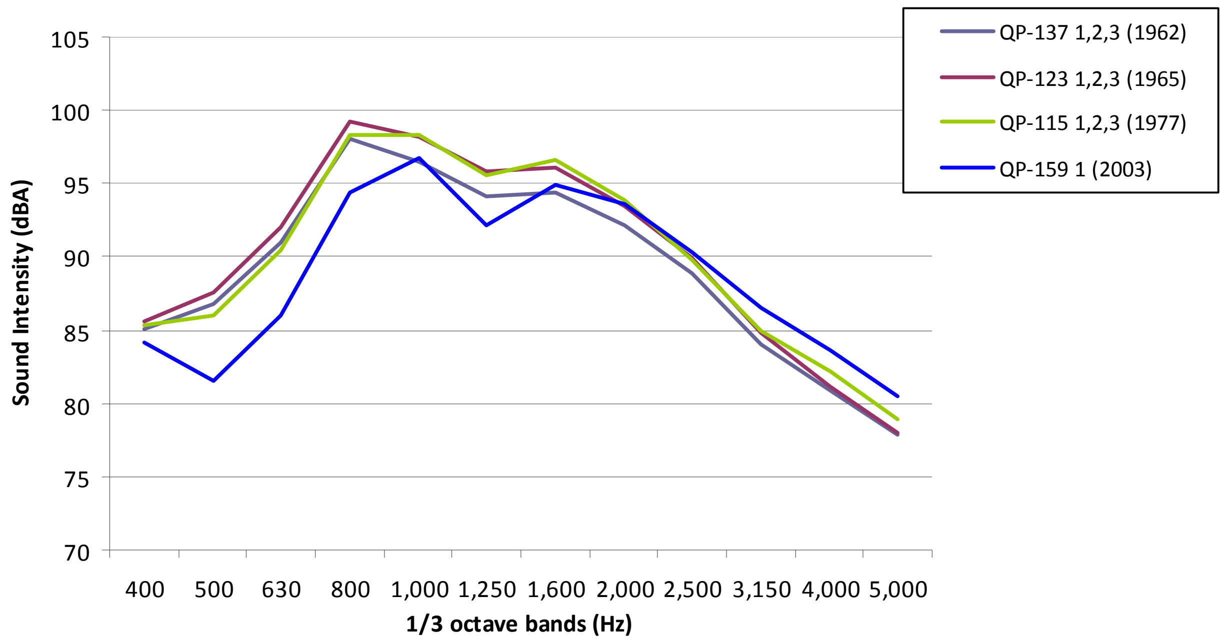

Figure 3.1: OBSI spectral content for burlap drag sections, texture *aged*.

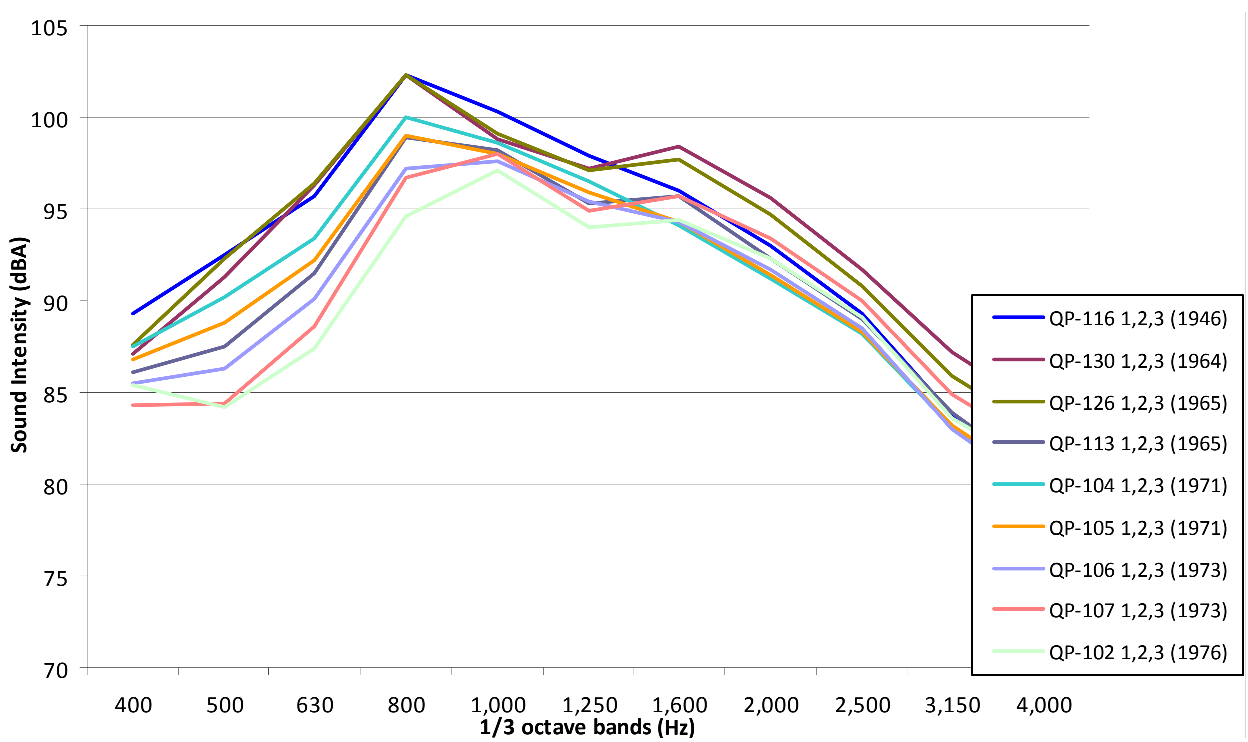

Figure 3.2: OBSI spectral content for burlap drag sections, texture *worn out*.

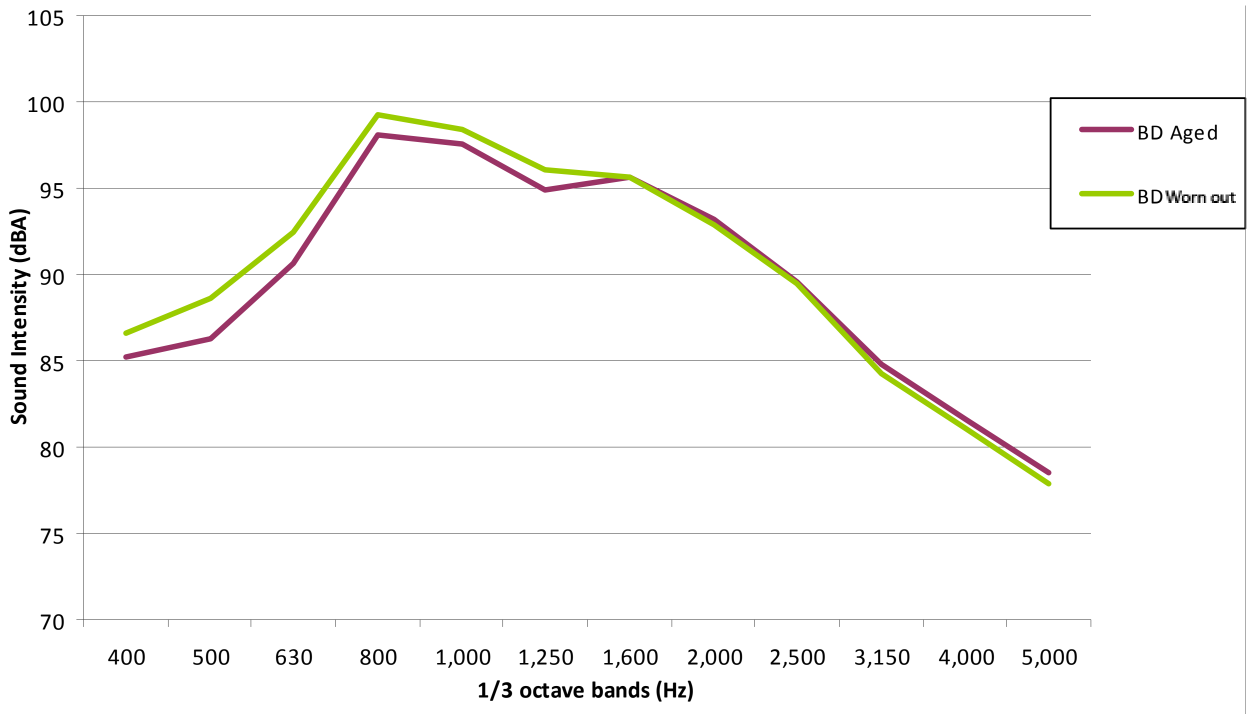

Figure 3.3: Comparison of average OBSI spectral content for burlap drag sections with texture in different conditions.

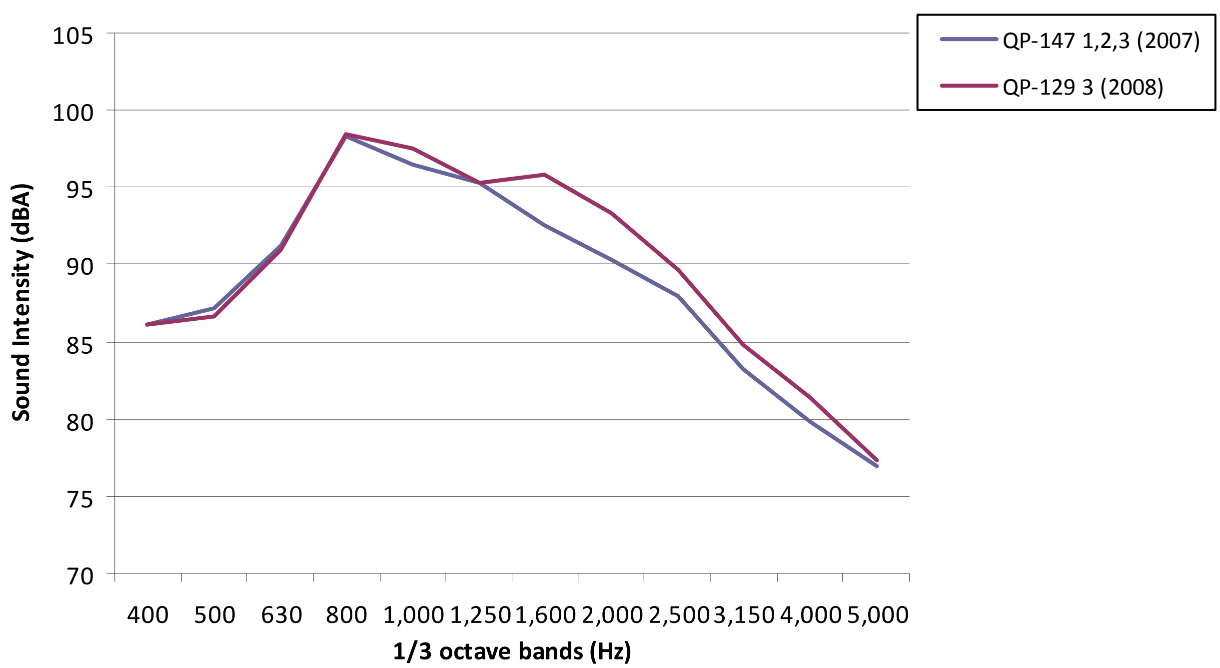

Figure 3.4: OBSI spectral content for diamond ground sections, texture *new.*

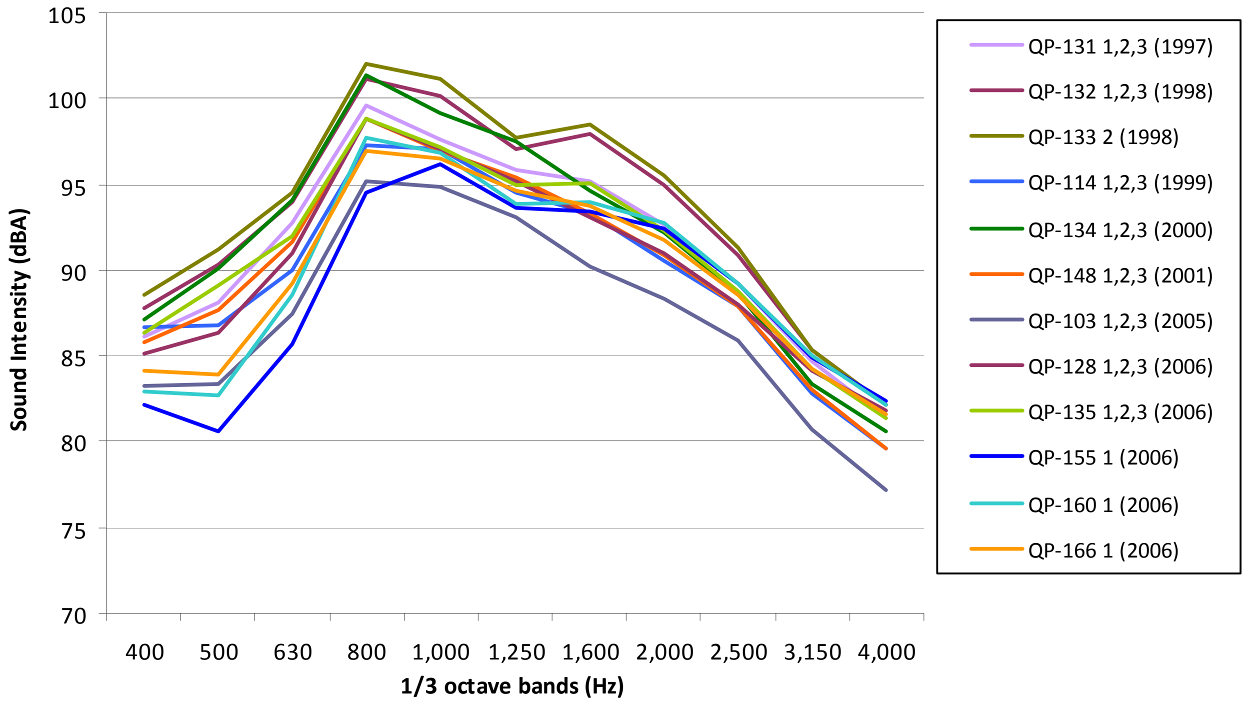

Figure 3.5: OBSI spectral content for diamond ground sections, texture *aged*.

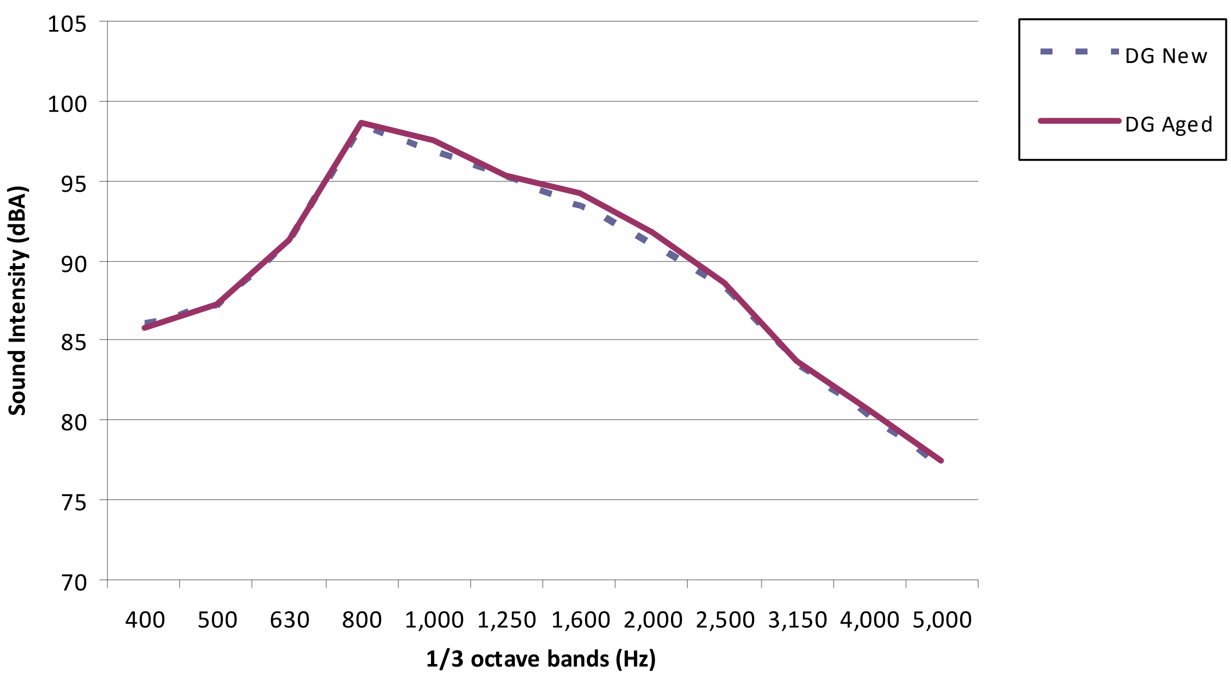

Figure 3.6: Comparison of OBSI spectral content for diamond ground sections with texture in different conditions.

3.1.3 Diamond Grooved Sections

All diamond grooved sections fall in the *aged* texture category, so comparison against other conditions is not possible. Figure 3.7 shows the results at each site, while Figure 3.8 presents the average of all sites. There is a range of 4 to 5 dB(A) for every frequency within the *aged* texture category. The older sections, built in 1996, appear to have lower OBSI levels for frequencies of 2,000 Hz and higher frequencies, and to have OBSI levels in the middle of the range of the other sections built in 2006 for frequencies below 2,000 Hz.

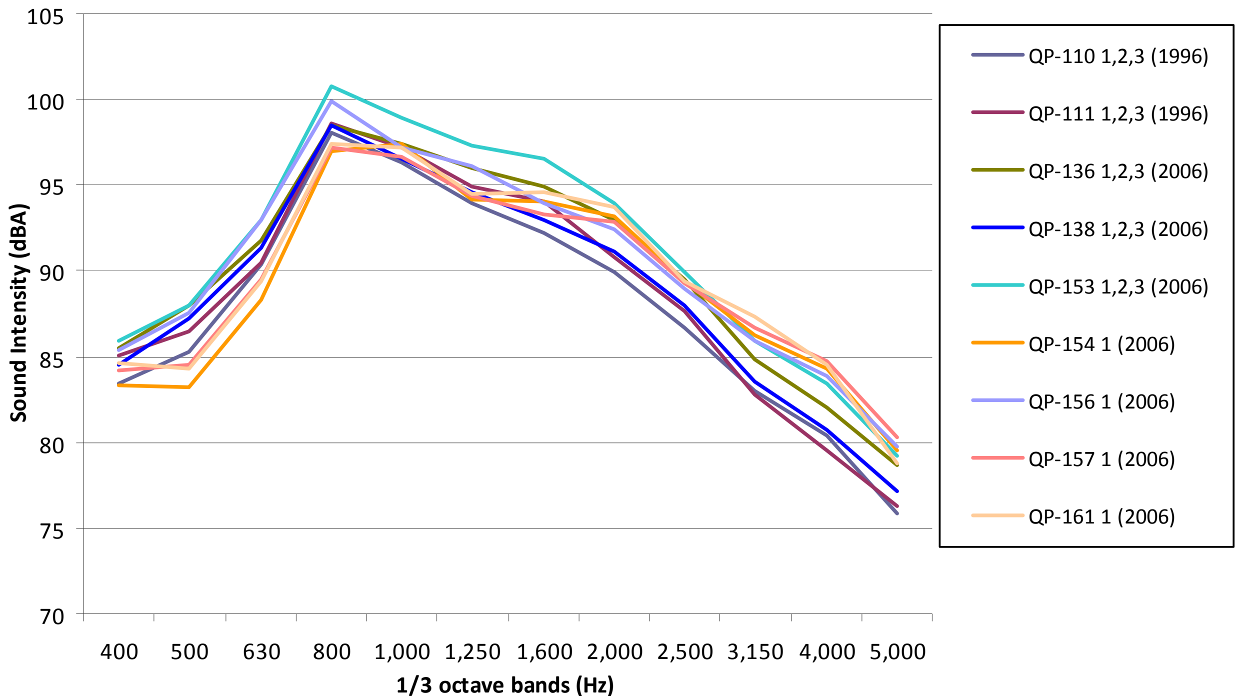

Figure 3.7: OBSI spectral content for diamond grooved sections, texture *aged*.

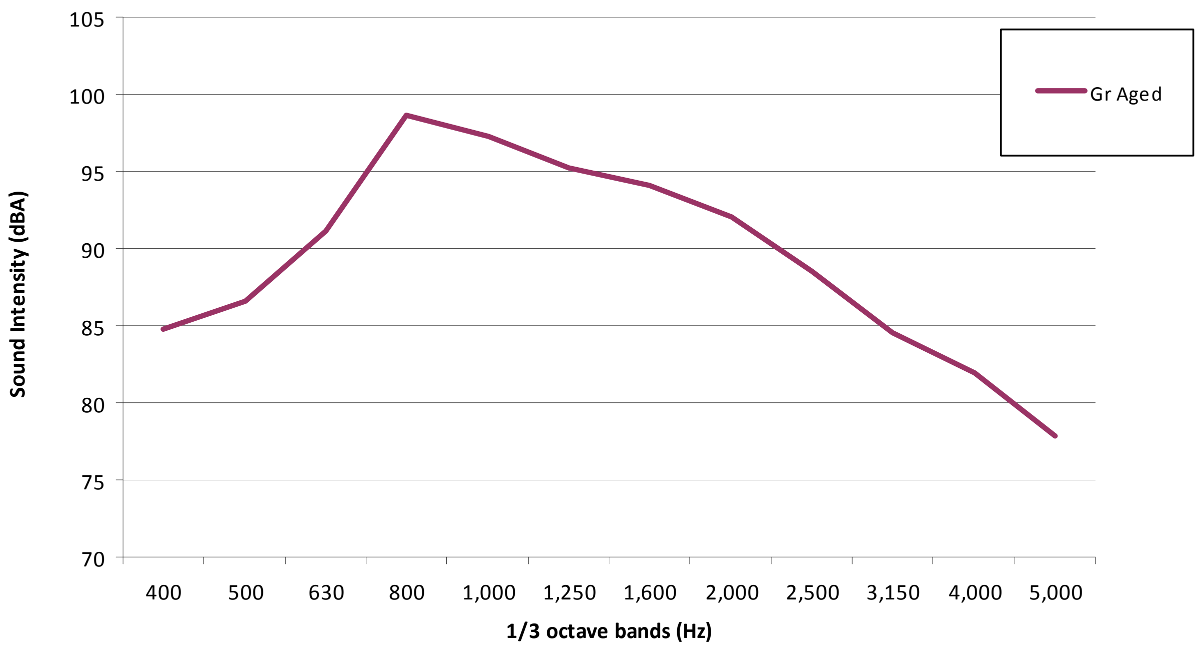

Figure 3.8: Average of OBSI spectral content for diamond grooved sections.

3.1.4 Longitudinally Broomed Sections

There were no sections with longitudinally broomed texture in the *new* texture category. The texture *aged* and texture *worn out* sections are shown in Figure 3.9 and Figure 3.10 respectively. A comparison of the average spectral content for the two texture conditions is shown in Figure 3.11. It can be seen that there is not much difference between the two texture conditions. Differences within each texture condition category are greater than the differences between the average spectra for each category.

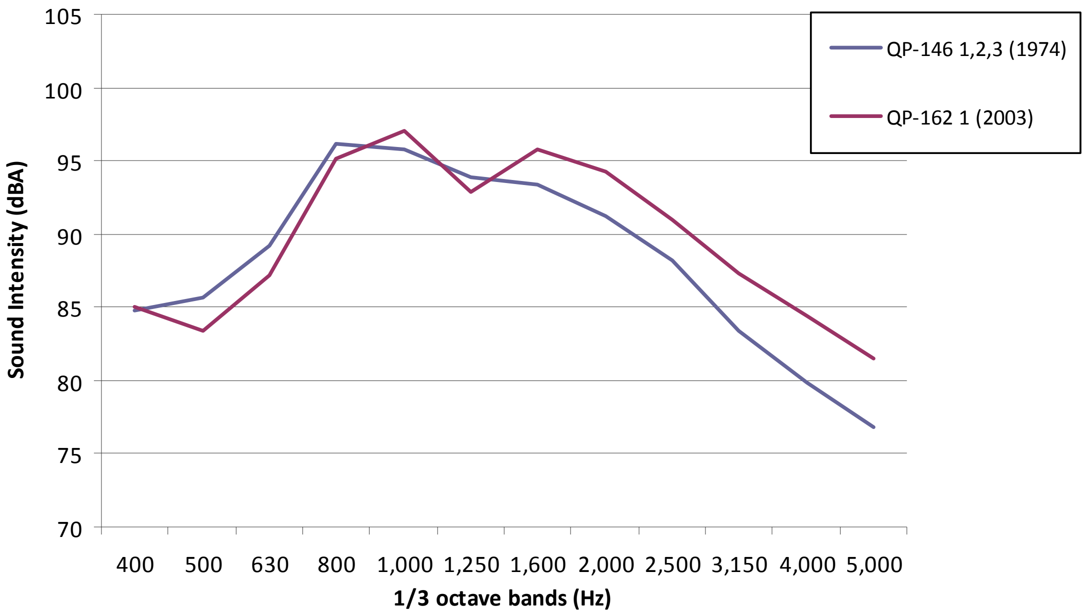

Figure 3.9: OBSI spectral content for longitudinally broomed sections, texture *aged*.

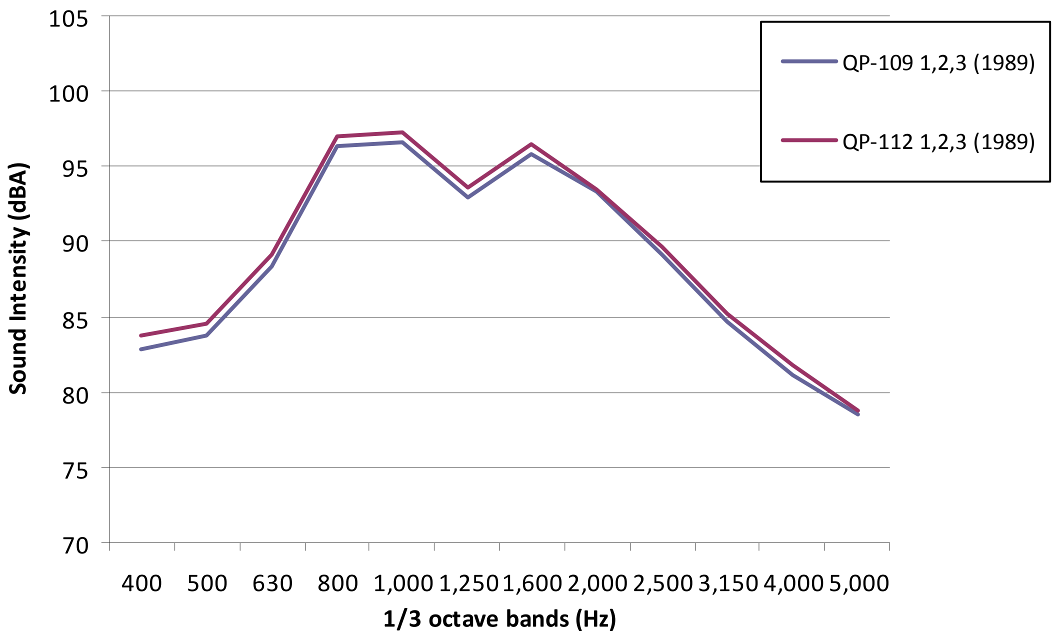

Figure 3.10: OBSI spectral content for longitudinally broomed sections, texture *worn out*.

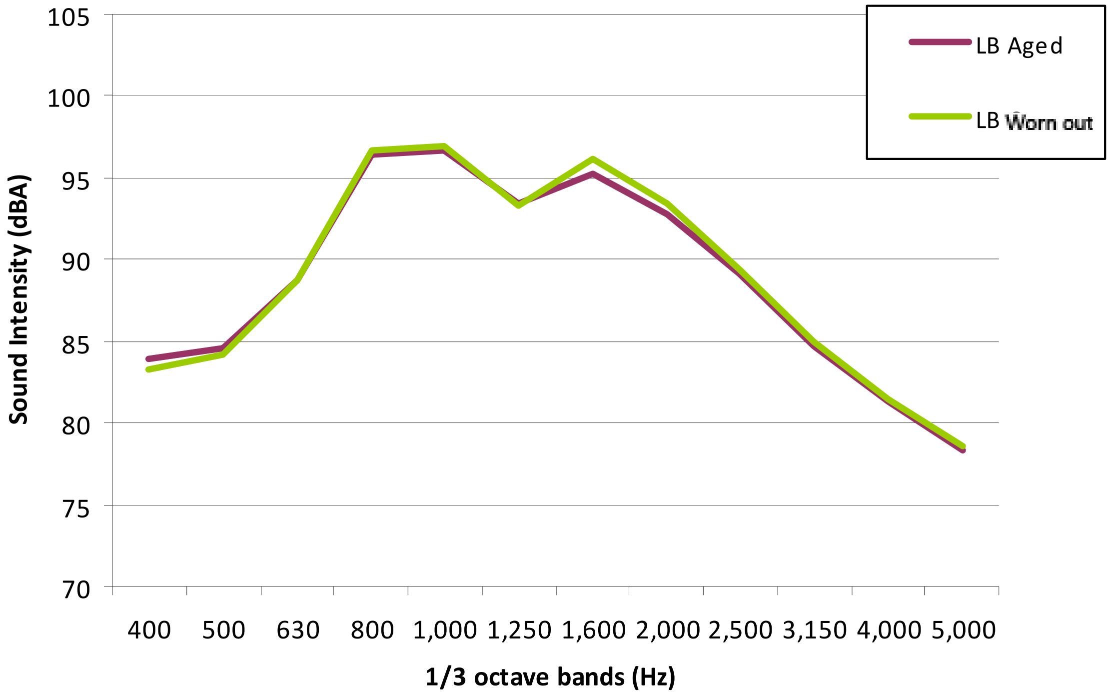

Figure 3.11: Comparison of OBSI spectral content for longitudinally broomed sections with texture in different conditions.

3.1.5 Longitudinally Tined Sections

This is the only texture type with sections found in the three texture conditions. Sections with longitudinally tined texture in the texture *new*, texture *aged*, and texture *worn out* categories are presented in Figure 3.12, Figure 3.13, and Figure 3.14 respectively. The second year results from Section 142 were excluded from the analysis because of extensive damage to the pavement surface caused by truck chain wear. A comparison of the average spectral content for the conditions is shown in Figure 3.15. The average spectra for the three conditions are very similar, with the primary differences being that the OBSI level for the very low frequencies increases after the first year, and that OBSI increases some for the 1,250 Hz frequency as the texture ages. Differences within each texture condition category are greater than differences between the average spectra for each category.

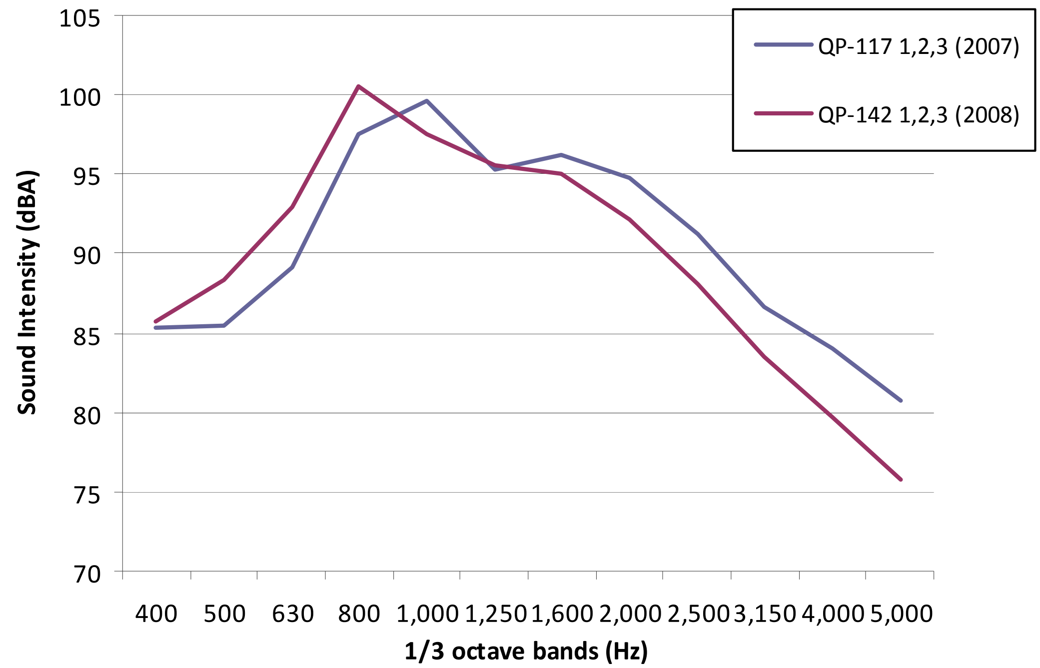

Figure 3.12: OBSI spectral content for longitudinally tined sections, texture *new*.

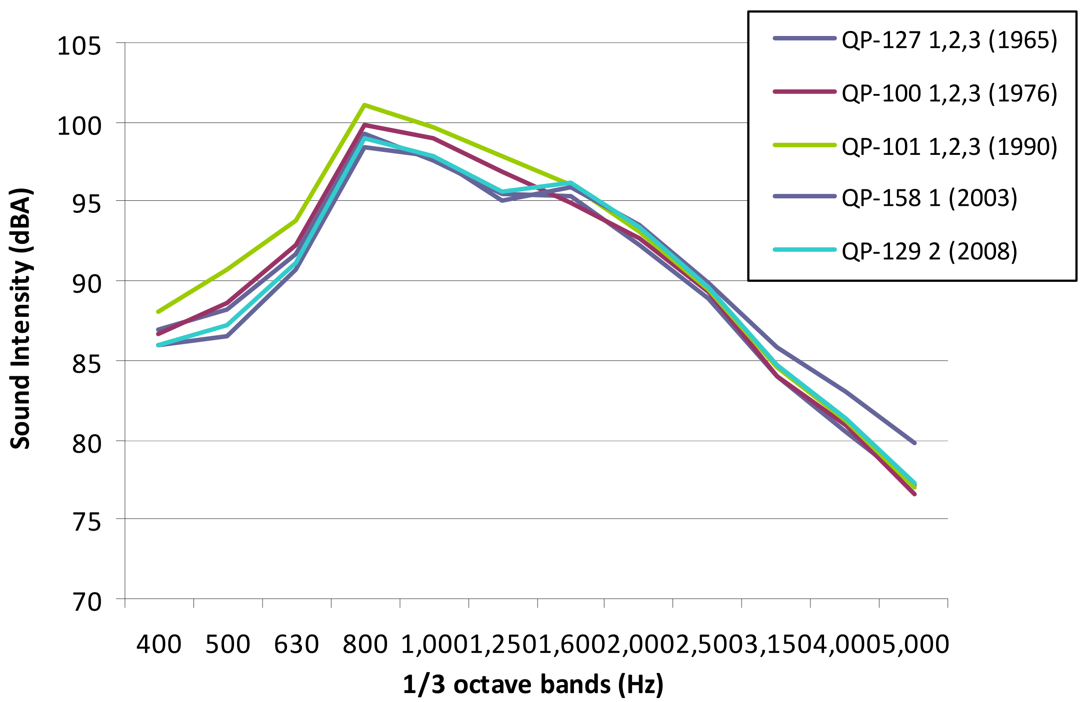

Figure 3.13: OBSI spectral content for longitudinally tined sections, texture *aged*.

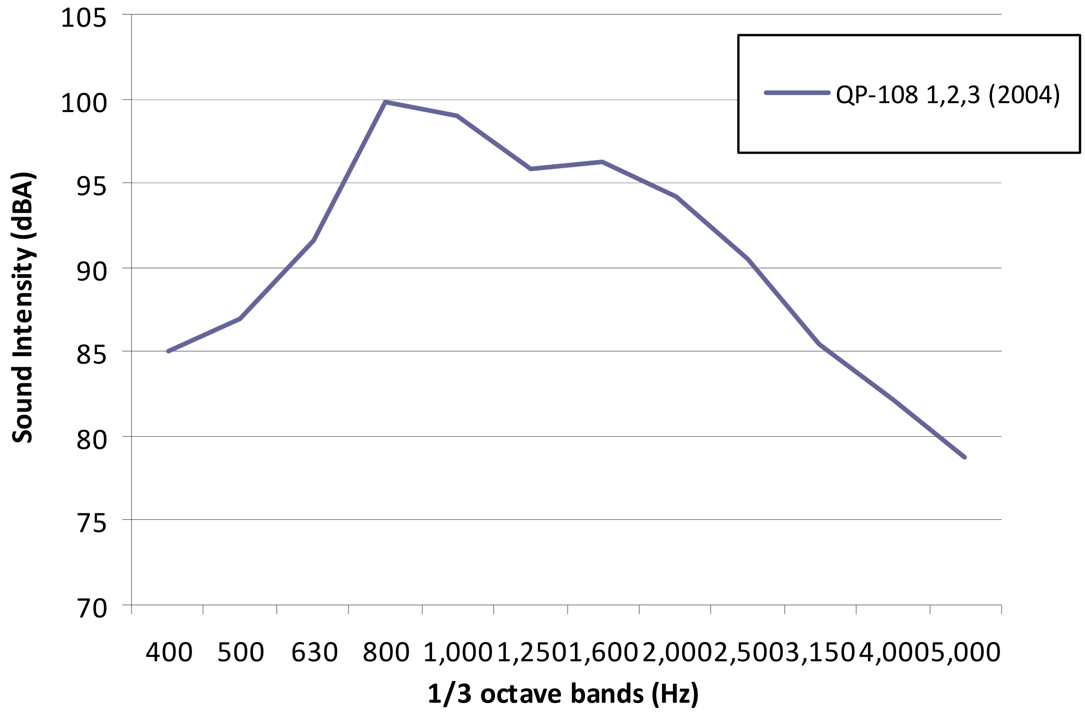

Figure 3.14: OBSI spectral content for longitudinally tined sections, texture *worn out.*

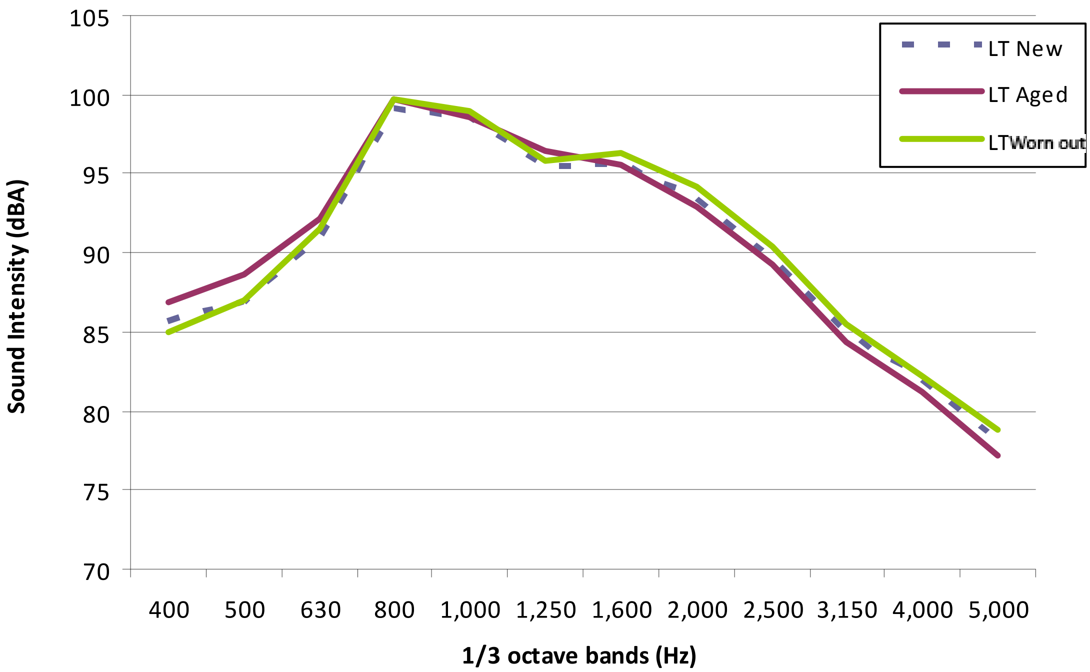

Figure 3.15: Comparison of OBSI spectral content for longitudinally tined sections with texture in different conditions.

3.1.6 Comparison of Textures

To begin the examination of the noise characteristics of concrete pavement surface textures in more detail, Figure 3.16 presents the one-third octave sound intensity levels, using the average for each texture type and including textures of all three conditions. The longitudinally broomed texture has markedly lower levels at frequencies below 1,250 Hz. The other surface types are difficult to distinguish from each other in terms of average OBSI spectra. Given that once the texture of a surface has disappeared, it is no longer considered to be designed, and it is more appropriate to consider only those sections with *aged* texture, as presented in Figure 3.17.

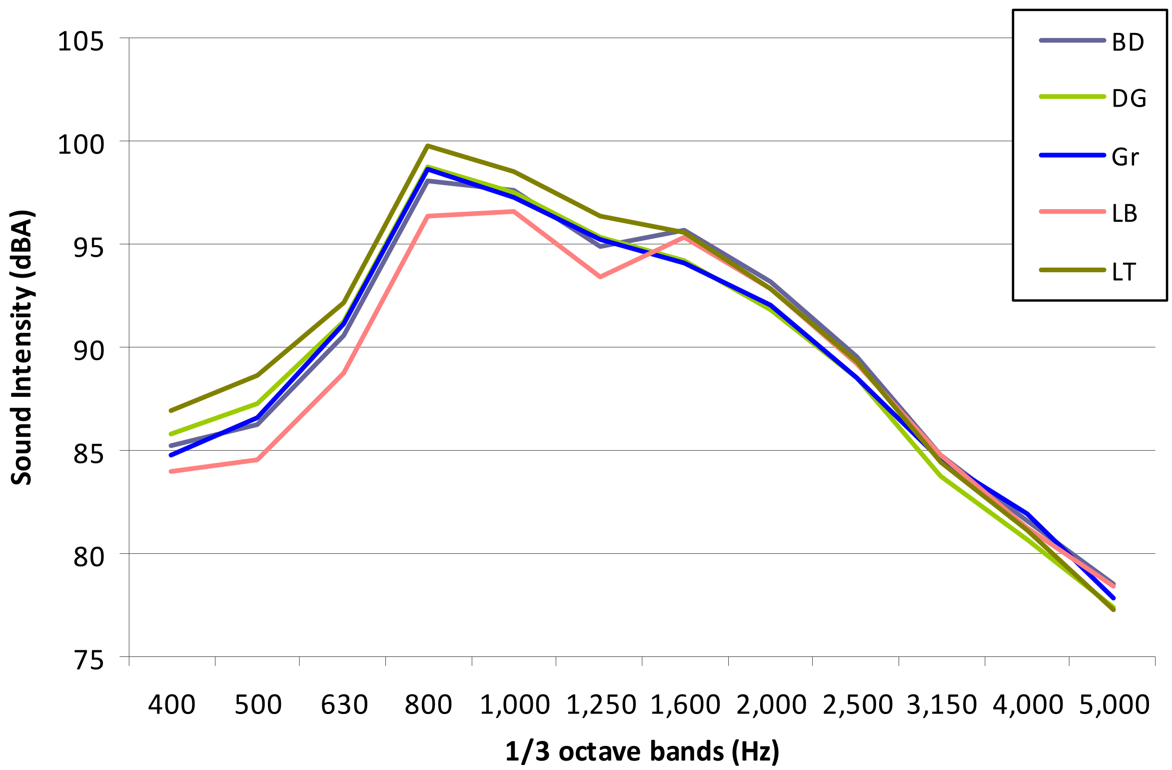

Figure 3.16: Comparison of OBSI spectral content of sections with different texture types, average of all sections of a texture type.
(Note: **BD = burlap drag, DG=diamond ground, Gr=diamond grooved, LB=longitudinally broomed, LT=longitudinally tined.)**

Because an average spectrum is just a mathematical construction of a fictitious average section, it is convenient to include in the plots the actual spectra for the sections with the highest and lowest OBSI (of the *aged* texture category). This is presented in Figure 3.18.

The results of Figure 3.18 are presented again in Table 3.1, along with the average overall OBSI for the *aged* texture category for each texture type.

Between DG and BD the analysis is as follows: the Max spectra and the Average spectra are similar for the two texture types. At 1,250 Hz, the BD is lower than at the adjacent 1 kHz and 1.6 kHz frequency bands. Below 800 Hz the Min spectra are similar for BD and DG. At 1,000 Hz the BD texture minimum noise level is higher than the DG, but they are similar again at 1,250 Hz. Above 1,600 Hz the BD texture minimum spectrum is similar to the average levels, whereas the Min DG spectrum remains considerably lower than the average spectrum.

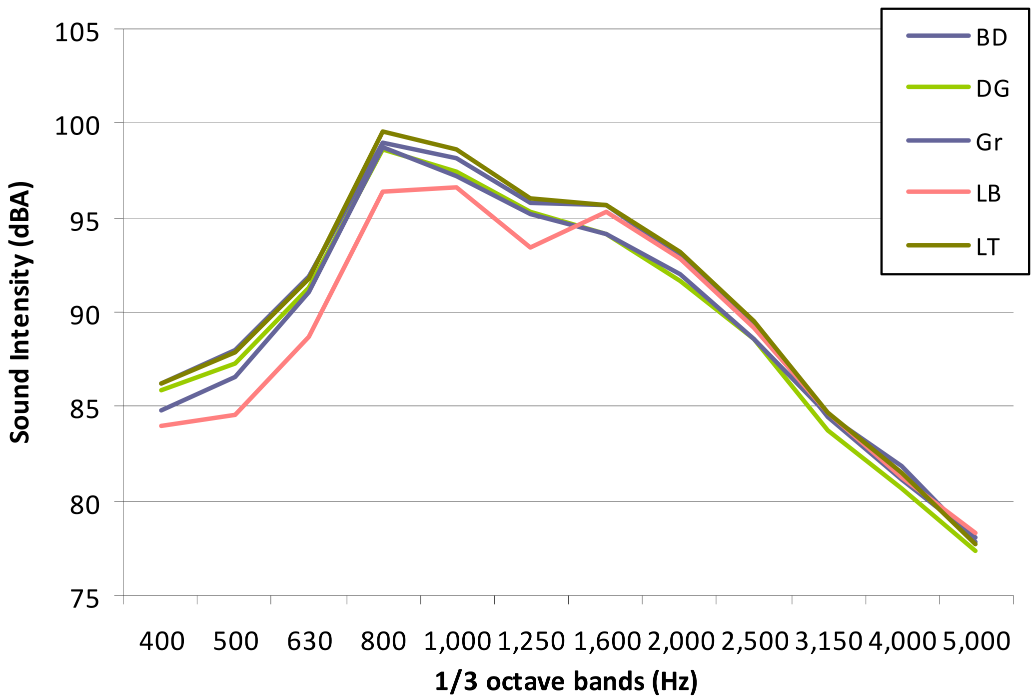

Figure 3.17: Comparison of OBSI spectral content of sections with different texture types, average of sections with texture *aged*.
(Note: **BD = burlap drag, DG=diamond ground, Gr=diamond grooved, LB=longitudinally broomed, LT=longitudinally tined.)**

The mechanism that increases the loudness of BD texture occurs at low frequencies because above 1,600 Hz the Min, the Average, and the Max spectra are all similar. The mechanism that increases the loudness of DG texture involves the entire spectrum.

The average spectra for all texture types and conditions was shown previously in Figure 3.16. The minimum and maximum spectra values for the one-third octaves are shown for all sections with aged texture in Figure 3.19 and Figure 3.20, respectively.

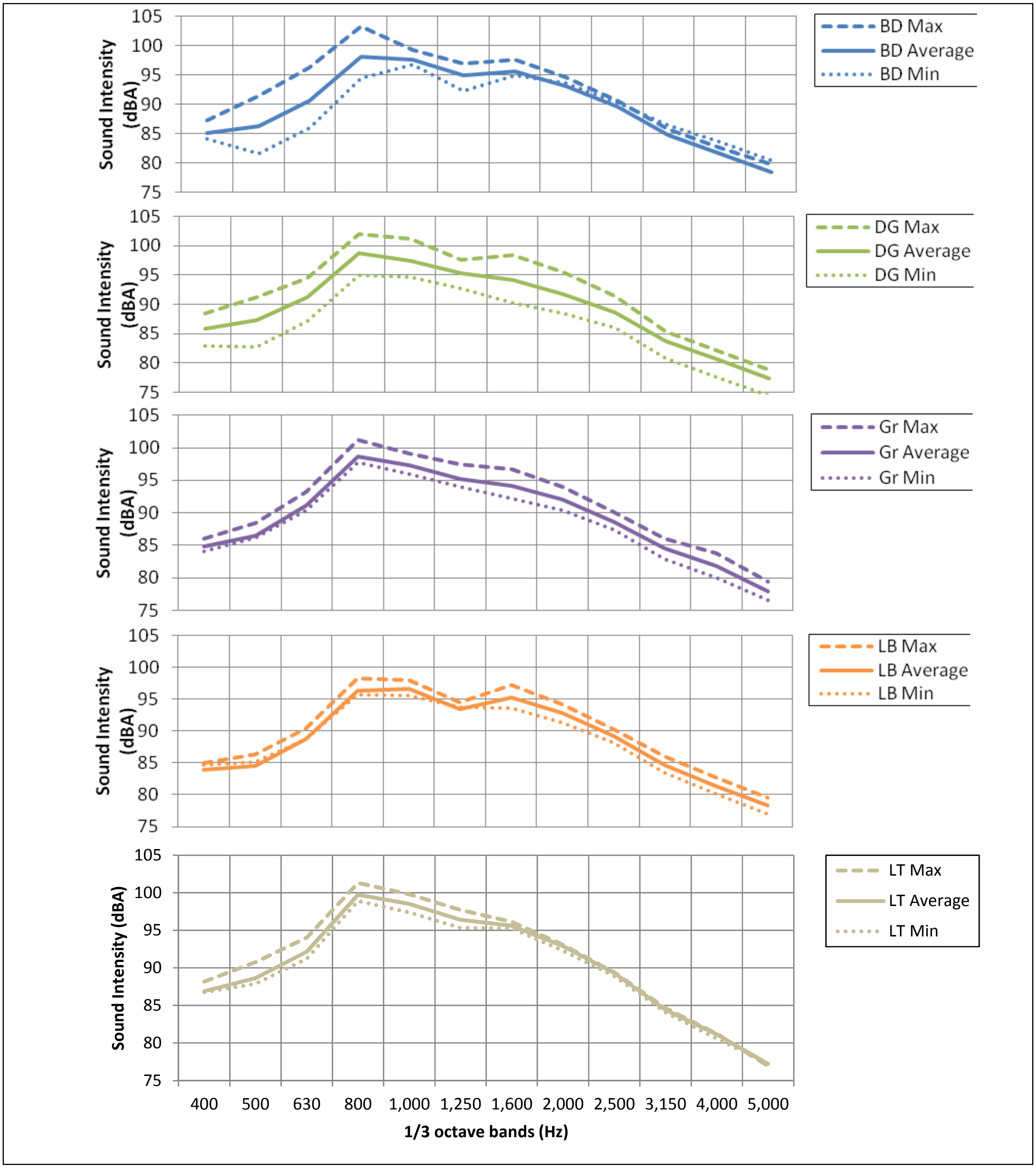

Figure 3.18: Comparison of OBSI spectral content of sections of different texture type (only texture *aged*).

Table 3.1. Sound Intensity in One-Third Octaves of Sections with Texture *Aged*

		400	500	630	800	1,000	1,250	1,600	2,000	2,500	3,150	4,000	5,000	Overall
BD	Max	87.3	91.5	96.3	103.2	99.3	96.9	97.7	94.6	90.7	85.9	82.7	79.9	107.2
	Average	85.2	86.3	90.6	98.1	97.6	94.9	95.6	93.2	89.6	84.8	81.6	78.5	103.7
	Min	84.1	81.6	86.0	94.4	96.7	92.2	94.9	93.6	90.3	86.5	83.6	80.5	102.0
DG	Max	88.5	91.2	94.5	102.0	101.2	97.7	98.4	95.5	91.3	85.3	82.1	78.9	107.3
	Average	85.8	87.3	91.3	98.7	97.5	95.3	94.2	91.8	88.6	83.7	80.7	77.4	103.5
	Min	82.9	82.7	87.2	94.9	94.7	92.8	90.3	88.5	85.9	80.9	77.5	74.5	99.4
Gr	Max	86.0	88.5	93.3	101.1	99.1	97.5	96.7	94.0	90.1	86.1	83.8	79.5	105.9
	Average	84.8	86.5	91.1	98.7	97.3	95.2	94.1	92.0	88.5	84.6	81.9	77.9	103.4
	Min	84.1	86.1	90.3	97.7	95.9	94.0	92.2	90.4	87.4	82.9	80.1	76.5	101.7
LB	Max	84.9	86.3	90.5	98.3	98.1	94.5	97.3	94.2	90.3	86.1	82.7	79.6	104.1
	Average	83.9	84.5	88.7	96.4	96.6	93.4	95.3	92.8	89.2	84.7	81.3	78.4	102.0
	Min	84.7	85.2	88.8	95.7	95.6	93.7	93.6	91.4	88.2	83.5	80.1	76.9	101.6
LT	Max	88.2	90.8	94.0	101.3	99.8	97.7	96.1	93.1	89.4	84.6	81.2	76.9	106.1
	Average	86.9	88.6	92.2	99.7	98.5	96.4	95.6	92.9	89.3	84.4	81.1	77.2	104.8
	Min	86.8	87.9	91.2	98.9	97.4	95.3	95.3	92.3	88.9	84.1	80.6	77.2	103.8

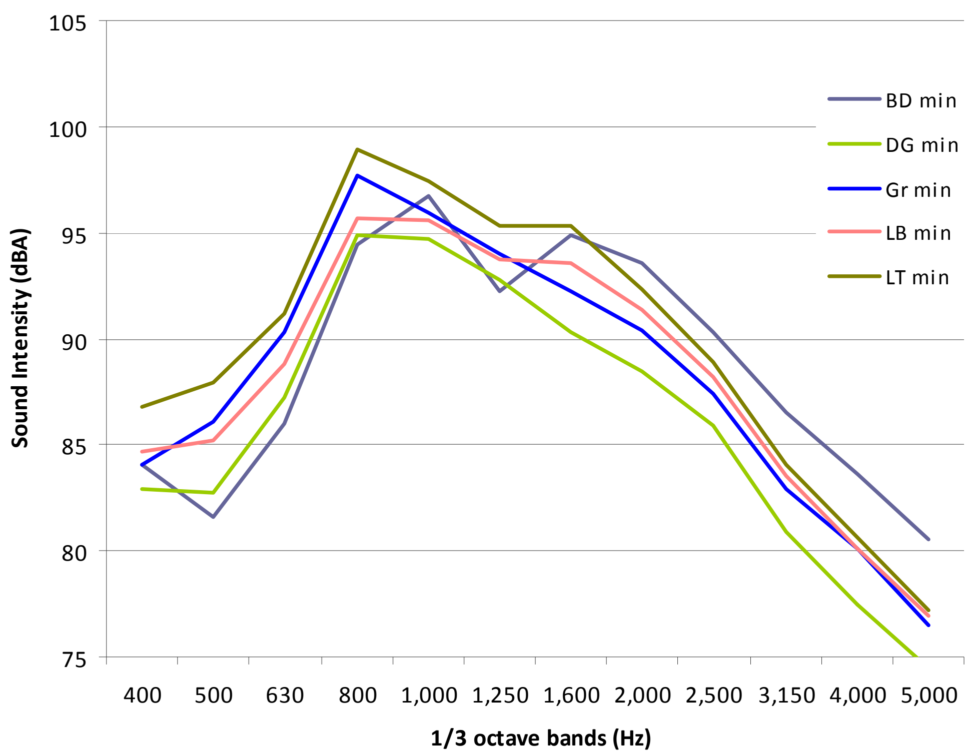

Figure 3.19: Comparison of OBSI spectral content of sections with different texture types, minimum of sections with *aged* texture.
(*Note:* BD = burlap drag, DG=diamond ground, Gr=diamond grooved, LB=longitudinally broomed, LT=longitudinally tined.)

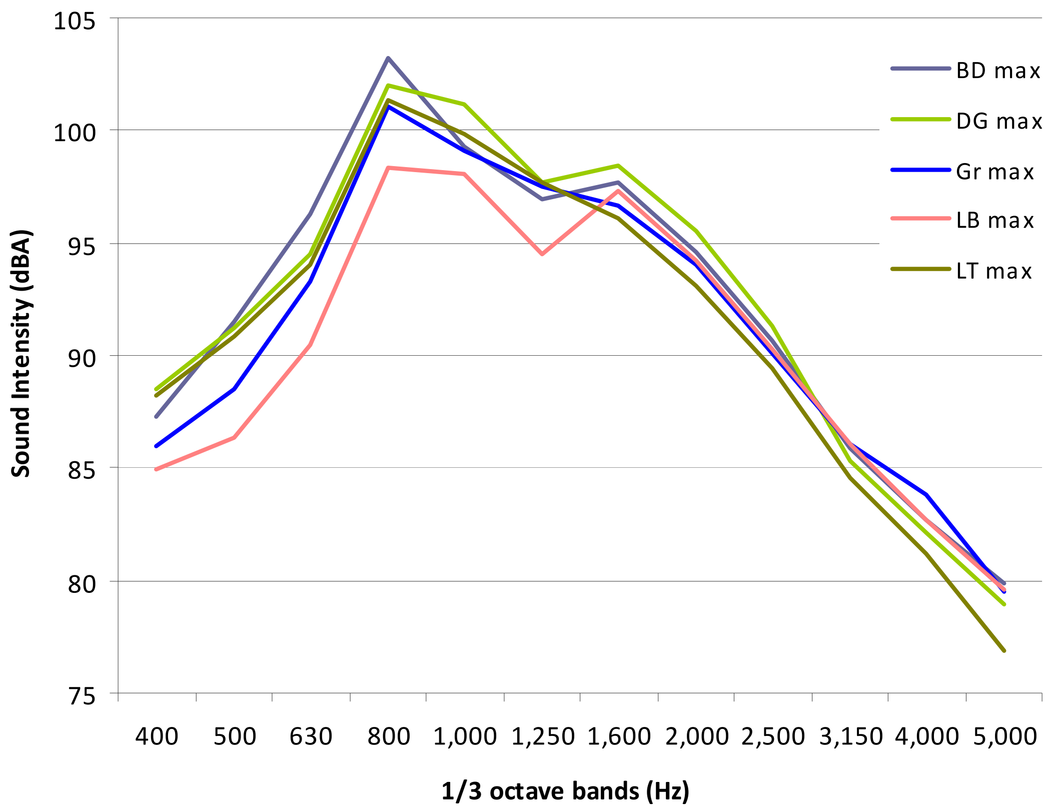

Figure 3.20: Comparison of OBSI spectral content of sections with different texture types, maximum of sections with texture *aged*.
(Note: **BD = burlap drag, DG=diamond ground, Gr=diamond grooved, LB=longitudinally broomed, LT=longitudinally tined.)**

To better visualize the difference, two texture types are presented together in each of the following figures.

Between LB and Gr the analysis is as follows: The Max spectrum is higher for Gr than LB below 1,600 Hz. The Average spectrum is higher for Gr than LB below 1,250 Hz. The LB Average spectrum shows intensities at 800 Hz and 1,000 Hz very similar to those for Gr. The Min LB spectrum is lower than the Average LB spectrum only at the 1,600 and 2,000 Hz bands. The Max and Average LB spectra show markedly lower intensities at 800, 1,000, and 1,250 Hz compared to the Gr spectra, which are the primary contributors to overall sound intensity.

Between LT and BD the analysis is as follows: The LT spectrum is very similar for the Max, the Average, and the Min curves for both textures at frequencies higher than 1,600 Hz, with the differences in the low frequencies. In these low frequencies the BD texture is quieter than the LT texture for the Average and the Min curves.

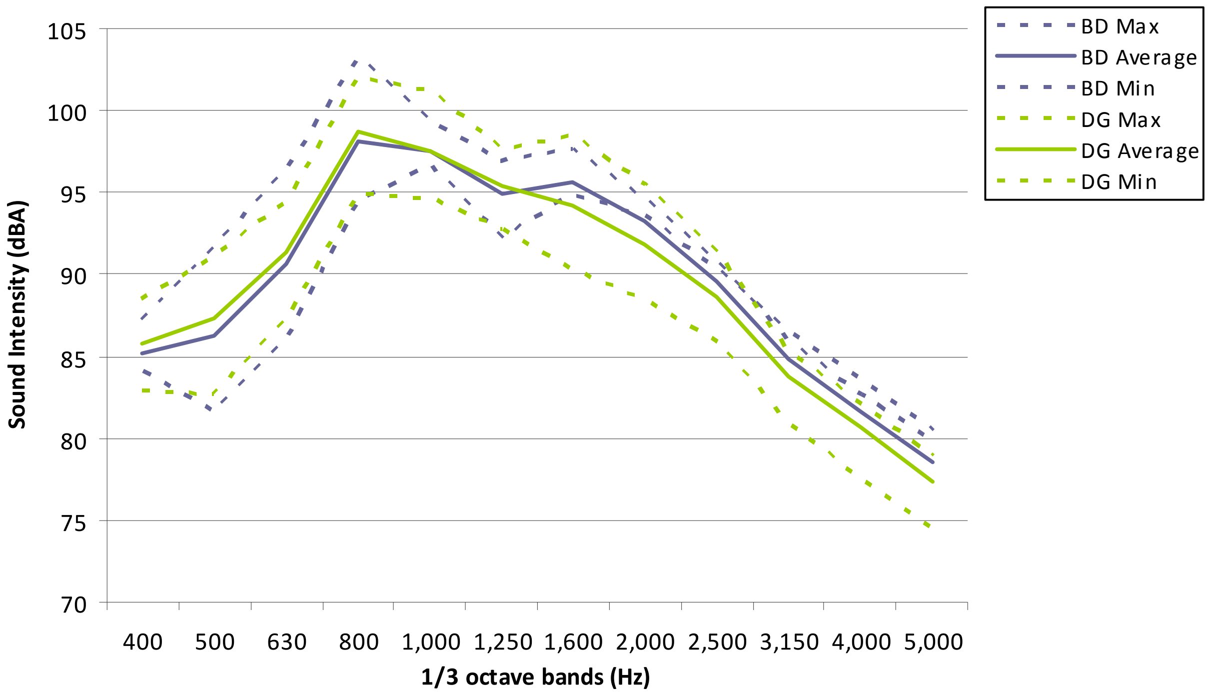

Figure 3.21: Comparison of OBSI spectral content of diamond ground (DG) and burlap drag (BD), texture *aged* sections.

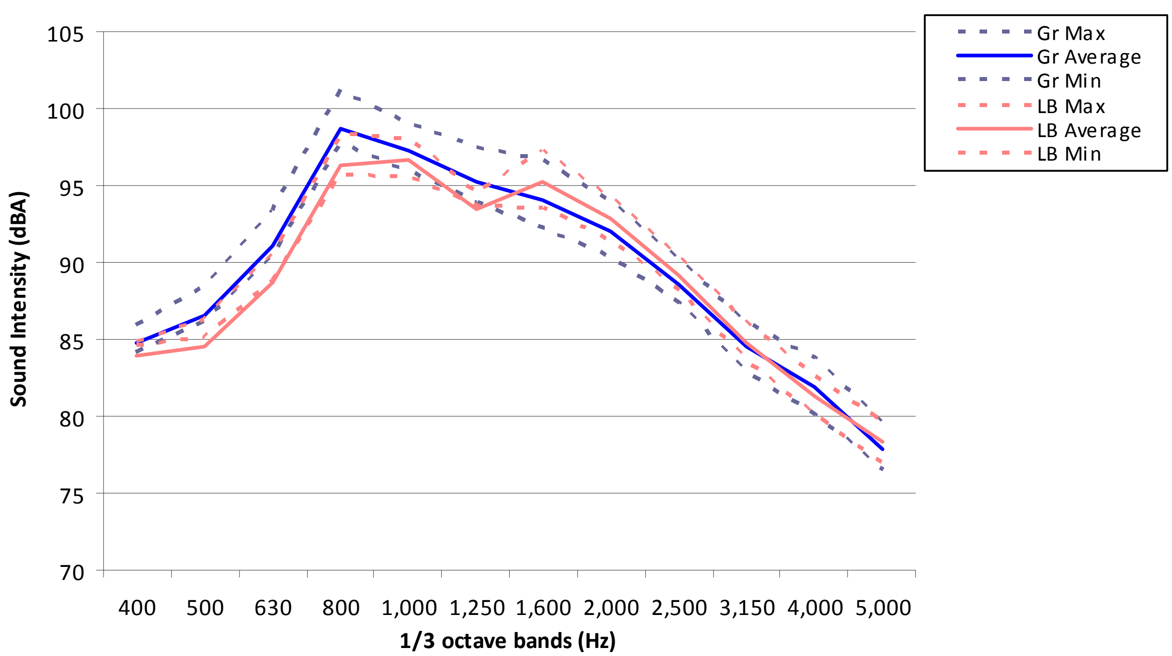

Figure 3.22: Comparison of OBSI spectral content of longitudinally broomed (LB) and diamond grooved (Gr), texture *aged* sections.

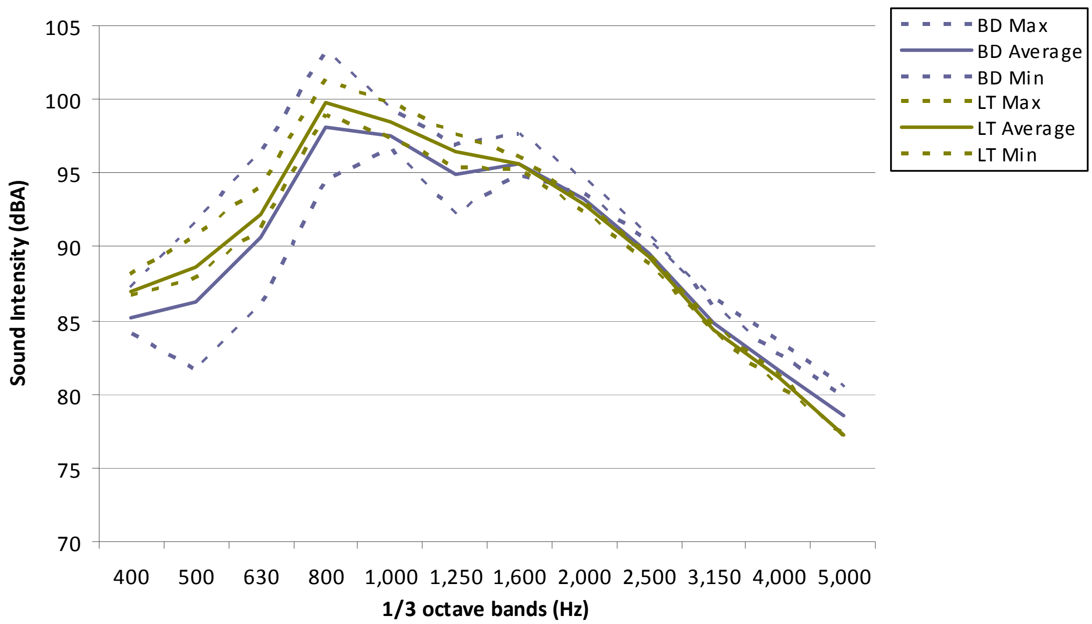

Figure 3.23: Comparison of OBSI spectral content of longitudinally tined (LT) and burlap drag (BD) sections.

3.2 Overall Sound Intensity

The results of OBSI measurements are presented by surface type in three sets: Year 1 results, Year 2 results, and Year 1 and Year 2 results combined. Combining the two years of data provides a larger sample size, while the results of the year-by-year analysis are of interest because of some differences within each surface type of individual sections. Sections in all conditions *(new, aged, worn out)* are included here. Each texture type and details of the OBSI level of each section measured in Years 1 and 2 appear in Appendix A.

The box plots in Figure 3.24 through Figure 3.26 show the OBSI level by texture type respectively for the data set corresponding to Year 1, Year 2, and the combined Year 1 and Year 2 data. The values shown in the box plots are the minimum and the maximum, and the 1st and 3rd quartiles.

The mean results for overall OBSI by surface type along with standard deviation and sample size are presented in Table 3.2.

Table 3.3 presents the same information, but only for *new* and *aged* textures, i.e., the sections with texture *worn out* are excluded. It can be seen that separating out the texture *worn out* sections did not have much effect on the mean overall OBSI levels, except for the BD texture type.

Figure 3.27 is similar to Figure 3.26 but only showing sections with *new* and *aged* textures.

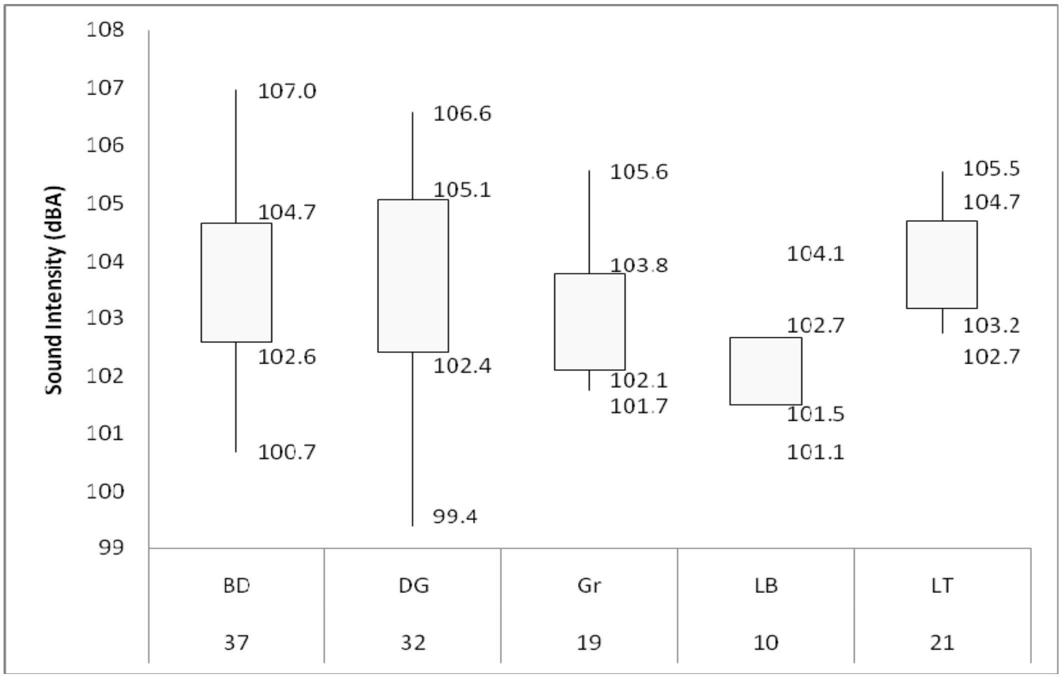

Figure 3.24: Box plots of OBSI results by texture type, Year 1.
(Notes: **BD = burlap drag, DG=diamond ground, Gr=diamond grooved, LB=longitudinally broomed, LT=longitudinally tined; number of observations in sample shown below texture type.)**

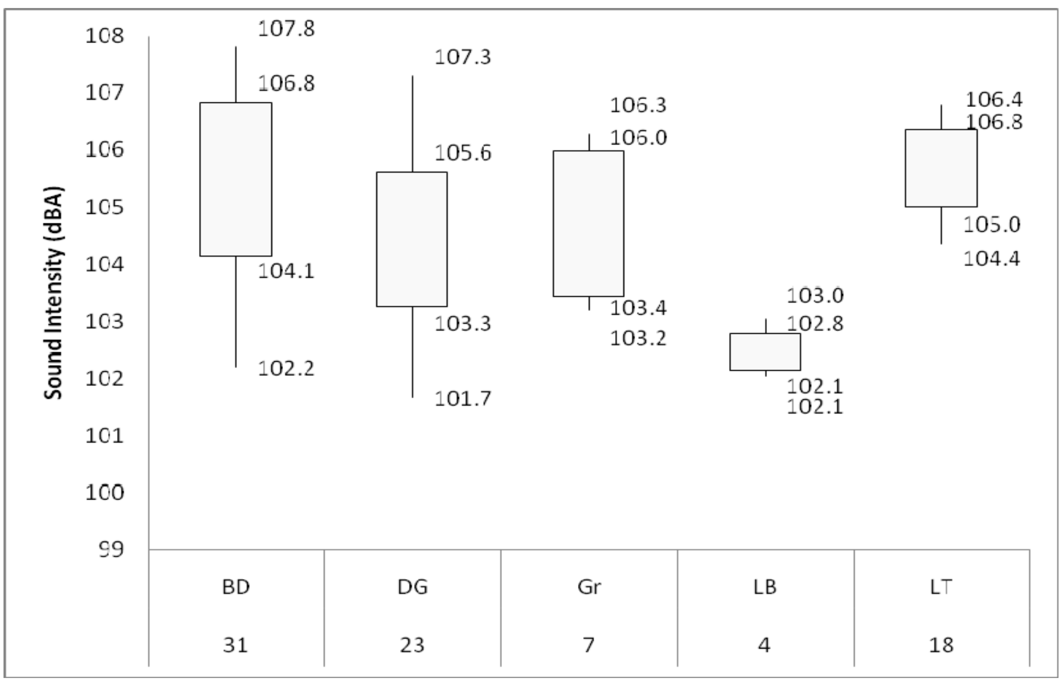

Figure 3.25: Box plots of OBSI results by texture type, Year 2.
(Notes: **BD = burlap drag, DG=diamond ground, Gr=diamond grooved, LB=longitudinally broomed, LT=longitudinally tined; number of observations in sample shown below texture type.)**

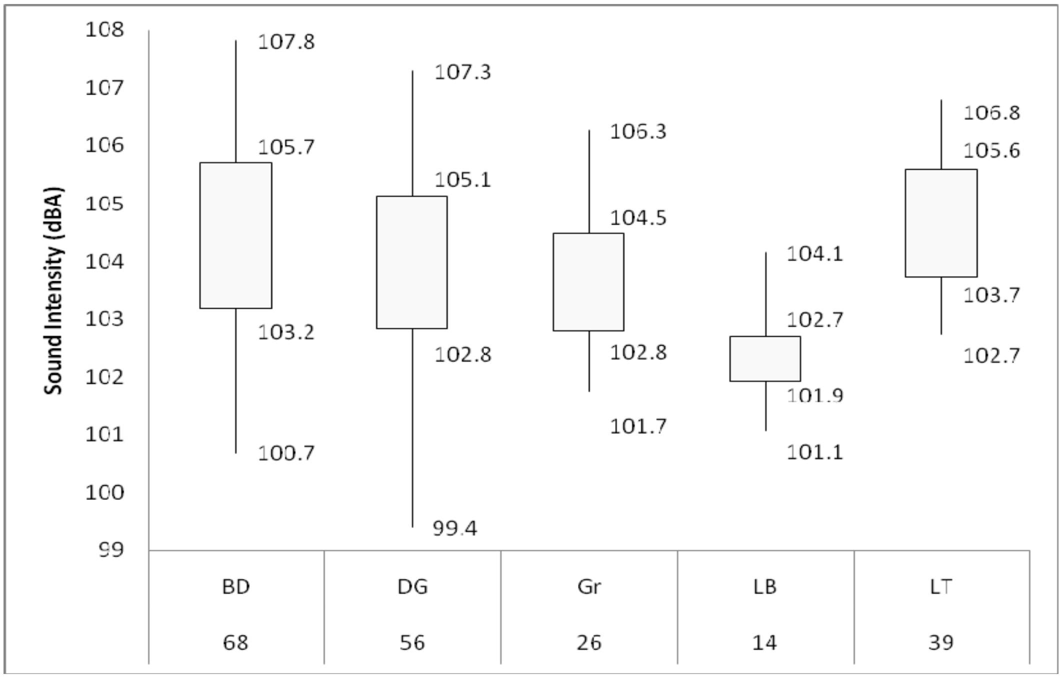

Figure 3.26: Box plots of OBSI results by texture type, Years 1 and 2 combined.
(Notes: **BD = burlap drag, DG=diamond ground, Gr=diamond grooved, LB=longitudinally broomed, LT=longitudinally tined; number of observations in sample shown below texture type.)**

The quietest texture type, when considering the mean of the OBSI results of all sections with the same nominal surface type with all texture conditions *(new, aged and worn out)* and combining Year 1 and Year 2 data, was found to be the longitudinally broomed (LB), although this conclusion must be treated with some caution because of the smaller sample size for this texture type. The longitudinally broomed group presented a mean OBSI level of 102.3 dB(A) based on 14 measurements obtained by combining the two years of results on 10 sections located at four different sites (Table 2.5). Next, the diamond grooved and diamond ground texture types showed values similar to each other in terms of mean OBSI level—103.6 and 103.8 dB(A), respectively—and are therefore ranked as the second quietest. The value for diamond ground sections is the result of 56 measurements on 32 sections located at 14 sites, and for diamond grooved it is the result of 26 measurements on 19 sections located at 9 different sites. Burlap drag and longitudinally tined surfaces had mean OBSI levels of 104.5 and 104.8 dB(A), respectively. There were 42 measurements on 21 longitudinally tined sections located at eight different sites, and 68 measurements for burlap drag on 37 sections at 13 sites.

Figure 3.27 shows a box plot of overall OBSI for each texture type for the *new* and *aged* textures, with those sections with *worn out* textures removed. Figure 3.28 shows the normal distribution curves of OBSI results by texture type, all sections. Figure 3.29 shows the normal distribution curves of OBSI results by texture for the *new* and *aged* textures, with the *worn out* textures removed.

If the sections with *worn out* texture condition are excluded, the results of the analysis are similar. The quietest type is still the longitudinally broomed sections with a mean OBSI level of 102.0 dB(A). The diamond grooved sections follow at 103.6 dB(A), then the diamond ground and the burlap drag at 103.8 dB(A) each. The longitudinally tined sections presented a mean level of 104.7 dB(A). It should be noted that human hearing can generally only perceive differences in sound of 2 to 3 dB(A) or more.

The normal distribution curves were prepared using the mean and standard deviation of OBSI levels that were presented in Table 3.2 and

Table 3.3 for the combined data from Year 1 and Year 2, and for each texture type. The resulting charts are presented in Figure 3.28 including all sections and in Figure 3.29 excluding sections with the texture *worn out* condition. The legend includes the mean OBSI level in dB(A) next to the texture-type abbreviation.

Table 3.2: Mean Values of Overall OBSI Levels (dB[A]) by Surface Texture Type, All Sections (All Conditions: *New, Aged, Worn out)*

Surface Type	Year 1			Year 2			Combined Years 1 and 2		
	Mean	Std. Dev.	Sample Size	Mean	Std. Dev.	Sample Size	Mean	Std. Dev.	Sample Size
Burlap drag (BD)	103.8	1.8	37	105.2	1.5	31	104.5	1.8	68
Diamond ground (DG)	103.3	1.9	32	104.4	1.6	23	103.8	1.9	56
Diamond grooved (Gr)	103.2	1.1	19	104.7	1.4	7	103.6	1.4	26
Longitudinally broomed (LB)	102.2	0.9	10	102.5	0.5	4	102.3	0.8	14
Longitudinally tined (LT)	104.0	0.8	21	105.7	0.8	18	104.8	1.2	39

Table 3.3: Mean Values of Overall OBSI Levels (dB[A]) by Surface Texture Type, Only *New* and *Aged* Textures

Surface Type	Year 1			Year 2			Combined Years 1 and 2		
	Mean	Std. Dev.	Sample Size	Mean	Std. Dev.	Sample Size	Mean	Std. Dev.	Sample Size
Burlap drag (BD)	103.3	0.8	10	104.6	1.1	7	103.8	1.1	17
Diamond ground (DG)	103.3	1.9	32	104.4	1.6	23	103.8	1.9	56
Diamond grooved (Gr)	103.2	1.1	19	104.7	1.4	7	103.6	1.4	26
Longitudinally broomed (LB)	101.5	0.7	4	102.5	0.5	4	102.0	0.7	8
Longitudinally tined (LT)	103.9	0.9	18	105.7	0.9	15	104.7	1.3	33

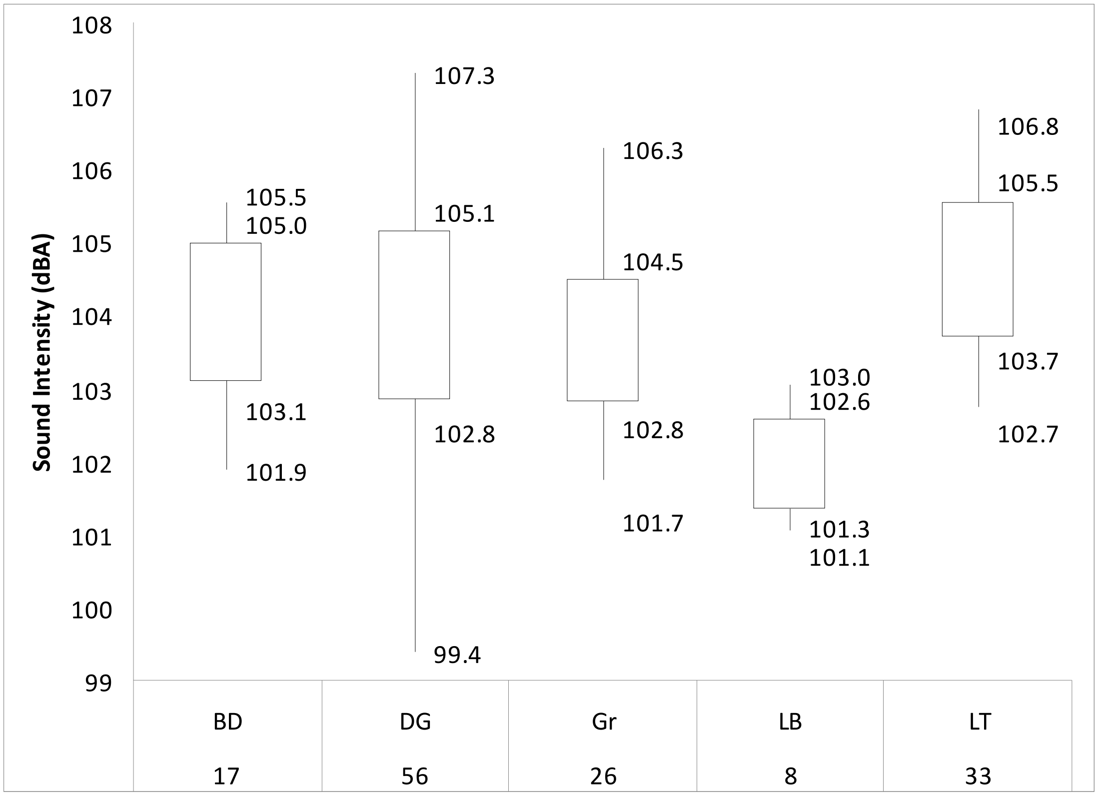

Figure 3.27: Box plots of overall OBSI results by texture type, Years 1 and 2 combined, only sections with *new* and *aged* textures (sections with texture *worn out* are excluded). *(Notes:* BD = burlap drag, DG=diamond ground, Gr=diamond grooved, LB=longitudinally broomed, LT=longitudinally tined; number of observations in sample shown below texture type.)

It must be noted that the number of sections for the longitudinally broomed (LB) texture is considerably less than for the other textures when all sections are considered. The number of sections for the burlap drag (BD) texture are also fewer than those for the diamond ground (DG), diamond grooved (Gr), and longitudindally tined (LT) textures when the texture *worn out* condition is excluded, since many of the BD sections are older and have lost their texture.

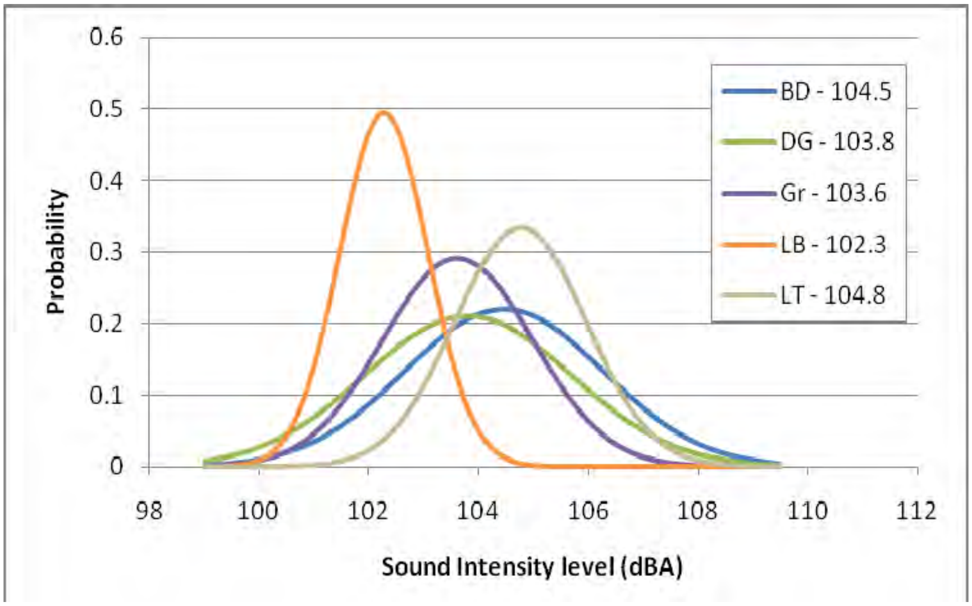

Figure 3.28: Normal distribution curves of OBSI results by texture type, all sections.
(Notes: **BD=burlap drag, DG=diamond ground, Gr=diamond grooved, LB=longitudinally broomed, LT=longitudinally tined; sample sizes for LB and Gr are smaller than for other textures.)**

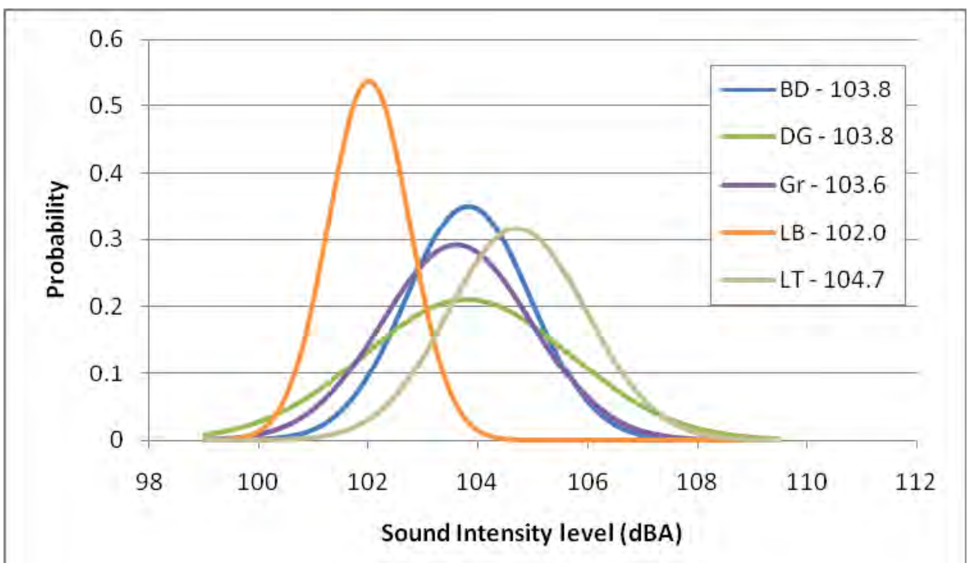

Figure 3.29: Normal distribution curves of OBSI results by texture type, only *new* and *aged* texture.
(Note: **Sample sizes for LB and BD are smaller than for other textures.)**

The differences in OBSI observed between the various texture types are in general fairly small. The largest difference in mean OBSI levels is between the longitudinally broomed (LB) and longitudinally tined (LT) sections, which have a difference of 2.5 dB(A) in the combined two-year pooled data. Since there are five texture types in the study, evaluating the difference in mean OBSI values among them requires use of 10 combinations of paired textures. A simple two-tailed t-test was used to determine if the difference for each pair is significant or not.

The Student's t-value and the degrees of freedom were calculated as follows:

$$t = \frac{\overline{x_1} - \overline{x_2}}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}$$

$$d.f. = \frac{\left(S_1^2 / n_1 + S_2^2 / n_2 \right)^2}{\left(S_1^2 / n_1 \right)^2 / (n_1 - 1) + \left(S_2^2 / n_2 \right)^2 / (n_2 - 1)}$$

This formula for the degrees of freedom *(d.f.* in equation) is used because the variances in OBSI level of two different types of surface are assumed to be different. Therefore t-tests were conducted for unequal sample sizes and unequal variances.

The significance level adopted was 0.05. The results are presented in Table 3.4. Following is an example interpretation of the analysis based on table (for the first row, all sections): "The 0.7 dB(A) difference between the mean OBSI of the burlap drag (BD) and diamond ground (DG) sections is not significant at the 95% confidence level." The significant differences are labeled "Y" (Yes), others were not found to be significant. A positive difference indicates that the first texture presented a higher mean OBSI than the second one in the comparison. It can be seen that when only *new* and *aged* sections are considered, the mean overall OBSI of LB sections was found to be significantly different from that of BD, DG, and Gr. The only other statistically significant difference was between diamond ground (DG) and diamond grooved (Gr) sections, with the mean DG overall OBSI being 0.2 dB(A) louder than that of Gr, which is a difference imperceptible to the human ear.

Table 3.4: Difference of Means and Significance Test For Pairs of Texture Types

		All Sections		Only *New* and *Aged* Sections	
Texture 1	**Texture 2**	**Difference**	**Significant?**	**Difference**	**Significant?**
BD	DG	0.7	-	0.0	-
BD	Gr	0.8	Y	0.2	-
BD	LB	2.2	Y	1.8	Y
BD	LT	-1.1	-	-1.1	-
DG	Gr	0.2	Y	0.2	Y
DG	LB	1.5	Y	1.8	Y
DG	LT	-1.0	-	-0.9	-
Gr	LB	1.3	Y	1.6	Y
Gr	LT	-1.1	-	-1.1	-
LB	LT	-2.5	-	-2.7	-

3.3 Results by Age and Texture Type

This section of the report presents the results of OBSI levels by pavement surface age. Each of the following charts shows the combined results for Year 1 and Year 2.

Figure 3.30 shows OBSI results for the burlap drag sections. The vast majority of the burlap drag sections were built in the 1960s and 1970s. The only "young" section, which was about six years old at the time of testing, is QP-159.1 at the Mojave Bypass. The oldest sections, which were 62 years old, are on Interstate 80 in Solano County (QP-116.1, QP-116.2, and QP-116.3). Older sections have higher OBSI levels. Figure 3.31 shows all texture conditions for the burlap drag sections plotted versus the number of years since they were last surfaced, including all Year 1 and Year 2 measurements.

Figure 3.32 shows OBSI results for the diamond ground sections. The oldest sections evaluated were 11 years old at the time of testing. It seems again that older sections have higher OBSI levels. Figure 3.33 shows all texture conditions for the diamond ground sections plotted versus the number of years since they were last surfaced, including all Year 1 and Year 2 measurements.

Figure 3.34 shows OBSI results for the diamond grooved sections. Although some of the pavements on US 101 in Sonoma County were built in 1962 (QP-136 and QP-138), records indicate that the sections were diamond grooved in 2006. Older sections were about 12 years old after grooving, and were located on Interstate 80 in Nevada County (QP-110 and QP-111). It is not possible to observe a trend in OBSI level over time with the available data. Figure 3.35 shows all texture conditions for the diamond grooved sections plotted versus the number of years since they were last surfaced, including all Year 1 and Year 2 measurements.

Figure 3.36 shows OBSI results for the longitudinally broomed sections. The six-year old section is at the Mojave Bypass on State Route 58. The 19-year old sections are on Interstate 80 in Nevada County (QP-109 and QP-112), but were overlaid with asphalt between Year 1 and Year 2. The 34-year-old sections are on Interstate 280 in San Mateo County (QP-146). From the limited available data, it seems that OBSI levels on this type of surface texture do not increase much over time. Figure 3.37 shows all texture conditions for the longitudinally broomed sections plotted versus the number of years since they were last surfaced, including all Year 1 and Year 2 measurements.

Figure 3.38 shows OBSI results for the longitudinally tined sections. The OBSI levels remain mostly between 103 and 107 dB(A), even for sections that are over 30 and 40 years old. Figure 3.39 shows all texture conditions for the longitudinally tined sections plotted versus the number of years since they were last surfaced, including all Year 1 and Year 2 measurements.

3.4 Year 1 to Year 2 Variation

A comparison of Year 1 and Year 2 was done using OBSI data for 83 sections, excluding the second year of data on Section 142 which experienced excessive loss of concrete to the point of creating rutting due to chain wear. The average Year 2 OBSI level for these sections is 1.1 dB(A) higher than in Year 1. Although there is a level of uncertainty in the measurement, which could be estimated at around 0.8 to 1.0 dB(A) *(3)*, by looking into the one-year change it might be possible to develop a preliminary indication of differences in wearing rate. The graphs previously shown in Figure 3.30, Figure 3.32, Figure 3.34, Figure 3.36, and Figure 3.38 show the one-year change in OBSI levels for all sections of each texture type, using the years since construction or grind/groove as the x-axis. These plots were intended to provide a preliminary assessment regarding whether the rate of OBSI change from Year 1 to Year 2 is dependent on the age of the concrete pavement surface. Figure 3.31, Figure 3.33, Figure 3.35, Figure 3.37, and Figure 3.39 show both years of OBSI levels versus the age of the surface for each texture type, with all texture condition categories included in each figure.

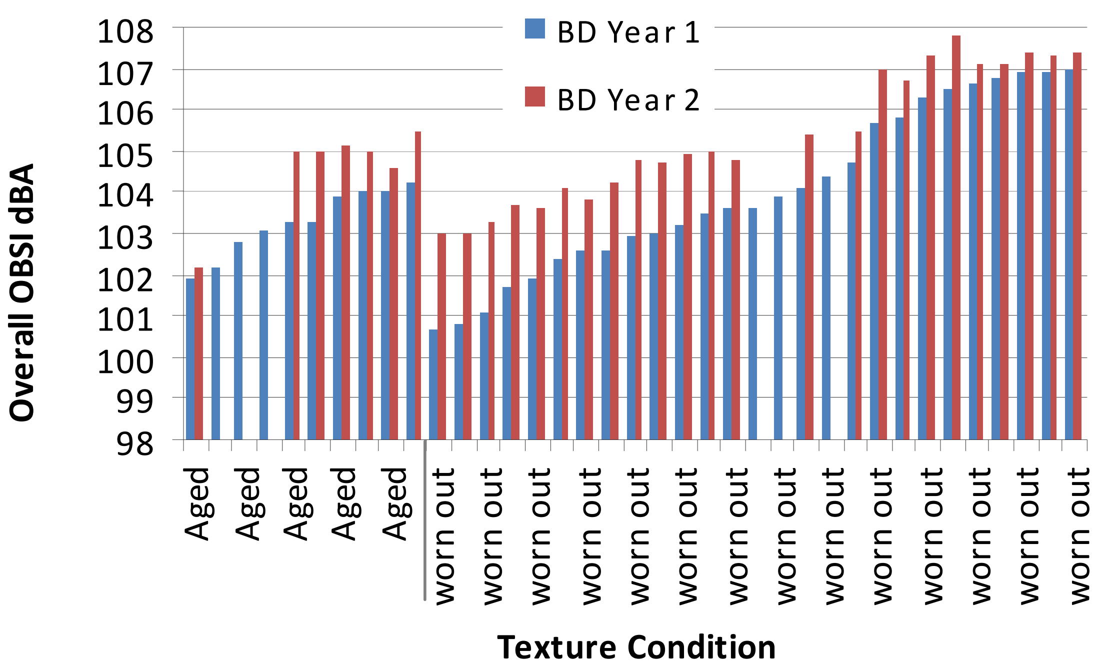

Figure 3.30: Year 1 and Year 2 OBSI values for all burlap drag sections.

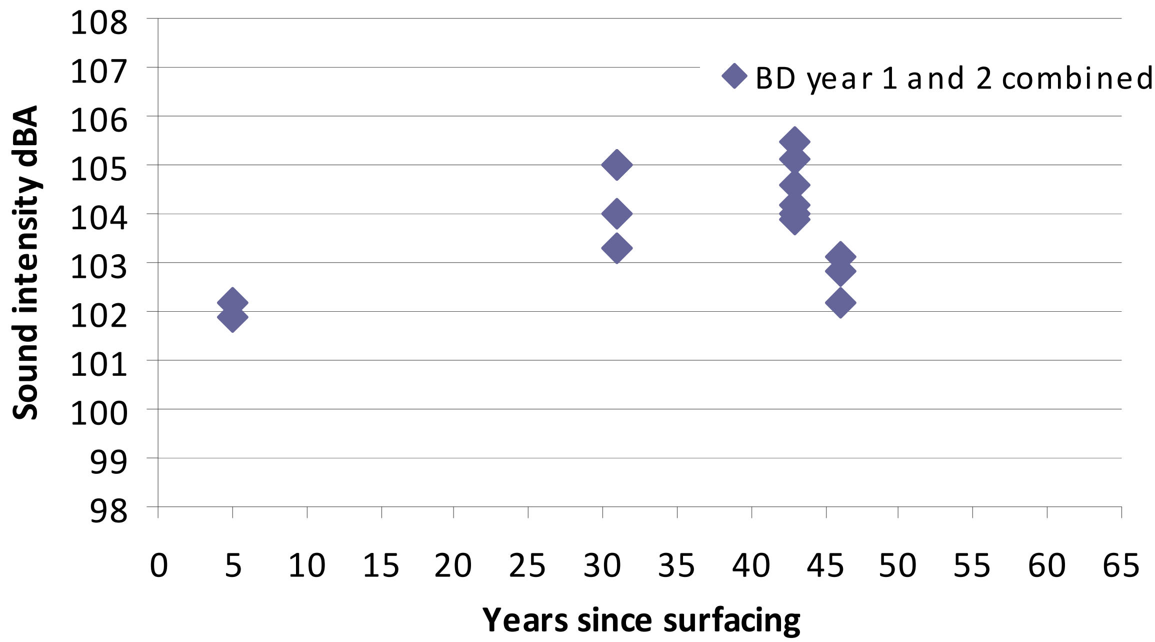

Figure 3.31: Year 1 and Year 2 OBSI values for all burlap drag sections versus years since last surfacing.

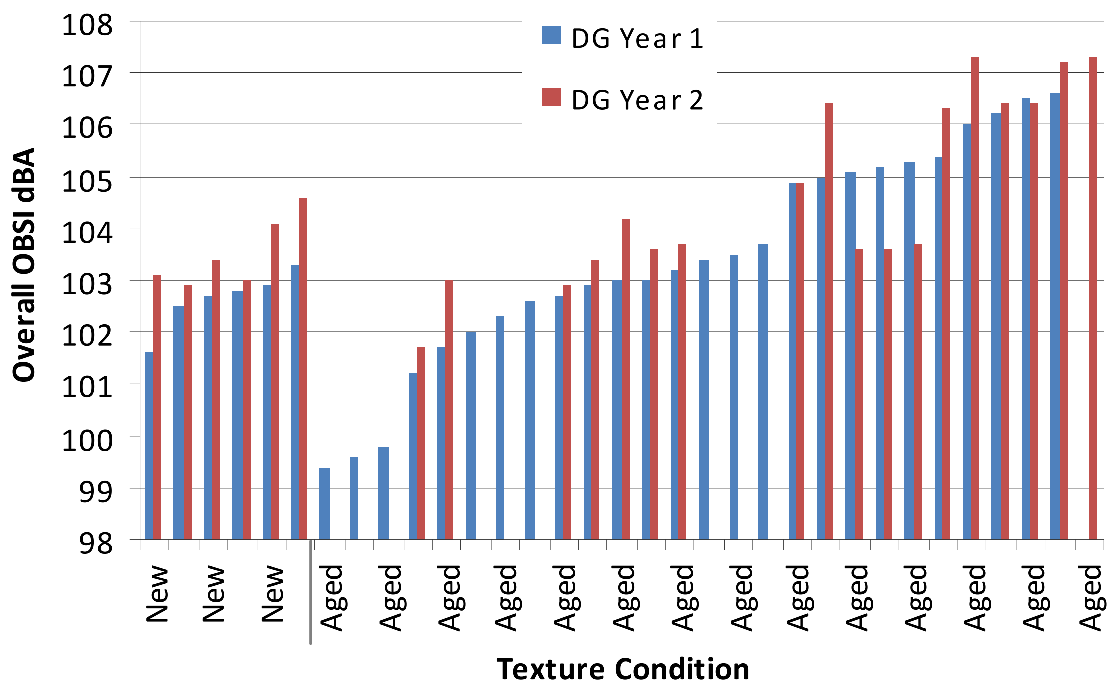

Figure 3.32: Year 1 and Year 2 OBSI values for all diamond ground sections.

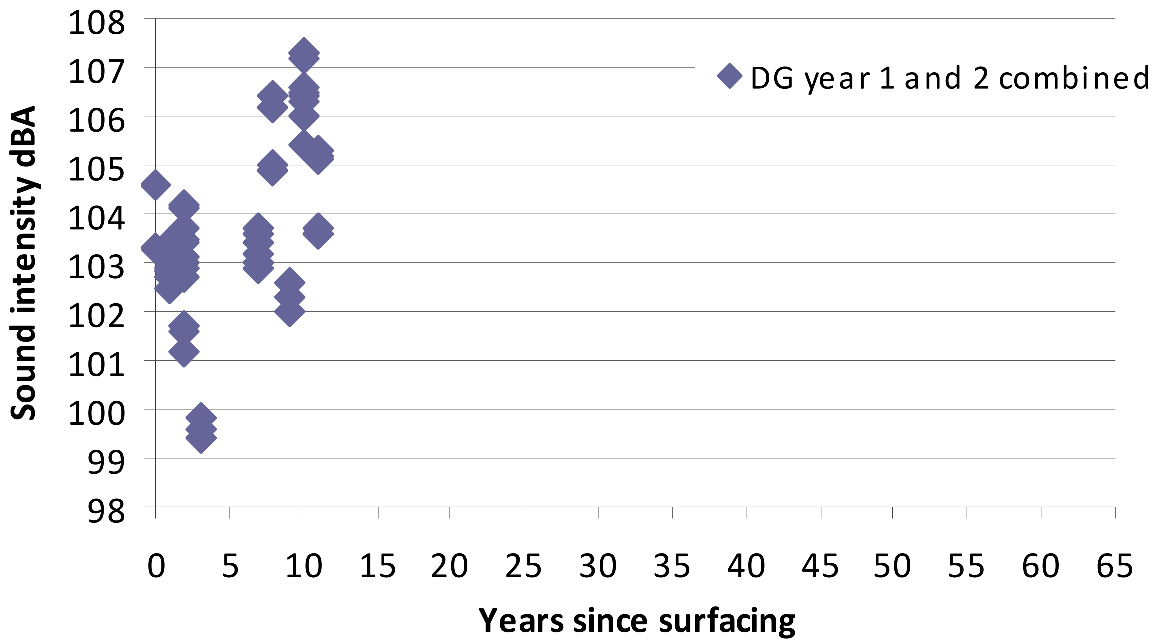

Figure 3.33: Year 1 and Year 2 OBSI values for all diamond ground sections versus years since last surfacing.

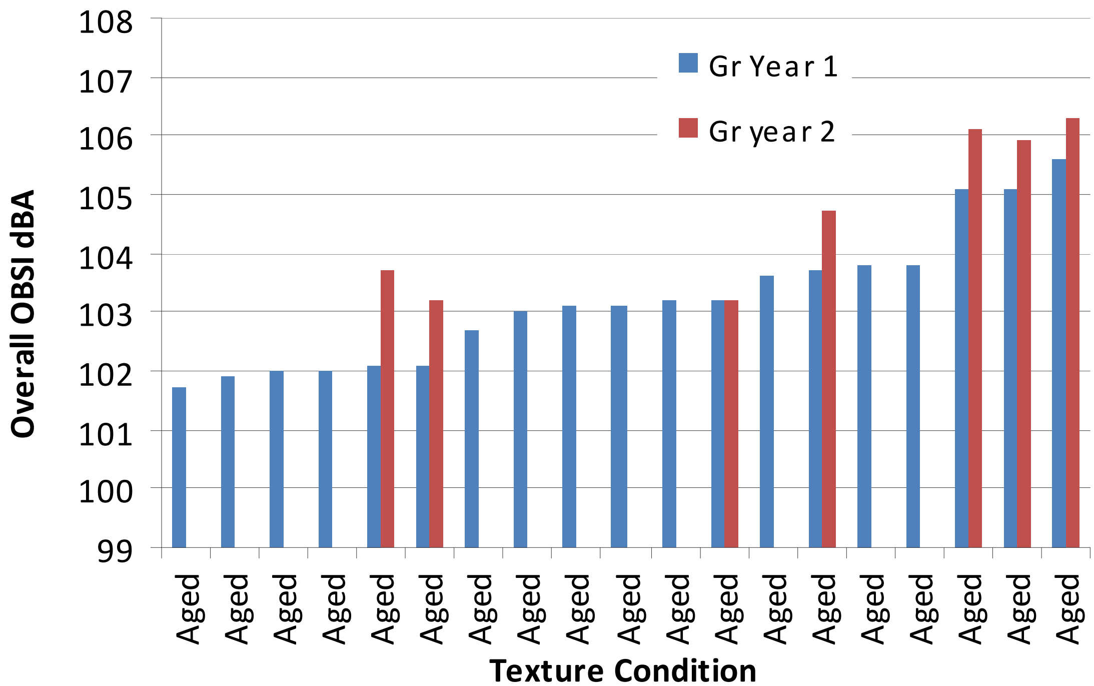

Figure 3.34: Year 1 and Year 2 OBSI values for all diamond grooved sections.

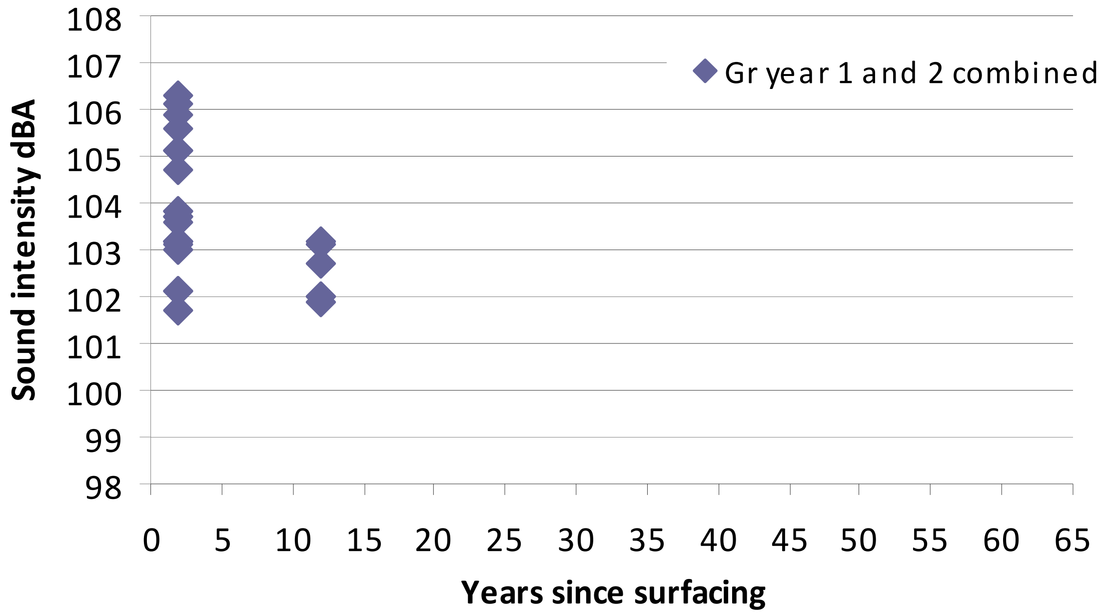

Figure 3.35: Year 1 and Year 2 OBSI values for all diamond grooved sections versus years since last surfacing.

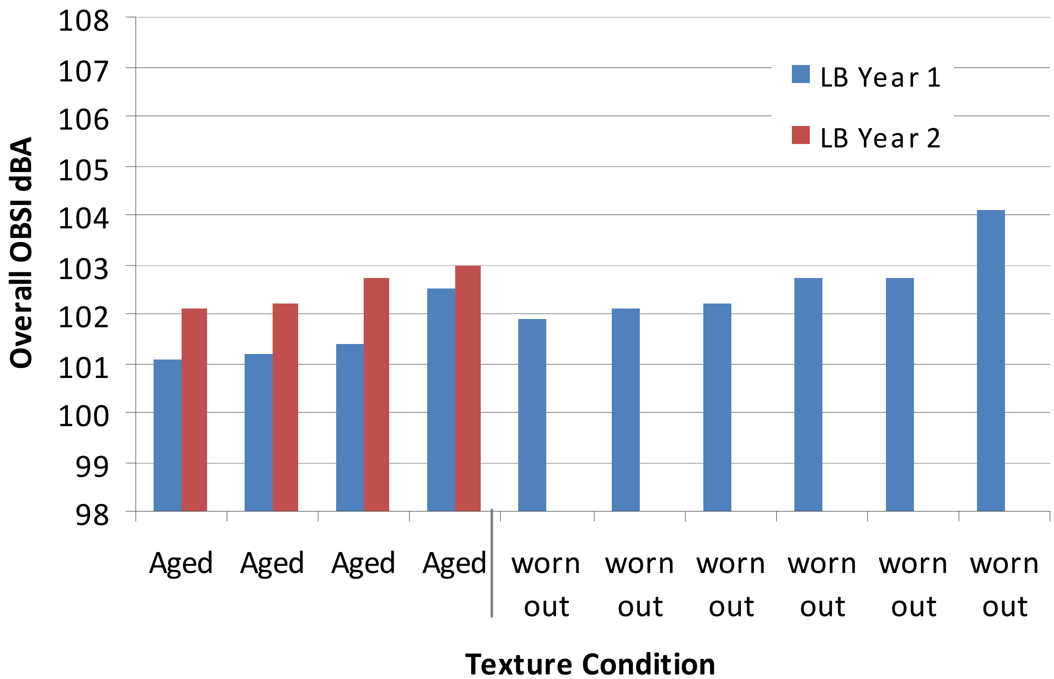

Figure 3.36: Year 1 and Year 2 OBSI values for all longitudinally broomed sections.

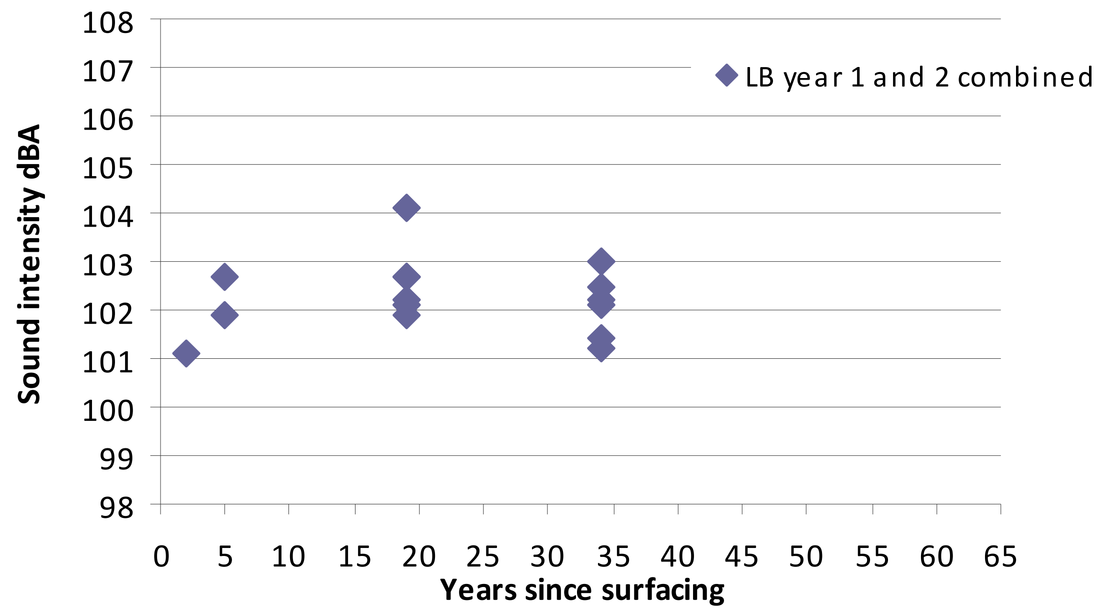

Figure 3.37: Year 1 and Year 2 OBSI values for all longitudinally broomed sections versus years since last surfacing.

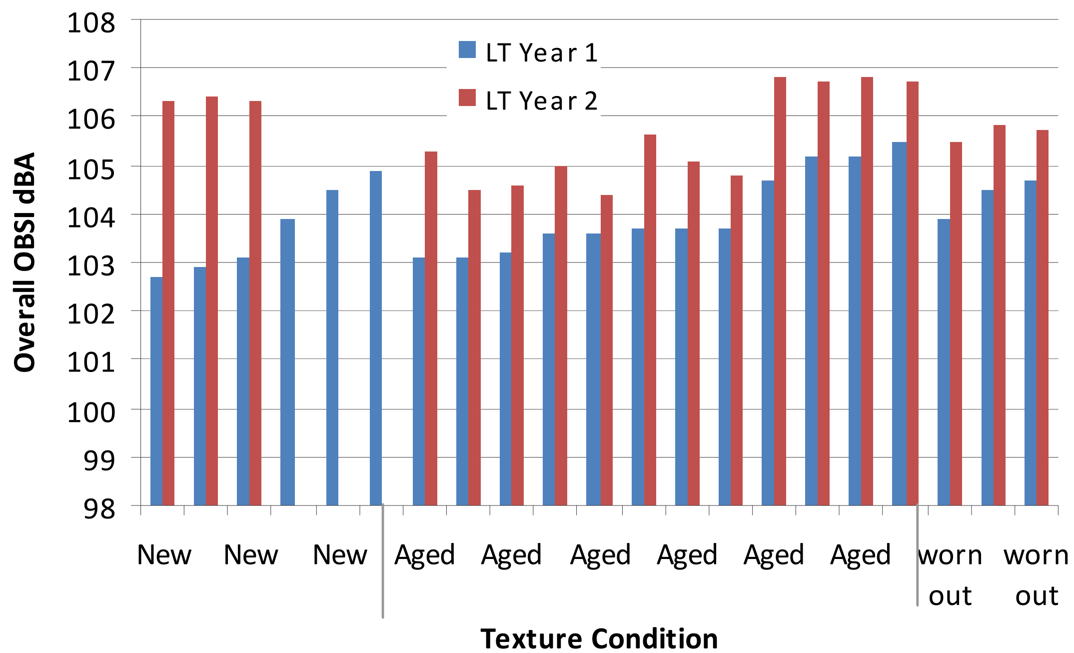

Figure 3.38: Year 1 and Year 2 OBSI values for all longitudinally tined sections.

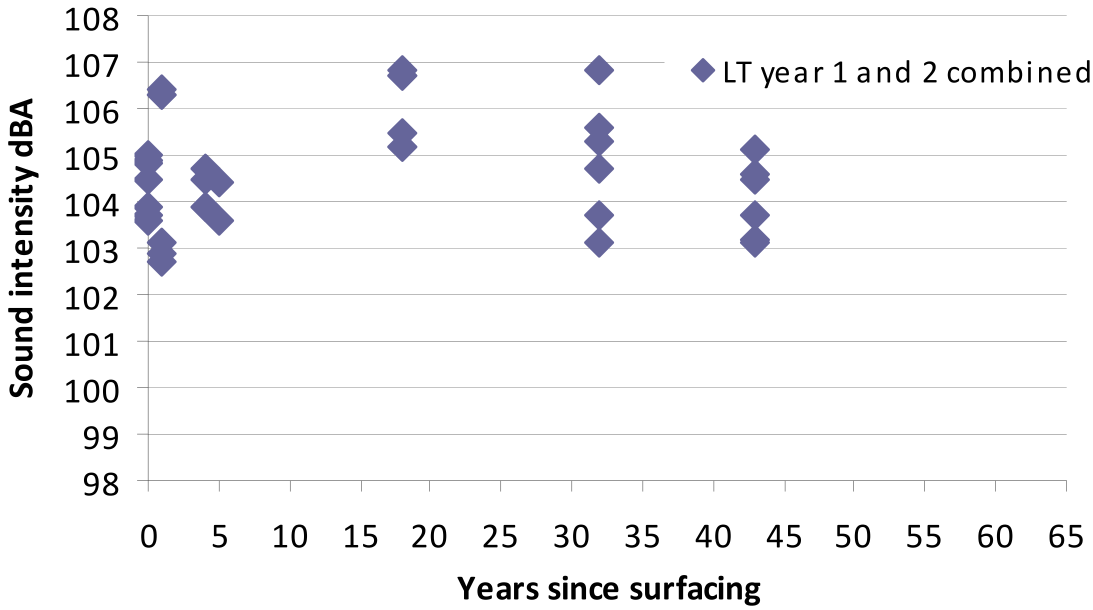

Figure 3.39: Year 1 and Year 2 OBSI values for all longitudinally tined sections versus years since last surfacing.

The scatter associated with the inherent measurement error makes it difficult to directly draw conclusions on the annual rate of change in OBSI measurements after only one year, especially considering the possible change in tire/pavement OBSI over one year relative to the measurement uncertainty with the required change in SRTT tire and analyzer.

$$t = \frac{\overline{x_1} - \overline{x_2}}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}} \qquad d.f. = \frac{\left(S_1^2 / n_1 + S_2^2 / n_2 \right)^2}{\left(S_1^2 / n_1 \right)^2 / (n_1 - 1) + \left(S_2^2 / n_2 \right)^2 / (n_2 - 1)}$$

$$SI\left(dBA\right) \geq 99.5 + IRI\left(\frac{m}{Km}\right) \qquad SI\left(dBA\right) \geq 101.1 + 2 \times MPD\left(mm\right)$$

3.5 Effects of Joints on Tire/Pavement Noise

The measured OBSI levels presented in this chapter include the effects of joint slap, faulting, and sealant providing positive texture (referred to as overbanding) in addition to the effect of the pavement texture, all of which would increase the OBSI level if they are present. These effects were not separated from the tire/pavement noise associated with the surface texture of the concrete. Faulting and overbanded sealant could not be considered because a method of measuring faulting and overbanding using the high-speed profilometer was not established at the time the project scope and budget were determined, and traffic closures to measure faulting, joint width, and overbanding manually were not included in the project budget. Some initial analysis was performed regarding the effects of joints on overall OBSI measurements, without separating the effects of slap caused by the joint groove, faulting and overbanded sealant. An example of that initial analysis is shown in Figure 3.40 for a faulted jointed concrete pavement on I-80 near Davis, CA, with the pavement profile measured with a high-speed laser in the right wheelpath shown above and OBSI in 15-ms intervals shown below. The example shows a maximum spike of about 8 dB(A) at the third joint from the left (joints indicated by arrows in the figure), where the fault height is approximately 9 mm (0.36 inches). The effects of faulting and joint groove cross-sectional area are not separated at that joint. Analysis of these results was extremely labor-intensive and there was insufficient funding in the project to fully analyze and consider these effects in the results, or to automate the analysis.

Similar effects have been identified previously, and some preliminary data indicating the added effects of joint faulting, joint groove cross-sectional area, and joint sealant recess depth on overall OBSI for concrete pavement surfaces has been developed by Purdue University and the American Concrete Pavement Association using the Purdue Tire Pavement Test Apparatus in the laboratory with some field validation at the MnROAD test track in Minnesota *(8).*

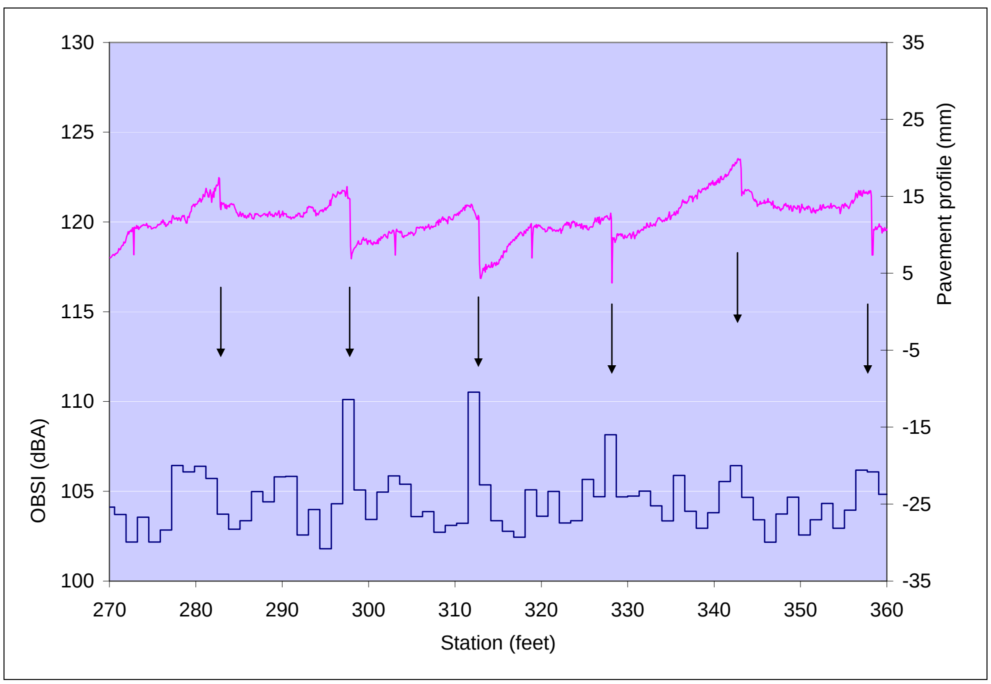

Figure 3.40: Noise level spikes and correspondence to joint faulting.

Since the data collection and analysis for this report were completed, a method has become available for estimating the effect of joint slap based on a theoretical acoustical model validated with field measurements where the primary pavement input variable is the cross-sectional area of the joint groove. The model does not consider faulting or sealant overbanding *(7).*

4 ANALYSIS

4.1 Analysis of Results of this Study

Five different texture types were evaluated in this study. These broad categories encompass common texturing techniques that are either currently used on concrete pavement projects or were used in the past: burlap drag, diamond ground, diamond grooved, longitudinally broomed, and longitudinally tined. However, the variability found visually on the surface of the sections, as well as in the measured noise levels, indicate that there is a wide range of textures within each nominal type. These changes in texture, caused by wearing due to traffic, further contribute to the variability. This chapter presents a detailed analysis of the results for each texture type, and compares the findings to previous research studies.

4.1.1 Burlap Drag

The oldest concrete pavement sections evaluated in this study have burlap drag texture, with sections on Interstate 80 in Solano County having been in service for over 60 years according to the available records (QP-116). Due to their long service life, some of the sections in this category had pavements that showed no signs of applied surface texture, and were then categorized as *worn out* texture. Burlap drag sections are not constructed in California highways any more, which is why no “young” sections, other than one built for a field evaluation experiment, were included in the experiment. This young section, which was about five years old when first tested, yielded an OBSI level of about 102 dB(A). Other than the experimental section, all burlap drag sections were older than 30 years, and had OBSI levels ranging between 101 and 108 dB(A). These values indicate that the actions of traffic, often combined with rainfall, will tend to polish some concrete surfaces and remove positive texture (stones protruding from the surface) without damaging the paste around the stones. The same combination of traffic and environment will tend to ravel asphalt surfaces and cause loss of paste around the aggregates in some concrete surfaces, creating positive texture by leaving the stones protruding from the surface. The quieter sections seem to be, judging from the pictures, those with shallow texture, as shown in Figure 4.1. Therefore, a possible reason for variability of OBSI for the burlap drag sections is variation in the macrotexture caused by the protrusion of aggregates. A summary of the information for burlap drag sections is presented in Table 4.1.

Table 4.1. Summary Information for Burlap Drag Sections

Number of sections evaluated Year 1	37 *(new:* 0, *aged:* 10, *worn out:* 27)
Number of sections evaluated Year 2	31 *(new:* 0, *aged:* 7, *worn out*: 24)
Average OBSI level (dB[A])	104.5 (only *new* & *aged:* 103.8)
OBSI level interquartile range (dB[A])	103.2 – 105.7 (only *new* & *aged:* 103.1 – 105.0)
OBSI level range (dB[A])	100.7 – 107.8 (only *new* & *aged:* 101.9 – 105.5)
Range of surface age (years)	5.4 – 61.4

QP-102.2 (103.0 dB[A]) **QP-107.3 (103.7 dB[A])**

QP-130.1 (107.3 dB[A]) **QP-116.1 (107.8 dB[A])**

Figure 4.1: Example photographs of burlap drag surfaces and their OBSI levels.

4.1.2 Diamond Ground

Diamond grinding is a technique commonly used in California to correct texture and profile. Older diamond-ground sections included in this study were about 11 years old. A summary of the information for diamond grinding is presented in Table 4.2. Texture depth (macrotexture) is a possible reason for the variability in OBSI levels, in this case measured as the height of the fins left in the concrete between the diamond grinding blades. Photographs of example diamond ground surfaces are shown in Figure 4.2.

Table 4.2. Summary Information for Diamond Ground Sections

Number of sections evaluated Year 1	32 (*new:* 6, *aged:* 26, *worn out*: 0)
Number of sections evaluated Year 2	24 (*new:* 7, *aged:* 17, *worn out*: 0)
Average OBSI level (dB[A])	103.8
OBSI level interquartile range (dB[A])	102.8 – 105.1
OBSI level range (dB[A])	99.4 – 107.3
Range of surface age (years)	1.4 – 11.2

QP-155.1 (101.7 dB[A])

QP-147.1 (102.9 dB[A])

QP-132.3 (107.3 dB[A])

QP-134.1 (107.3 dB[A])

Figure 4.2: Example photographs of diamond ground surfaces and their OBSI levels.

4.1.3 Diamond Grooved

Prior to this testing, it was uncertain whether diamond grooving without diamond grinding had an effect on noise level because the grooves leave most of the contact area between the tire and the pavement unchanged, and therefore diamond grooving might not be as effective as diamond grinding for reducing the noise level on existing concrete pavements. However, based on this study's results for 19 diamond grooved sections and 32 diamond ground sections (7 and 24 sections in Year 2, respectively), the two techniques appear to yield similar OBSI levels. Comparison of Figure 3.33 (diamond ground) and Figure 3.35 (diamond grooved) shows that experiment samples of both texture types have similar ages, with less than 15 years since their last resurfacing. It can also be seen from Table 2.1 that the DG and Gr sample sections are distributed across both passenger car and truck lanes and in both dry and wet parts of state, except for the very wet North Coast region. A summary of the information for diamond grooved sections is presented in Table 4.3. Photographs of example diamond grooved surfaces are shown in Figure 4.3.

Table 4.3. Summary Information for Diamond Grooved Sections

Number of sections evaluated Year 1	19 (*new:* 0, *aged:* 19, *worn out*: 0)
Number of sections evaluated Year 2	7 (*new:* 0, *aged:* 7, *worn out*: 0)
Average OBSI level (dB[A])	103.6
OBSI level interquartile range (dB[A])	102.8 – 104.5
OBSI level range (dB[A])	101.7 – 106.3
Range of surface age (years)	2.3 – 12.1

QP-157.1 (103.2 dB[A]) QP-161.1 (103.2 dB[A])

QP-156.1 (104.7 dB[A]) QP-153.1 (106.1 dB[A])

Figure 4.3: Example photographs of diamond grooved surfaces and their OBSI levels.

4.1.4 Longitudinally Broomed

Longitudinally broomed pavement surface texture is uncommon on California highways. The difference between longitudinally broomed and burlap drag surface textures is only clear on surfaces that are not *worn out* (i.e., texture has not been worn off by traffic) and still show the striations caused by the texturing tool. The difference between the two techniques is less apparent in the case of *worn out* surfaces. In this study, the presence of striations of more than 1 or 2 mm depth (as evaluated subjectively from photographs) was considered reason to label a texture as longitudinally broomed. If only shallower striations or none were observed, then the section was labeled as having a burlap drag texture type. This resulted in a low number of longitudinally broomed sections, and affected the balance of the experimental factorial, complicating the interpretation of results. From a practical point of view, longitudinal brooming could be considered equivalent to a "heavy drag" texture. A summary of the information for longitudinally broomed sections is presented in Table 4.4. Photographs of example longitudinally broomed surfaces are shown in Figure 4.4.

Table 4.4: Summary Table for Longitudinally Broomed Sections

Number of sections evaluated Year 1	10 *(new:* 0, *aged:* 4, *worn out:* 6)
Number of sections evaluated Year 2	4 *(new:* 0, *aged:* 4, *worn out:* 0)
Average OBSI level (dB[A)])	102.3 (only *new* & *aged:* 102.0)
OBSI level interquartile range (dB[A])	101.9 – 102.7 (only *new* & *aged:* 101.3 – 102.6)
OBSI level range (dB[A])	101.1 – 104.1 (only *new* & *aged:* 101.1 – 103.0)
Range of surface age (years)	5.6 – 33.9

QP-146.3 (102.1 dB[A])

QP-146.2 (102.2 dB[A])

QP-146.1 (102.7 dB[A])

QP-162.1 (103.0 dB[A])

Figure 4.4: Example photographs of longitudinally broomed surfaces and their OBSI levels.

4.1.5 Longitudinally Tined

Longitudinal tining is the texture type most commonly found on California highways. Sections tested in the study ranged in surface age from several months to 42 years. The interquartile range reveals that 50 percent of the sections of this texture type are expected to fall between 103.7 and 105.6 dB(A). This is interesting because the longitudinal grooves that result from the tining process vary widely in depth, spacing, the amount of material displaced that protrudes from the surface, and how straight they are (often they appear to be "waves" of different wavelengths, but in other cases they are perfectly straight). Four examples of longitudinally tined sections are shown in Figure 4.5. A summary of the information for longitudinally tined sections is presented in Table 4.5.

Table 4.5: Summary Information for Longitudinally Tined Sections

Number of sections evaluated Year 1	21 (*new:* 6, *aged:* 12, *worn out:* 3)
Number of sections evaluated Year 2	18 (*new:* 3, *aged:* 12, *worn out:* 3)
Average OBSI level (dB[A])	104.8 (only *new* & *aged:* 104.7)
OBSI level interquartile range (dB[A])	103.7 – 105.6 (only *new* & *aged:* 103.7 – 105.5)
OBSI level range (dB[A])	102.7 – 106.8 (only *new* & *aged:* 102.7 – 106.8)
Range of surface age (years)	0.4 – 42.7

QP-158.1 (104.4 dB[A])

QP-127.3 (104.5 dB[A])

QP-101.1 (106.7 dB[A])

QP-100.2 (106.8 dB[A])

Figure 4.5: Example photographs of longitudinally tined surfaces and their OBSI levels.

4.1.6 Mojave Test Sections

Table 4.6, Figure 4.6, and Figure 4.7 present the results of the pavement sections in the Mojave test site (Kern 58). The quietest sections were those with a diamond-ground surface. Figure 4.6 shows the results of the sections averaged across the two years while Figure 4.7 shows each year of measurement individually, ordered by the Year 1 OBSI measured value. The one-year change on the Mojave sections in the reported data for the corrected OBSI values ranges from 0 to 1.6 dB(A), averaging 0.7 db(A), which is greater than expected. It should be noted that the effects of the error term for the tire correction equation discussed in Chapter 2 is accentuated on a small sample such as the Mojave sections. In this case, since there are only two years of data the error term is large relative to the expected annual change (noise to signal ratio), and the error does not get averaged out well on a small sample. Additional years of data will be needed to clarify the rate of change of OBSI on these sections.

The results at Mojave, which are all of the same concrete mix, traffic and climate, and of similar ages (some textured in 2003 and the others in 2006), were compared with the ranges of noise from the factorial experiment shown in Figure 3.24 and Figure 3.25. That comparison showed that the burlap drag, diamond ground, diamond grooved and longitudinally tined textures at Mojave are generally similar to or quieter than the same textures on the rest of the state highway network, while the longitudinally broomed texture at Mojave is noisier than nearly all of the longitudinally broomed sections measured on the rest of the network. These results again indicate that the variability within a given texture type is much greater than the differences between texture types, as measured in this study.

Table 4.6: Summary Information for Mojave Sections

Section ID	Location	Texture	Construction Year	Surfacing Year	OBSI Level Year 1	OBSI Level Year 2	Average Y1 and Y2
QP-159.1	06Ker58E110.3	BD	2003	2003	101.9	102.2	102.0
QP-155.1	06Ker58E110.6	DG	2003	2006	101.2	101.7	101.4
QP-160.1	06Ker58E110.0	DG	2003	2006	102.7	102.9	102.8
QP-166.1	06Ker58E111.7	DG	2003	2006	101.7	103.0	102.4
QP-154.1	06Ker58E110.2	Gr	2003	2006	102.1	103.7	102.9
QP-156.1	06Ker58E111.2	Gr	2003	2006	103.7	104.7	104.2
QP-157.1	06Ker58E111.4	Gr	2003	2006	102.1	103.2	102.7
QP-161.1	06Ker58E110.4	Gr	2003	2006	103.2	103.2	103.2
QP-162.1	06Ker58E111.5	LB	2003	2003	102.5	103.0	102.8
QP-158.1	06Ker58E109.5	LT	2003	2003	103.6	104.4	104.0

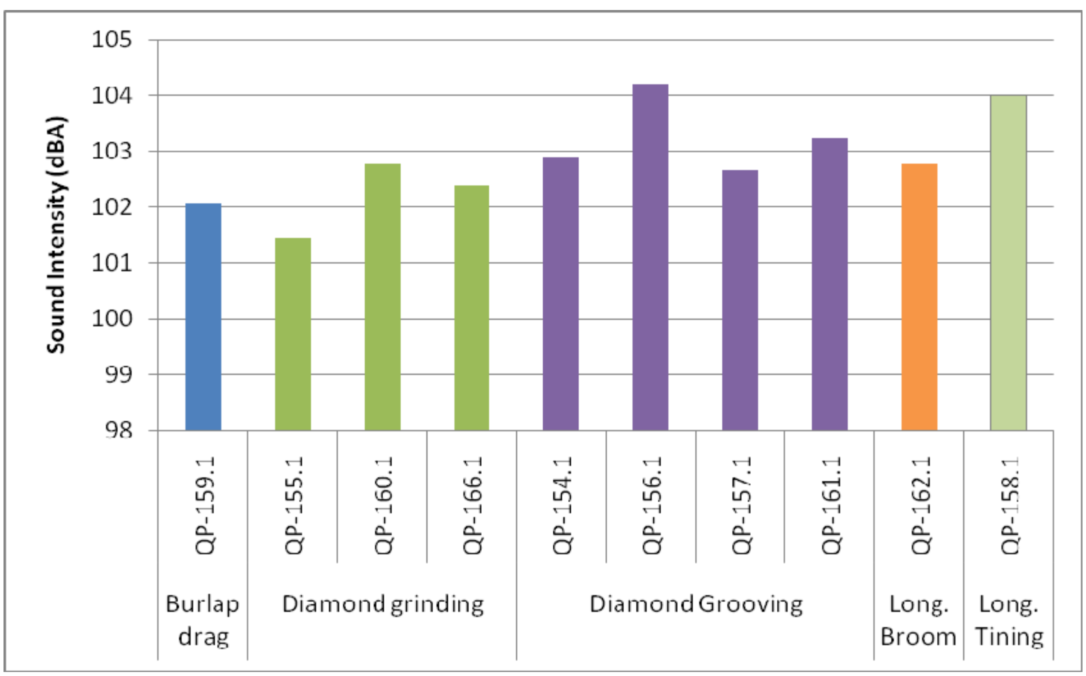

Figure 4.6: Comparison of OBSI noise levels of concrete pavement textures in Mojave sections averaged over the two years of measurement.

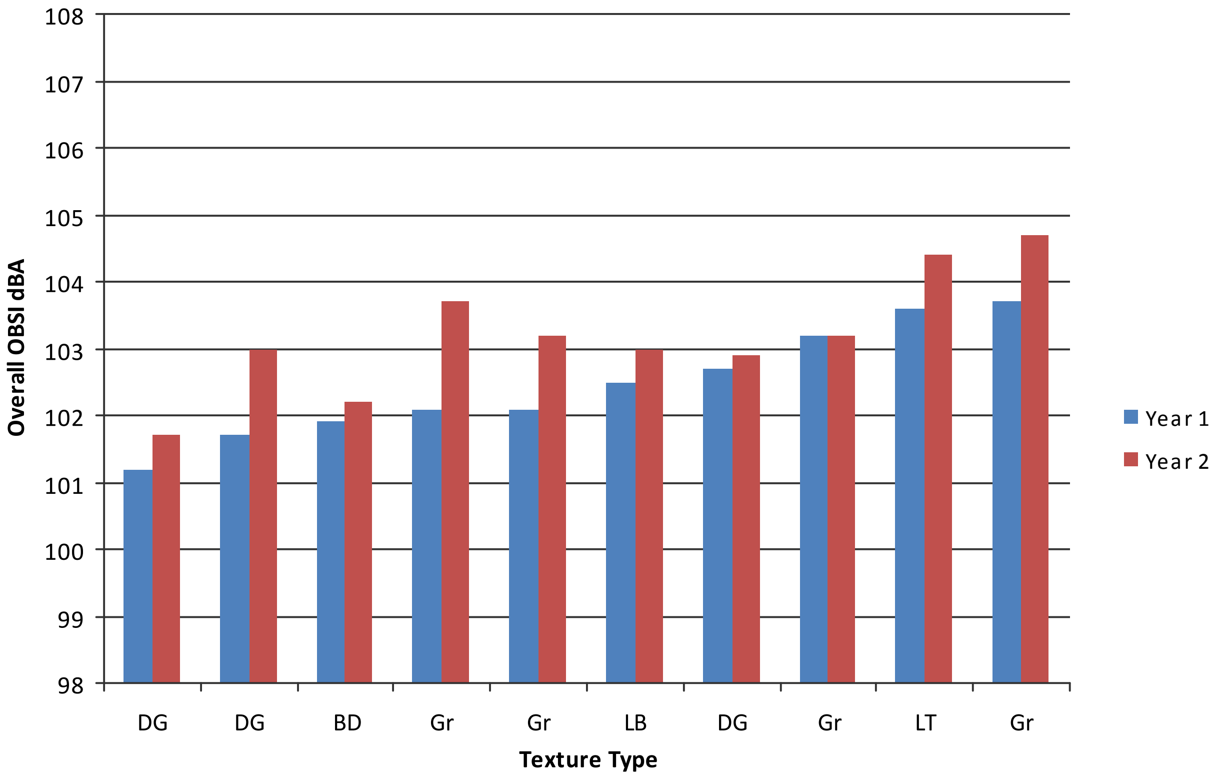

Figure 4.7: Comparison of average OBSI noise levels of concrete pavement textures in Mojave sections ranked from quietest to loudest in Year 1 (Year 1 on the left and Year 2 on the right).

4.2 Comparison with Previous Studies

A report in 2008 by the National Concrete Pavement Technology Center (NCPTC) *(4)* compiled tire/pavement noise data measured with the OBSI method from several locations around the United States, which indicated that diamond-ground pavements offer low levels of tire pavement noise. The study ranked four texture types as follows: (1) diamond ground, (2) burlap drag, (3) longitudinal tining, and (4) transverse tining. The NCPTC report did not include diamond grooved or longitudinally broomed concrete pavement sections. The study presented in this report included diamond grooved and longitudinally broomed texture types but did not include transverse tining, which has only been used on bridge decks and not pavements on California state highways.

Table 4.7 compares the rankings for the common texture types that are included in both reports. There is agreement between the 2008 NCPTC report and this study in that both found diamond-ground surfaces to be quieter than most surfaces; that longitudinally tined surfaces are generally noisier than diamond-ground surfaces; and, that tire/pavement noise levels on burlap drag sections were between those of diamond-ground and longitudinally tined surfaces.

Table 4.7: Ranked Order of Quieter Textures in this Study and Previous Research

Ranking in This Study	Ranking in the 2008 NCPTC Report
1. Longitudinally broomed	1. Diamond ground
2. Diamond grooved	2. Burlap drag
3. Diamond ground	3. Longitudinally tined
4. Burlap drag	4. Transversely tined
5. Longitudinally tined	

Although the rankings are similar, the OBSI levels included in the 2008 NCPTC report were consistently lower than those measured in this study, as can be seen in Figure 4.8 and Figure 4.9.

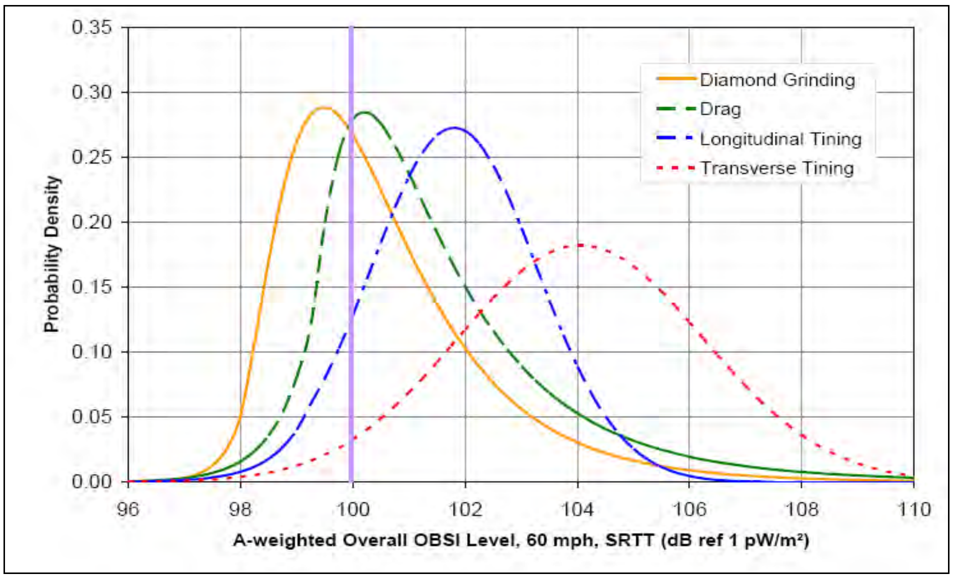

Figure 4.8: Probability distributions of OBSI noise levels for concrete pavement textures as reported by the National Concrete Pavement Technology Center *(4).*

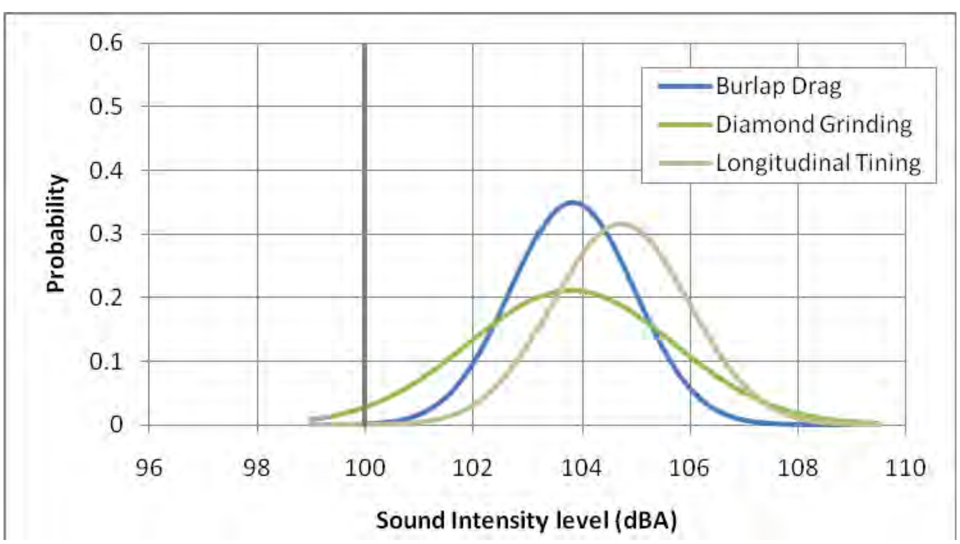

Figure 4.9: Distributions of OBSI noise levels in this study (excluding LB and Gr because of limited amount of data).

The NCPTC study has been ongoing, with a very large sample. It can be expected that results will change as more measurements are taken. A more recent conference presentation, titled "Quieter Concrete Pavements: An Update of Pooled Fund TPF-5(139)" in October 2010 at the Pavement Evaluation Conference in Roanoke, Virginia, indicates that the NCPTC data is indicating higher OBSI levels than those shown previously. Continued comparisons of California data and NCPTC data will be worthwhile to identify common conclusions and where California and NCPTC data differ, and comparison will provide better understanding of reasons for variability within surface textures.

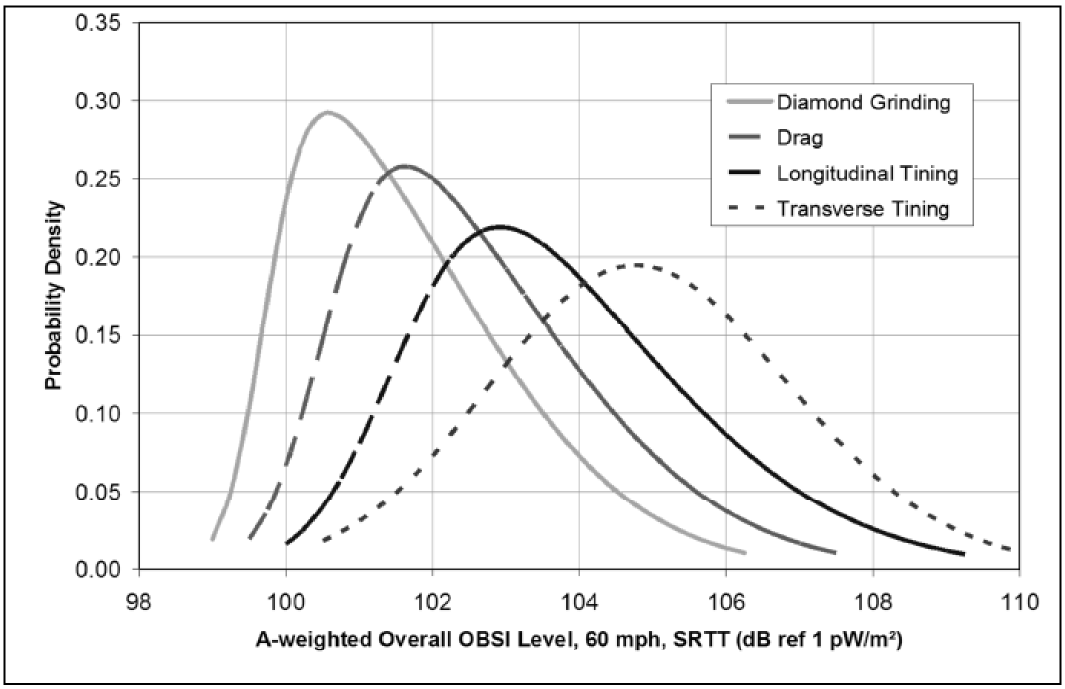

Figure 4.10: Updated probability distributions of OBSI noise levels for concrete pavement textures from NCPTC study.

5 CONCLUSIONS

The following conclusions can be drawn from the results found in this study.

The first set of conclusions pertains to the first objective of this study: To identify relationships between the design variables of concrete pavement surface textures and tire/pavement noise, covering the majority of surface textures used in California. The primary design variable investigated in this study was texture type, and the second was texture condition (*new, aged,* and *worn out*). Taking into account all sections, regardless of texture type, the OBSI levels on existing concrete pavements in California range from about 99 dB(A) to about 107 dB(A). The range does not change when the sections where the texture has been *worn out* (meaning that the constructed texture has been worn off by traffic) are removed. It is understood that the range was unchanged because of two cases introduced by the loss of texture: on texture types that lacked a significant amount of positive texture at construction, the wearing of traffic could produce a positive texture and increased OBSI, and alternately, texture types that had positive texture at construction could have that texture worn off by traffic, resulting in decreased OBSI. An example of the former case could be loss of paste around large aggregates, and an example of the latter case could be wearing off of fins from diamond grinding. These results indicate that a more in-depth investigation to characterize the textures should be included in the next years of this study. This will require texture measurements within traffic closures.

There is a large variation in tire/pavement noise level for each of the five texture types evaluated. The difference between the lowest and highest OBSI levels for the same nominal texture type could exceed 5 dB(A) without considering texture conditions, pavement age, and traffic and climatic conditions. Given that the average OBSI levels for the different texture types are similar to one another, this means that there is a large overlap in the OBSI levels for different types of surface textures that are found on the state highway network.

The comparison of the network results with those from the Mojave sections that have same the concrete mix and other variables showed that the burlap drag, diamond ground, diamond grooved, and longitudinally tined textures at Mojave are generally similar to or quieter than the same textures on the rest of the state highway network, while the longitudinally broomed texture at Mojave is noisier than nearly all of the longitudinally broomed sections measured on the rest of the network. This conclusion from the Mojave sections again indicates that a more in-depth characterization of the pavement textures—besides their nominal type and condition *(new, aged, worn out)*—is necessary to explain differences within texture type, such as the fact that the longitudinally broomed (LB) sections at Mojave are louder than other texture types at the same location, while other LB sections are generally quieter than other texture types.

The overall conclusion with regard to design variables is that texture type is not sufficient as a design variable to predict tire/pavement noise across the design life.

The second set of conclusions pertains to the second objective of this study: To determine trends in noise levels versus age for concrete pavements. It is clear from this study that the two years of data collected in this experiment is insufficient to develop equations for the rate of change of tire/pavement noise. The data presented in this report does not present clear trends for change in OBSI versus time. Better characterization of texture in conjunction with collection of OBSI over longer periods of time is necessary to develop better understanding of the effects of time and traffic on tire/pavement noise, and the changes in texture parameters that explain it.

The third set of conclusions pertains to the third objective of this study: To develop recommendations for concrete pavement surface textures that minimize tire/pavement noise. The ranking of texture types for the sections evaluated in this research project from quietest to loudest, without considering differences in age, traffic, or climate, is shown below.

1. Longitudinally broomed (small sample size, 102.0, *101.9 to 105.5)*
2. Diamond grooved (103.6, *101.7 to 106.3)*
3. Diamond ground (103.8, *99.4 to 107.3)*
4. Burlap drag (103.8, *101.1 to 103.0)*
5. Longitudinally tined (104.8, *102.7 to 106.8)*

(Key to values in parentheses: The first number indicates the average overall OBSI excluding *worn out* texture conditions, and the range of numbers in italic that follows indicates the minimum and maximum values of overall OBSI excluding sections with *worn out* textures.)

Although OBSI measurements on the diamond ground surfaces included the quietest in the entire sample (99.4 dB[A]), they also yielded a wide range of noise levels whose average exceeded that of the limited sample of longitudinally broomed sections. Out of the five textures evaluated, longitudinal tining was the loudest, regardless of age, and cannot be the recommended texture when the only concern is tire/pavement interaction noise. Longitudinally broomed textures appear to be adequate because on average they are quieter than the other textures and tire/pavement noise from them seems to have little increase over time. However, only a very limited number of sections of this texture type could be included in this study. Longitudinally broomed and burlap drag textures may not be good options in some places because of their possible lack of capacity to evacuate water from under tires, which is an issue outside the scope of this study. Longitudinal tining could be an option but since it was found to produce higher OBSI levels than diamond grooving, the latter should probably be preferred between the two. From a cost point of view (which was not evaluated in the study), longitudinal tining might be preferred over diamond grooving.

The measured OBSI levels include the effects of joint slap, faulting, and sealant providing positive texture (referred to as overbanding), all of which would increase the OBSI level if they are present. These effects were not separated. Faulting and overbanded sealant could not be considered because no method for measuring faulting and overbanding using the profilometer was available, and traffic closures were not included in the budget for the project to permit manual measurements. Some initial analysis was performed regarding the combined effects of joint slap, faulting, and sealing of the joints on overall OBSI measurements. However, there was insufficient funding in the project to fully analyze and consider these effects in the results.

In summary, where quieter pavement is needed, the data collected to date indicate that each of the textures evaluated can produce pavements with OBSI less than 102 dB(A). All of the textures evaluated were generally quieter than the longitudinally tined sections. However, the factors that control tire/pavement noise for a given texture type, and which produce the wide range of tire/pavement noise measured for each texture, could not be measured as part of this study.

It is therefore recommended that diamond-grooving, diamond-grinding, and longitudinal-tining techniques be further investigated to better understand the wide range of OBSI values, so that best practice can be identified to consistently reduce their OBSI levels. It is recommended that the next steps in the Caltrans QPR study of concrete pavements include better characterization of the textures on the sections, expansion of the experiment to better consider age, climate, and traffic levels, and inclusion of new generation concrete textures that are currently being constructed in the state. It is also recommended that the effects of faulting, overbanding of sealant, and joint slap should be considered in future surveys of concrete pavement noise separately from the effects of texture. As part of that effort, data should be collected to develop a model (theoretical if possible, empirical if not) that will permit calculation of the effects of joint faulting and sealant overbanding on the total measured tire/pavement noise.

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APPENDIX A: PHOTOGRAPHS OF SURFACE TEXTURE

Two photographs of the same texture type are shown on each page, displaying the surface texture as observed with the camera held directly on the pavement surface. The top and bottom photographs show respectively sections with low and high OBSI level. Surface type, section ID, and OBSI level are presented in the caption.

Figure A.1: Burlap drag, OBSI=103.0 dB(A) (Section QP-102.2).

Figure A.2: Burlap drag, OBSI=107.3 dB(A) (Section QP-130.1).

Figure A.3: Diamond ground, OBSI=99.4 dB(A) (Section QP-103.3).

Figure A.4: Diamond ground, OBSI=107.2 dB(A) (Section QP-132.2).

Figure A.5: Diamond grooved, OBSI=101.7 dB(A) (Section QP-138.3).

Figure A.6: Diamond grooved, OBSI=105.6 dB(A) (Section QP-153.2).

Figure A.7: Longitudinally broomed, OBSI=101.1 dB(A) (Section QP-146.3).

Figure A.8: Longitudinally broomed, OBSI=104.1 dB(A) (Section QP-112.3).

Figure A.9: Longitudinally tined, OBSI=102.7 dB(A) (Section QP-117.2).

Figure A.10: Longitudinally tined, SI=105.5 dB(A) (Section QP-101.2).

APPENDIX B: OBSI BAR CHARTS

The overall OBSI levels of each section measured in Year 1 and Year 2 are presented here.

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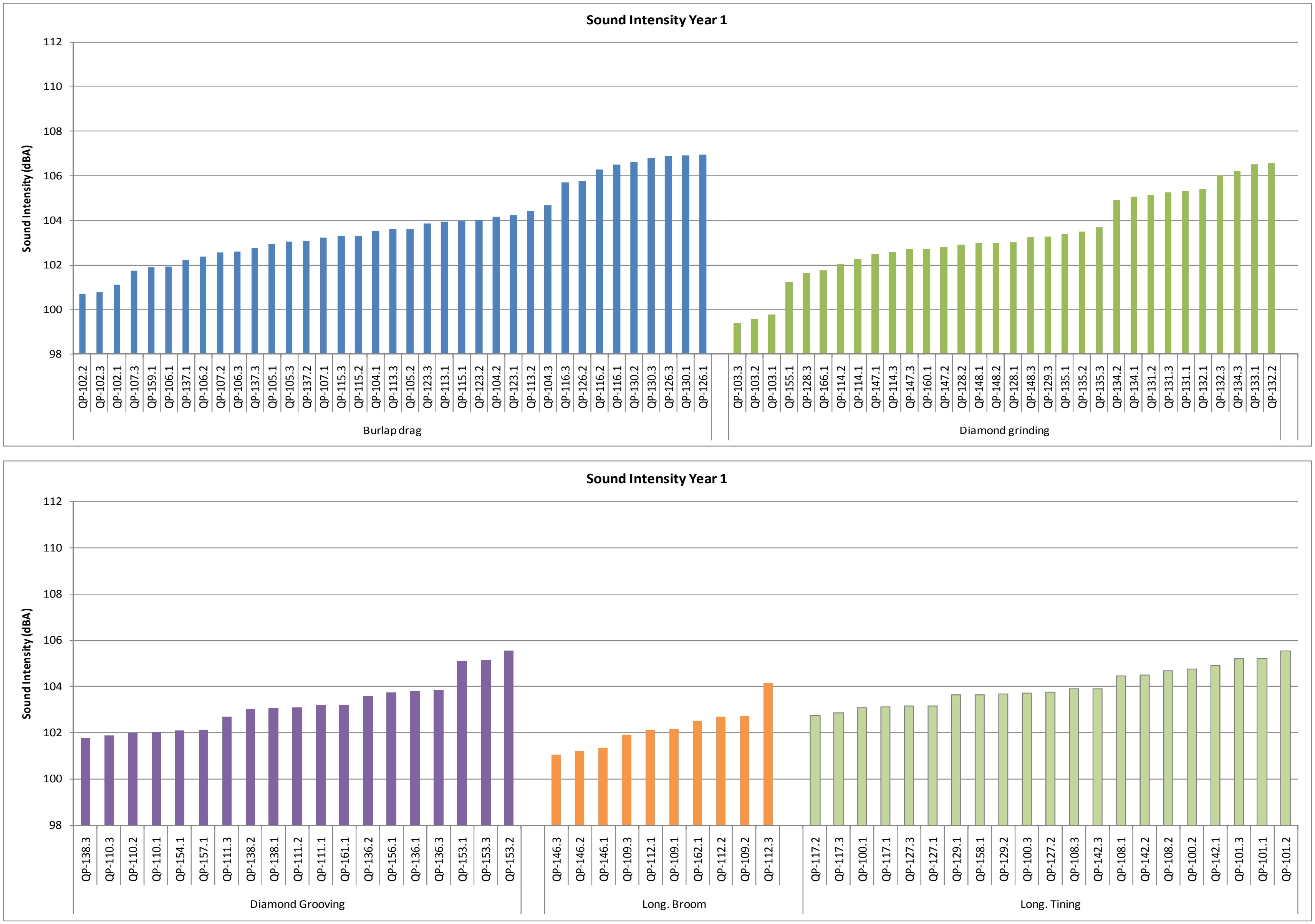
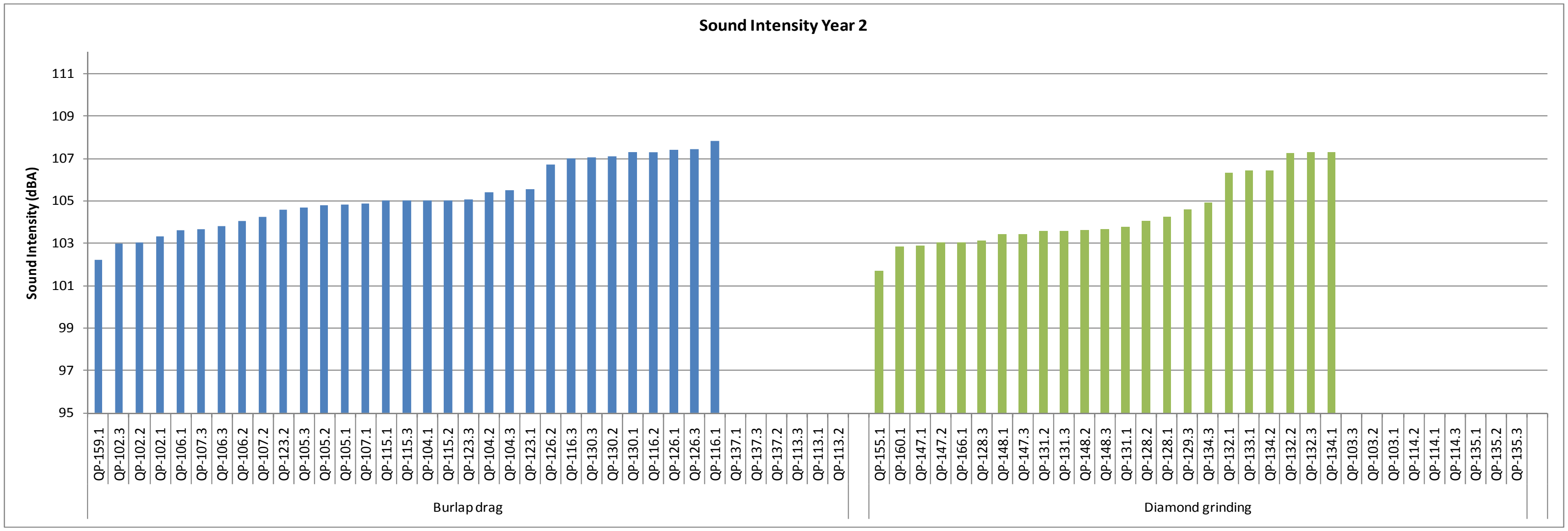


Figure B.1: On-board Sound Intensity levels of all sections as measured in Year 1.



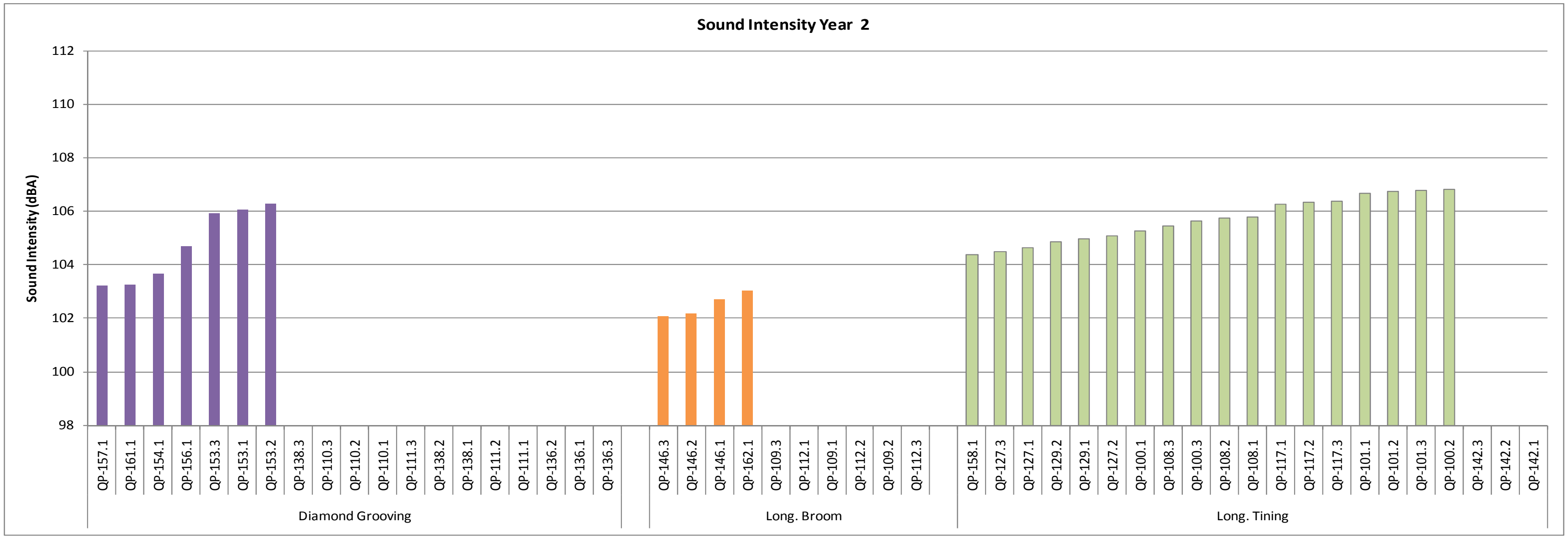


Figure B.2: On-board Sound Intensity levels of all sections as measured in Year 2.

APPENDIX C: SITE WITH LARGE ONE-YEAR INCREASE IN NOISE LEVEL

The pavement at Sections QP-142.1, 142.2, and 142.3 all experienced a large increase in noise level from Year 1 to Year 2. The increase was due to an unusual rapid wearing of the longitudinal texture, which disappeared completely, leaving a surface where the concrete paste was recessed and the aggregates were exposed and protruding. The average OBSI values of these sections changed from 104.4 dBA (104.9, 104.5, and 103.9) to 111.8 dBA (111.4, 111.2, and 112.6), an increase of 7.4 dBA.

Images of the surface texture of Sections QP-142.1 and QP-142.3 at approximately the same spots are shown in Appendix D, with the pictures on the left taken in November 2008 and the ones on the right in September 2009. This pavement was new—it had been opened to traffic in the summer of 2008—and is located at 5,900 feet above sea level, where it was subjected to chain wear during snow season. Appendix D shows that the longitudinal tining remains outside the wheelpath, while it has been completely obliterated in the wheelpaths by the chains.

Figure C.1: Change in texture after one year at Sections QP-142.1 (top) and QP-142.3 (bottom).

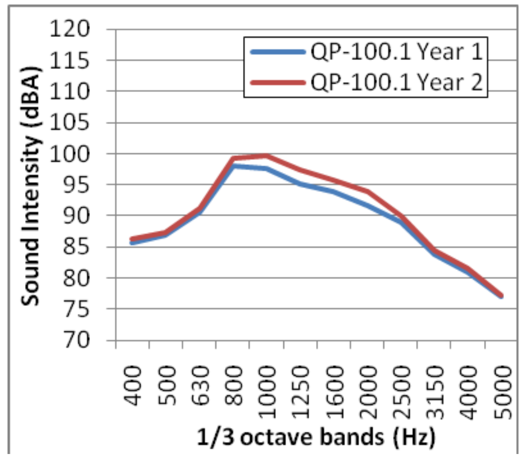
Figure C.2: Evidence of original longitudinal tines outside of the wheelpaths of Section QP-142.2 after one year of traffic.

APPENDIX D: SECTION DETAILS, PICTURES, AND OBSI SPECTRA

QP-100.1

Type of section: Pavement Field testing Year 1: 9/3/2008 15:09
Location: 03Yol113N3.0 Field testing Year 2: 9/4/2009 14:07
Comments: Longitudinally tined. Aggressive texture, sealed joints.
Surface Year: 1976

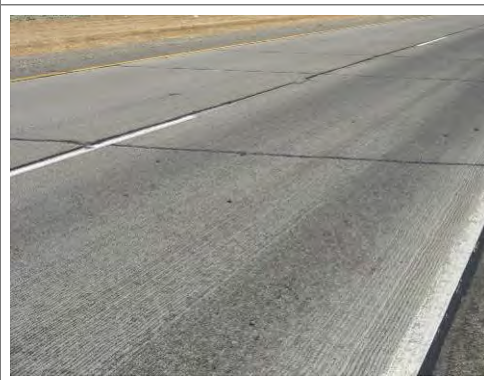
Onboard picture Year 1



Texture detail

Texture detail

Google Earth view

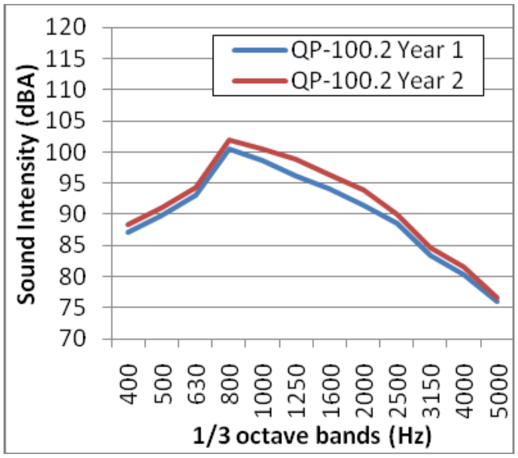


General view

QP-100.2

Type of section: Pavement Field testing Year 1: 9/3/2008 15:59
Location: 03Yol113N3.1 Field testing Year 2: 9/4/2009 14:24
Comments: Longitudinally tined. Aggressive texture, sealed joints.
Surface Year: 1976

Onboard picture Year 1



Texture detail

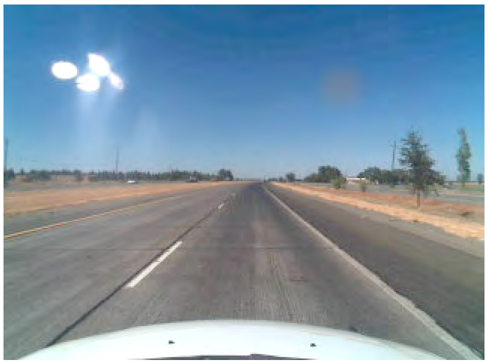
Texture detail

Google Earth view

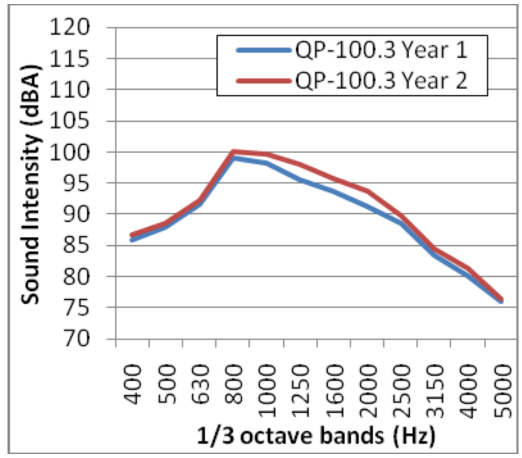
General view

QP-100.3

Type of section: Pavement Field testing Year 1: 9/3/2008 16:10
Location: 03Yol113N3.2 Field testing Year 2: 9/4/2009 14:40
Comments: Longitudinally tined. Aggressive texture, sealed joints.
Surface Year: 1976

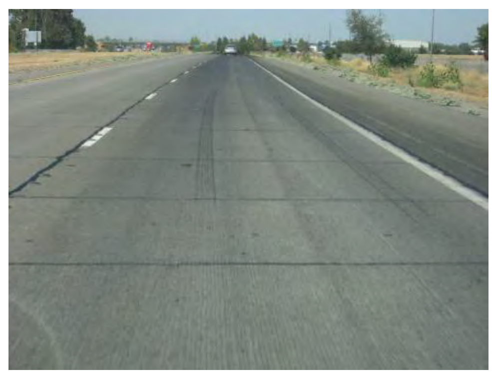


Onboard picture Year 1

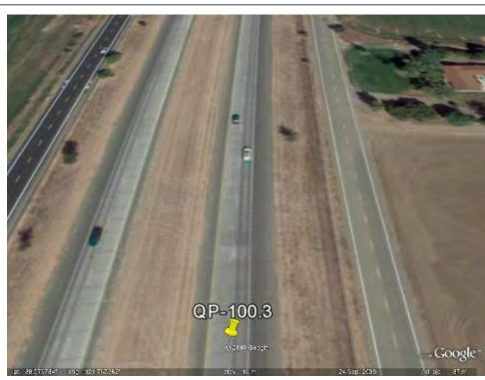


Onboard picture Year 2

Texture detail



Texture detail



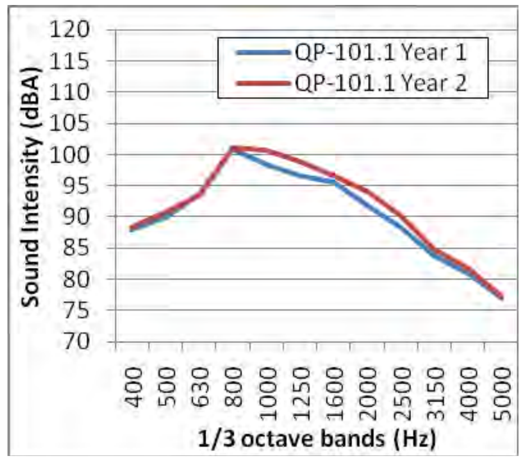
Google Earth view

General view

QP-101.1

Type of section: Pavement Field testing Year 1: 9/23/2008 10:42
Location: 03Yol113N6.0 Field testing Year 2: 9/4/2009 14:16
Comments: Longitudinally tined. Deep tining. Rubber built-up.
Surface Year: 1990

Onboard picture Year 1



Texture detail

Texture detail

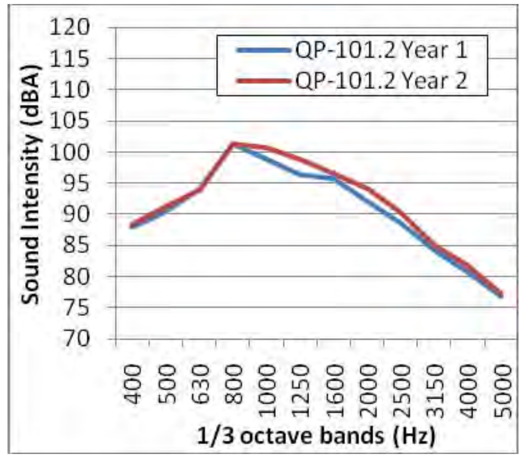
Google Earth view

General view

QP-101.2

Type of section: Pavement Field testing Year 1: 9/23/2008 11:00
Location: 03Yol113N6.1 Field testing Year 2: 9/4/2009 14:29
Comments: Longitudinally tined. Deep tines. Rubber built-up. Overcross at middle of section.
Surface Year: 1990

Onboard picture Year 1



Texture detail

Texture detail

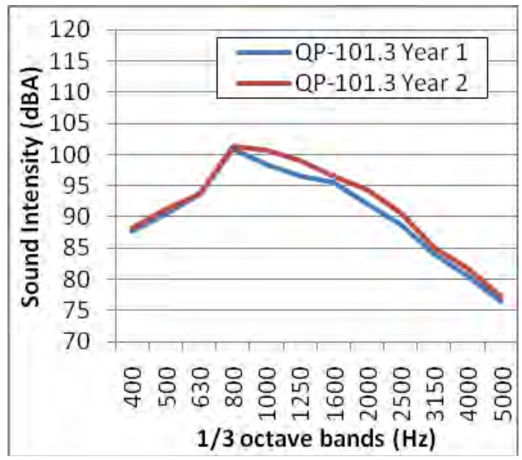
Google Earth view

General view

QP-101.3

Type of section: Pavement Field testing Year 1: 9/23/2008 11:09
Location: 03Yol113N6.2 Field testing Year 2: 9/4/2009 14:46
Comments: Longitudinally tined. Deep tines. Rubber built-up.
Surface Year: 1990

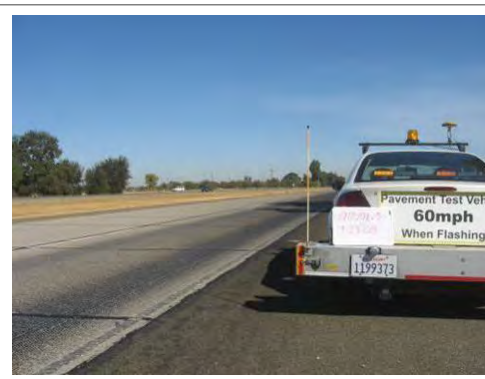
Onboard picture Year 1



Texture detail

Joint detail

Google Earth view

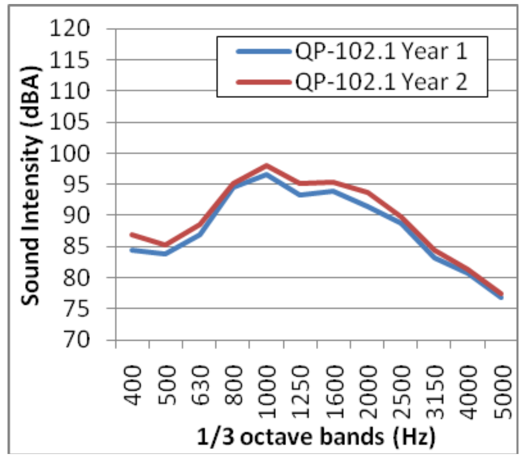


General view

QP-102.1

Type of section: Pavement Field testing Year 1: 9/23/2008 13:12
Location: 03Yol113S5.5 Field testing Year 2: 9/4/2009 14:20
Comments: Burlap drag. Rubber built-up, some transverse cracks.
Surface Year: 1976

Onboard picture Year 1



Texture detail

Texture detail

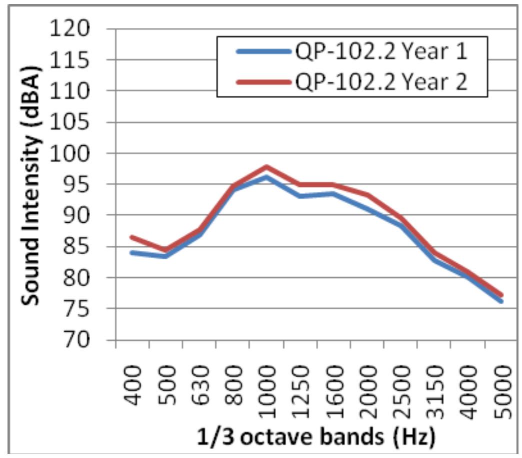
Google Earth view

Joints view

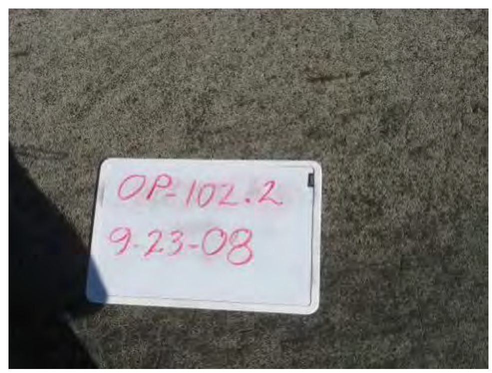
QP-102.2

Type of section: Pavement   Field testing Year 1: 9/23/2008 13:46
Location: 03Yol113S5.4   Field testing Year 2: 9/4/2009 14:49
Comments: Burlap drag. Rubber built-up, some transverse cracks.
Surface Year: 1976

Onboard picture Year 1



Texture detail



Texture detail

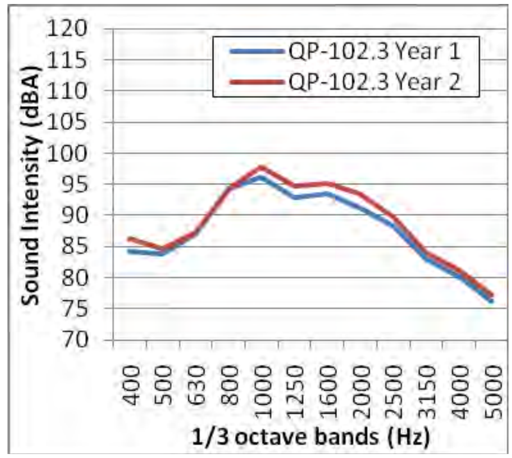
Google Earth view

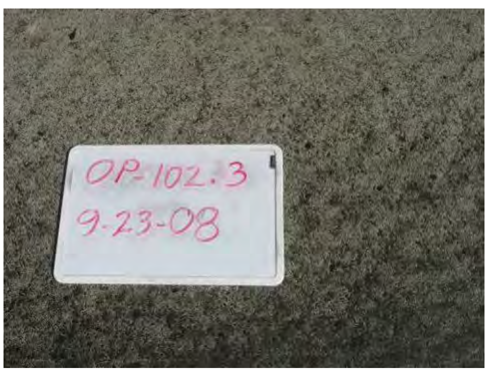
Joint & crack view

QP-102.3

Type of section: Pavement
Location: 03Yol113S5.3
Field testing Year 1: 9/23/2008 13:58
Field testing Year 2: 9/4/2009 14:49
Comments: Burlap drag. Rubber build-up, some transverse cracks.
Surface Year: 1976

Onboard picture Year 1





Texture detail

Texture detail

Google Earth view

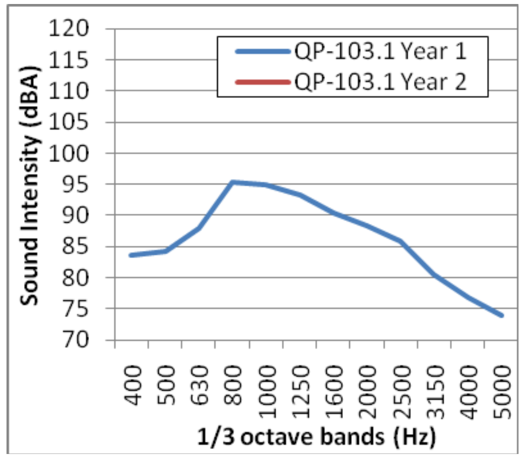
Joint & crack view

QP-103.1

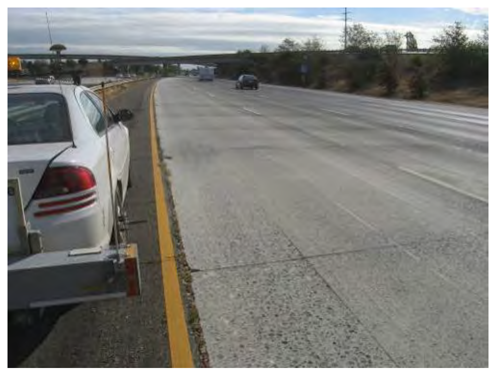
Type of section: Pavement
Location: 03Yol50E0.2
Comments: Diamond ground.
Surface Year: 2005

Field testing Year 1: 10/2/2008 10:35
Field testing Year 2:

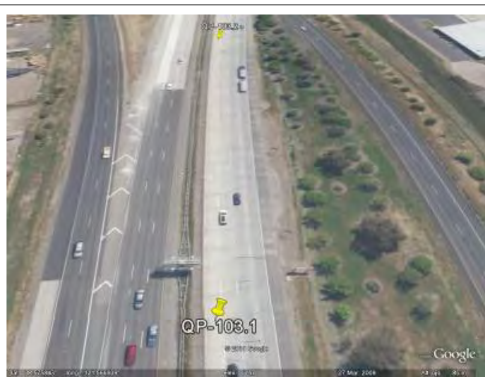
Onboard picture Year 1



Texture detail



Texture detail



Google Earth view

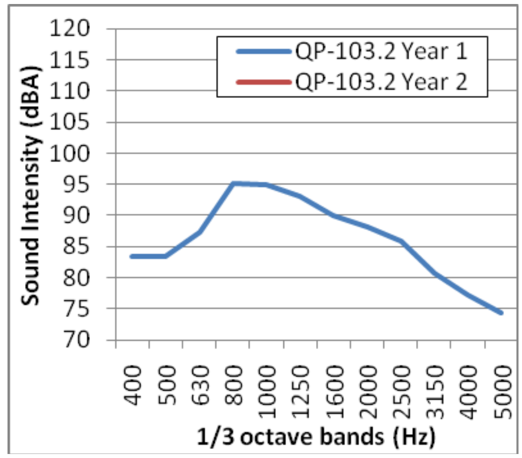
General view

QP-103.2

Type of section: Pavement
Location: 03Yol50E0.2
Comments: Diamond ground.
Surface Year: 2005

Field testing Year 1: 10/2/2008 10:35
Field testing Year 2:

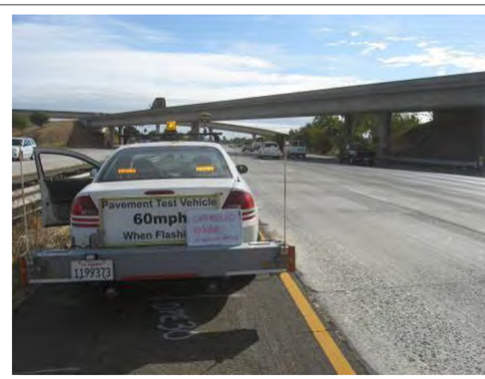
Onboard picture Year 1



Texture detail

Texture detail

Google Earth view



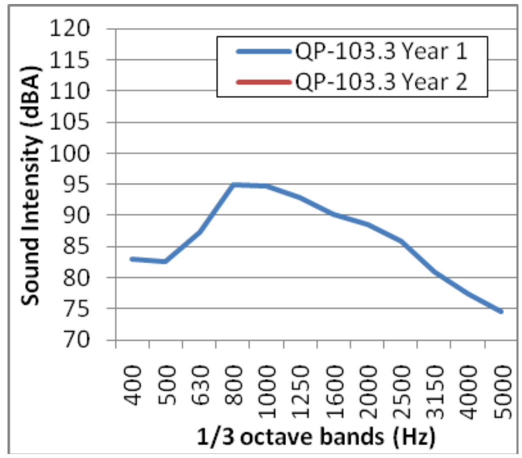
General view

QP-103.3

Type of section: Pavement
Location: 03Yol50E0.3
Comments: Diamond ground.
Surface Year: 2005

Field testing Year 1: 10/2/2008 10:45
Field testing Year 2:

Onboard picture Year 1



Texture detail

Texture & joint detail

Google Earth view

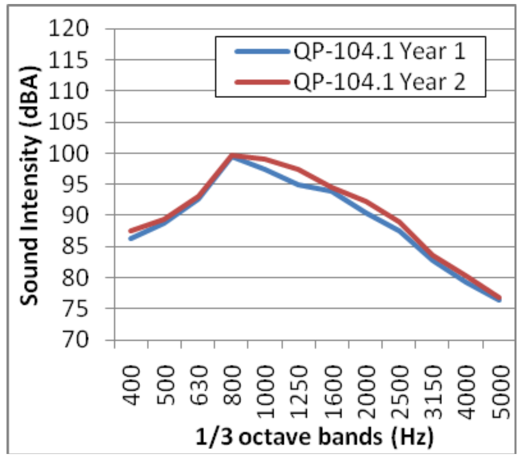
General view

QP-104.1

Type of section: Pavement
Location: 03Sac50E3.2
Comments: Burlap drag. Worn BD.
Surface Year: 1971

Field testing Year 1: 10/3/2008 13:56
Field testing Year 2: 9/11/2009 11:12


Onboard picture Year 1




Texture detail


Joint detail

Google Earth view

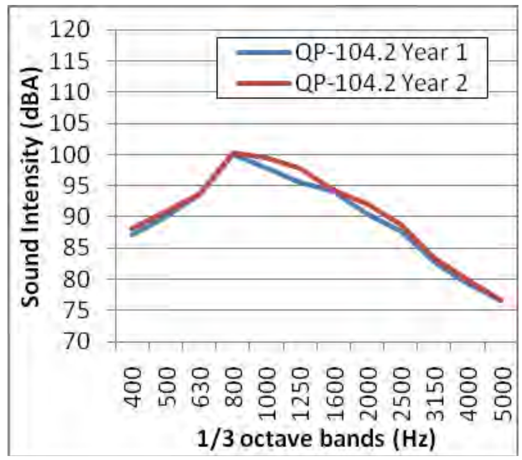
General view

QP-104.2

Type of section: Pavement
Location: 03Yol50E0.4
Comments: Burlap drag.
Surface Year: 1971

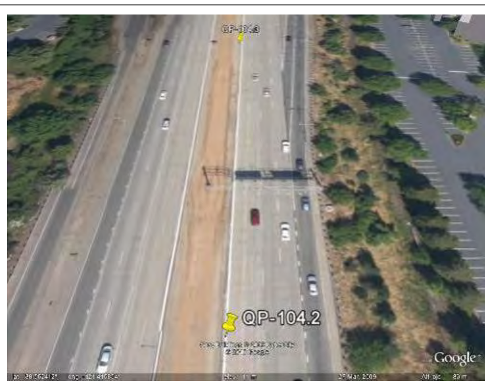
Field testing Year 1: 10/2/2008 10:56
Field testing Year 2:

Onboard picture Year 1



Texture detail

Joint detail



Google Earth view

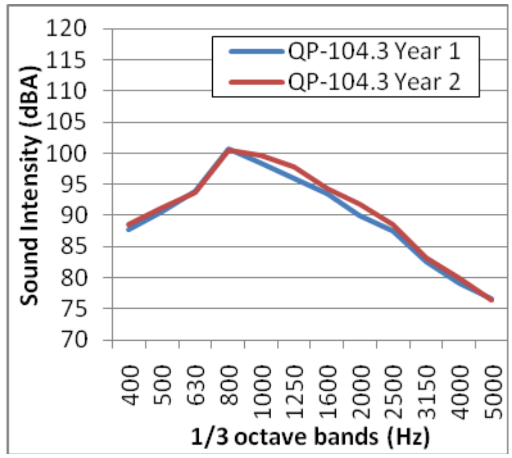
General view

QP-104.3

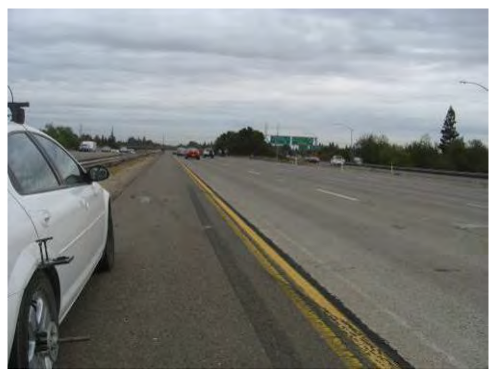
Type of section: Pavement
Location: 03Sac50E3.2
Comments: Burlap drag. moderately worn BD.
Surface Year: 1971

Field testing Year 1: 10/3/2008 13:56
Field testing Year 2: 9/11/2009 11:12

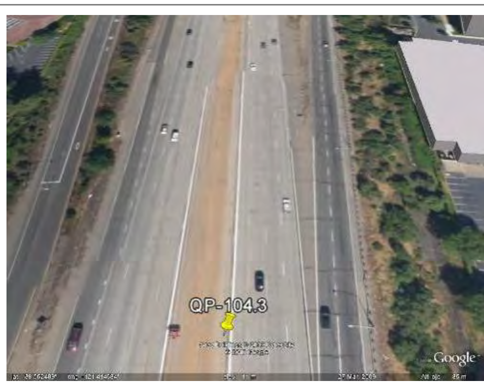
Onboard picture Year 1



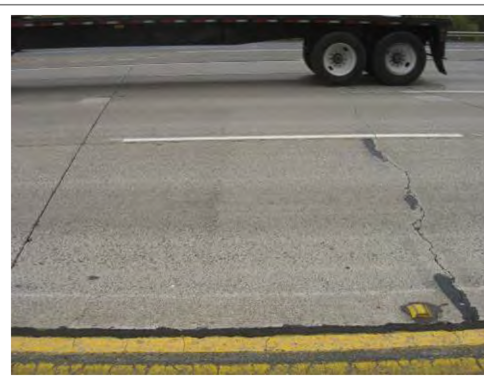
Texture detail



General view



Google Earth view

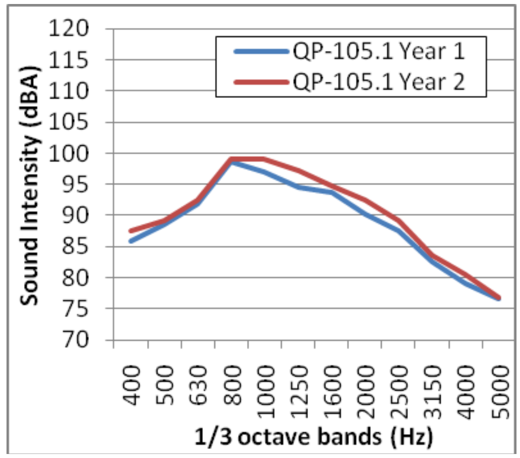


General view

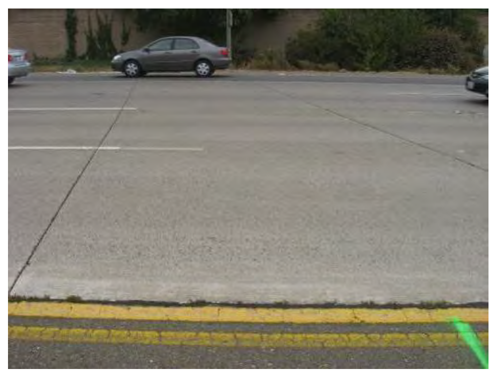
QP-105.1

Type of section: Pavement Field testing Year 1: 10/3/2008 14:00
Location: 03Sac50E4.0 Field testing Year 2: 9/11/2009 11:43
Comments: Burlap drag. Worn texture, unsealed joints.
Surface Year: 1971

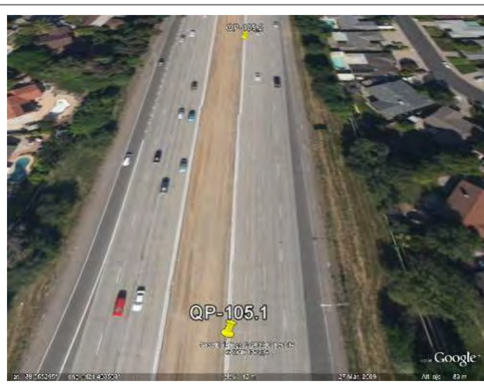
Onboard picture Year 1



Texture detail



Joint detail



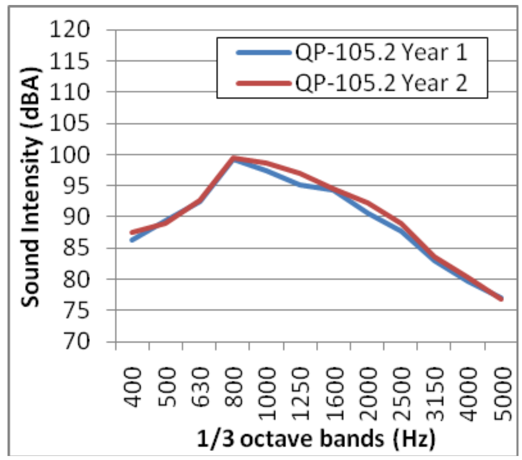
Google Earth view

General view

QP-105.2

Type of section: Pavement Field testing Year 1: 10/3/2008 14:11
Location: 03Sac50E4.1 Field testing Year 2: 9/11/2009 11:55
Comments: Burlap drag. Worn texture, unsealed joints.
Surface Year: 1971

Onboard picture Year 1



Texture detail

Joint detail

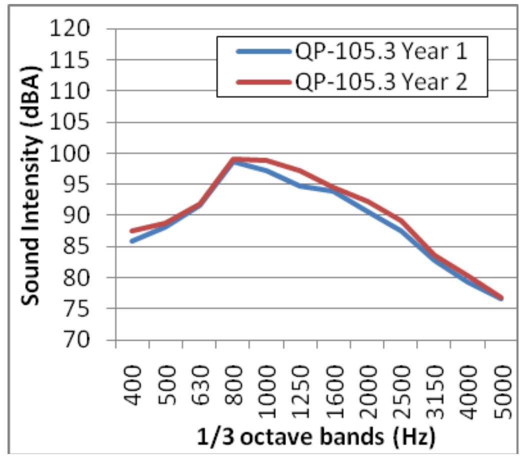
Google Earth view

General view

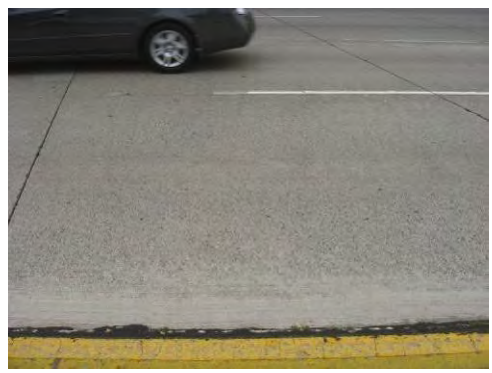
QP-105.3

Type of section: Pavement
Field testing Year 1: 10/3/2008 14:46
Location: 03Sac50E4.2
Field testing Year 2: 9/11/2009 12:06
Comments: Burlap drag. Worn texture, unsealed joints.
Surface Year: 1971

Onboard picture Year 1

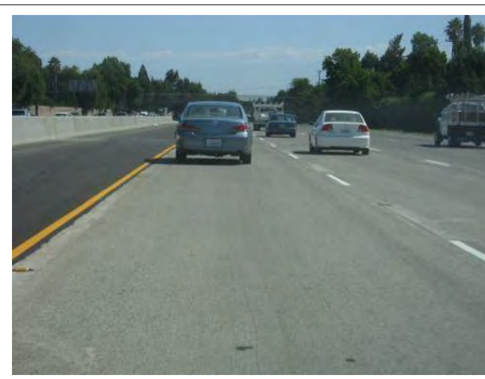


Texture detail



Joint detail

Google Earth view

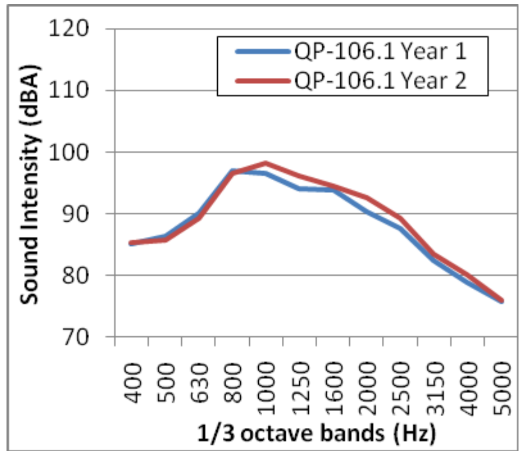


General view

QP-106.1

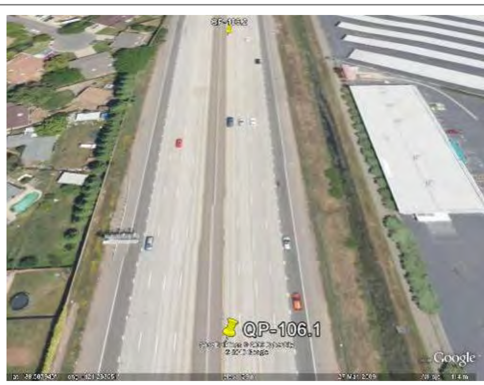
Type of section: Pavement	Field testing Year 1: 10/13/2008 14:48
Location: 03Sac50E10.5	Field testing Year 2: 9/11/2009 14:11
Comments: Burlap drag. Worn texture, unsealed joints.
Surface Year: 1973

Onboard picture Year 1

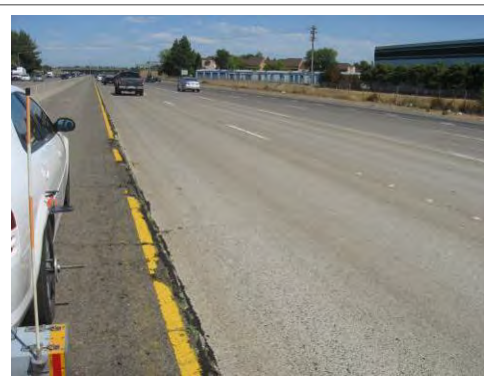


Texture detail

Joint detail



Google Earth view

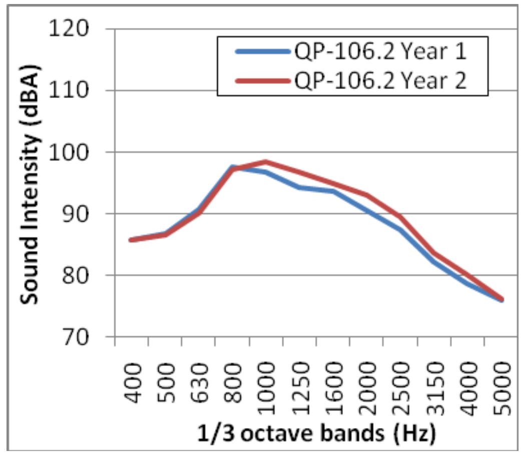


General view

QP-106.2

Type of section: Pavement Field testing Year 1: 10/13/2008 14:55
Location: 03Sac50E10.6 Field testing Year 2: 9/11/2009 14:36
Comments: Burlap drag. Worn texture, unsealed joints.
Surface Year: 1973

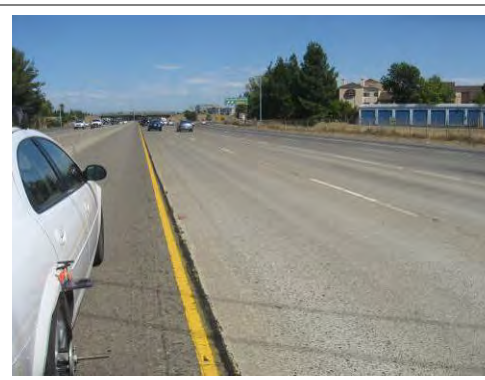
Onboard picture Year 1



Texture detail

Joint detail

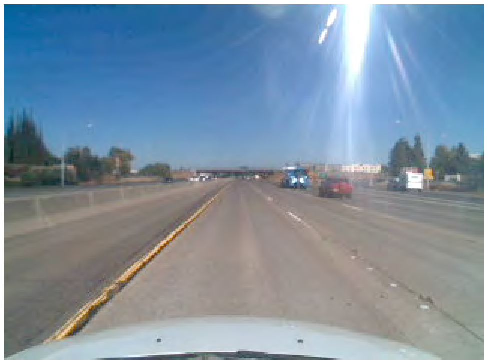
Google Earth view



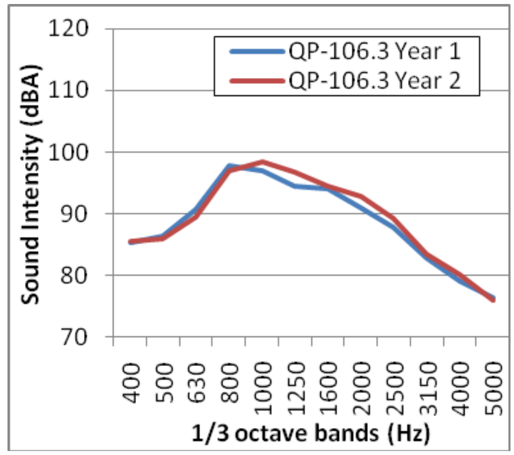
General view

QP-106.3

Type of section: Pavement　　Field testing Year 1: 10/13/2008 15:14
Location: 03Sac50E10.7　　Field testing Year 2: 9/11/2009 14:42
Comments: Burlap drag. Worn texture, unsealed joints.
Surface Year: 1973

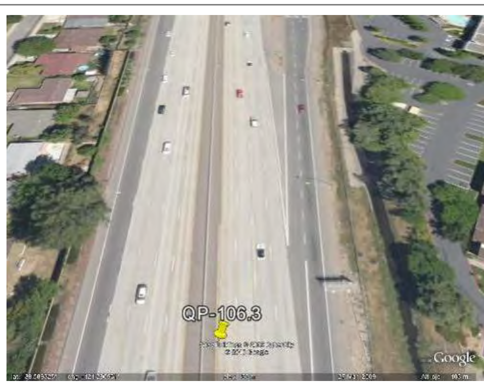


Onboard picture Year 1



Texture detail

Texture detail



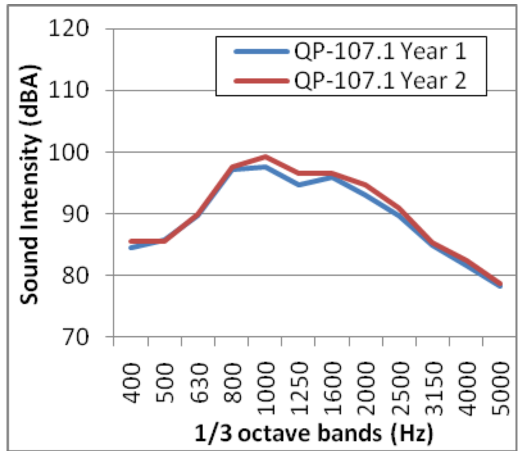
Google Earth view

General view

QP-107.1

Type of section: Pavement   Field testing Year 1: 10/16/2008 14:23
Location: 03Sac80E13.6   Field testing Year 2: 9/9/2009 13:03
Comments: Burlap drag. Shallow texture.
Surface Year: 1973

Onboard picture Year 1



Texture detail

Joint detail

Google Earth view

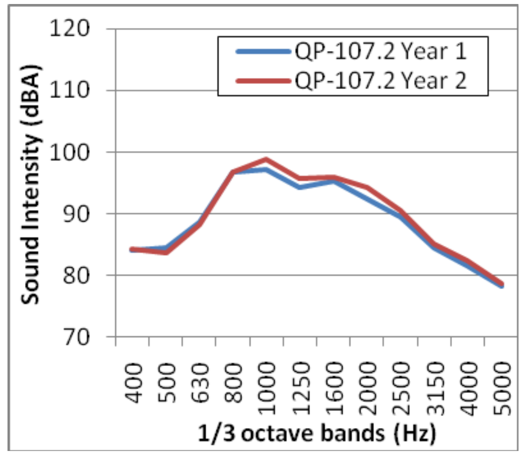
General view

QP-107.2

Type of section: Pavement
Location: 03Sac80E13.7
Comments: Burlap drag. Shallow texture.
Surface Year: 1973

Field testing Year 1: 10/16/2008 14:29
Field testing Year 2: 9/9/2009 13:14

Onboard picture Year 1



Texture detail

Joint detail

Google Earth view

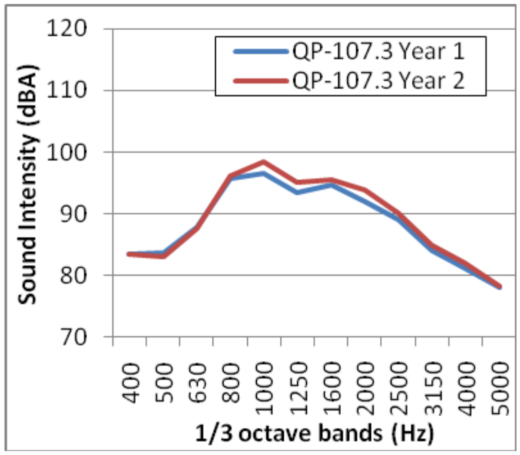
General view

QP-107.3

Type of section: Pavement
Location: 03Sac80E13.8
Comments: Burlap drag. Shallow texture.
Surface Year: 1973

Field testing Year 1: 10/16/2008 14:36
Field testing Year 2: 9/9/2009 13:18

Onboard picture Year 1



Texture detail

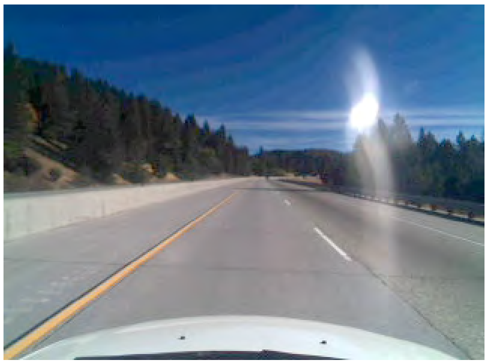
Joint detail

Google Earth view

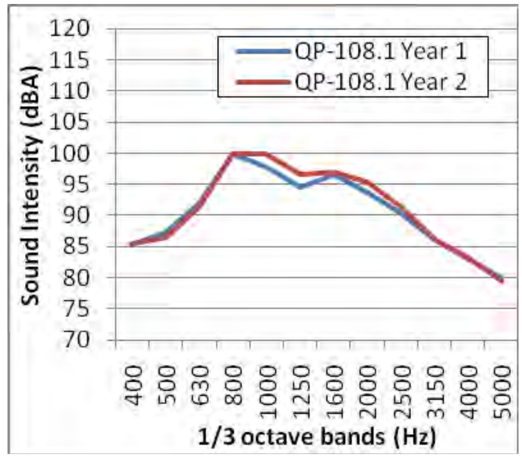
General view

QP-108.1

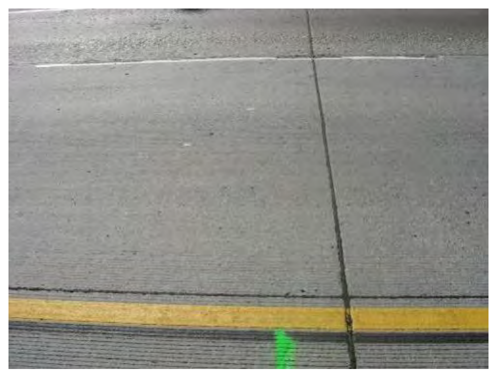
Type of section: Pavement Field testing Year 1: 10/21/2008 11:24
Location: 03Pla80E45.0 Field testing Year 2: 9/16/2009 12:26
Comments: Longitudinally tined. Shallow texture, worn out.
Surface Year: 2004



Onboard picture Year 1

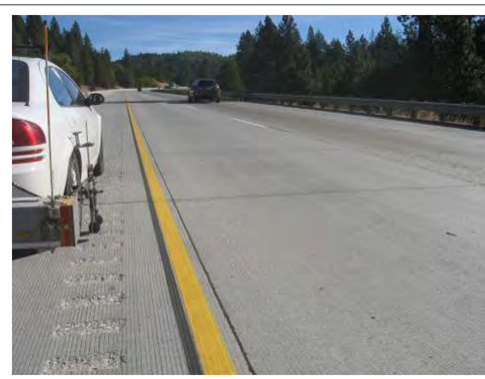


Texture detail



Joint detail

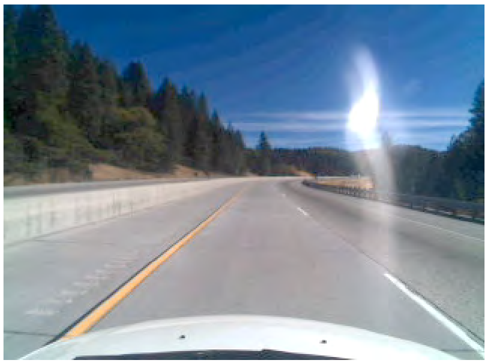
Google Earth view



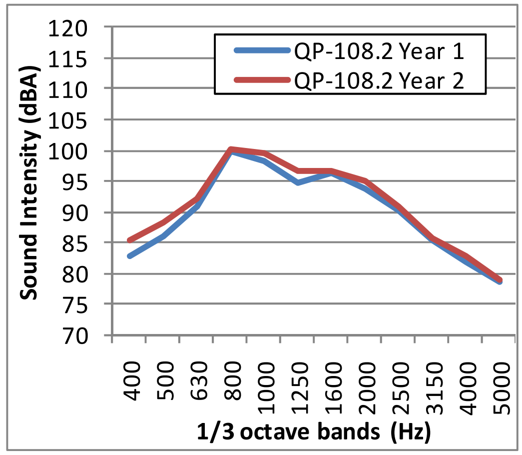
General view

QP-108.2

Type of section: Pavement Field testing Year 1: 10/21/2008 11:42
Location: 03Pla80E45.1 Field testing Year 2: 9/16/2009 12:35
Comments: Longitudinally tined. Texture shallower than 108.1.
Surface Year: 2004



Onboard picture Year 1



Texture detail

Joint detail

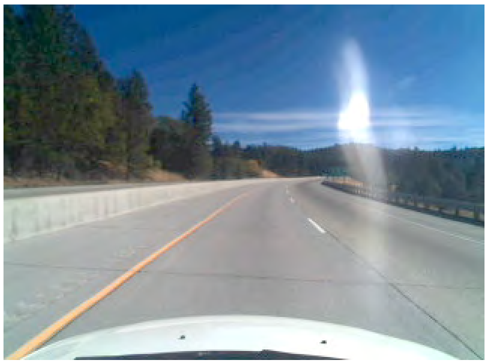
Google Earth view

General view

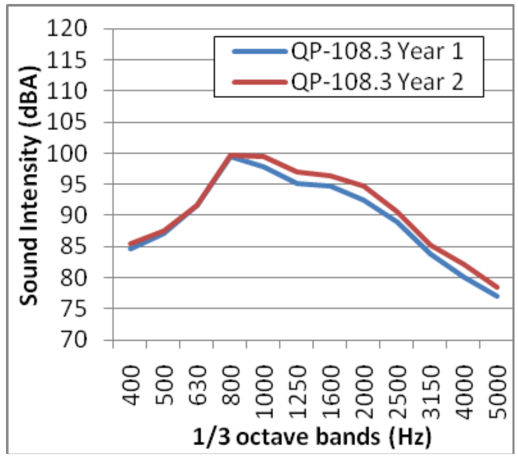
QP-108.3

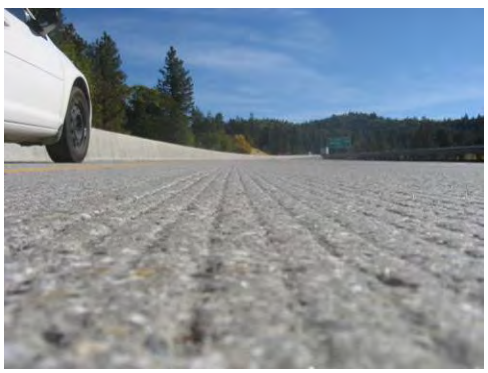
Type of section: Pavement
Location: 03Pla80E45.2
Comments: Longitudinally tined. Texture deeper than 108.1.
Surface Year: 2004

Field testing Year 1: 10/21/2008 11:48
Field testing Year 2: 9/16/2009 12:45



Onboard picture Year 1

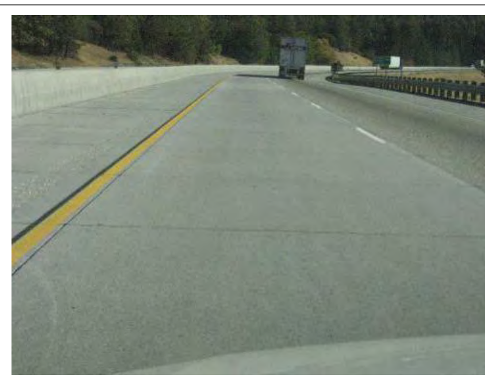




Texture detail

Joint detail

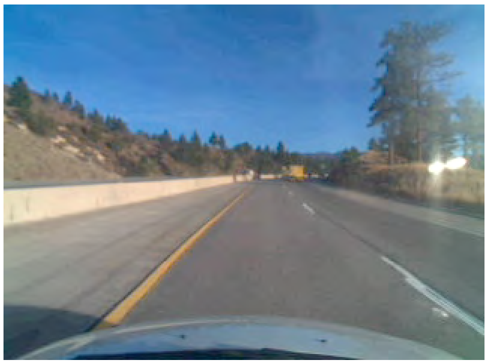
Google Earth view



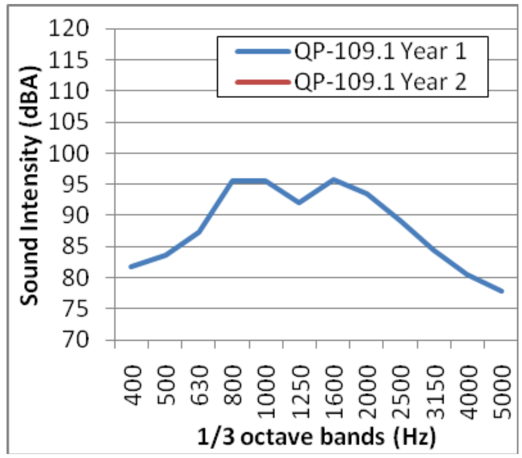
General view

QP-109.1

Type of section: Pavement
Field testing Year 1: 10/21/2008 17:02
Location: 03Nev80E22.6
Field testing Year 2:
Comments: Longitudinally broomed. Worn out texture.
Surface Year: 1989



Onboard picture Year 1



Texture detail

Joint detail

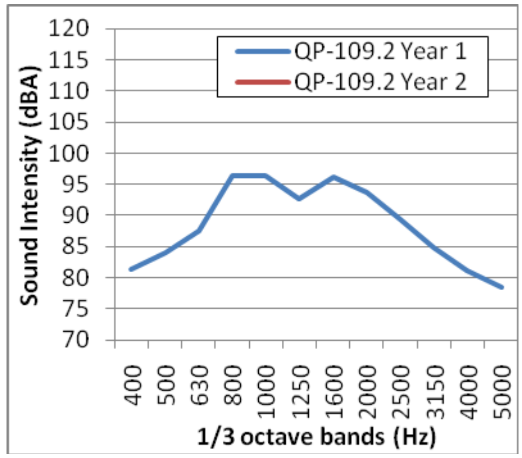
Google Earth view

General view

QP-109.2

Type of section: Pavement
Field testing Year 1: 10/21/2008 17:24
Location: 03Nev80E22.6
Field testing Year 2:
Comments: Longitudinally broomed. Worn out texture.
Surface Year: 1989

Onboard picture Year 1



Texture detail

Joint detail

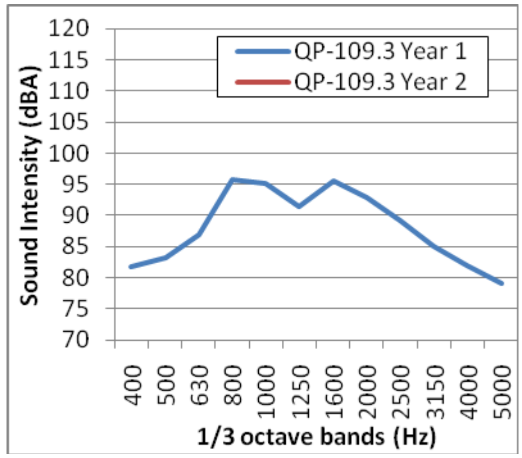
Google Earth view

General view

QP-109.3

Type of section: Pavement — Field testing Year 1: 10/21/2008 17:35
Location: 03Nev80E22.6 — Field testing Year 2:
Comments: Longitudinally broomed. Worn out texture.
Surface Year: 1989

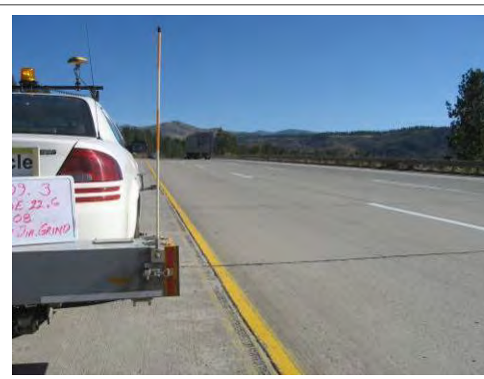
Onboard picture Year 1



Texture detail

Joint detail

Google Earth view



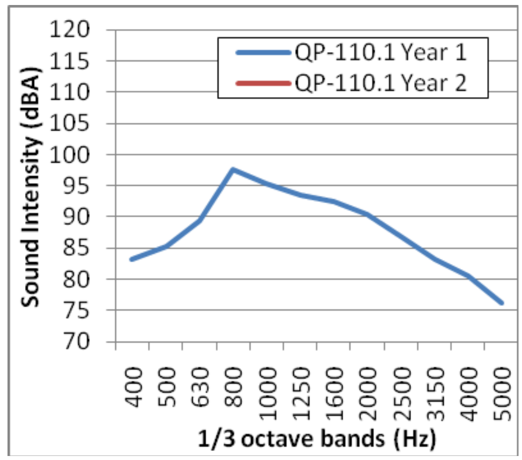
General view

QP-110.1

Type of section: Pavement
Location: 03Nev80E24.0
Comments: Diamond grooved.
Surface Year: 1996

Field testing Year 1: 10/21/2008 17:13
Field testing Year 2:

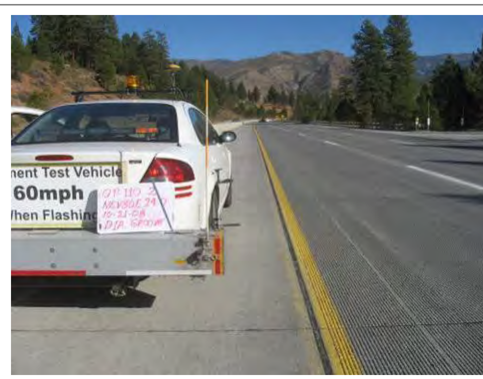
Onboard picture Year 1



Texture detail

Joint detail

Google Earth view

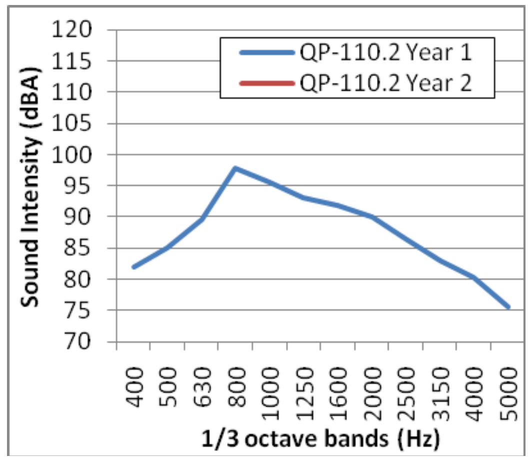


General view

QP-110.2

Type of section: Pavement
Location: 03Nev80E24.1
Comments: Diamond grooved.
Surface Year: 1996

Field testing Year 1: 10/21/2008 17:25
Field testing Year 2:

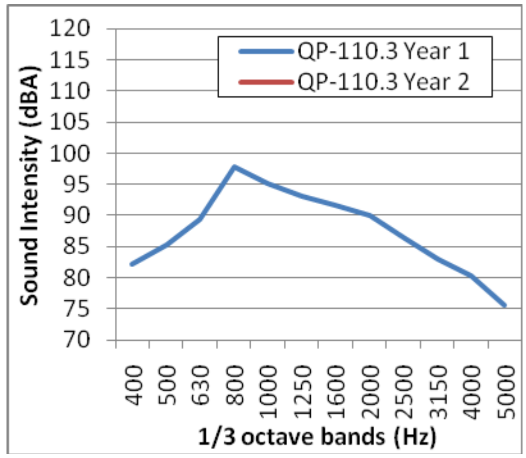
 Onboard picture Year 1	
 Texture detail	 Joint detail
 Google Earth view	 General view

QP-110.3

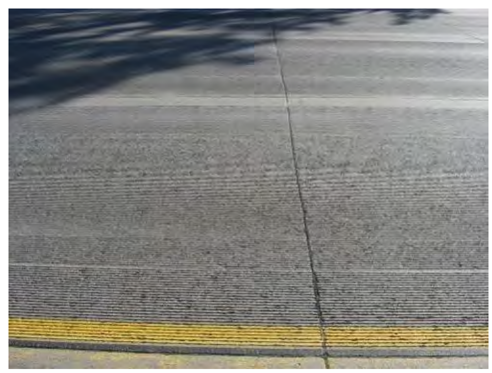
Type of section: Pavement
Location: 03Nev80E24.2
Comments: Diamond grooved.
Surface Year: 1996

Field testing Year 1: 10/21/2008 17:37
Field testing Year 2:

Onboard picture Year 1

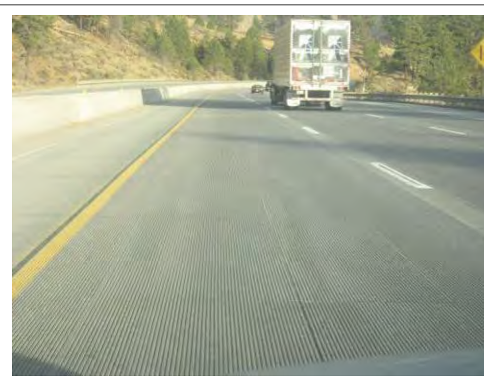


Texture detail



Joint detail

Google Earth view



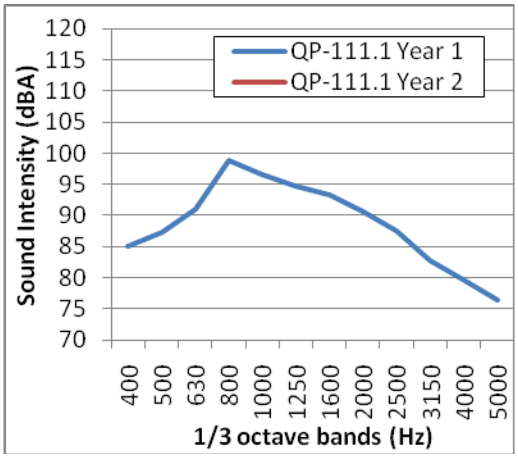
General view

QP-111.1

Type of section: Pavement
Location: 03Nev80W24.2
Comments: Diamond grooved.
Surface Year: 1996

Field testing Year 1: 10/21/2008 17:16
Field testing Year 2:

Onboard picture Year 1



Texture detail

Joint detail

Google Earth view

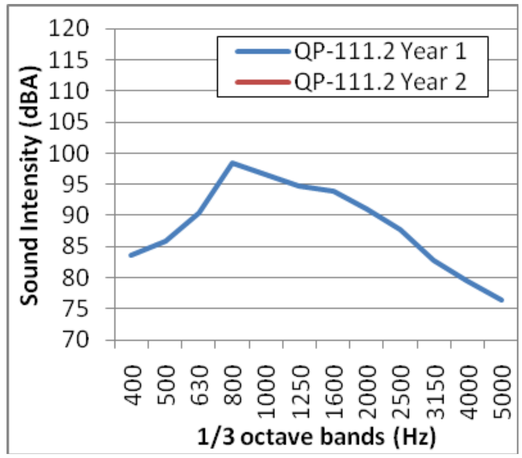
General view

QP-111.2

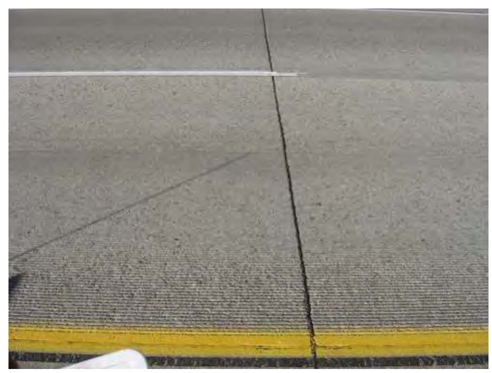
Type of section: Pavement
Location: 03Nev80W24.1
Comments: Diamond grooved.
Surface Year: 1996

Field testing Year 1: 10/21/2008 17:26
Field testing Year 2:

Onboard picture Year 1

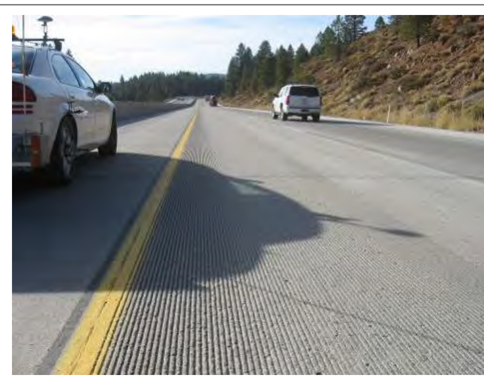


Texture detail



Joint detail

Google Earth view



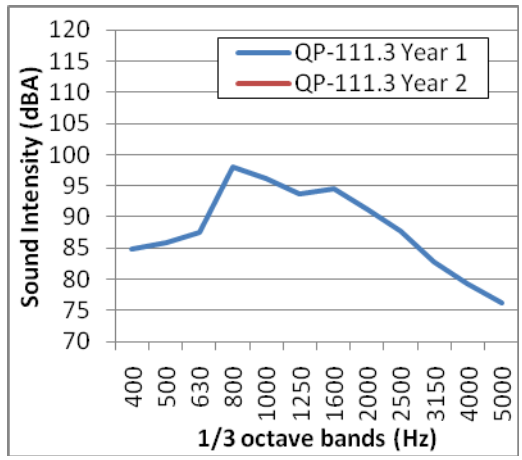
General view

QP-111.3

Type of section: Pavement
Location: 03Nev80W24.0
Comments: Diamond grooved.
Surface Year: 1996

Field testing Year 1: 10/21/2008 17:38
Field testing Year 2:

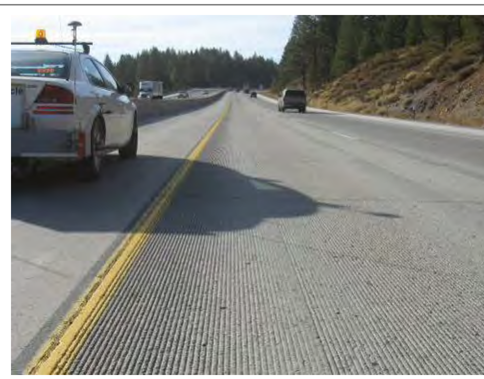

Onboard picture Year 1




Texture detail


Joint detail

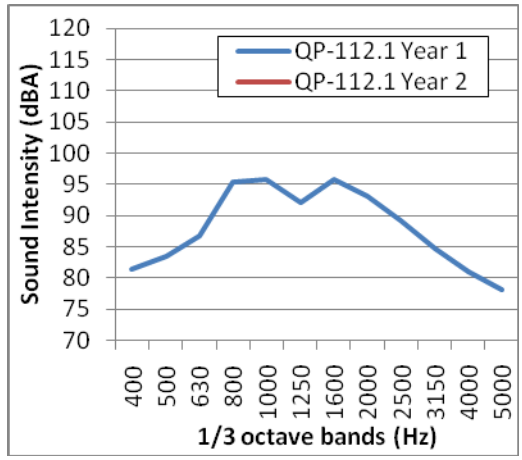
Google Earth view


General view

QP-112.1

Type of section: Pavement | Field testing Year 1: 10/21/2008 17:21
Location: 03Nev80W23.0 | Field testing Year 2:
Comments: Longitudinally broomed. Uneven wear along section. Wide joints.
Surface Year: 1989

Onboard picture Year 1



Texture detail

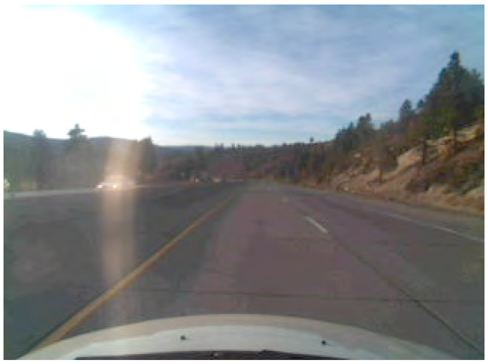
Joint detail

Google Earth view

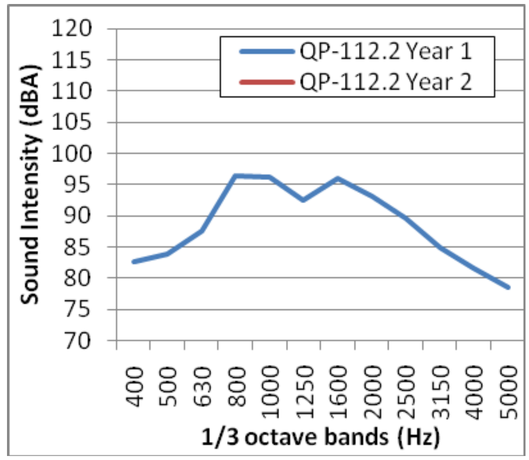
General view

QP-112.2

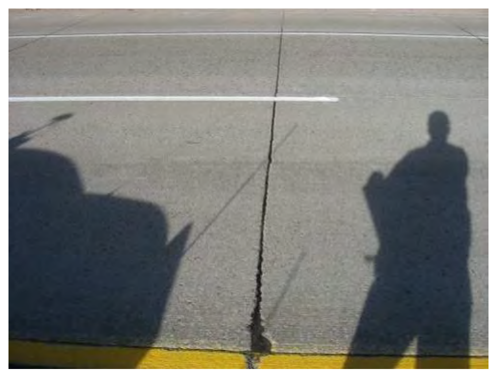
Type of section: Pavement   Field testing Year 1: 10/21/2008 17:33
Location: 03Nev80W22.9   Field testing Year 2:
Comments: Longitudinally broomed. Uneven wear along section. Wide joints.
Surface Year: 1989



Onboard picture Year 1

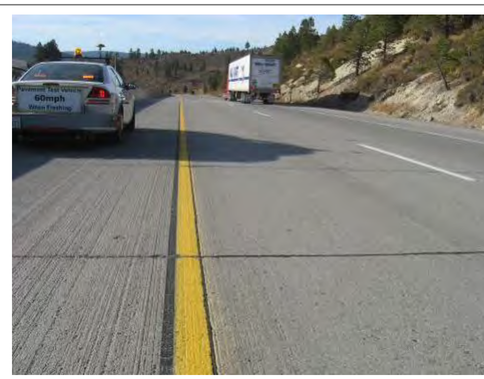


Texture detail



Joint detail

Google Earth view

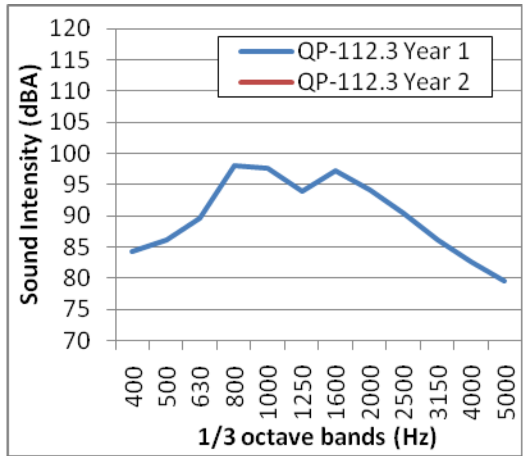


General view

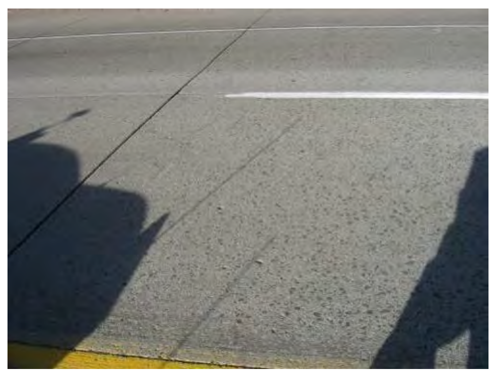
QP-112.3

Type of section: Pavement Field testing Year 1: 10/21/2008 17:45
Location: 03Nev80W22.8 Field testing Year 2:
Comments: Longitudinally broomed. Uneven wear along section. Wide joints.
Surface Year: 1989

Onboard picture Year 1



Texture detail



Joint detail

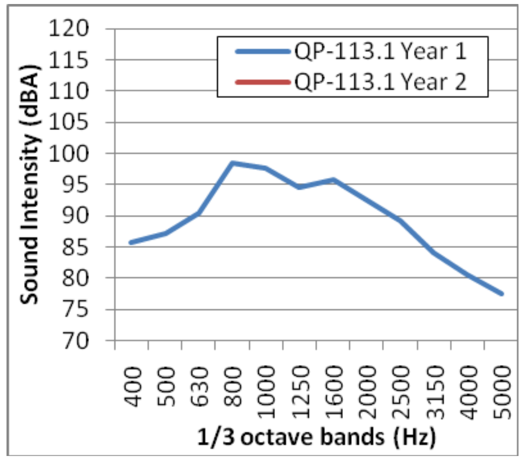
Google Earth view

General view

QP-113.1

Type of section: Pavement
Field testing Year 1: 10/23/2008 12:37
Location: 03Yol80W22.9
Field testing Year 2:
Comments: Burlap drag. Worn out texture.
Surface Year: 1965

Onboard picture Year 1



Texture detail

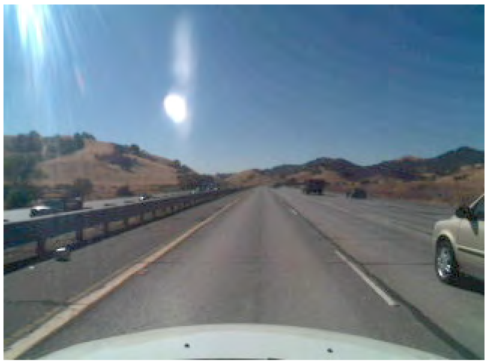
Joint detail

Google Earth view

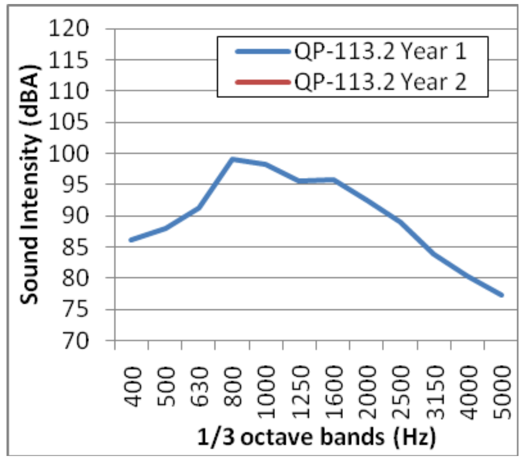
General view

QP-113.2

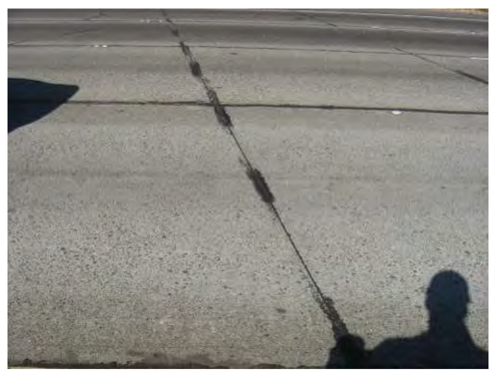
Type of section: Pavement
Field testing Year 1: 10/23/2008 12:45
Location: 03Yol80W22.8
Field testing Year 2:
Comments: Burlap drag. Worn out texture.
Surface Year: 1965



Onboard picture Year 1

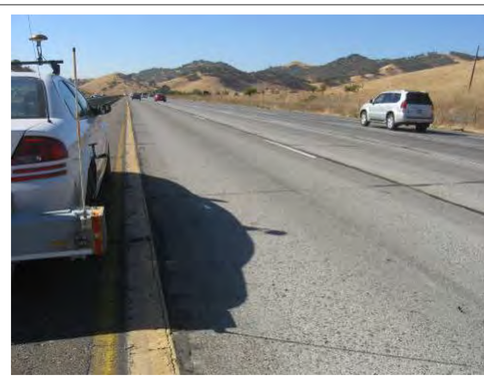


Texture detail



Joint detail

Google Earth view

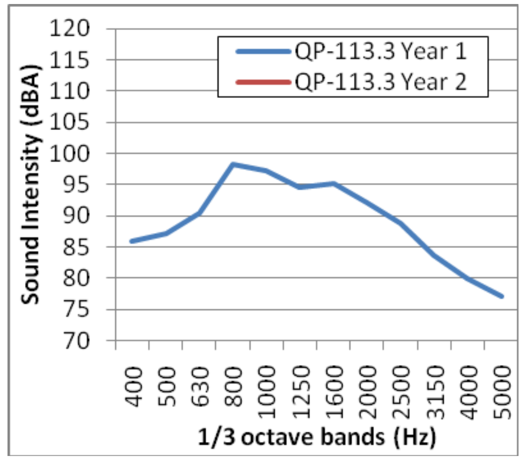


General view

QP-113.3

Type of section: Pavement — Field testing Year 1: 10/23/2008 12:54
Location: 03Yol80W22.7 — Field testing Year 2:
Comments: Burlap drag. Worn out texture.
Surface Year: 1965

Onboard picture Year 1



Texture detail

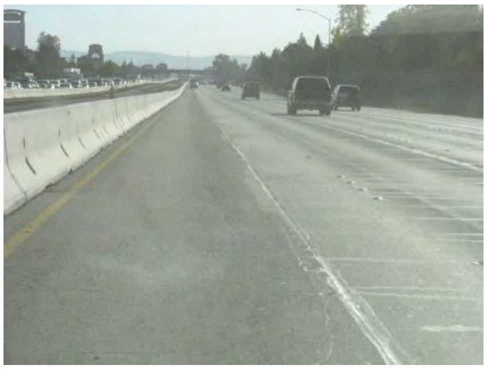
Joint detail

Google Earth view

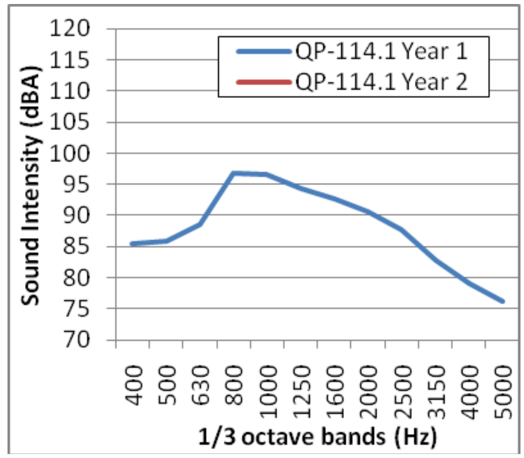
General view

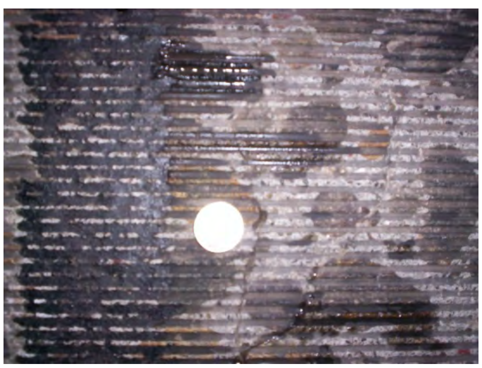
QP-114.1

Type of section: Pavement — Field testing Year 1: 10/23/2008 14:45
Location: 04Sol80W18.7 — Field testing Year 2:
Comments: Diamond ground. Right wheelpath on DG CRCP.
Surface Year: 1999



Onboard picture Year 1

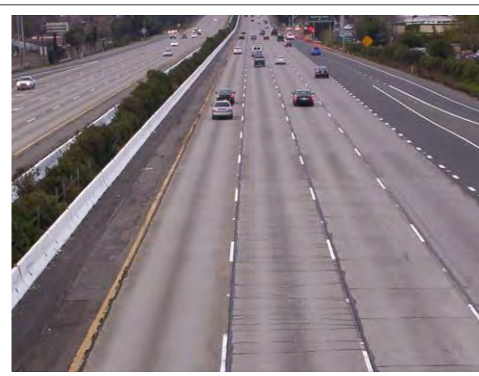




Texture detail

Transverse cracks detail

Google Earth view

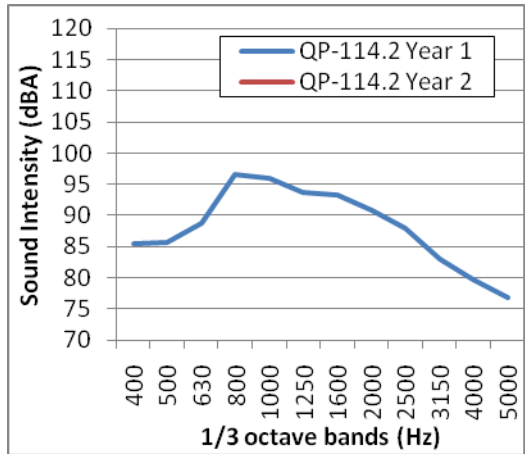


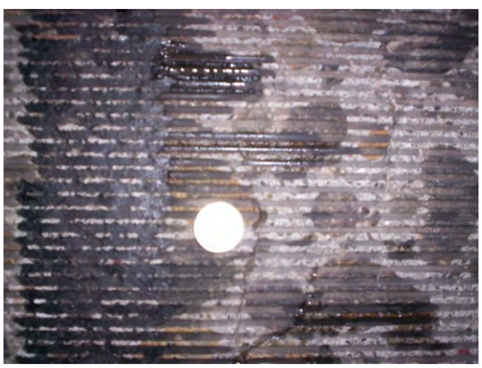
General view

QP-114.2

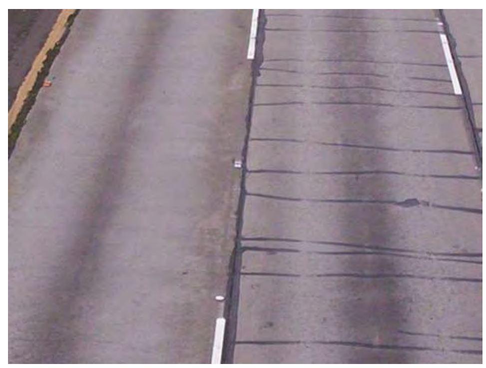
Type of section: Pavement　　　Field testing Year 1: 10/23/2008 15:11
Location: 04Sol80W18.6　　　Field testing Year 2:
Comments: Diamond ground. Right wheelpath on DG CRCP.
Surface Year: 1999

Onboard picture Year 1





Texture detail



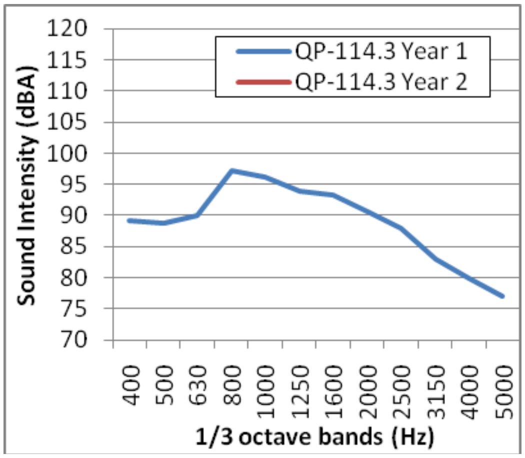
From overcross

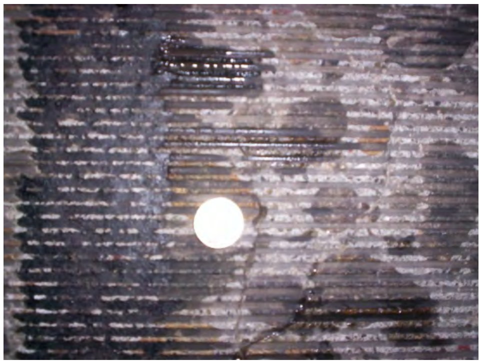
Google Earth view

QP-114.3

Type of section: Pavement | Field testing Year 1: 10/23/2008 15:31
Location: 04Sol80W18.5 | Field testing Year 2:
Comments: Diamond ground. Right wheelpath on DG CRCP.
Surface Year: 1999

Onboard picture Year 1





Texture detail

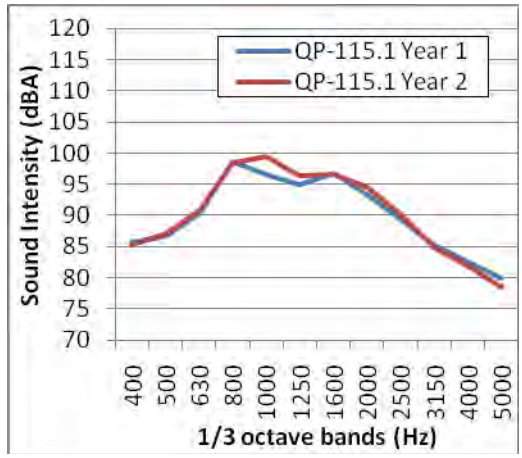
Google Earth view

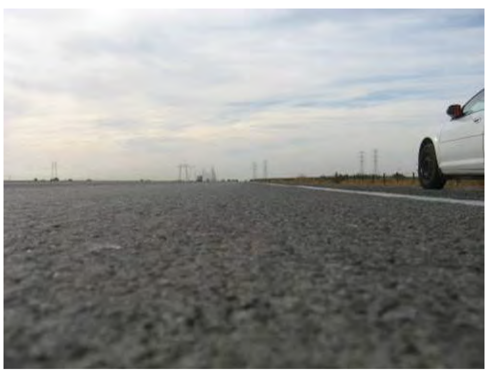
QP-115.1

Type of section: Pavement
Location: 03Yol505S13.1
Comments: Burlap drag.
Surface Year: 1977

Field testing Year 1: 10/27/2008 10:33
Field testing Year 2: 9/8/2009 11:33

Onboard picture Year 1

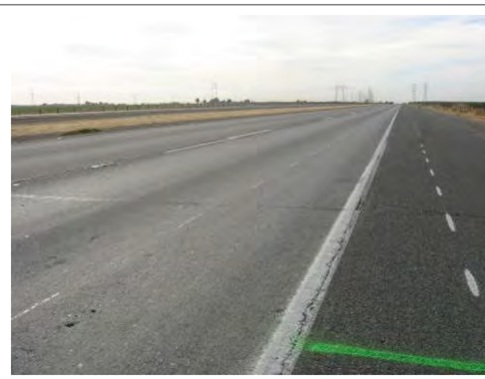




Texture detail

Joint detail

Google Earth view



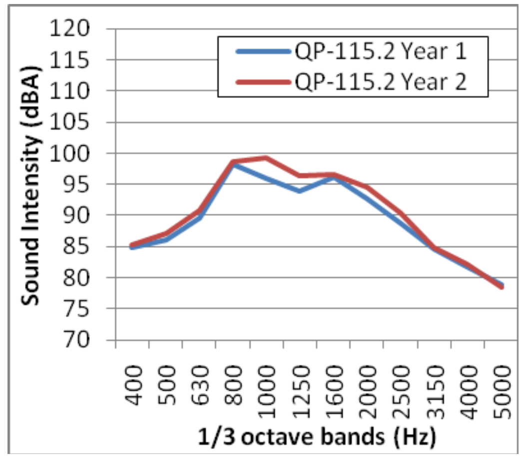
General view

QP-115.2

Type of section: Pavement
Location: 03Yol505S13.0
Comments: Burlap drag.
Surface Year: 1977

Field testing Year 1: 10/27/2008 10:56
Field testing Year 2: 9/8/2009 11:46

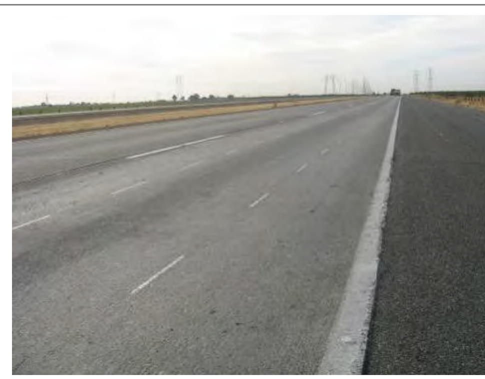
Onboard picture Year 1



Texture detail

Joint detail

Google Earth view



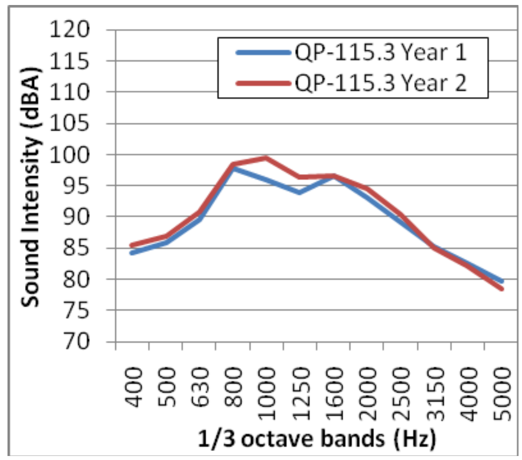
General view

QP-115.3

Type of section: Pavement
Location: 03Yol505S12.9
Comments: Burlap drag.
Surface Year: 1977

Field testing Year 1: 10/27/2008 11:21
Field testing Year 2: 9/8/2009 12:05

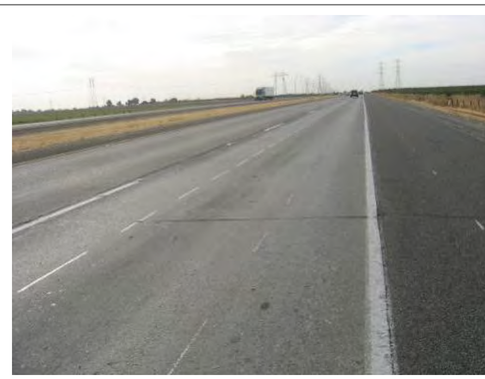
Onboard picture Year 1



Texture detail

Joint detail

Google Earth view

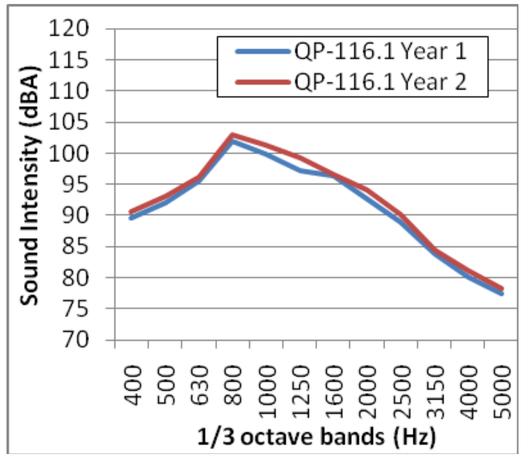


General view

QP-116.1

Type of section: Pavement Field testing Year 1: 10/28/2008 10:35
Location: 04Sol80E32.0 Field testing Year 2: 9/10/2009 11:06
Comments: Burlap drag. Looks like aggressive exposed agg. Maybe no original texture.
Surface Year: 1946

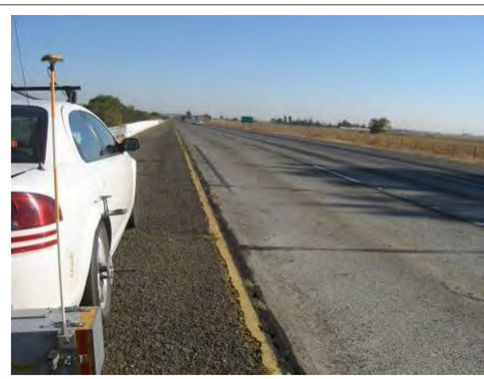
Onboard picture Year 1



Texture detail

Joint detail

Google Earth view

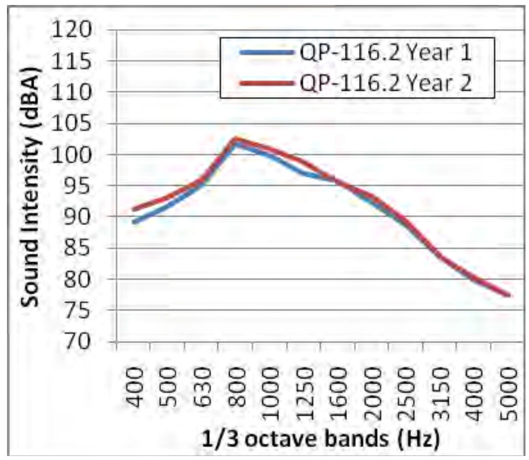


General view

QP-116.2

Type of section: Pavement   Field testing Year 1: 10/28/2008 11:06
Location: 04Sol80E32.1   Field testing Year 2: 9/10/2009 11:20
Comments: Burlap drag. Looks like aggressive exposed agg. Maybe no original texture.
Surface Year: 1946

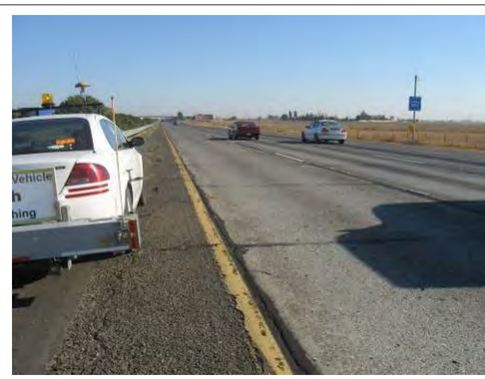

Onboard picture Year 1




Texture detail


Joint detail

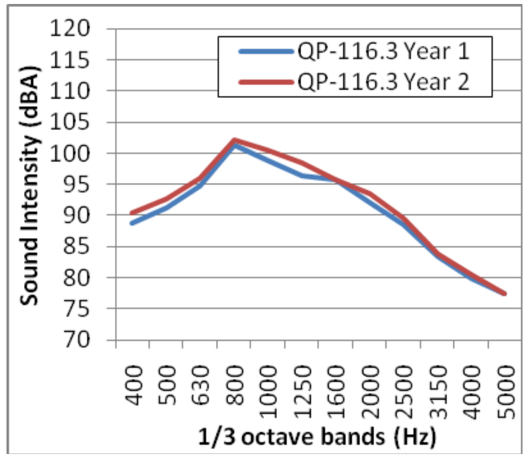
Google Earth view


General view

QP-116.3

Type of section: Pavement Field testing Year 1: 10/28/2008 11:06
Location: 04Sol80E32.2 Field testing Year 2: 9/10/2009 11:22
Comments: Burlap drag. Looks like aggressive exposed agg. Maybe no original texture.
Surface Year: 1946

Onboard picture Year 1



Texture detail

Joint detail

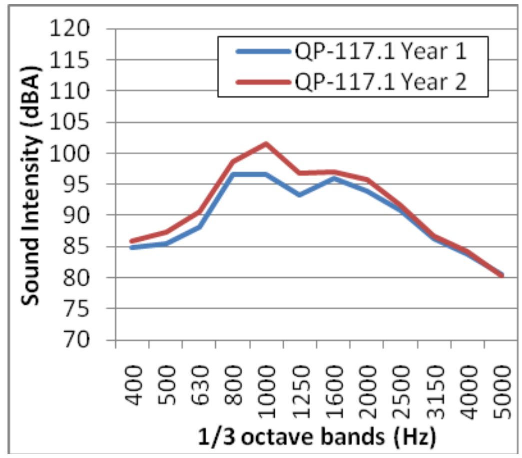
Google Earth view

General view

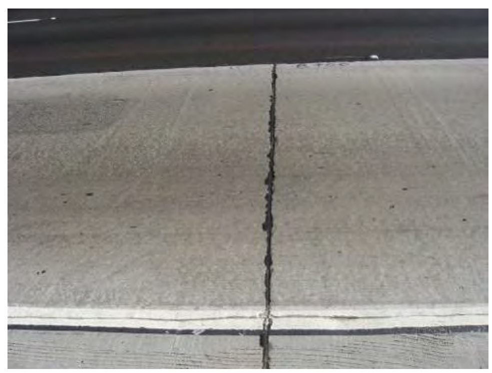
QP-117.1

Type of section: Pavement　　Field testing Year 1: 10/28/2008 14:14
Location: 04CC80W10.3　　Field testing Year 2: 10/29/2009 14:57
Comments: Longitudinally tined. Shallow and squiggly LT.
Surface Year: 2007

Onboard picture Year 1

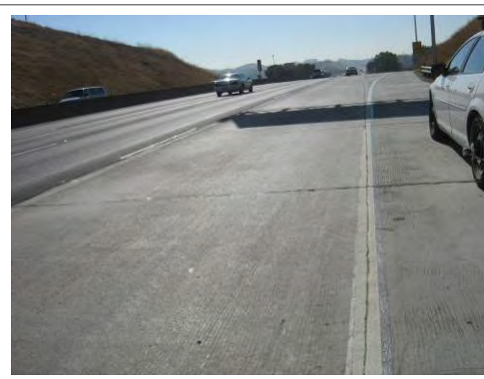


Texture detail



Joint detail

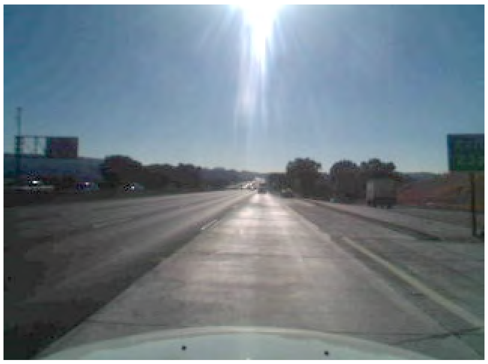
Google Earth view



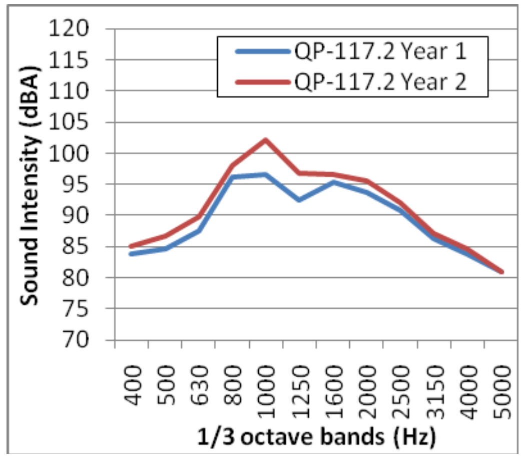
General view

QP-117.2

Type of section: Pavement	Field testing Year 1: 10/28/2008 14:45
Location: 04CC80W10.2	Field testing Year 2: 10/29/2009 15:03
Comments: Longitudinally tined. Shallow and squiggly LT.
Surface Year: 2007



Onboard picture Year 1



Texture detail

Overall view

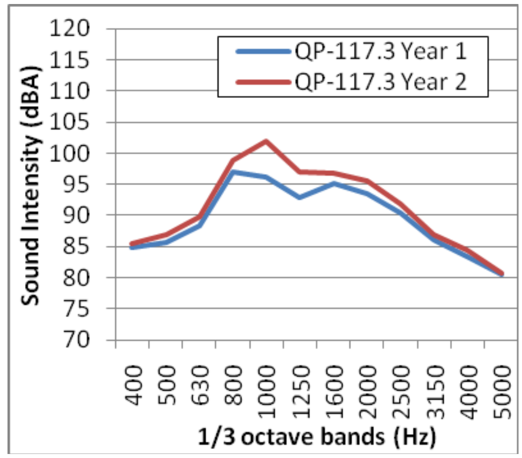
Google Earth view

General view

QP-117.3

Type of section: Pavement
Field testing Year 1: 10/28/2008 14:54
Location: 04CC80W10.1
Field testing Year 2: 10/29/2009 15:12
Comments: Longitudinally tined. Shallow and squiggly LT.
Surface Year: 2007

Onboard picture Year 1



Texture detail

Joint detail

Google Earth view

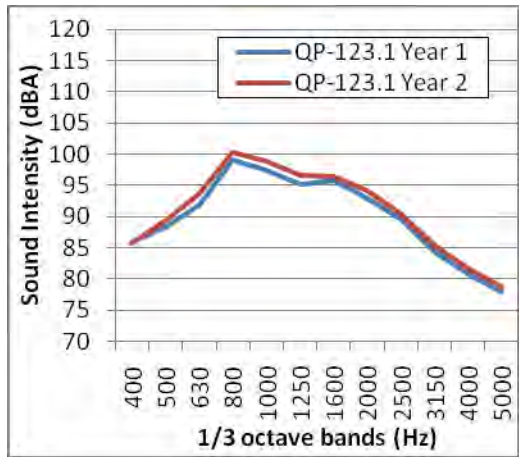
End of QP-117.3

QP-123.1

Type of section: Pavement
Location: 04ALA580E37.2
Comments: Burlap drag.
Surface Year: 1965

Field testing Year 1: 11/5/2008 15:30
Field testing Year 2: 11/12/2009 14:14

Onboard picture Year 1



Texture detail

Joint detail

Google Earth view

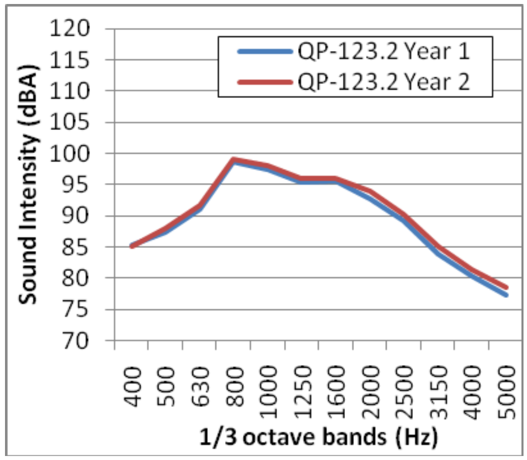
General view

QP-123.2

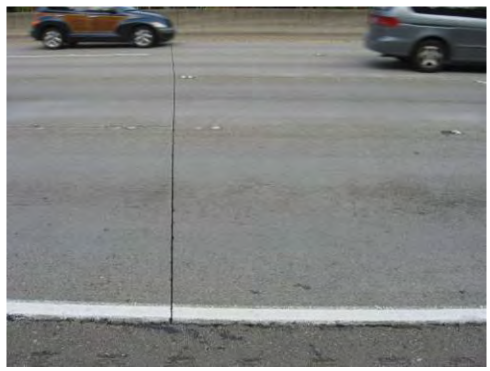
Type of section: Pavement
Location: 04ALA580E37.2
Comments: Burlap drag.
Surface Year: 1965

Field testing Year 1: 11/5/2008 15:51
Field testing Year 2: 11/12/2009 14:20

Onboard picture Year 1



Texture detail



Joint detail

Google Earth view

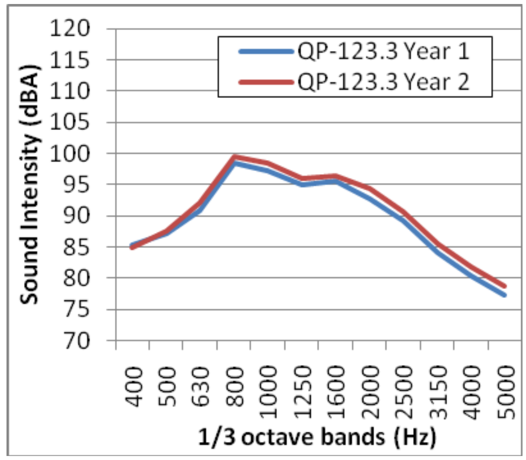
General view

QP-123.3

Type of section: Pavement
Location: 04ALA580E37.3
Comments: Burlap drag.
Surface Year: 1965

Field testing Year 1: 11/5/2008 15:52
Field testing Year 2: 11/12/2009 14:26

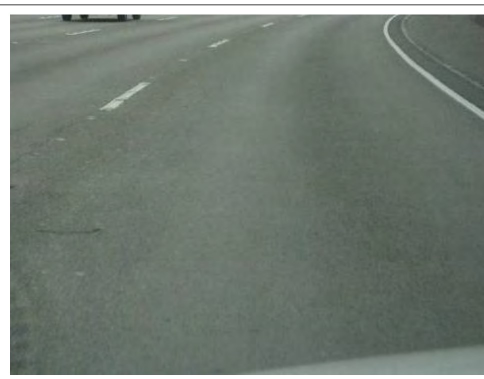
Onboard picture Year 1



Texture detail

Joint detail

Google Earth view



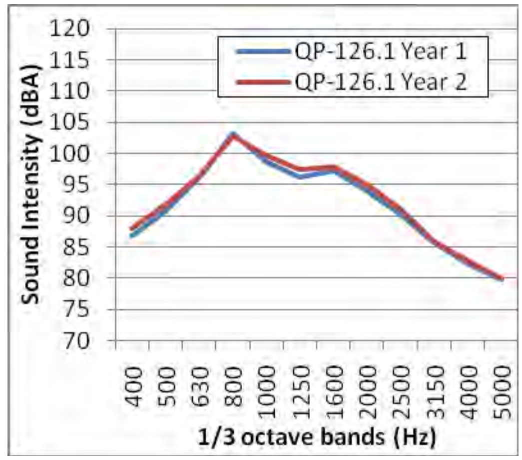
General view

QP-126.1

Type of section: Pavement
Location: 04SCL85S21.5L3
Comments: Burlap drag.
Surface Year: 1965

Field testing Year 1: 11/7/2008 11:52
Field testing Year 2: 11/18/2009 12:38

Onboard picture Year 1



Texture detail

Joint detail

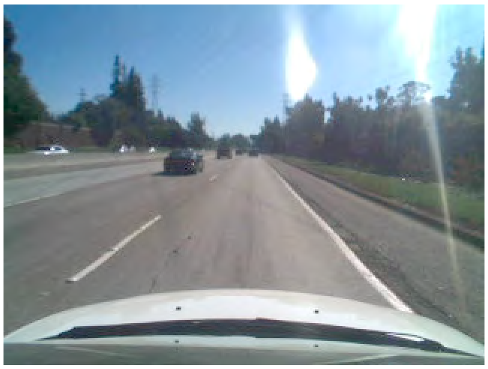
Google Earth view

General view

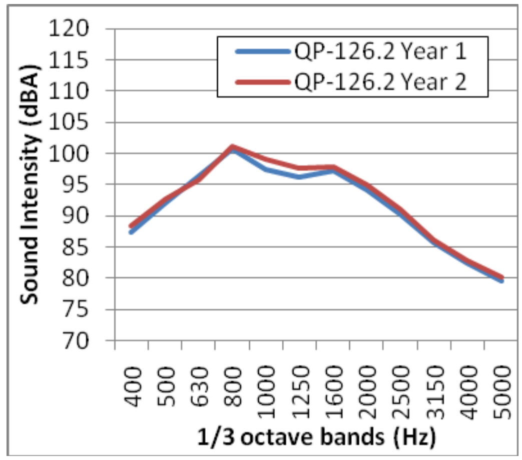
QP-126.2

Type of section: Pavement
Location: 04SCL85S21.4L3
Comments: Burlap drag.
Surface Year: 1965

Field testing Year 1: 11/7/2008 11:57
Field testing Year 2: 11/18/2009 12:48



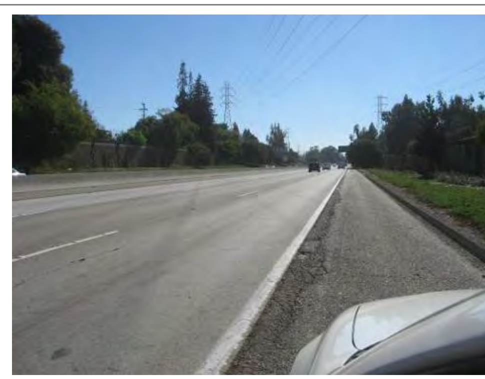
Onboard picture Year 1



Texture detail

Joint detail

Google Earth view



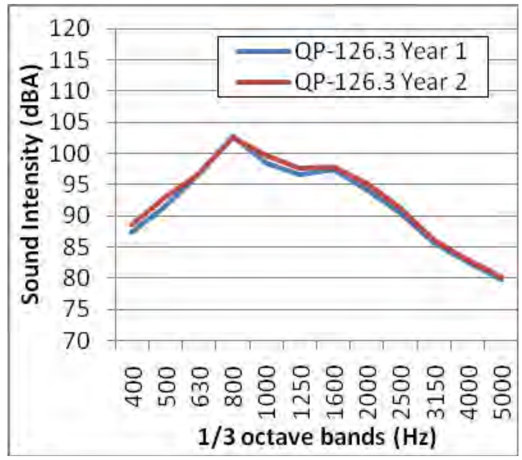
General view

QP-126.3

Type of section: Pavement
Location: 04SCL85S21.3L3
Comments: Burlap drag.
Surface Year: 1965

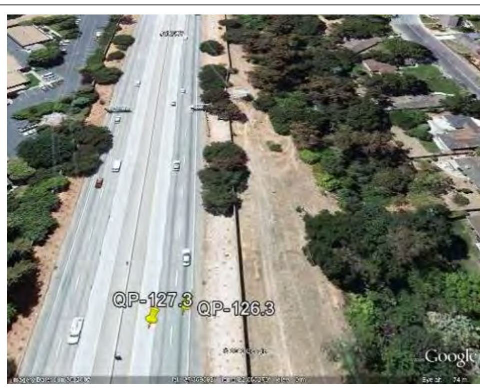
Field testing Year 1: 11/7/2008 12:13
Field testing Year 2: 11/18/2009 12:53

Onboard picture Year 1

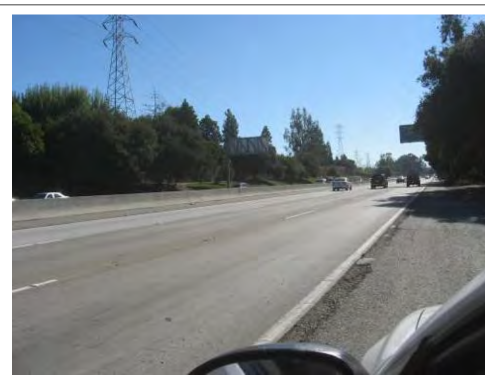


Texture detail

Joint detail



Google Earth view



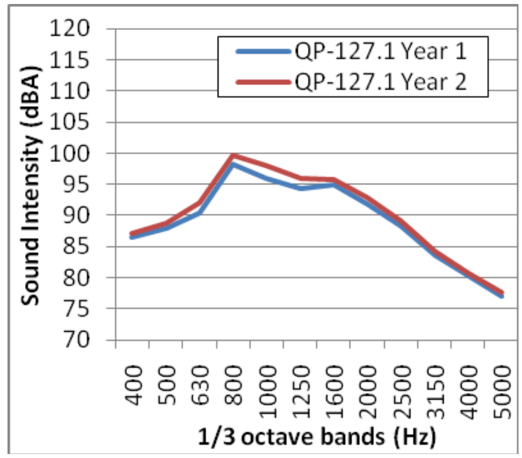
General view

QP-127.1

Type of section: Pavement
Location: 04SCL85S21.5L1
Comments: Longitudinally tined.
Surface Year: 1965

Field testing Year 1: 11/7/2008 12:51
Field testing Year 2: 11/18/2009 13:03

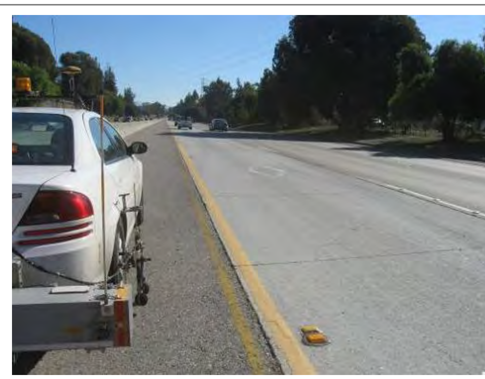
Onboard picture Year 1



Texture detail

Joint detail

Google Earth view



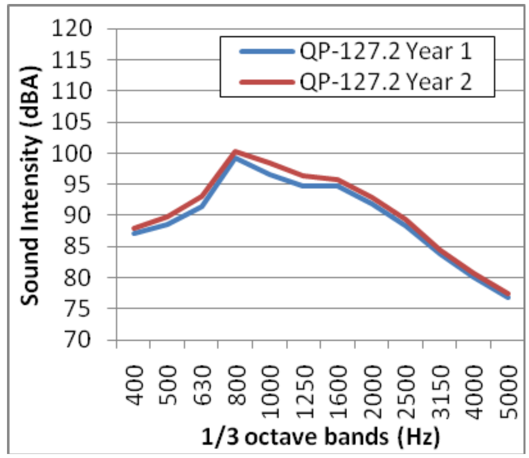
General view

QP-127.2

Type of section: Pavement
Location: 04SCL85S21.4L1
Comments: Longitudinally tined.
Surface Year: 1965

Field testing Year 1: 11/7/2008 13:18
Field testing Year 2: 11/18/2009 13:09

Onboard picture Year 1



Texture detail

Joint detail

Google Earth view

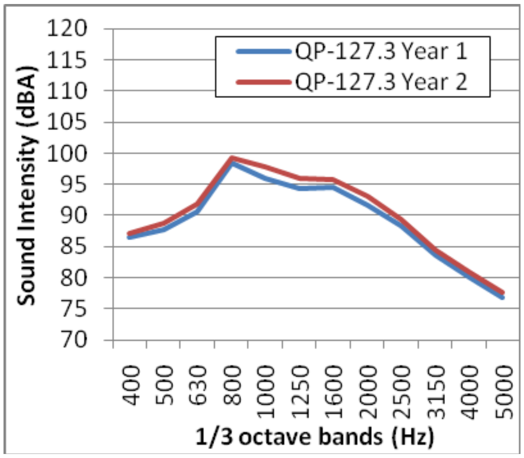
General view

QP-127.3

Type of section: Pavement
Location: 04SCL85S21.3L1
Comments: Longitudinally tined.
Surface Year: 1965

Field testing Year 1: 11/7/2008 13:24
Field testing Year 2: 11/18/2009 13:16

Onboard picture Year 1



Texture detail

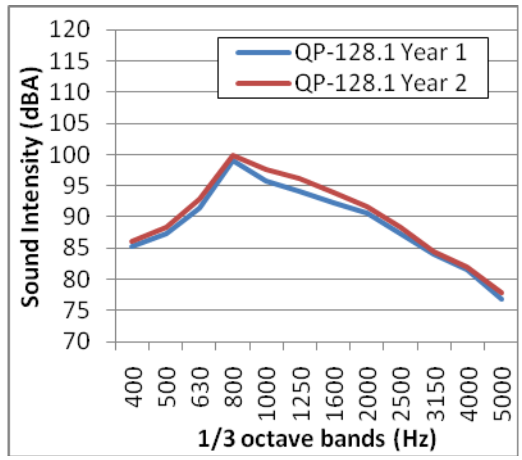
Joint detail

Google Earth view

QP-128.1

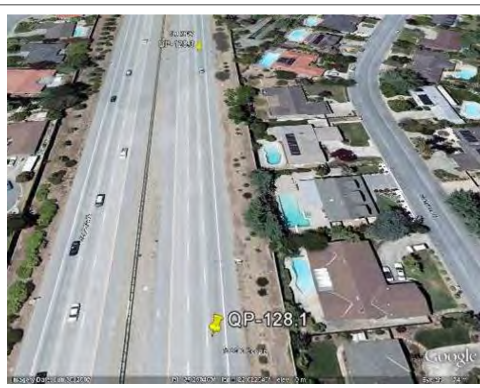
Type of section: Pavement Field testing Year 1: 11/7/2008 14:59
Location: 04SCL85N14.8 Field testing Year 2: 11/18/2009 14:57
Comments: Diamond ground. Pre-existing longitudinal tining.
Surface Year: 2006

Onboard picture Year 1

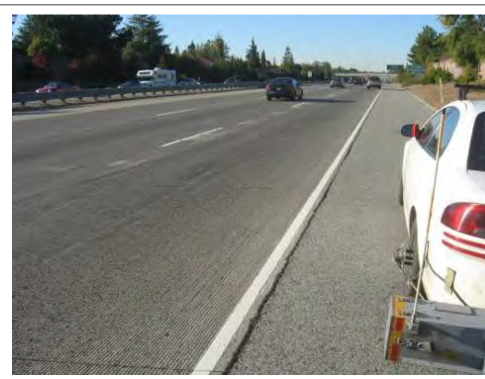


Texture detail

Joint detail



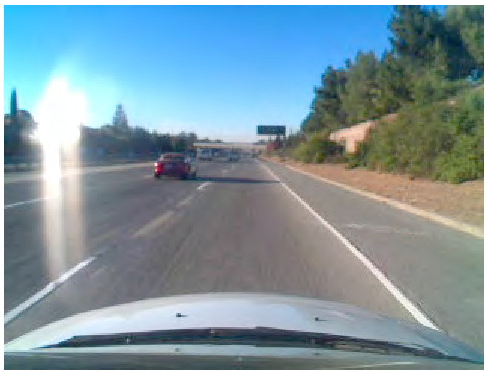
Google Earth view



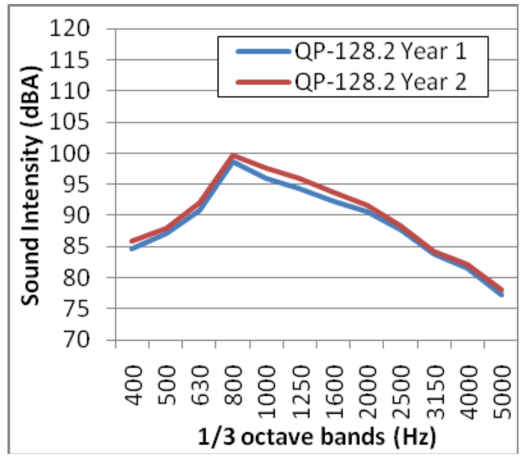
General view

QP-128.2

Type of section: Pavement
Location: 04SCL85N14.9
Field testing Year 1: 11/7/2008 15:38
Field testing Year 2: 11/18/2009 15:06
Comments: Diamond ground. Pre-existing longitudinal tining.
Surface Year: 2006



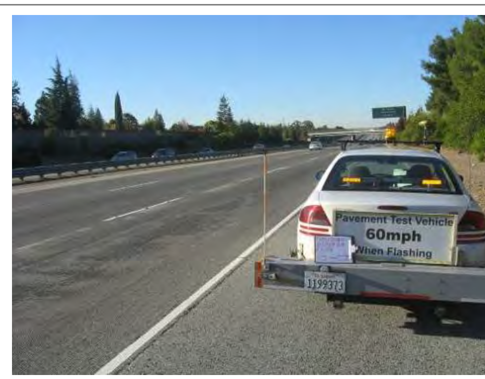
Onboard picture Year 1



Texture detail

Joint detail

Google Earth view

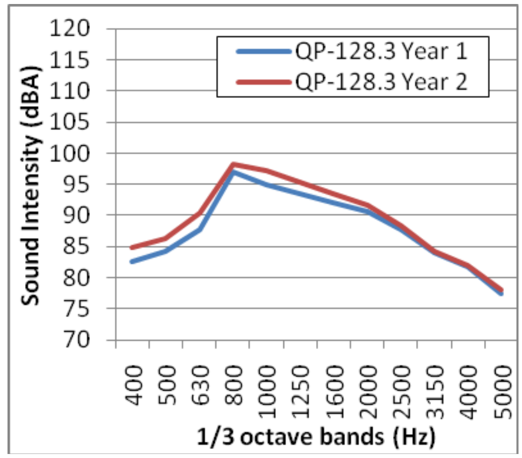


General view

QP-128.3

Type of section: Pavement Field testing Year 1: 11/7/2008 15:46
Location: 04SCL85N14.10 Field testing Year 2: 11/18/2009 15:15
Comments: Diamond ground. Pre-existing longitudinal tining.
Surface Year: 2006

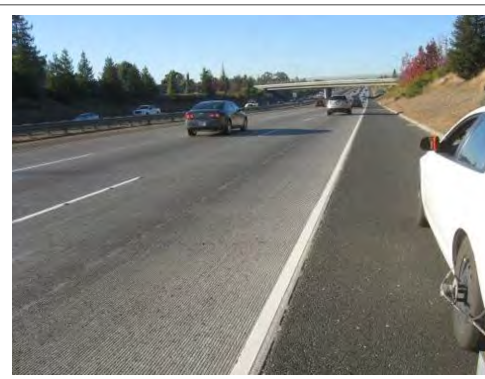
Onboard picture Year 1



Texture and joint detail

General view

Google Earth view



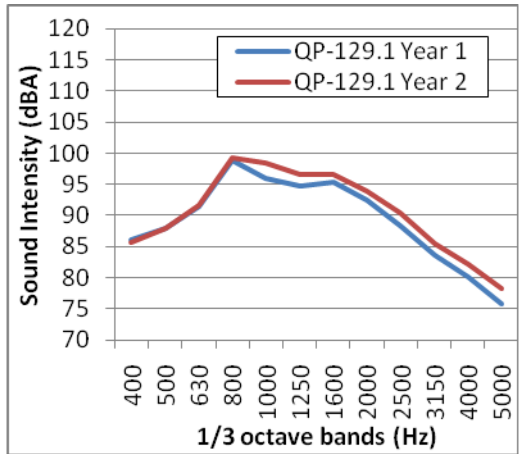
General view

QP-129.1

Type of section: Pavement
Location: 06FRE180W55.7
Comments: Longitudinally tined.
Surface Year: 2008

Field testing Year 1: 11/10/2008 17:02
Field testing Year 2: 11/13/2009 15:03

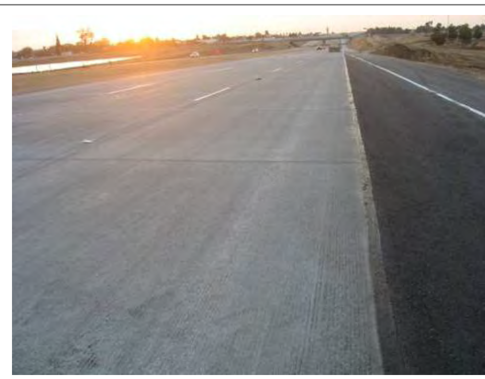
Onboard picture Year 1



Texture detail

Joint detail

Google Earth view



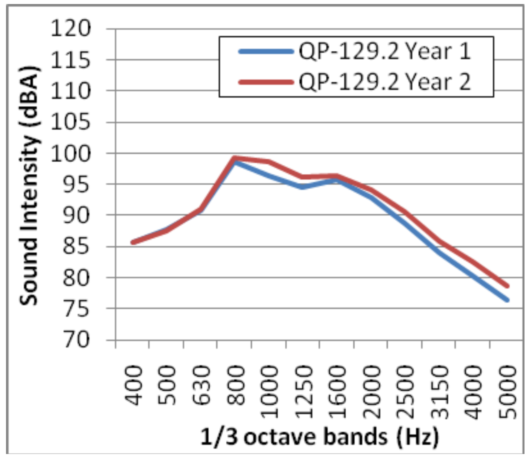
General view

QP-129.2

Type of section: Pavement
Location: 06FRE180W55.6
Comments: Longitudinally tined.
Surface Year: 2008

Field testing Year 1: 11/10/2008 17:09
Field testing Year 2: 11/13/2009 15:13

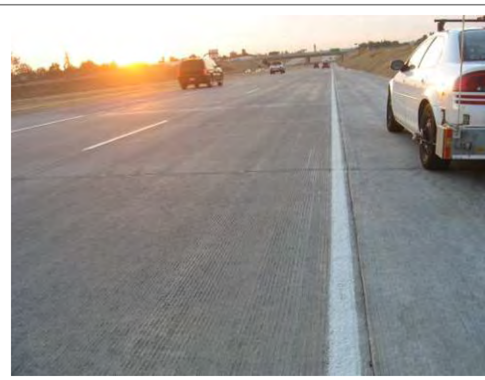
Onboard picture Year 1



Texture detail

Joint detail

Google Earth view

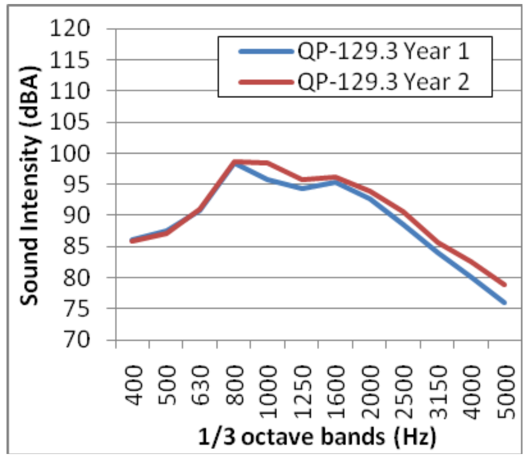


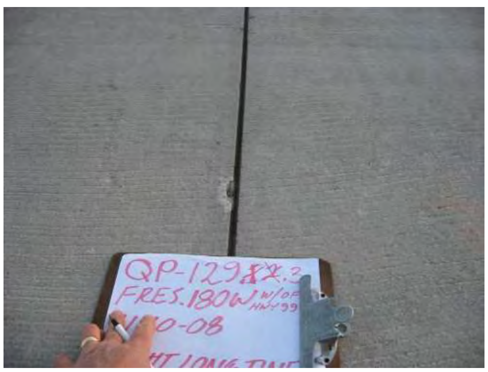
General view

QP-129.3

Type of section: Pavement
Field testing Year 1: 11/10/2008 17:17
Location: 06FRE180W55.5
Field testing Year 2: 11/13/2009 15:19
Comments: Diamond ground. DG on LT.
Surface Year: 2008

Onboard picture Year 1

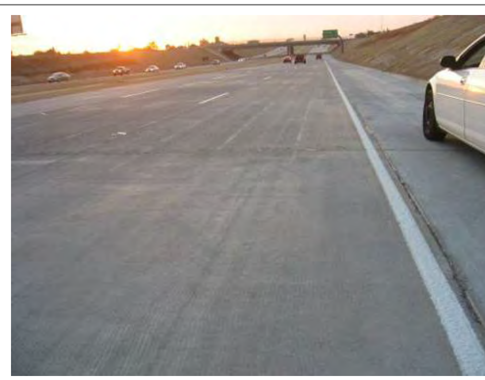




Texture detail

Joint detail

Google Earth view

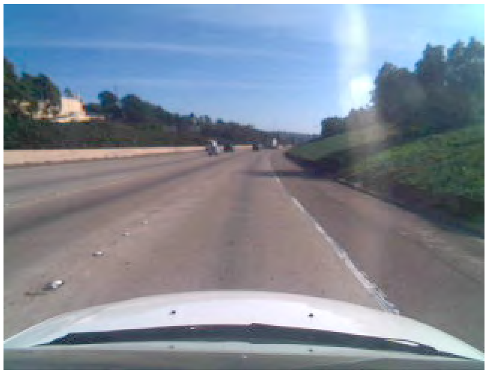


General view

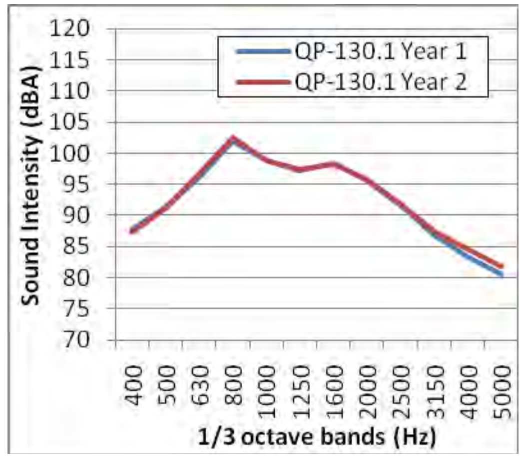
QP-130.1

Type of section: Pavement
Location: 11SD5S39.7
Comments: Burlap drag.
Surface Year: 1964

Field testing Year 1: 11/11/2008 13:33
Field testing Year 2: 11/22/2009 13:20



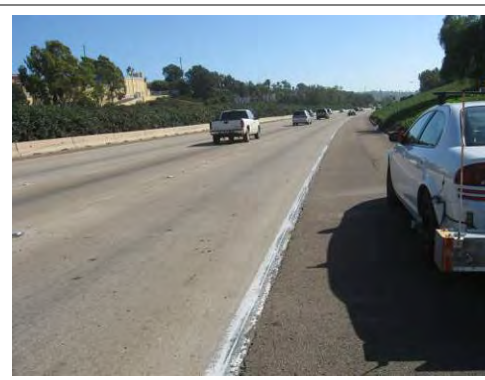
Onboard picture Year 1



Texture detail

Joint detail

Google Earth view



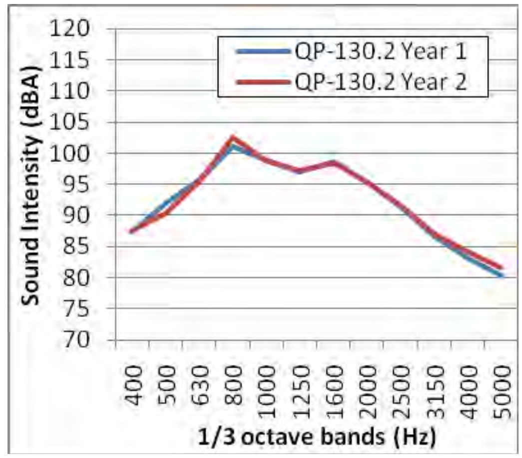
General view

QP-130.2

Type of section: Pavement
Location: 11SD5S39.6
Comments: Burlap drag.
Surface Year: 1964

Field testing Year 1: 11/11/2008 13:46
Field testing Year 2: 11/22/2009 13:28

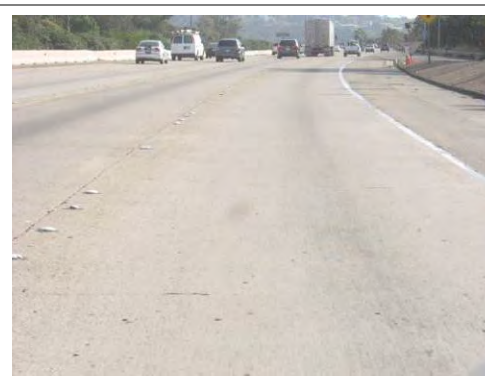
Onboard picture Year 1



Texture detail

Joint detail

Google Earth view



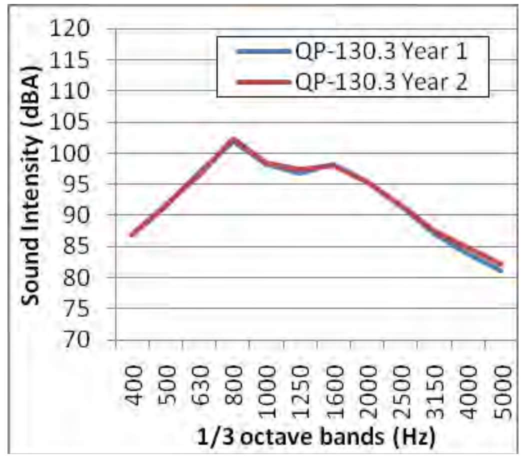
General view

QP-130.3

Type of section: Pavement
Location: 11SD5S39.5
Comments: Burlap drag.
Surface Year: 1964

Field testing Year 1: 11/11/2008 13:56
Field testing Year 2: 11/22/2009 13:33

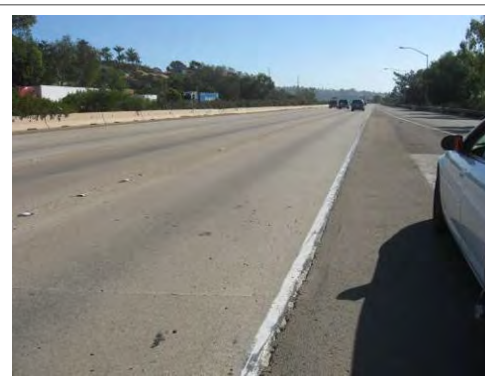
Onboard picture Year 1



Texture detail

Texture detail

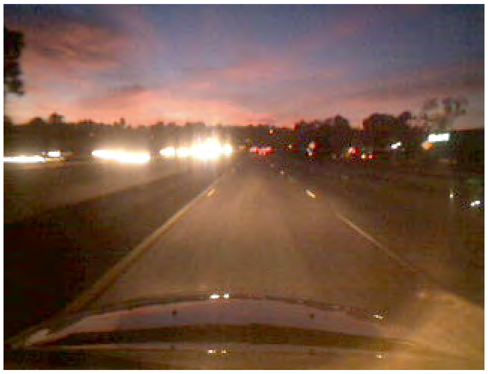
Google Earth view



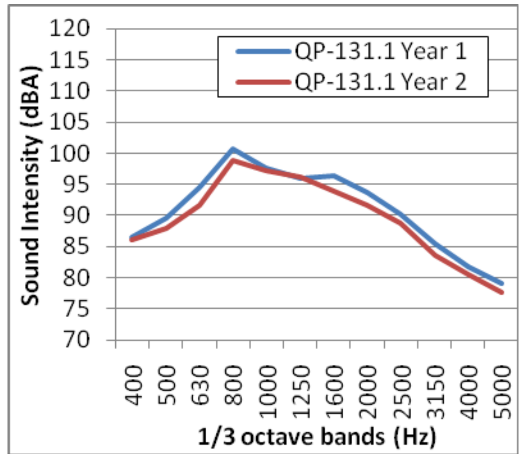
General view

QP-131.1

Type of section: Pavement
Field testing Year 1: 11/11/2008 17:01
Location: 11SD8W15.5
Field testing Year 2: 11/23/2009 9:33
Comments: Diamond ground. DG on LT.
Surface Year: 1997

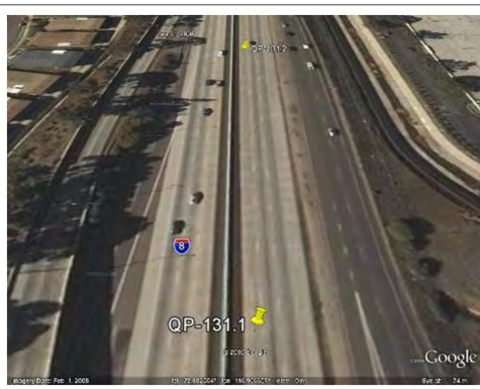


Onboard picture Year 1

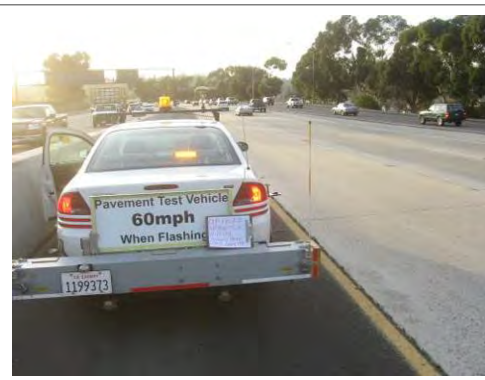


Texture detail

Joint detail



Google Earth view

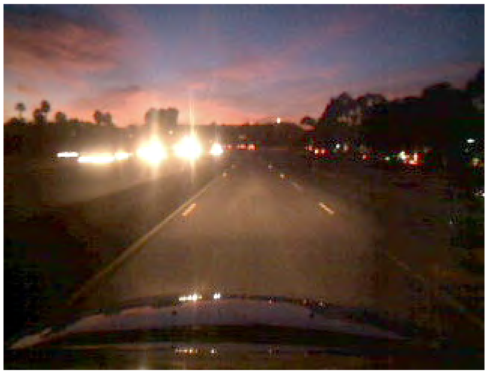


General view

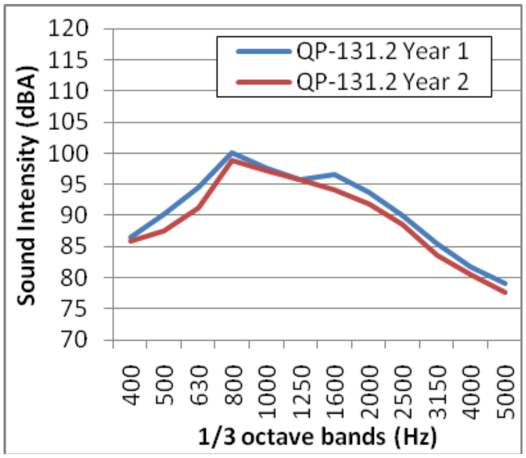
QP-131.2

Type of section: Pavement
Location: 11SD8W15.6
Comments: Diamond ground.
Surface Year: 1997

Field testing Year 1: 11/11/2008 17:11
Field testing Year 2: 11/23/2009 9:40

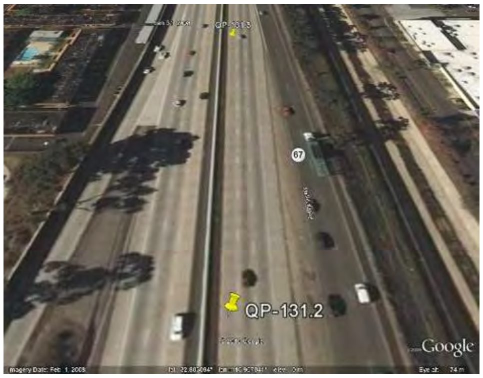


Onboard picture Year 1

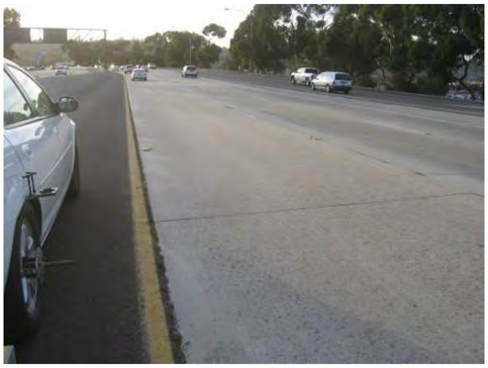


Texture detail

Joint detail



Google Earth view



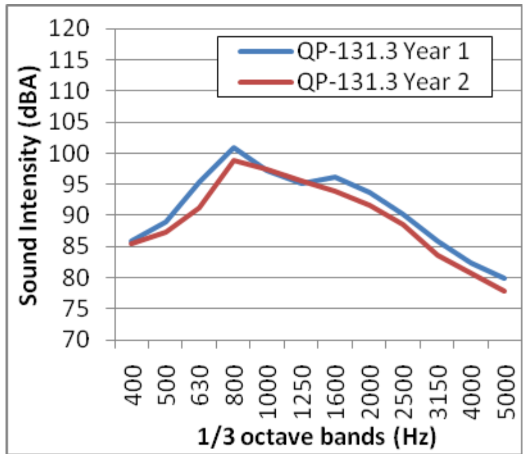
General view

QP-131.3

Type of section: Pavement
Location: 11SD8W15.7
Comments: Diamond ground.
Surface Year: 1997

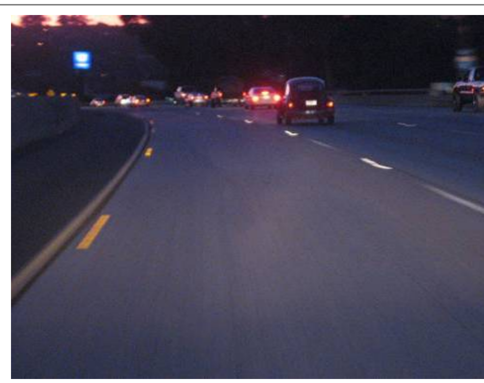
Field testing Year 1: 11/11/2008 17:26
Field testing Year 2: 11/23/2009 9:49

Onboard picture Year 1



Texture detail

Google Earth view

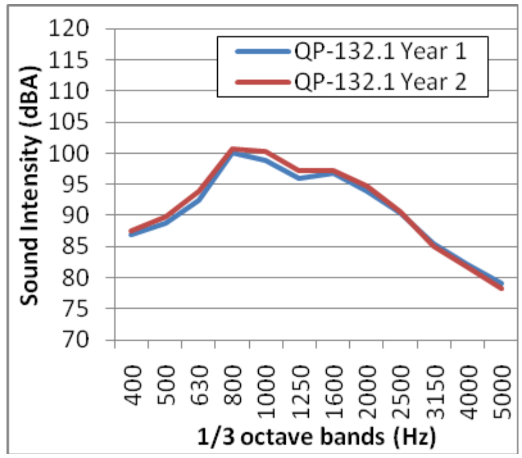


General view

QP-132.1

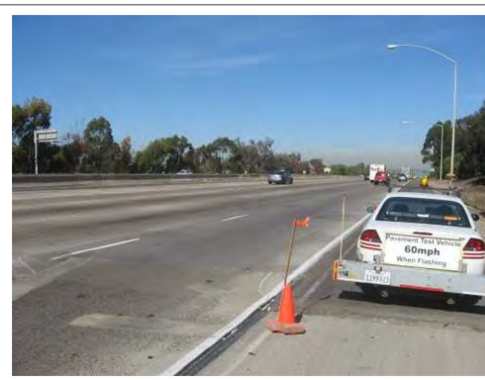
Type of section: Pavement
Field testing Year 1: 11/12/2008 12:39
Location: 11SD805N2.1
Field testing Year 2: 11/24/2009 11:06
Comments: Diamond ground. DG on LB.
Surface Year: 1998

Onboard picture Year 1



Joint detail

Google Earth view



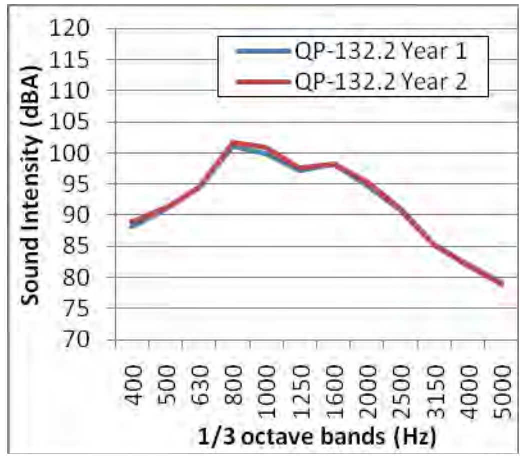
General view

QP-132.2

Type of section: Pavement
Location: 11SD805N2.2
Comments: Diamond ground.
Surface Year: 1998

Field testing Year 1: 11/12/2008 13:04
Field testing Year 2: 11/24/2009 11:24

Onboard picture Year 1



Texture detail

Joint detail

Google Earth view

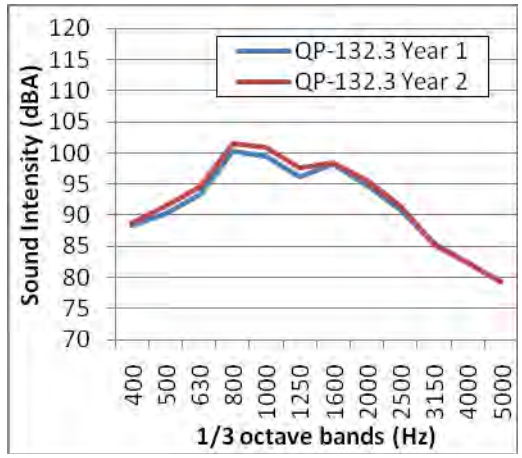
General view

QP-132.3

Type of section: Pavement
Location: 11SD805N2.3
Comments: Diamond ground.
Surface Year: 1998

Field testing Year 1: 11/12/2008 13:16
Field testing Year 2: 11/24/2009 11:36

Onboard picture Year 1



Texture detail

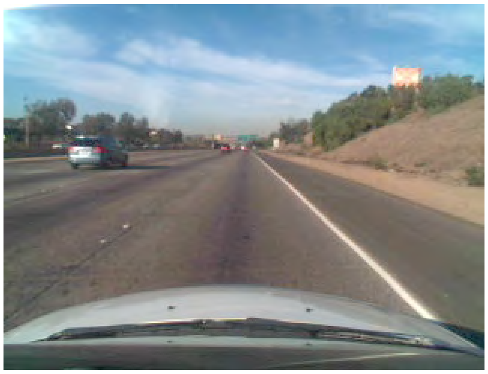
Joint detail

Google Earth view

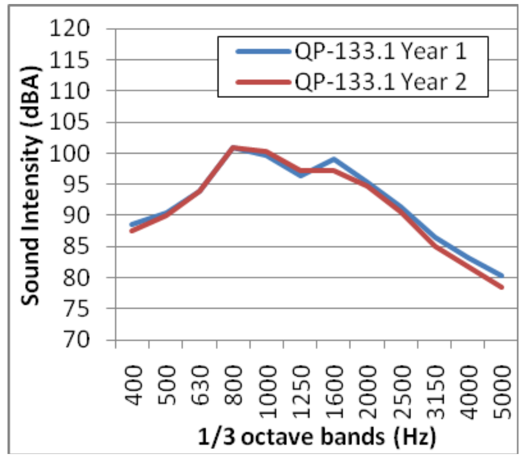
General view

QP-133.1

Type of section: Pavement
Field testing Year 1: 11/12/2008 14:36
Location: 11SD805N2.3
Field testing Year 2: 11/24/2009 11:50
Comments: Diamond ground. DG on transverse tining.
Surface Year: 1998



Onboard picture Year 1



Texture detail

Texture detail

Google Earth view

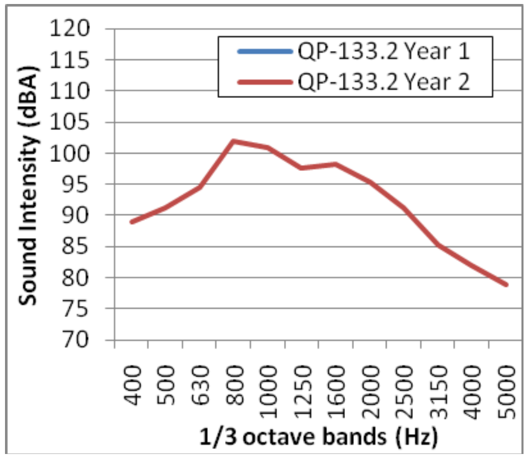
General view

QP-133.2

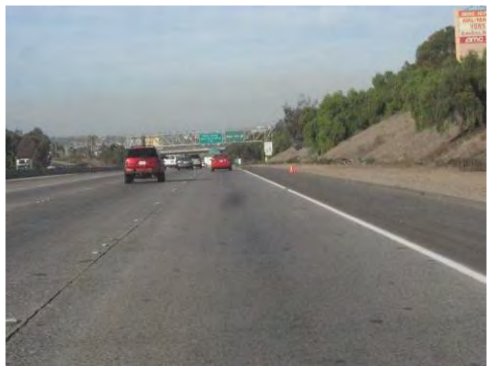
Type of section: Pavement
Location: 11SD805N2.4
Comments: Diamond ground.
Surface Year: 1998

Field testing Year 1: 11/12/2008 15:01
Field testing Year 2: 11/24/2009 12:03

Onboard picture Year 1

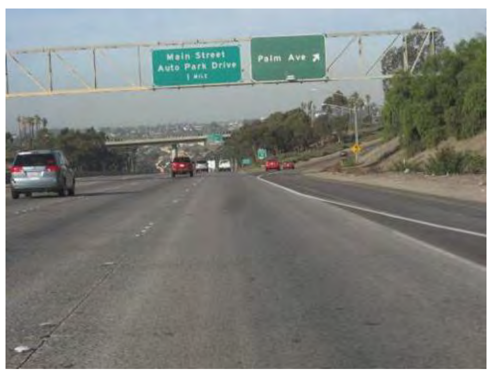


Texture detail



General view

Google Earth view

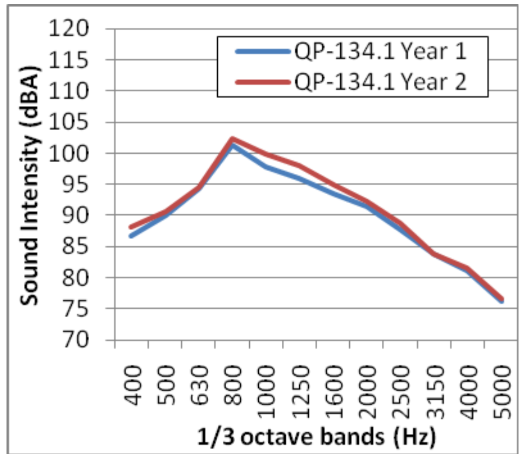


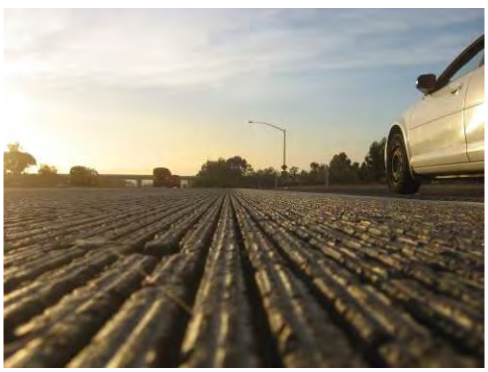
General view

QP-134.1

Type of section: Pavement | Field testing Year 1: 11/12/2008 16:03
Location: 11SD905W5.2 | Field testing Year 2: 11/24/2009 12:21
Comments: Diamond ground. DG on deep longitudinal tining. Off-ramp.
Surface Year: 2000

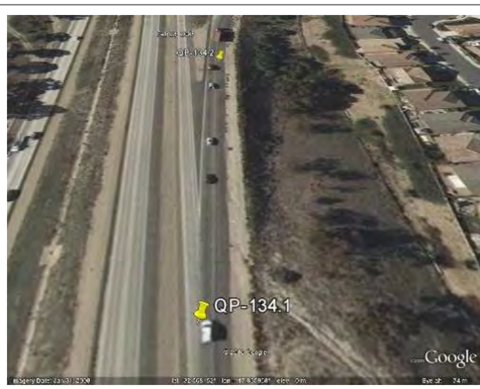
Onboard picture Year 1



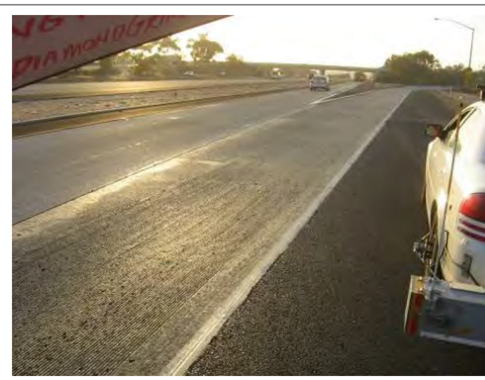


Texture detail

General view



Google Earth view

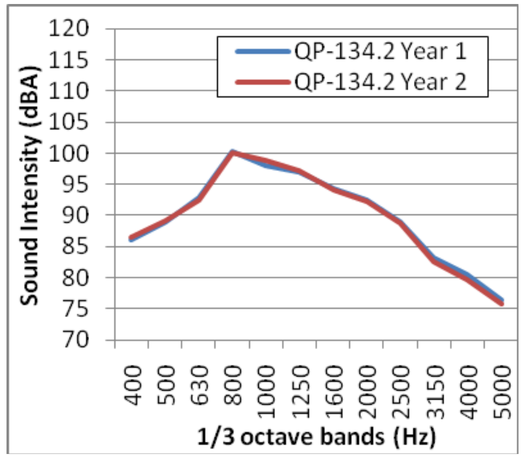


General view

QP-134.2

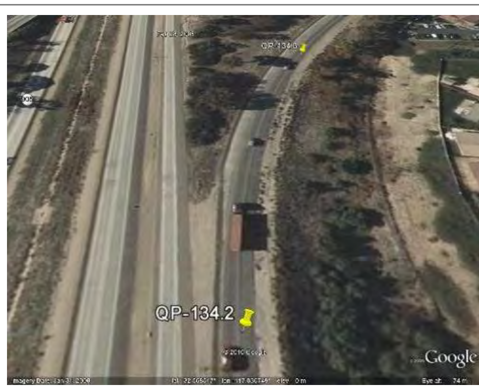
Type of section: Pavement   Field testing Year 1: 11/12/2008 16:35
Location: 11SD905W5.1   Field testing Year 2: 11/24/2009 12:31
Comments: Diamond ground. DG on deep longitudinal tining. Off-ramp.
Surface Year: 2000

Onboard picture Year 1



Texture detail

Joint detail



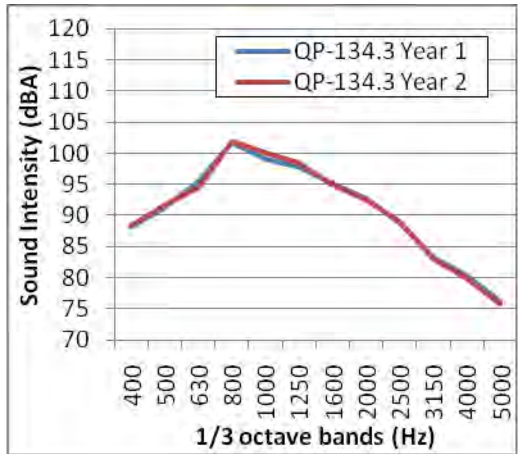
Google Earth view

General view

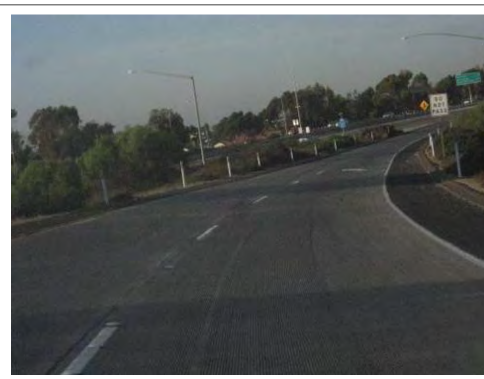
QP-134.3

Type of section: Pavement Field testing Year 1: 11/12/2008 16:39
Location: 11SD905W5.0 Field testing Year 2: 11/24/2009 12:35
Comments: Diamond ground. DG on deep longitudinal tining. Off-ramp.
Surface Year: 2000

Onboard picture Year 1



Google Earth view



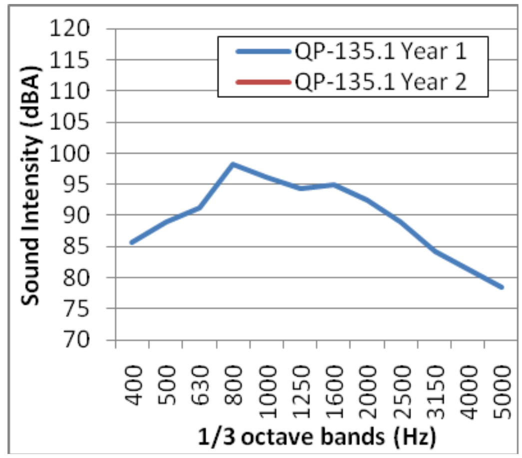
General view

QP-135.1

Type of section: Pavement
Location: 04SON101N25.4L2
Comments: Diamond ground.
Surface Year: 2006

Field testing Year 1: 11/17/2008 12:27
Field testing Year 2:

Onboard picture Year 1



Texture detail

Joint detail

Google Earth view

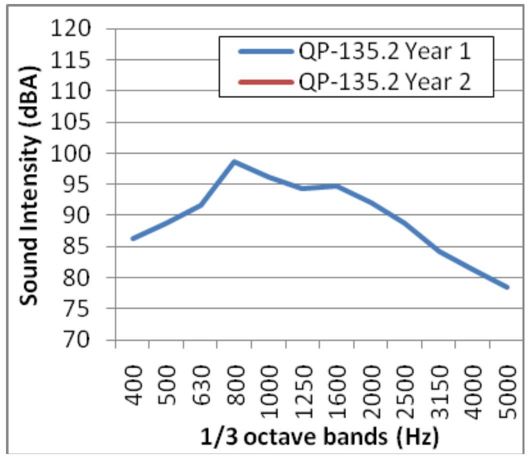
General view

QP-135.2

Type of section: Pavement
Location: 04SON101N25.5L2
Comments: Diamond ground.
Surface Year: 2006

Field testing Year 1: 11/17/2008 12:50
Field testing Year 2:

Onboard picture Year 1



Texture detail

Joint detail

Google Earth view

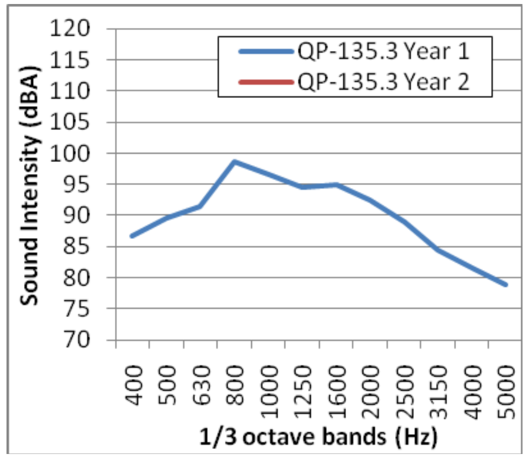
General view

QP-135.3

Type of section: Pavement
Location: 04SON101N25.6
Comments: Diamond ground.
Surface Year: 2006

Field testing Year 1: 11/17/2008 12:57
Field testing Year 2:

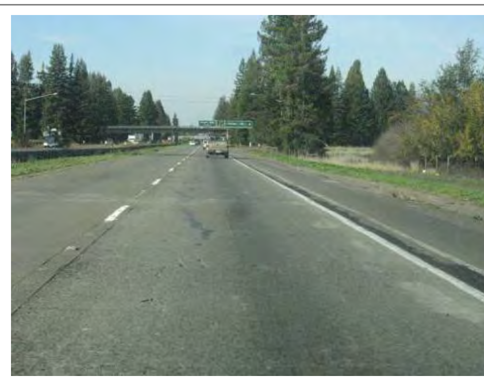
Onboard picture Year 1



Texture detail

Joint detail

Google Earth view



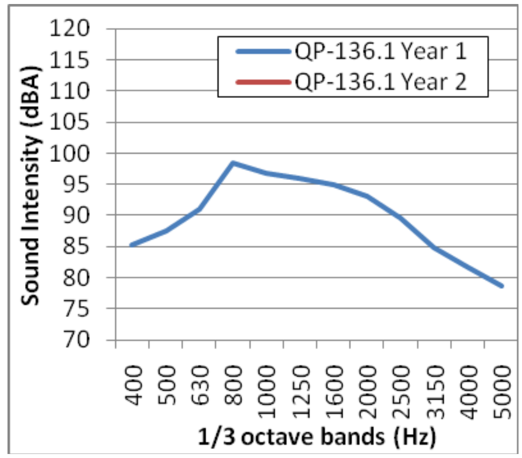
General view

QP-136.1

Type of section: Pavement
Location: 04SON101S27.3 L2
Comments: Diamond grooved.
Surface Year: 2006

Field testing Year 1: 11/17/2008 12:40
Field testing Year 2:

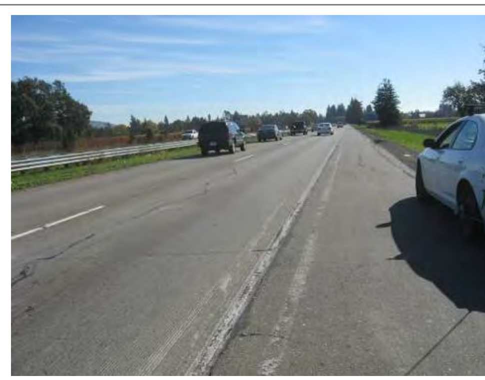
Onboard picture Year 1



Texture detail

Joint detail

Google Earth view



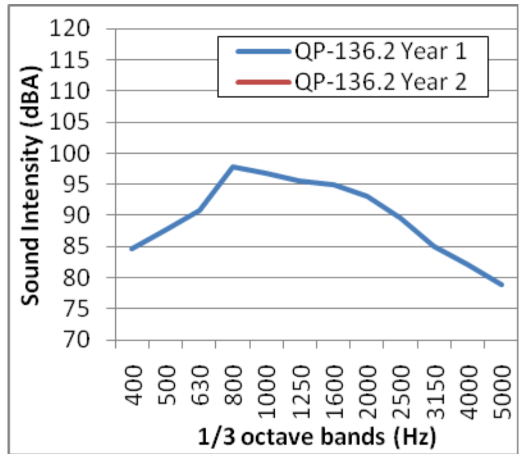
General view

QP-136.2

Type of section: Pavement
Location: 04SON101S27.2 L2
Comments: Diamond grooved.
Surface Year: 2006

Field testing Year 1: 11/17/2008 12:52
Field testing Year 2:

Onboard picture Year 1



Texture detail

Joint detail

Google Earth view

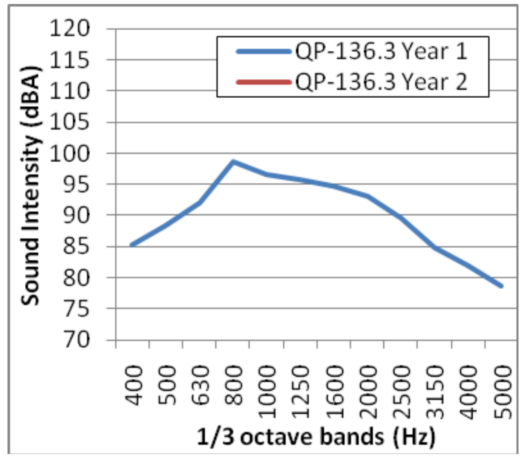
General view

QP-136.3

Type of section: Pavement
Location: 04SON101S27.1L2
Comments: Diamond grooved.
Surface Year: 2006

Field testing Year 1: 11/17/2008 13:00
Field testing Year 2:

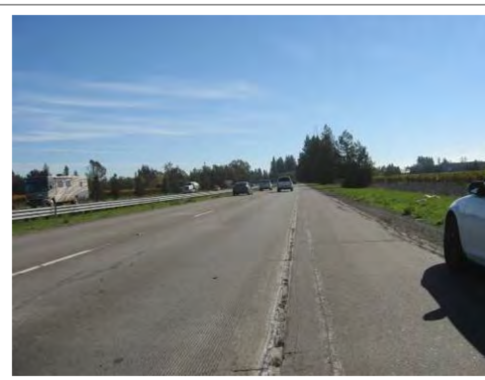
Onboard picture Year 1



Texture detail

Joint detail

Google Earth view



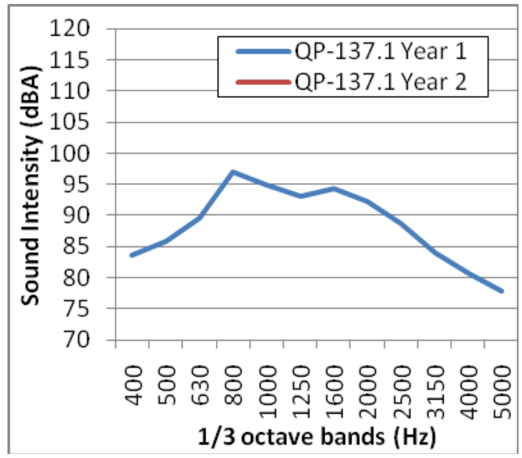
General view

QP-137.1

Type of section: Pavement
Location: 04SON101N25.4L1
Comments: Burlap drag.
Surface Year: 1962

Field testing Year 1: 11/17/2008 14:07
Field testing Year 2:


Onboard picture Year 1




Texture detail


Joint detail

Google Earth view

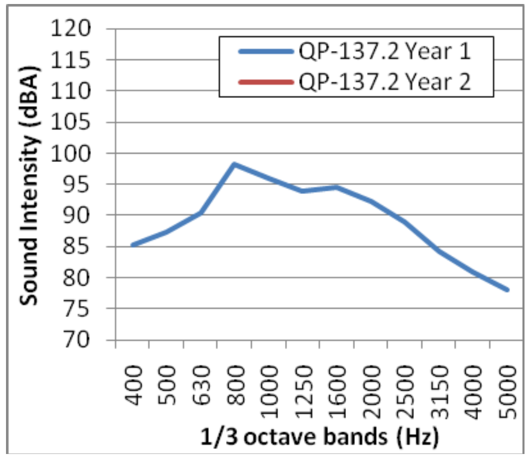

General view

QP-137.2

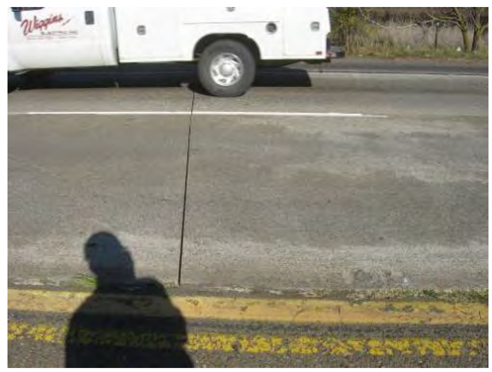
Type of section: Pavement
Location: 04SON101N25.4L1
Comments: Burlap drag.
Surface Year: 1962

Field testing Year 1: 11/17/2008 14:36
Field testing Year 2:

Onboard picture Year 1



Texture detail



Joint detail

Google Earth view

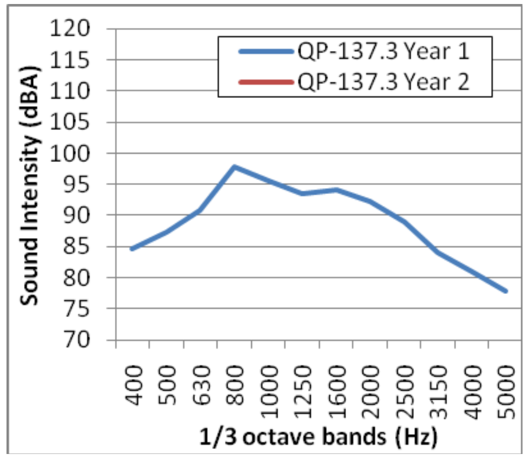
General view

QP-137.3

Type of section: Pavement
Location: 04SON101N25.4L1
Comments: Burlap drag.
Surface Year: 1962

Field testing Year 1: 11/17/2008 14:55
Field testing Year 2:

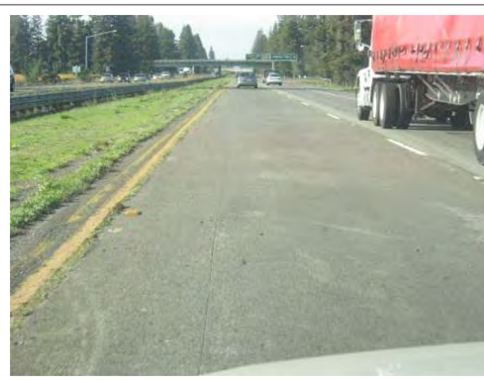
Onboard picture Year 1



Texture detail

Joint detail

Google Earth view



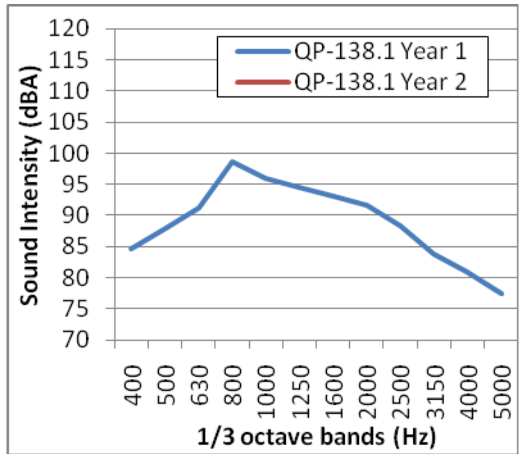
General view

QP-138.1

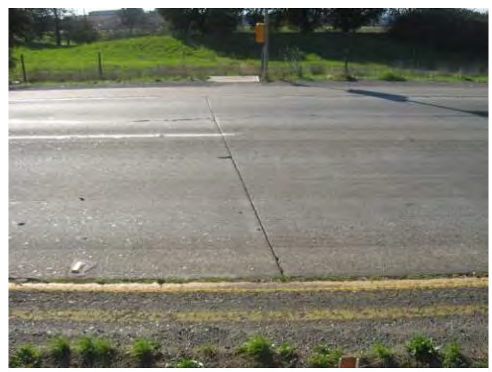
Type of section: Pavement
Location: 04SON101S27.3L1
Comments: Diamond grooved.
Surface Year: 2006

Field testing Year 1: 11/17/2008 14:27
Field testing Year 2:

Onboard picture Year 1



Texture detail



Joint detail

Google Earth view

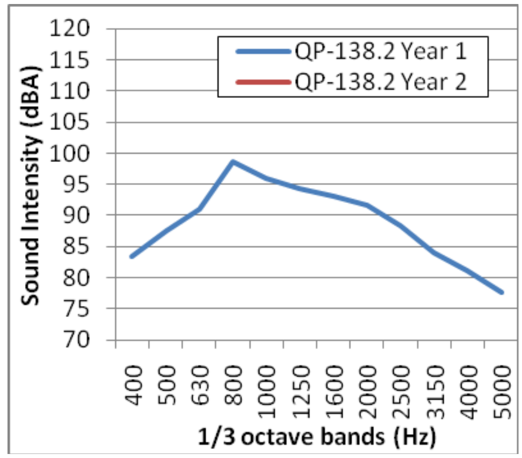
General view

QP-138.2

Type of section: Pavement
Location: 04SON101S27.3L1
Comments: Diamond grooved.
Surface Year: 2006

Field testing Year 1: 11/17/2008 14:41
Field testing Year 2:

Onboard picture Year 1



Texture detail

Joint detail

Google Earth view

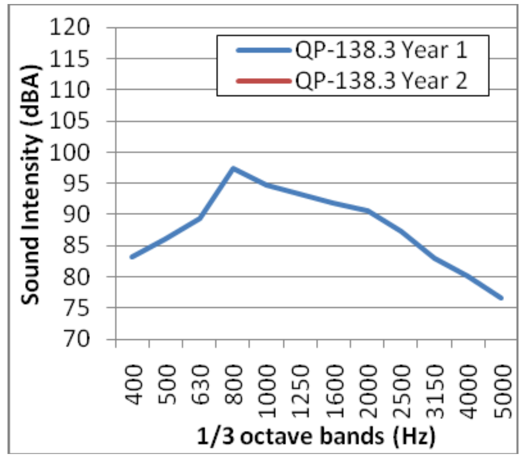
General view

QP-138.3

Type of section: Pavement
Location: 04SON101S27.3L1
Comments: Diamond grooved.
Surface Year: 2006

Field testing Year 1: 11/17/2008 15:01
Field testing Year 2:

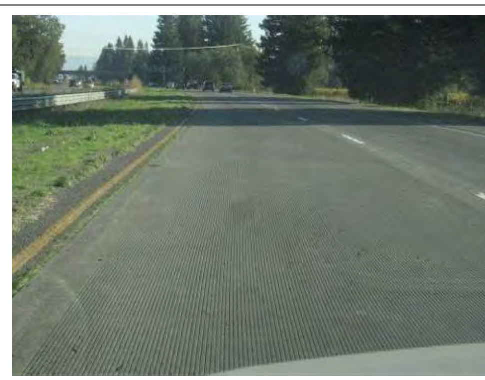
Onboard picture Year 1



Texture detail

Joint detail

Google Earth view

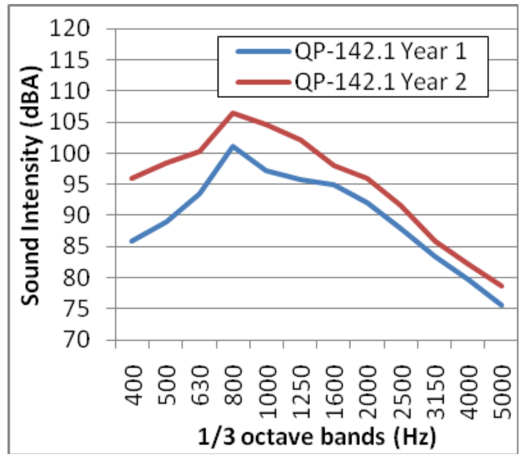


General view

QP-142.1

Type of section: Pavement
Field testing Year 1: 11/24/2008 15:10
Location: 03NEV80W1.0
Field testing Year 2: 9/17/2009 12:31
Comments: Longitudinally tined. New LT.
Surface Year: 2008

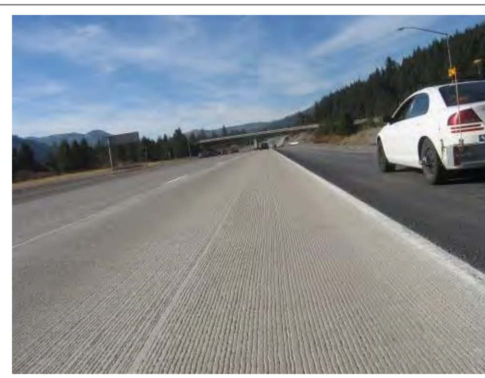
Onboard picture Year 1



Texture detail

Joint detail

Google Earth view

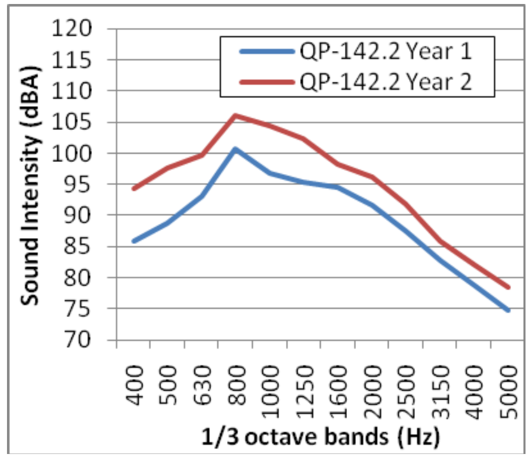


General view

QP-142.2

Type of section: Pavement
Field testing Year 1: 11/24/2008 15:16
Location: 03NEV80W0.9
Field testing Year 2: 9/17/2009 12:49
Comments: Longitudinally tined. New LT.
Surface Year: 2008

Onboard picture Year 1



Texture detail

Joint detail

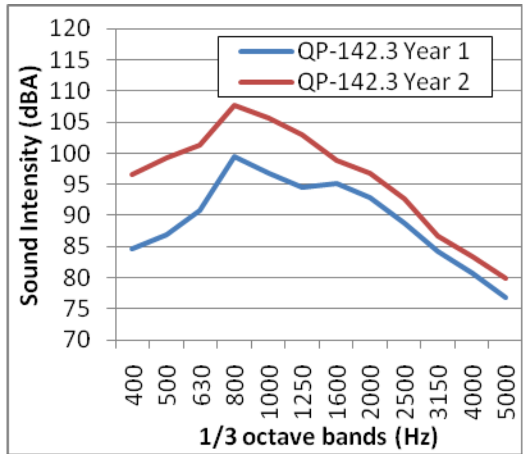
Google Earth view

General view

QP-142.3

Type of section: Pavement
Field testing Year 1: 11/24/2008 15:19
Location: 03NEV80W0.8
Field testing Year 2: 9/17/2009 12:52
Comments: Longitudinally tined. New LT.
Surface Year: 2008

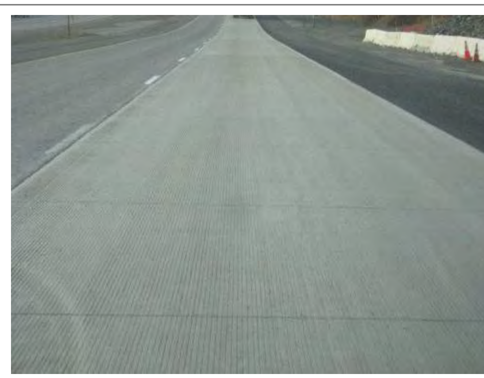
Onboard picture Year 1



Texture detail

Joint detail

Google Earth view

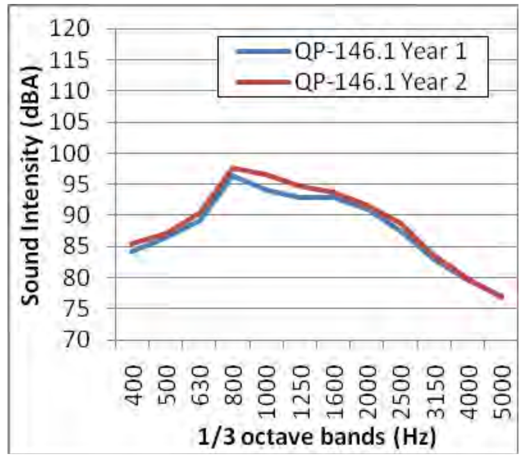


General view

QP-146.1

Type of section: Pavement
Field testing Year 1: 12/2/2008 14:05
Location: 04SM280N10.6
Field testing Year 2: 11/16/2009 11:28
Comments: Longitudinally broomed.
Surface Year: 1974

Onboard picture Year 1



Texture detail

Joint detail

Google Earth view

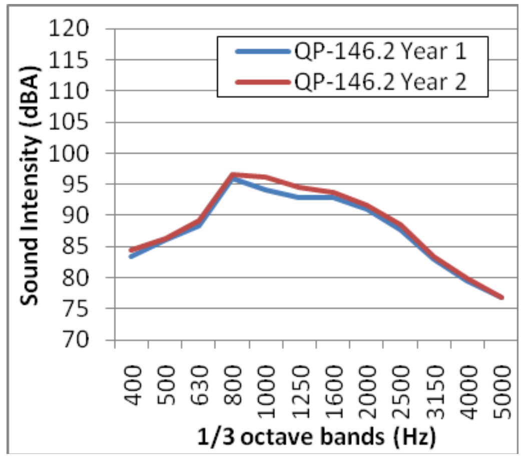
General view

QP-146.2

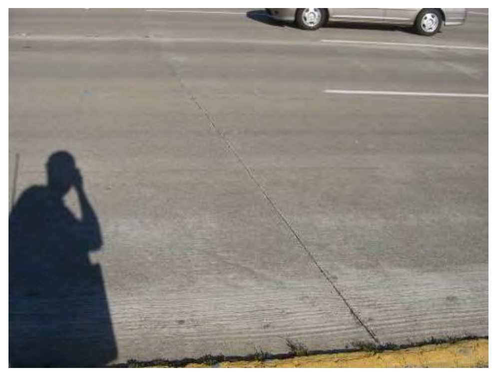
Type of section: Pavement
Location: 04SM280N10.6
Comments: Longitudinally broomed.
Surface Year: 1974

Field testing Year 1: 12/2/2008 14:11
Field testing Year 2: 11/16/2009 12:32

Onboard picture Year 1

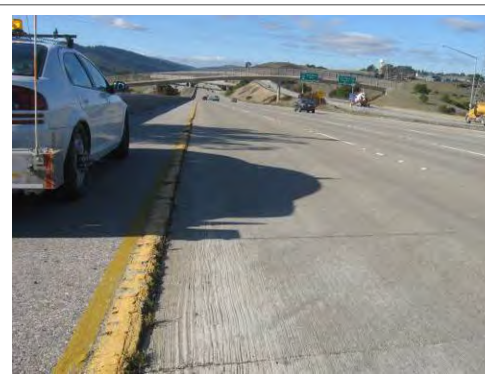


Texture detail



Joint detail

Google Earth view



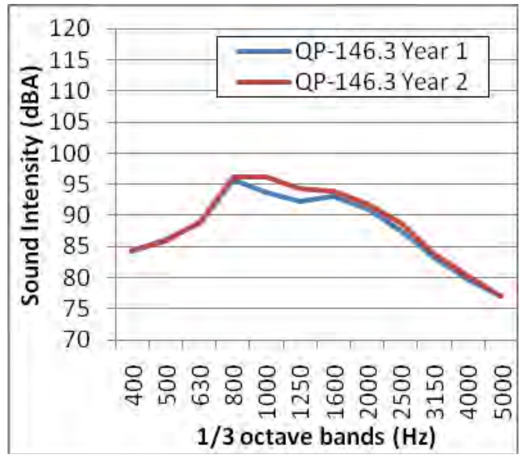
General view

QP-146.3

Type of section: Pavement
Location: 04SM280N10.6
Comments: Longitudinally broomed.
Surface Year: 1974

Field testing Year 1: 12/2/2008 14:31
Field testing Year 2: 11/16/2009 12:41

Onboard picture Year 1



Texture detail

Joint detail

Google Earth view

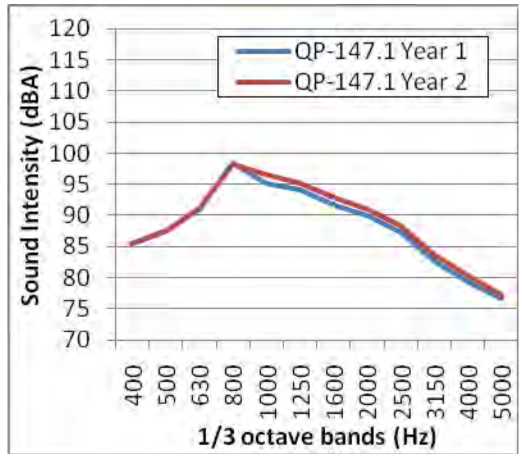
General view

QP-147.1

Type of section: Pavement
Location: 04SM280N11.6
Comments: Diamond ground.
Surface Year: 2007

Field testing Year 1: 12/2/2008 15:46
Field testing Year 2: 11/16/2009 12:29

Onboard picture Year 1



Texture detail

Joint detail

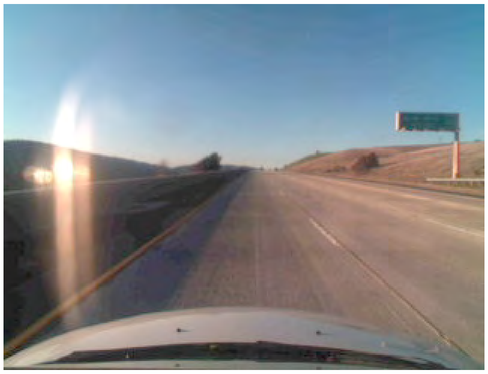
Google Earth view

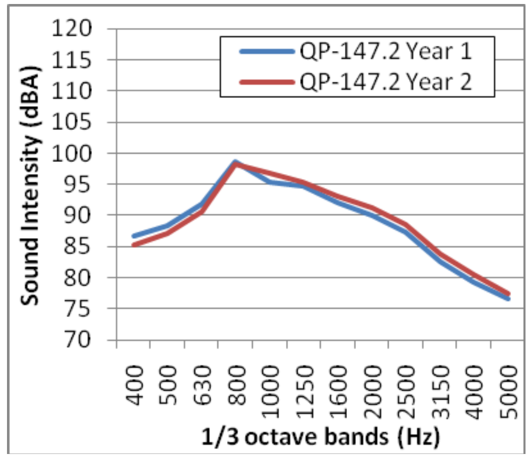
General view

QP-147.2

Type of section: Pavement
Location: 04SM280N11.7
Comments: Diamond ground.
Surface Year: 2007

Field testing Year 1: 12/2/2008 15:56
Field testing Year 2: 11/16/2009 12:39

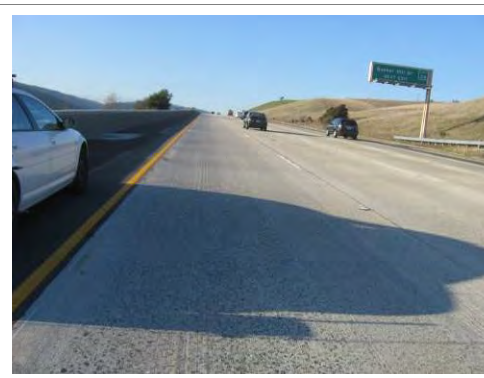

Onboard picture Year 1




Texture detail


Joint detail

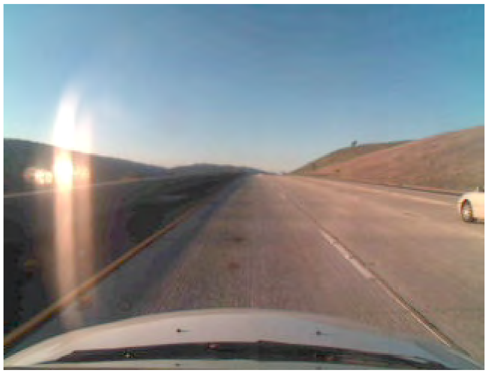
Google Earth view

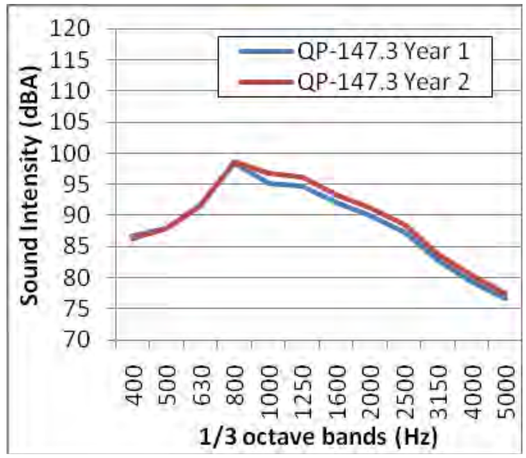

General view

QP-147.3

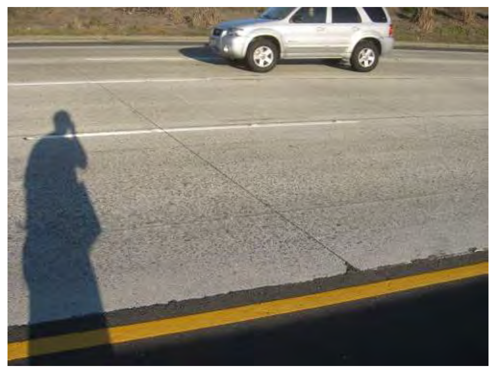
Type of section: Pavement
Location: 04SM280N11.8
Comments: Diamond ground.
Surface Year: 2007

Field testing Year 1: 12/2/2008 16:09
Field testing Year 2: 11/16/2009 12:46

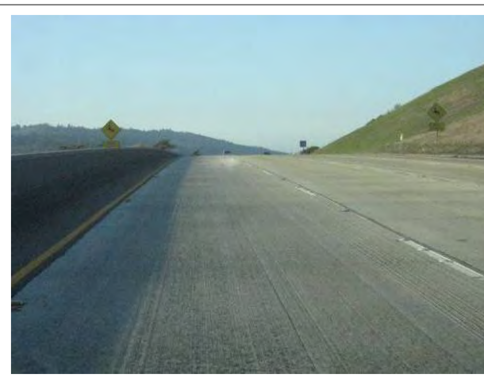

Onboard picture Year 1




Texture detail


Joint detail

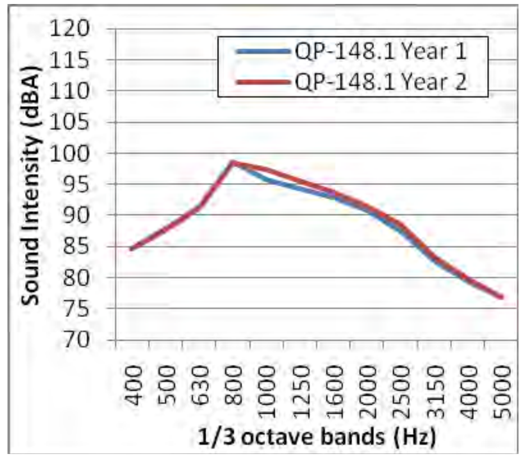
Google Earth view


General view

QP-148.1

Type of section: Pavement
Field testing Year 1: 12/3/2008 13:07
Location: 04SM280N1.6
Field testing Year 2: 11/16/2009 14:36
Comments: Diamond ground. Old DG.
Surface Year: 2001

Onboard picture Year 1



Texture detail

Joint detail

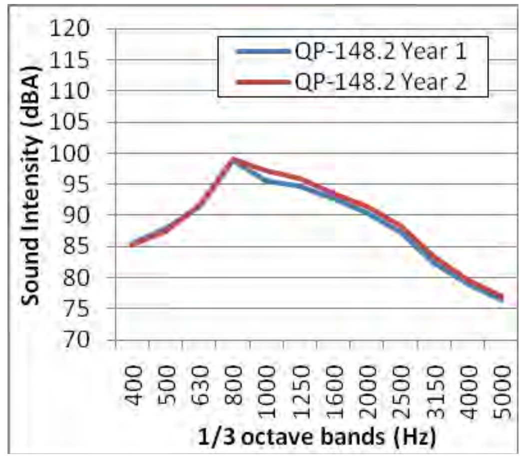
Google Earth view

General view

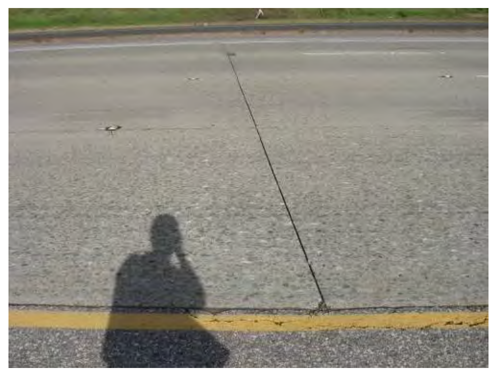
QP-148.2

Type of section: Pavement
Location: 04SM280N1.6
Field testing Year 1: 12/3/2008 13:25
Field testing Year 2: 11/16/2009 14:51
Comments: Diamond ground. Old DG.
Surface Year: 2001

Onboard picture Year 1



Texture detail



Joint detail

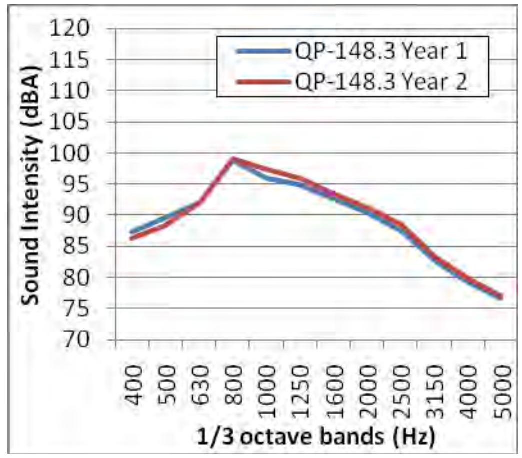
Google Earth view

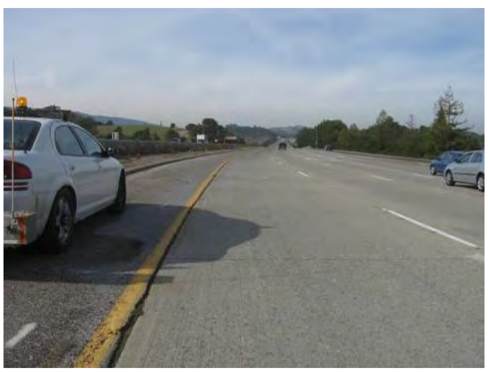
General view

QP-148.3

Type of section: Pavement
Field testing Year 1: 12/3/2008 13:34
Location: 04SM280N1.6
Field testing Year 2: 11/16/2009 15:00
Comments: Diamond ground. Old DG.
Surface Year: 2001

Onboard picture Year 1

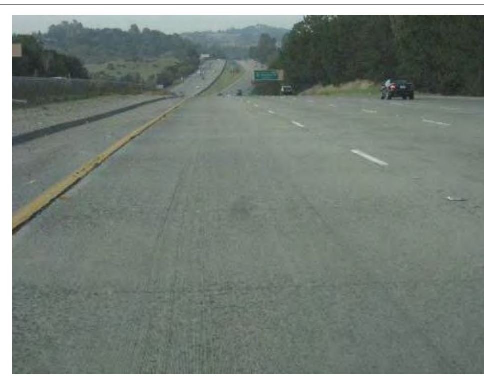




Texture detail

Joint detail

Google Earth view



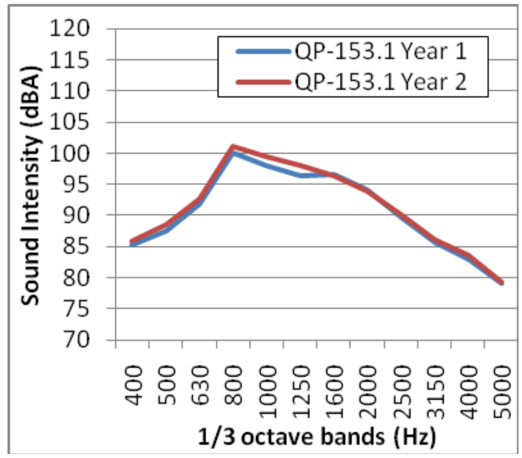
General view

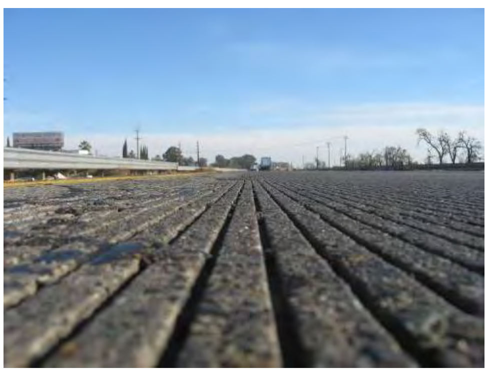
QP-153.1

Type of section: Pavement
Location: 10Mer99S17.5
Comments: Diamond grooved.
Surface Year: 2006

Field testing Year 1: 12/17/2008 14:53
Field testing Year 2: 11/13/2009 13:03

Onboard picture Year 1

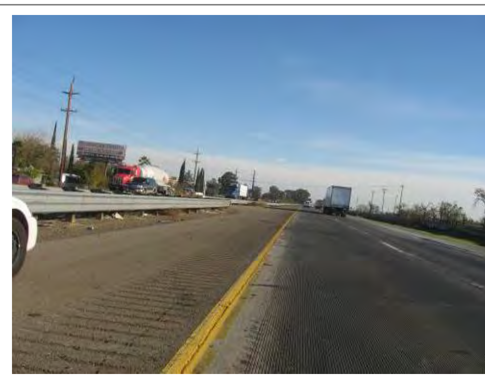




Texture detail

Joint detail

Google Earth view

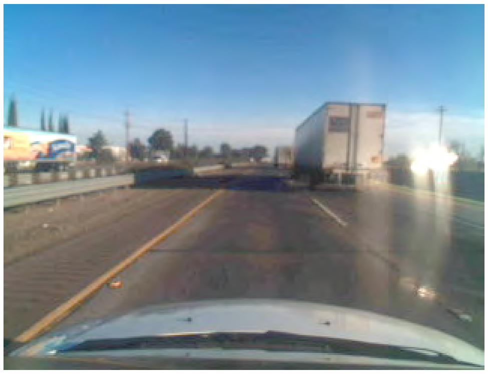


General view

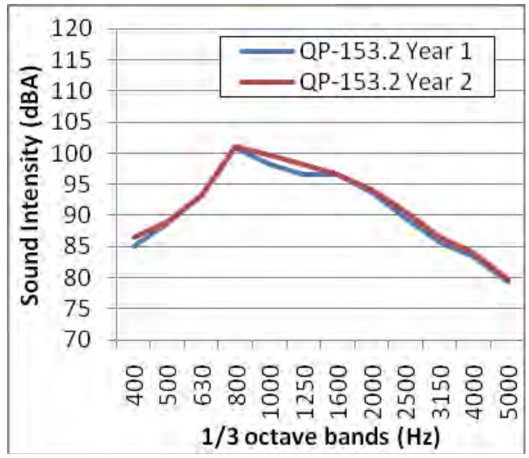
QP-153.2

Type of section: Pavement
Location: 10Mer99S17.4
Comments: Diamond grooved.
Surface Year: 2006

Field testing Year 1: 12/17/2008 15:21
Field testing Year 2: 11/13/2009 13:16



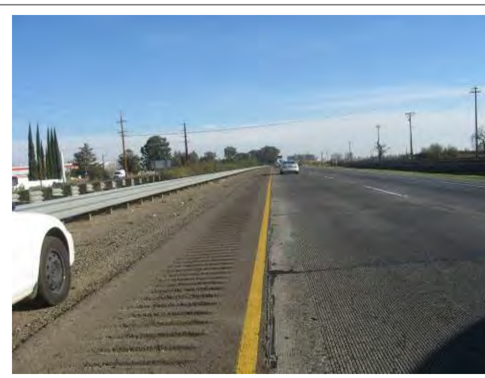
Onboard picture Year 1



Texture detail

Joint detail

Google Earth view



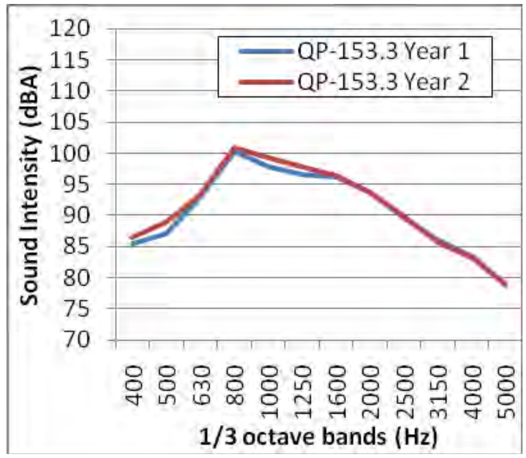
General view

QP-153.3

Type of section: Pavement
Location: 10Mer99S17.3
Comments: Diamond grooved.
Surface Year: 2006

Field testing Year 1: 12/17/2008 15:34
Field testing Year 2: 11/13/2009 13:28

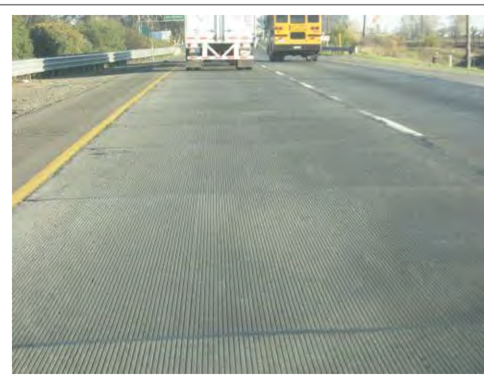
Onboard picture Year 1



Texture detail

Joint detail

Google Earth view



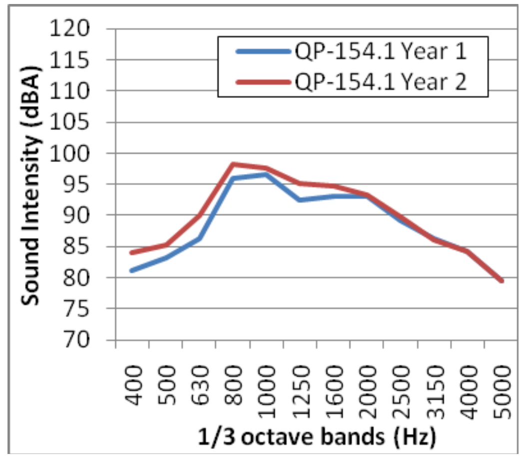
General view

QP-154.1

Type of section: Pavement
Location: 06Ker58E110.2
Comments: Diamond grooved.
Surface Year: 2006

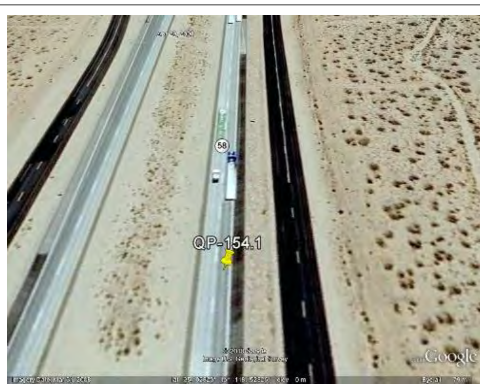
Field testing Year 1: 1/8/2009 14:27
Field testing Year 2: 12/2/2009 11:42

Onboard picture Year 1

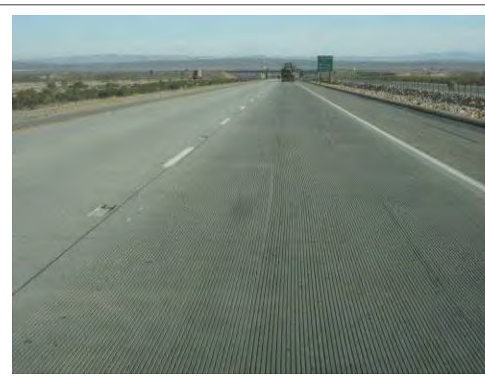


Texture detail

Joint detail



Google Earth view



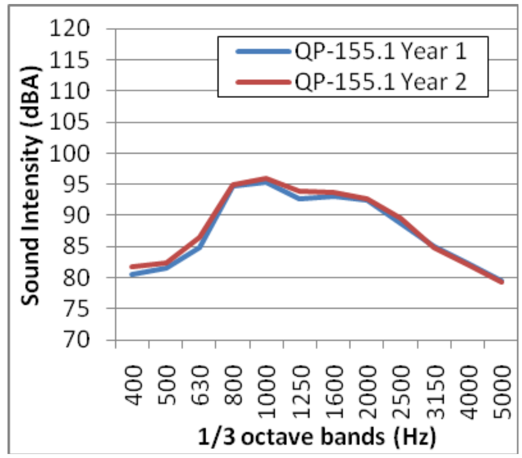
General view

QP-155.1

Type of section: Pavement
Location: 06Ker58E110.6
Comments: Diamond ground.
Surface Year: 2006

Field testing Year 1: 1/8/2009 14:54
Field testing Year 2: 12/2/2009 14:17

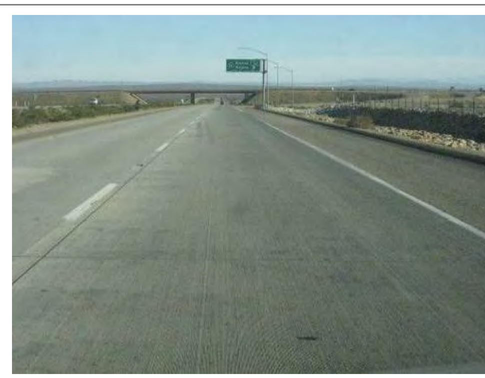
Onboard picture Year 1



Texture detail

Joint detail

Google Earth view



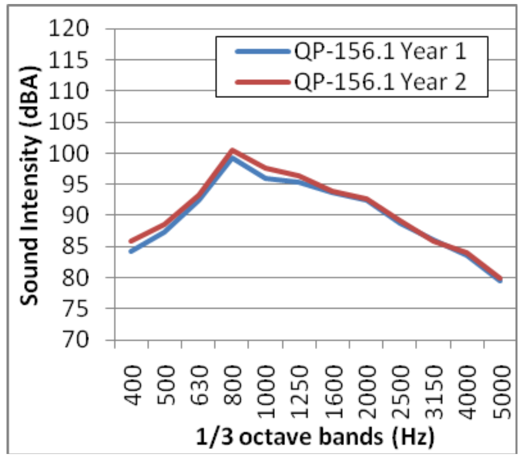
General view

QP-156.1

Type of section: Pavement
Location: 06Ker58E111.2
Comments: Diamond grooved. DG+Gr.
Surface Year: 2006

Field testing Year 1: 1/9/2009 7:57
Field testing Year 2: 12/2/2009 11:43

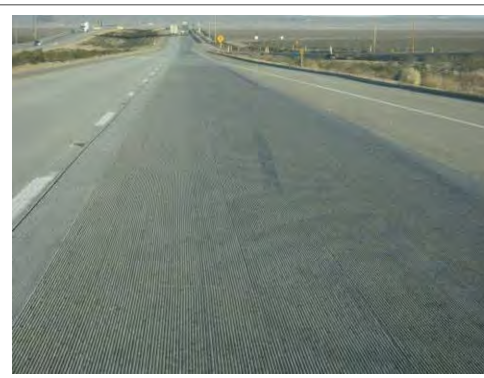
Onboard picture Year 1



Texture detail

Joint detail

Google Earth view



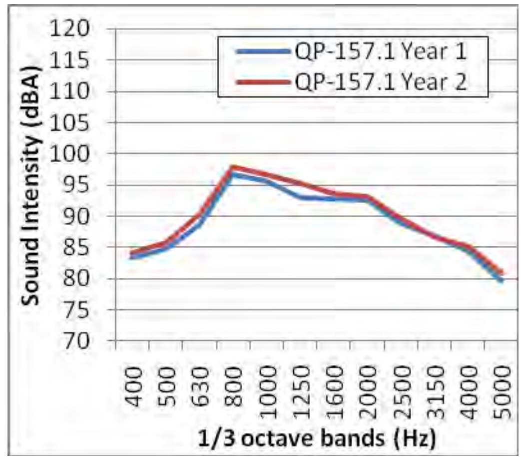
General view

QP-157.1

Type of section: Pavement
Location: 06Ker58E111.4
Comments: Diamond grooved.
Surface Year: 2006

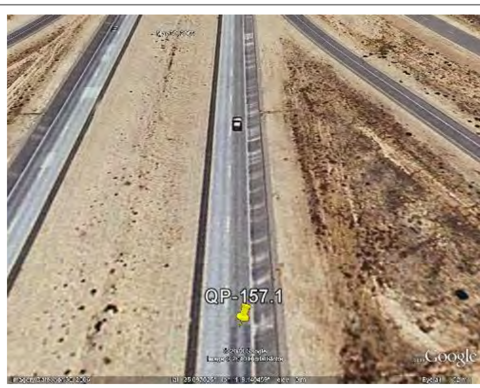
Field testing Year 1: 1/9/2009 8:40
Field testing Year 2: 12/2/2009 14:17

Onboard picture Year 1



Texture detail

Joint detail



Google Earth view

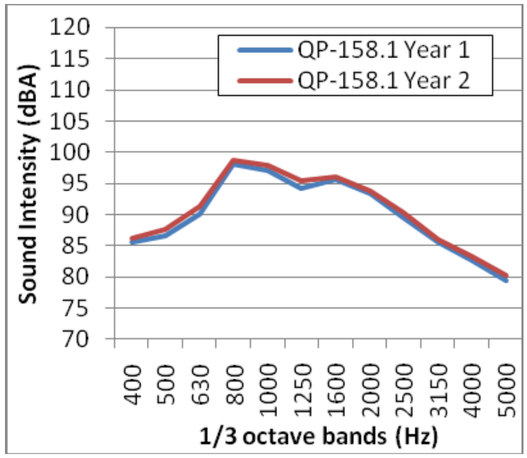
General view

QP-158.1

Type of section: Pavement
Location: 06Ker58E109.5
Comments: Longitudinally tined.
Surface Year: 2003

Field testing Year 1: 1/9/2009 9:58
Field testing Year 2: 12/2/2009 11:39

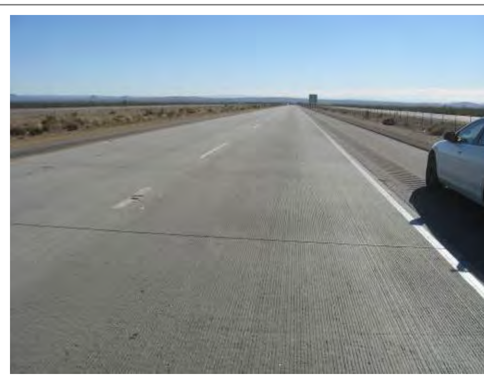
Onboard picture Year 1



Texture detail

Joint detail

Google Earth view



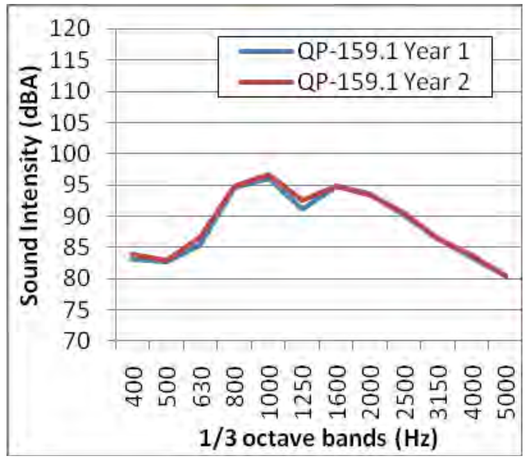
General view

QP-159.1

Type of section: Pavement
Location: 06Ker58E110.3
Comments: Burlap drag.
Surface Year: 2003

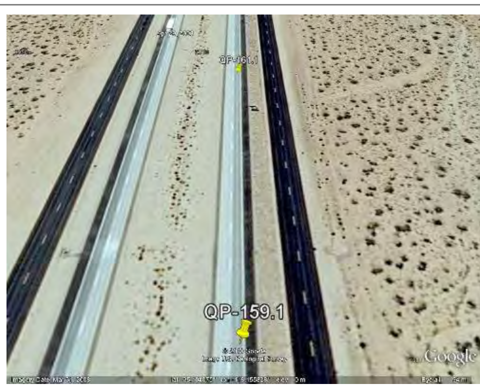
Field testing Year 1: 1/9/2009 10:38
Field testing Year 2: 12/3/2009 10:37

Onboard picture Year 1

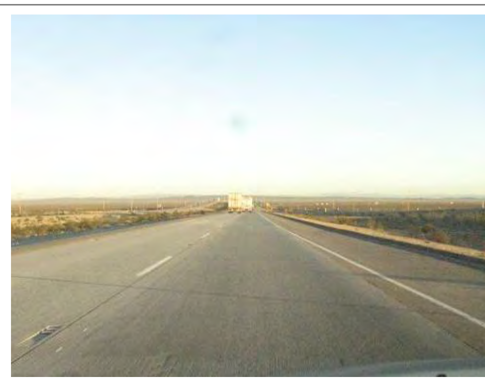


Texture detail

Joint detail



Google Earth view

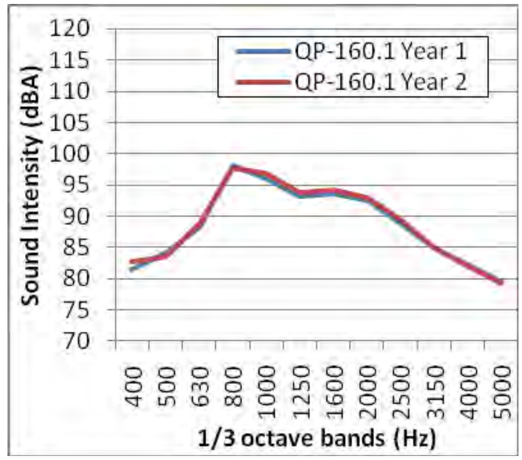


General view

QP-160.1

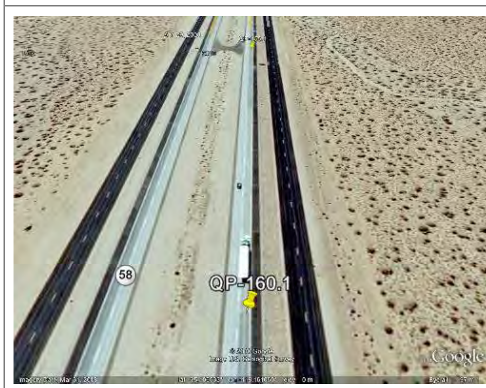
Type of section: Pavement Field testing Year 1: 2/23/2009 17:08
Location: 06Ker58E110.0 Field testing Year 2: 12/2/2009 14:13
Comments: Diamond ground. Caltrans section 2, DG 0.12" over burlap drag.
Surface Year: 2006

Onboard picture Year 1



Texture detail

Joint detail



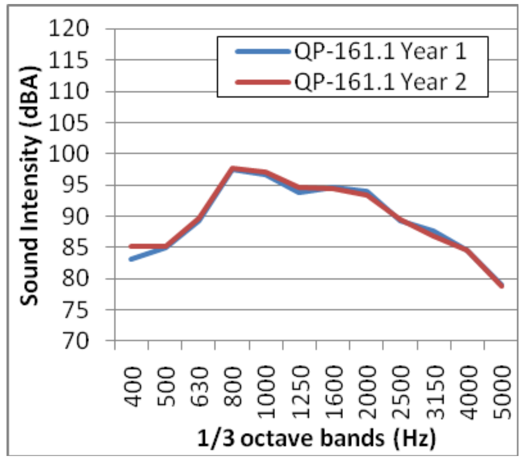
Google Earth view

General view

QP-161.1

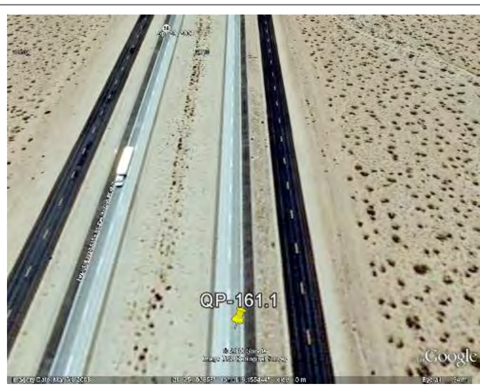
Type of section: Pavement
Field testing Year 1: 2/23/2009 17:44
Location: 06Ker58E110.4
Field testing Year 2: 12/3/2009 10:58
Comments: Diamond grooved. CT section 4, 3/4" spacing, 1/4"deep, over burlap drag.
Surface Year: 2006

Onboard picture Year 1



Texture detail

Joint detail



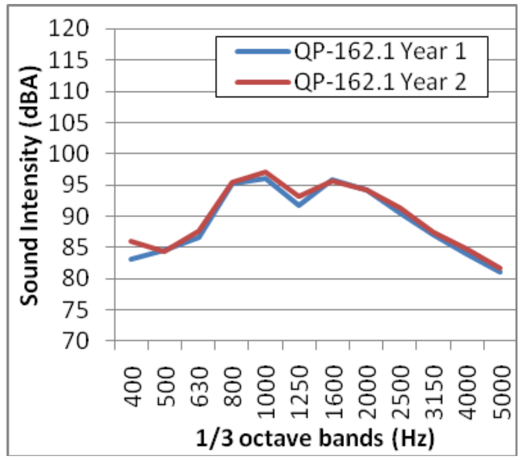
Google Earth view

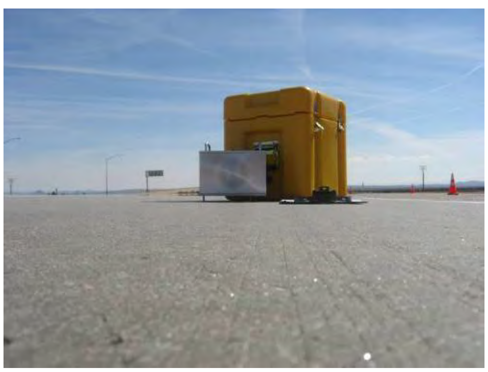
General view

QP-162.1

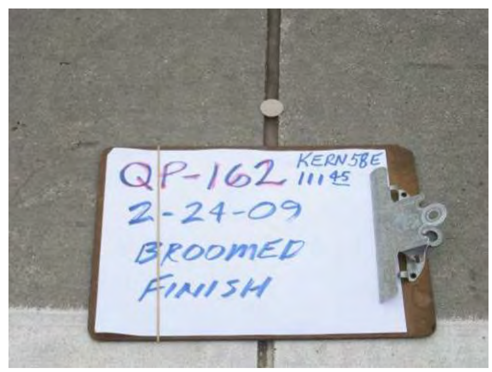
Type of section: Pavement — Field testing Year 1: 2/24/2009 16:53
Location: 06Ker58E111.5 — Field testing Year 2: 12/3/2009 10:41
Comments: Longitudinally broomed. Base texture for other sections in this area.
Surface Year: 2003

Onboard picture Year 1



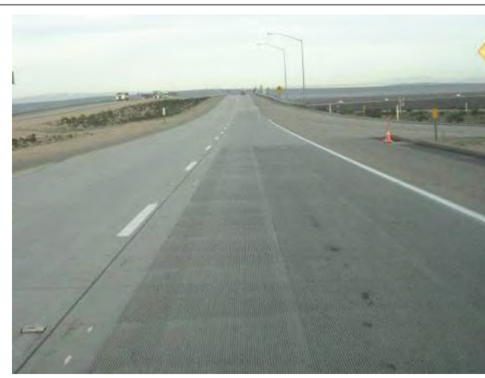


Texture detail



Joint detail

Google Earth view



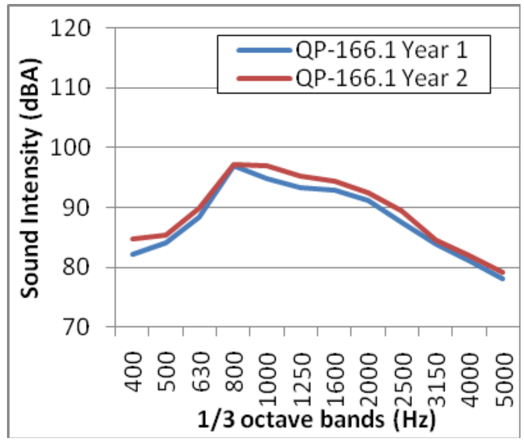
General view

QP-166.1

Type of section: Pavement
Location: 06Ker58E111.7
Comments: Diamond ground.
Surface Year: 2006

Field testing Year 1: 2/26/2009 9:13
Field testing Year 2: 12/2/2009 11:44

Onboard picture Year 1



Texture detail

Joint detail

Google Earth view

General view

APPENDIX E: SUMMARY TABLE AND SELECTED FIGURES WITH UNCORRECTED OBSI DATA

This appendix presents selected tables and figures from the main body of this report that have been remade using data without corrections for tire type and analyzer. The numbering and captions for the tables and figures are the same as those in the main body of the report to facilitate comparison.

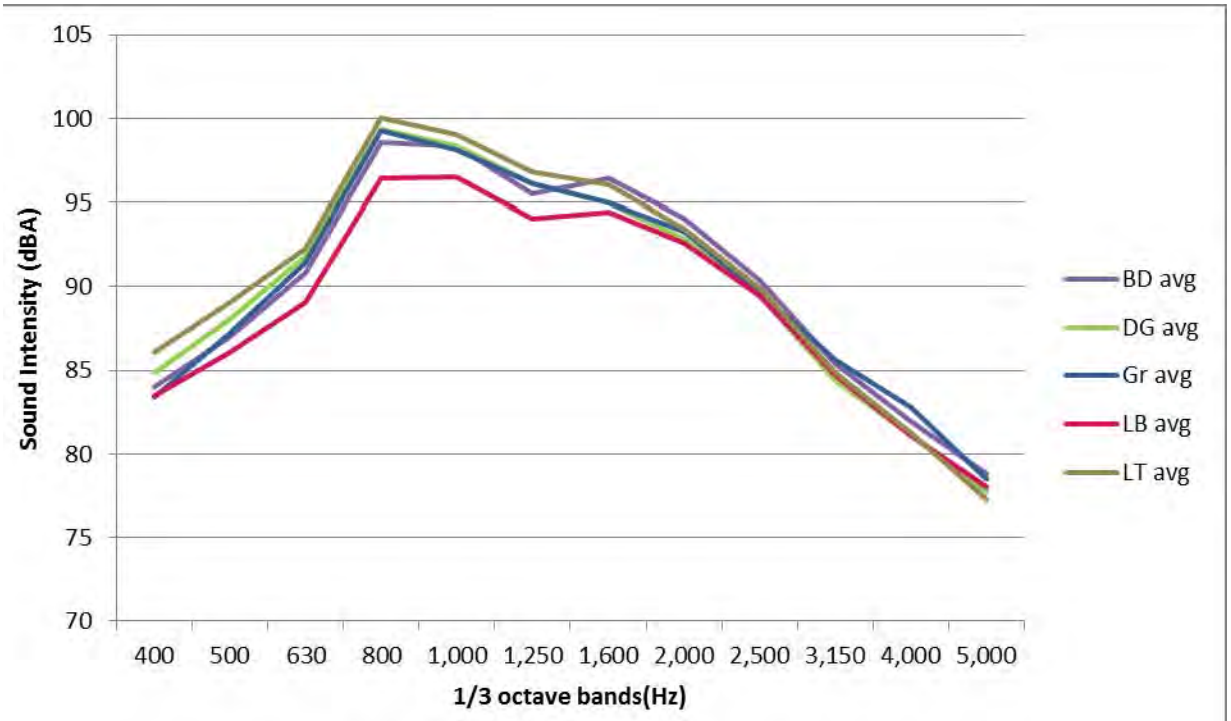


Figure E.1: Figure 3.17: Comparison of OBSI spectral content of sections with different texture types, average of sections with texture aged.
(Note: **BD = burlap drag, DG=diamond ground, Gr=diamond grooved, LB=longitudinally broomed, LT=longitudinally tined.)**

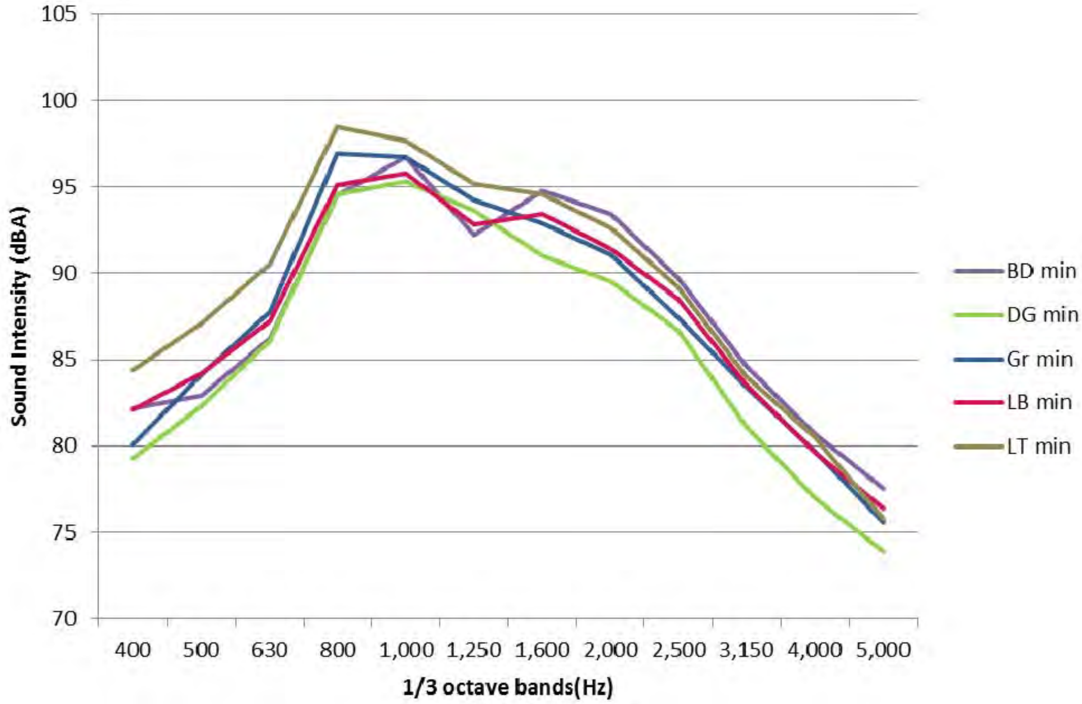


Figure E.2: Compare with Figure 3.19: Comparison of OBSI spectral content of sections with different texture types, minimum of sections with aged texture.
(Note: **BD = burlap drag, DG=diamond ground, Gr=diamond grooved, LB=longitudinally broomed, LT=longitudinally tined.)**

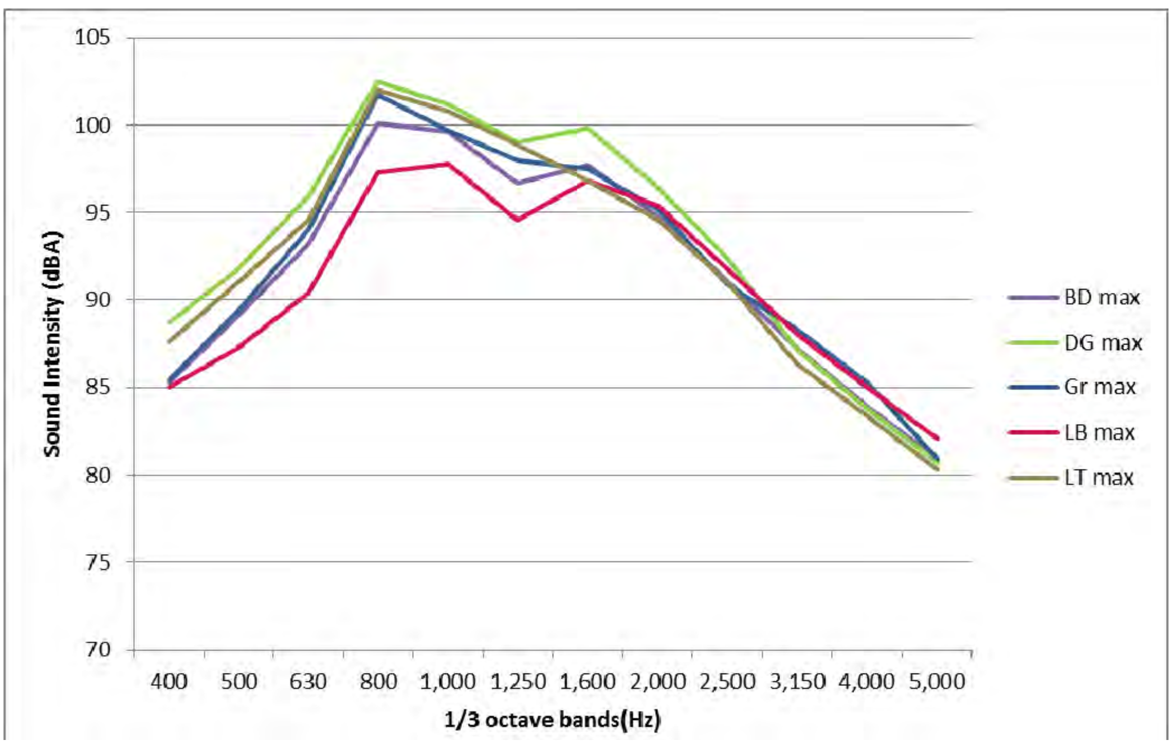


Figure E.3: Compare with Figure 3.20: Comparison of OBSI spectral content of sections with different texture types, maximum of sections with aged texture.
(Note: **BD = burlap drag, DG=diamond ground, Gr=diamond grooved, LB=longitudinally broomed, LT=longitudinally tined.)**

Table E.1: Compare with Table 3.2: Mean Values of Overall OBSI Levels (dB[A]) by Surface Texture Type, All Sections (All Conditions: *New, Aged, Worn out)*

	Year 1			Year 2			Combined Year1 and 2		
Surface Type	**Mean**	**Std. Dev.**	**Sample Size**	**Mean**	**Std. Dev.**	**Sample Size**	**Mean**	**Std. Dev.**	**Sample Size**
Burlap drag (BD)	105.3	1.5	37	105.6	1.3	31	105.4	1.4	68
Diamond ground (DG)	104.9	1.6	32	104.8	1.5	24	104.9	1.6	56
Diamond Grooved (Gr)	105.4	0.8	19	105.4	0.8	7	105.4	0.8	26
Longitudinally broomed (LB)	104.9	1.5	10	103.0	0.8	4	104.4	1.5	14
Longitudinally tined (LT)	105.9	1.1	21	106.1	0.9	18	106.0	1.0	39

Table E.2: Compare with Table 3.3: Mean Values of Overall OBSI Levels (dB[A]) by Surface Texture Type, Only *New* and *Aged* Textures

	Year 1			Year 2			Combined Year1 and 2		
Surface Type	**Mean**	**Std. Dev.**	**Sample Size**	**Mean**	**Std. Dev.**	**Sample Size**	**Mean**	**Std. Dev.**	**Sample Size**
Burlap drag (BD)	104.8	0.5	10	105.1	0.8	7	104.9	0.7	17
Diamond ground (DG)	104.9	1.6	32	104.8	1.5	24	104.9	1.6	56
Diamond Grooved (Gr)	105.4	0.8	19	105.4	0.8	7	105.4	0.8	26
Longitudinally broomed (LB)	103.5	1.0	4	103.0	0.8	4	103.3	0.9	8
Longitudinally tined (LT)	105.7	1.1	18	106.0	0.9	15	105.8	1.0	33

Table E.3: : Compare with Table 2.1: List of Locations, Texture Types and Conditions, and Construction and Resurfacing Years of Field Evaluation Sections

Section ID	Location: Dist-Cnty-Rte-Dir-PM	Lane[1]	Texture Type[2]	Const. Year	Surfacing Year	Texture Condition[3]	Test Tire Year 1	Uncorrected OBSI Year 1	Test Tire Year 2	Uncorrected OBSI Year 2	Corrected to SRTT #1 OBSI Year 1	Corrected to SRTT #1 OBSI Year 2
QP-117.1	04CC80W10.3	4 of 4	LT	2007	2007	New	SRTT #2	104.7	SRTT #3	106.4	103.1	106.3
QP-117.2	04CC80W10.2	4 of 4	LT	2007	2007	New	SRTT #2	104.4	SRTT #3	106.4	102.7	106.3
QP-117.3	04CC80W10.1	4 of 4	LT	2007	2007	New	SRTT #2	104.5	SRTT #3	106.5	102.9	106.4
QP-142.1	03NEV80W1.0	2 of 2	LT	2008	2008	New	SRTT #2	107.9	SRTT #3	113.3	104.9	111.4
QP-142.2	03NEV80W0.9	2 of 2	LT	2008	2008	New	SRTT #2	107.6	SRTT #3	113.0	104.5	111.2
QP-142.3	03NEV80W0.8	2 of 2	LT	2008	2008	New	SRTT #2	107.1	SRTT #3	114.3	103.9	112.6
QP-100.1	03Yol113N3.0	2 of 2	LT	1976	1976	Aged	SRTT #2	104.9	SRTT #3	105.7	103.1	105.3
QP-100.2	03Yol113N3.1	2 of 2	LT	1976	1976	Aged	SRTT #2	106.4	SRTT #3	107.1	104.7	106.8
QP-100.3	03Yol113N3.2	2 of 2	LT	1976	1976	Aged	SRTT #2	105.5	SRTT #3	106.1	103.7	105.6
QP-101.1	03Yol113N6.0	2 of 2	LT	1990	1990	Aged	SRTT #2	106.5	SRTT #3	107.1	105.2	106.7
QP-101.2	03Yol113N6.1	2 of 2	LT	1990	1990	Aged	SRTT #2	106.8	SRTT #3	107.1	105.5	106.7
QP-101.3	03Yol113N6.2	2 of 2	LT	1990	1990	Aged	SRTT #2	106.5	SRTT #3	107.2	105.2	106.8
QP-127.1	04SCL85S21.5L1	1 of 3	LT	1965	1965	Aged	SRTT #2	104.7	SRTT #3	104.7	103.2	104.6
QP-127.2	04SCL85S21.4L1	1 of 3	LT	1965	1965	Aged	SRTT #2	105.2	SRTT #3	105.1	103.7	105.1
QP-127.3	04SCL85S21.3L1	1 of 3	LT	1965	1965	Aged	SRTT #2	104.7	SRTT #3	104.5	103.1	104.5
QP-129.1	06FRE180W55.7	3 of 3	LT	2008	2008	Aged	SRTT #2	105.0	SRTT #3	105.1	103.6	105

Section ID	Location: Dist-Cnty-Rte-Dir-PM	Lane[1]	Texture Type[2]	Const. Year	Surfacing Year	Texture Condition[3]	Test Tire Year 1	Uncorrected OBSI Year 1	Test Tire Year 2	Uncorrected OBSI Year 2	Corrected to SRTT #1 OBSI Year 1	Corrected to SRTT #1 OBSI Year 2
QP-129.2	06FRE180W55.6	3 of 3	LT	2008	2008	Aged	SRTT #2	105.1	SRTT #3	105.0	103.7	104.8
QP-158.1	06Ker58E109.5	2 of 2	LT	2003	2003	Aged	SRTT #2	105.9	SRTT #3	105.6	103.6	104.4
QP-108.1	03Pla80E45.0	1 of 2	LT	1961	2004	Worn out	SRTT #2	106.9	SRTT #3	107.1	104.5	105.8
QP-108.2	03Pla80E45.1	1 of 2	LT	1961	2004	Worn out	SRTT #2	107.1	SRTT #3	107.1	104.7	105.7
QP-108.3	03Pla80E45.2	1 of 2	LT	1961	2004	Worn out	SRTT #2	106.5	SRTT #3	106.9	103.9	105.5
QP-162.1	06Ker58E111.5	2 of 2	LB	2003	2003	Aged	SRTT #2	105.0	SRTT #3	104.1	102.5	103
QP-146.1	04SM280N10.6	1 of 4	LB	1974	1974	Aged	SRTT #2	103.2	SRTT #3	103.0	101.4	102.7
QP-146.2	04SM280N10.7	1 of 4	LB	1974	1974	Aged	SRTT #2	103.0	SRTT #3	102.5	101.2	102.2
QP-146.3	04SM280N10.8	1 of 4	LB	1974	1974	Aged	SRTT #2	102.9	SRTT #3	102.4	101.1	102.1
QP-109.1	03Nev80E22.6	1 of 2	LB	1989	1989	Worn out	SRTT #2	105.5	Not Tested	Not Tested	102.2	
QP-109.2	03Nev80E22.6	1 of 2	LB	1989	1989	Worn out	SRTT #2	105.9	Not Tested	Not Tested	102.7	
QP-109.3	03Nev80E22.6	1 of 2	LB	1989	1989	Worn out	SRTT #2	105.2	Not Tested	Not Tested	101.9	
QP-112.1	03Nev80W23.0	1 of 2	LB	1989	1989	Worn out	SRTT #2	105.5	Not Tested	Not Tested	102.1	
QP-112.2	03Nev80W22.9	1 of 2	LB	1989	1989	Worn out	SRTT #2	105.9	Not Tested	Not Tested	102.7	
QP-112.3	03Nev80W22.8	1 of 2	LB	1989	1989	Worn out	SRTT #2	107.2	Not Tested	Not Tested	104.1	
QP-115.1	03Yol505S13.1	2 of 2	BD	1977	1977	Aged	SRTT #2	105.3	SRTT #3	105.4	104	105
QP-115.2	03Yol505S13.0	2 of 2	BD	1977	1977	Aged	SRTT #2	104.7	SRTT #3	105.5	103.3	105

Section ID	Location: Dist-Cnty-Rte-Dir-PM	Lane[1]	Texture Type[2]	Const. Year	Surfacing Year	Texture Condition[3]	Test Tire Year 1	Uncorrected OBSI Year 1	Test Tire Year 2	Uncorrected OBSI Year 2	Corrected to SRTT #1 OBSI Year 1	Corrected to SRTT #1 OBSI Year 2
QP-115.3	03Yol505S12.9	2 of 2	BD	1977	1977	Aged	SRTT #2	104.7	SRTT #3	105.4	103.3	105
QP-123.1	04ALA580E37.1	4 of 4	BD	1965	1965	Aged	SRTT #2	105.5	SRTT #3	105.9	104.2	105.5
QP-123.2	04ALA580E37.2	4 of 4	BD	1965	1965	Aged	SRTT #2	105.3	SRTT #3	105.0	104	104.6
QP-123.3	04ALA580E37.3	4 of 4	BD	1965	1965	Aged	SRTT #2	105.1	SRTT #3	105.5	103.9	105.1
QP-137.1	04SON101N25.4L1	1 of 2	BD	1962	1962	Aged	SRTT #2	103.9	Not Tested	Not Tested	102.2	
QP-137.2	04SON101N25.5L1	1 of 2	BD	1962	1962	Aged	SRTT #2	104.6	Not Tested	Not Tested	103.1	
QP-137.3	04SON101N25.6L1	1 of 2	BD	1962	1962	Aged	SRTT #2	104.4	Not Tested	Not Tested	102.8	
QP-159.1	06Ker58E110.3	2 of 2	BD	2003	2003	Aged	SRTT #2	104.3	SRTT #3	103.4	101.9	102.2
QP-102.1	03Yol113S5.5	2 of 2	BD	1976	1976	Worn out	SRTT #2	103.1	SRTT #3	104.0	101.1	103.3
QP-102.2	03Yol113S5.4	2 of 2	BD	1976	1976	Worn out	SRTT #2	102.7	SRTT #3	103.7	100.7	103
QP-102.3	03Yol113S5.3	2 of 2	BD	1976	1976	Worn out	SRTT #2	102.8	SRTT #3	103.7	100.8	103
QP-104.1	03Sac50E3.2	1 of 5	BD	1971	1971	Worn out	SRTT #2	105.1	SRTT #3	105.4	103.5	105
QP-104.2	03Sac50E3.2	1 of 5	BD	1971	1971	Worn out	SRTT #2	105.6	SRTT #3	105.8	104.1	105.4
QP-104.3	03Sac50E3.2	1 of 5	BD	1971	1971	Worn out	SRTT #2	106.0	SRTT #3	105.9	104.7	105.5
QP-105.1	03Sac50E4.0	1 of 4	BD	1971	1971	Worn out	SRTT #2	104.5	SRTT #3	105.3	102.9	104.8
QP-105.2	03Sac50E4.1	1 of 4	BD	1971	1971	Worn out	SRTT #2	105.1	SRTT #3	105.2	103.6	104.8
QP-105.3	03Sac50E4.2	1 of 4	BD	1971	1971	Worn out	SRTT #2	104.6	SRTT #3	105.1	103	104.7

Section ID	Location: Dist-Cnty-Rte-Dir-PM	Lane[1]	Texture Type[2]	Const. Year	Surfacing Year	Texture Condition[3]	Test Tire Year 1	Uncorrected OBSI Year 1	Test Tire Year 2	Uncorrected OBSI Year 2	Corrected to SRTT #1 OBSI Year 1	Corrected to SRTT #1 OBSI Year 2
QP-106.1	03Sac50E10.5	1 of 5	BD	1973	1973	Worn out	SRTT #2	103.7	SRTT #3	104.3	101.9	103.6
QP-106.2	03Sac50E10.6	1 of 5	BD	1973	1973	Worn out	SRTT #2	104.0	SRTT #3	104.7	102.4	104.1
QP-106.3	03Sac50E10.7	1 of 5	BD	1973	1973	Worn out	SRTT #2	104.2	SRTT #3	104.4	102.6	103.8
QP-107.1	03Sac80E13.6	5 of 5	BD	1973	1973	Worn out	SRTT #2	104.9	SRTT #3	105.3	103.2	104.9
QP-107.2	03Sac80E13.7	5 of 5	BD	1973	1973	Worn out	SRTT #2	104.3	SRTT #3	104.7	102.6	104.2
QP-107.3	03Sac80E13.8	5 of 5	BD	1973	1973	Worn out	SRTT #2	103.6	SRTT #3	104.2	101.7	103.7
QP-113.1	03Yol80W22.9	1 of 3	BD	1965	1965	Worn out	SRTT #2	105.5	Not Tested	Not Tested	103.9	
QP-113.2	03Yol80W22.8	1 of 3	BD	1965	1965	Worn out	SRTT #2	105.9	Not Tested	Not Tested	104.4	
QP-113.3	03Yol80W22.7	1 of 3	BD	1965	1965	Worn out	SRTT #2	105.2	Not Tested	Not Tested	103.6	
QP-116.1	04Sol80E32.0	1 of 3	BD	1946	1946	Worn out	SRTT #2	107.5	SRTT #3	108.0	106.5	107.8
QP-116.2	04Sol80E32.1	1 of 3	BD	1946	1946	Worn out	SRTT #2	107.3	SRTT #3	107.5	106.3	107.3
QP-116.3	04Sol80E32.2	1 of 3	BD	1946	1946	Worn out	SRTT #2	106.8	SRTT #3	107.3	105.7	107
QP-126.1	04SCL85S21.5L3	3 of 3	BD	1965	1965	Worn out	SRTT #2	107.9	SRTT #3	107.2	107	107.4
QP-126.2	04SCL85S21.4L3	3 of 3	BD	1965	1965	Worn out	SRTT #2	106.9	SRTT #3	106.6	105.8	106.7
QP-126.3	04SCL85S21.3L3	3 of 3	BD	1965	1965	Worn out	SRTT #2	107.8	SRTT #3	107.2	106.9	107.4
QP-130.1	11SD5S39.7	4 of 4	BD	1964	1964	Worn out	SRTT #2	108.0	SRTT #3	107.2	106.9	107.3
QP-130.2	11SD5S39.6	4 of 4	BD	1964	1964	Worn out	SRTT #2	107.7	SRTT #3	107.1	106.6	107.1

Section ID	Location: Dist-Cnty-Rte-Dir-PM	Lane[1]	Texture Type[2]	Const. Year	Surfacing Year	Texture Condition[3]	Test Tire Year 1	Uncorrected OBSI Year 1	Test Tire Year 2	Uncorrected OBSI Year 2	Corrected to SRTT #1 OBSI Year 1	Corrected to SRTT #1 OBSI Year 2
QP-130.3	11SD5S39.5	4 of 4	BD	1964	1964	Worn out	SRTT #2	107.9	SRTT #3	107.0	106.8	107.1
QP-128.2	04SCL85N14.9	3 of 3	DG	1993	2006	New	SRTT #2	104.5	SRTT #3	104.3	102.9	104.1
QP-128.3	04SCL85N14.10	3 of 3	DG	1993	2006	New	SRTT #2	103.4	SRTT #3	103.4	101.6	103.1
QP-129.3	06FRE180W55.5	3 of 3	DG	2008	2008	New	SRTT #2	104.7	SRTT #3	104.7	103.3	104.6
QP-147.1	04SM280N11.6	1 of 3	DG	1973	2007	New	SRTT #2	104.0	SRTT #3	103.3	102.5	102.9
QP-147.2	04SM280N11.7	1 of 3	DG	1973	2007	New	SRTT #2	104.3	SRTT #3	103.4	102.8	103
QP-147.3	04SM280N11.8	1 of 3	DG	1973	2007	New	SRTT #2	104.2	SRTT #3	103.8	102.7	103.4
QP-103.1	03Yol50E0.2	1 of 4	DG	1969	2005	Aged	SRTT #2	101.8	Not Tested	Not Tested	99.8	
QP-103.2	03Yol50E0.3	1 of 4	DG	1969	2005	Aged	SRTT #2	101.6	Not Tested	Not Tested	99.6	
QP-103.3	03Yol50E0.4	1 of 4	DG	1969	2005	Aged	SRTT #2	101.5	Not Tested	Not Tested	99.4	
QP-114.1	04Sol80W18.7	2 of 4	DG	1949	1999	Aged	SRTT #2	104.1	Not Tested	Not Tested	102.3	
QP-114.2	04Sol80W18.6	2 of 4	DG	1949	1999	Aged	SRTT #2	104.0	Not Tested	Not Tested	102	
QP-114.3	04Sol80W18.5	2 of 4	DG	1949	1999	Aged	SRTT #2	104.4	Not Tested	Not Tested	102.6	
QP-128.1	04SCL85N14.8	3 of 3	DG	1993	2006	Aged	SRTT #2	104.6	SRTT #3	104.4	103	104.2
QP-131.1	11SD8W15.5	1 of 3	DG	1985	1997	Aged	SRTT #2	106.6	SRTT #3	104.1	105.3	103.7
QP-131.2	11SD8W15.6	1 of 3	DG	1985	1997	Aged	SRTT #2	106.4	SRTT #3	103.9	105.1	103.6
QP-131.3	11SD8W15.7	1 of 3	DG	1985	1997	Aged	SRTT #2	106.5	SRTT #3	103.9	105.2	103.6

Section ID	Location: Dist-Cnty-Rte-Dir-PM	Lane[1]	Texture Type[2]	Const. Year	Surfacing Year	Texture Condition[3]	Test Tire Year 1	Uncorrected OBSI Year 1	Test Tire Year 2	Uncorrected OBSI Year 2	Corrected to SRTT #1 OBSI Year 1	Corrected to SRTT #1 OBSI Year 2
QP-132.1	11SD805N2.1	5 of 5	DG	1975	1998	Aged	SRTT #2	106.8	SRTT #3	106.6	105.4	106.3
QP-132.2	11SD805N2.2	5 of 5	DG	1975	1998	Aged	SRTT #2	107.8	SRTT #3	107.4	106.6	107.2
QP-132.3	11SD805N2.3	5 of 5	DG	1975	1998	Aged	SRTT #2	107.3	SRTT #3	107.4	106	107.3
QP-133.1	11SD805N2.3	4 of 4	DG	1975	1998	Aged	SRTT #2	107.6	SRTT #3	106.6	106.5	106.4
QP-133.2	11SD805N2.4	4 of 4	DG	1975	1998	Aged	SRTT #2	Not Tested	SRTT #3	107.4		107.3
QP-134.1	11SD905W5.2	2 of 2	DG	1975	2000	Aged	SRTT #2	106.3	SRTT #3	106.6	105	106.4
QP-134.2	11SD905W5.1	2 of 2	DG	1975	2000	Aged	SRTT #2	106.2	SRTT #3	105.3	104.9	104.9
QP-134.3	11SD905W5.0	2 of 2	DG	1975	2000	Aged	SRTT #2	107.3	SRTT #3	106.6	106.2	106.4
QP-135.1	04SON101N25.4L2	2 of 2	DG	1962	2006	Aged	SRTT #2	104.9	Not Tested	Not Tested	103.4	
QP-135.2	04SON101N25.5L2	2 of 2	DG	1962	2006	Aged	SRTT #2	105.0	Not Tested	Not Tested	103.5	
QP-135.3	04SON101N25.6L2	2 of 2	DG	1962	2006	Aged	SRTT #2	105.2	Not Tested	Not Tested	103.7	
QP-148.1	04SM280N1.6	1 of 4	DG	1969	2001	Aged	SRTT #2	104.4	SRTT #3	103.7	102.9	103.4
QP-148.2	04SM280N1.7	1 of 4	DG	1969	2001	Aged	SRTT #2	104.5	SRTT #3	103.9	103	103.6
QP-148.3	04SM280N1.8	1 of 4	DG	1969	2001	Aged	SRTT #2	104.7	SRTT #3	103.9	103.2	103.7
QP-155.1	06Ker58E110.6	2 of 2	DG	2003	2006	Aged	SRTT #2	104.0	SRTT #3	103.0	101.2	101.7
QP-160.1	06Ker58E110.0	2 of 2	DG	2003	2006	Aged	SRTT #2	105.2	SRTT #3	104.2	102.7	102.9
QP-166.1	06Ker58E111.7	2 of 2	DG	2003	2006	Aged	SRTT #2	104.2	SRTT #3	104.2	101.7	103

Section ID	Location: Dist-Cnty-Rte-Dir-PM	Lane[1]	Texture Type[2]	Const. Year	Surfacing Year	Texture Condition[3]	Test Tire Year 1	Uncorrected OBSI Year 1	Test Tire Year 2	Uncorrected OBSI Year 2	Corrected to SRTT #1 OBSI Year 1	Corrected to SRTT #1 OBSI Year 2
QP-110.1	03Nev80E24.0	1 of 3	Gr	1989	1996	Aged	SRTT #2	105.3	Not Tested	Not Tested	102	
QP-110.2	03Nev80E24.1	1 of 3	Gr	1989	1996	Aged	SRTT #2	105.3	Not Tested	Not Tested	102	
QP-110.3	03Nev80E24.2	1 of 3	Gr	1989	1996	Aged	SRTT #2	105.2	Not Tested	Not Tested	101.9	
QP-111.1	03Nev80W24.2	1 of 2	Gr	1989	1996	Aged	SRTT #2	106.4	Not Tested	Not Tested	103.2	
QP-111.2	03Nev80W24.1	1 of 2	Gr	1989	1996	Aged	SRTT #2	106.3	Not Tested	Not Tested	103.1	
QP-111.3	03Nev80W24.0	1 of 2	Gr	1989	1996	Aged	SRTT #2	105.9	Not Tested	Not Tested	102.7	
QP-136.1	04SON101S27.3L2	2 of 2	Gr	1962	2006	Aged	SRTT #2	105.3	Not Tested	Not Tested	103.8	
QP-136.2	04SON101S27.2L2	2 of 2	Gr	1962	2006	Aged	SRTT #2	105.1	Not Tested	Not Tested	103.6	
QP-136.3	04SON101S27.1L2	2 of 2	Gr	1962	2006	Aged	SRTT #2	105.3	Not Tested	Not Tested	103.8	
QP-138.1	04SON101S27.3L1	1 of 2	Gr	1962	2006	Aged	SRTT #2	104.7	Not Tested	Not Tested	103.1	
QP-138.2	04SON101S27.2L1	1 of 2	Gr	1962	2006	Aged	SRTT #2	104.6	Not Tested	Not Tested	103	
QP-138.3	04SON101S27.1L1	1 of 2	Gr	1962	2006	Aged	SRTT #2	103.5	Not Tested	Not Tested	101.7	
QP-153.1	10Mer99S17.5	1 of 2	Gr	1962	2006	Aged	SRTT #2	106.1	SRTT #3	106.1	105.1	106.1
QP-153.2	10Mer99S17.4	1 of 2	Gr	1962	2006	Aged	SRTT #2	106.5	SRTT #3	106.3	105.6	106.3
QP-153.3	10Mer99S17.3	1 of 2	Gr	1962	2006	Aged	SRTT #2	106.1	SRTT #3	106.0	105.1	105.9
QP-154.1	06Ker58E110.2	2 of 2	Gr	2003	2006	Aged	SRTT #2	104.7	SRTT #3	104.9	102.1	103.7
QP-156.1	06Ker58E111.2	2 of 2	Gr	2003	2006	Aged	SRTT #2	105.8	SRTT #3	105.7	103.7	104.7

Section ID	Location: Dist-Cnty-Rte-Dir-PM	Lane[1]	Texture Type[2]	Const. Year	Surfacing Year	Texture Condition[3]	Test Tire Year 1	Uncorrected OBSI Year 1	Test Tire Year 2	Uncorrected OBSI Year 2	Corrected to SRTT #1 OBSI Year 1	Corrected to SRTT #1 OBSI Year 2
QP-157.1	06Ker58E111.4	2 of 2	Gr	2003	2006	Aged	SRTT #2	104.4	SRTT #3	104.4	102.1	103.2
QP-161.1	06Ker58E110.4	2 of 2	Gr	2003	2006	Aged	SRTT #2	105.6	SRTT #3	104.3	103.2	103.2

Notes:

1. Lane # of total lanes (Lane #1 is next to the median.)

2. Texture Type:

BD = burlap drag (37 sections)
DG = diamond ground (33 sections)
Gr = diamond grooved (19 sections)
LB = longitudinally broomed (10 sections)
LT = longitudinally tined (21 sections)

3. Texture Condition:

New = Sections that had been open to traffic for less than a year at the time of the first measurements (12 sections)
Aged = Sections where the texture could be observed in the wheelpaths (72 sections)
Worn out = Sections where the texture had been worn out in the wheelpaths by traffic (36 sections)

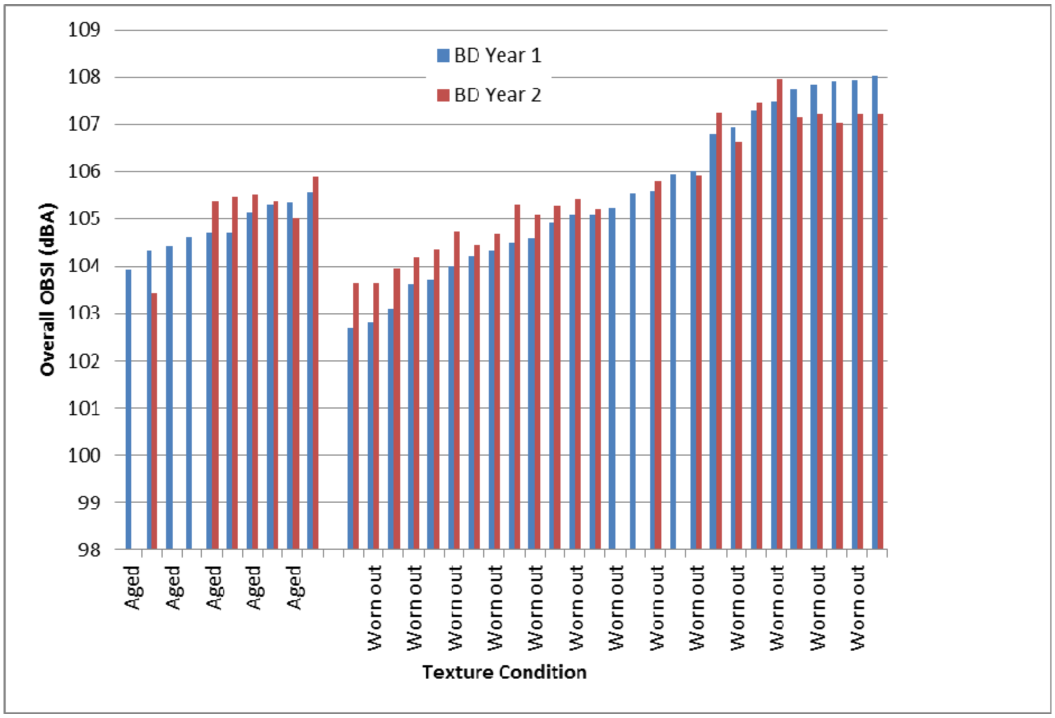


Figure E.4: Compare with Figure 3.30: Burlap drag Year 1 and Year 2 results for all texture conditions *(new, aged, worn out).*

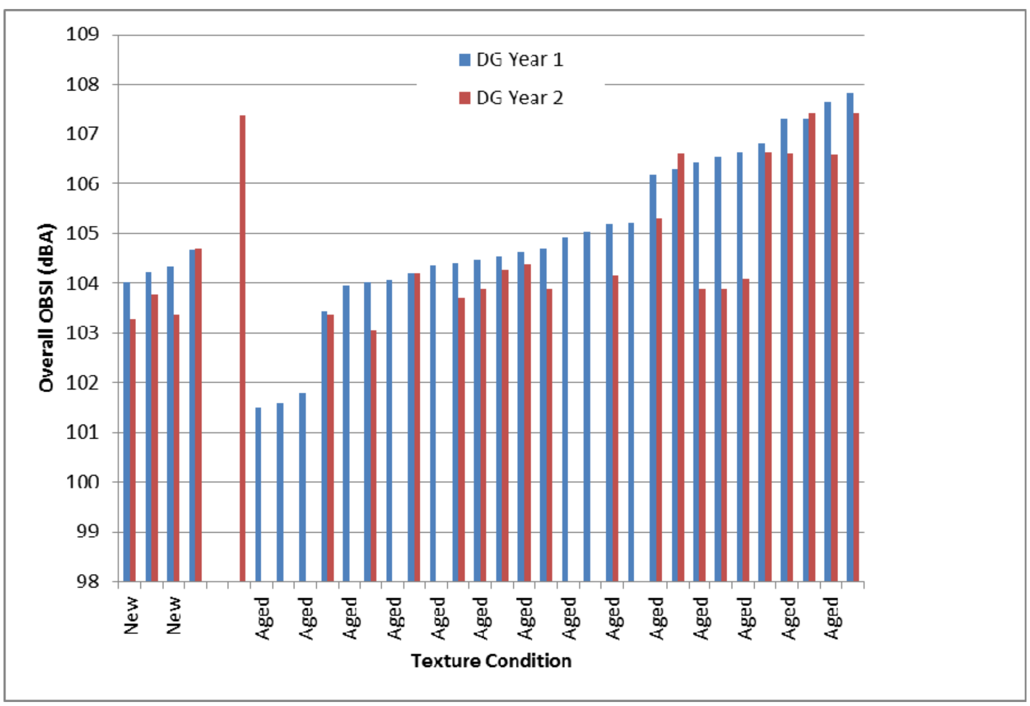


Figure E.5: Compare with Figure 3.32: Diamond ground Year 1 and Year 2 results for all texture conditions *(new, aged, and worn out).*

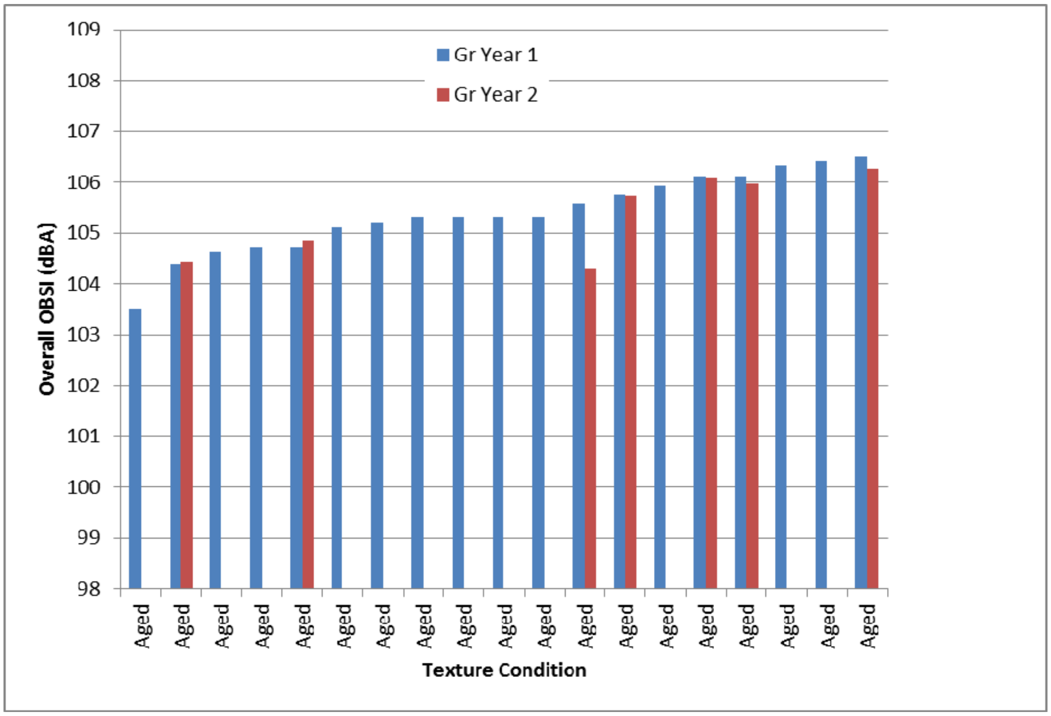


Figure E.6: Compare with Figure 3.34: Diamond grooved Year 1 and Year 2 results for all texture conditions *(new, aged, worn out).*

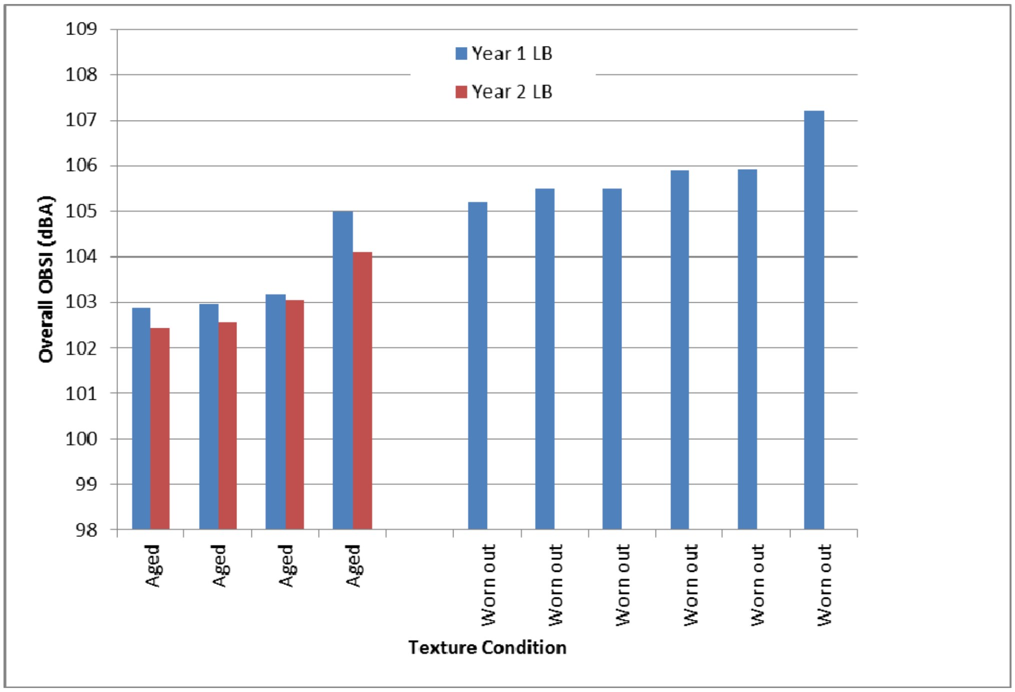


Figure E.7: Compare with Figure 3.36: Longitudinally broomed Year 1 and Year 2 results for all texture conditions *(new, aged, worn out).*

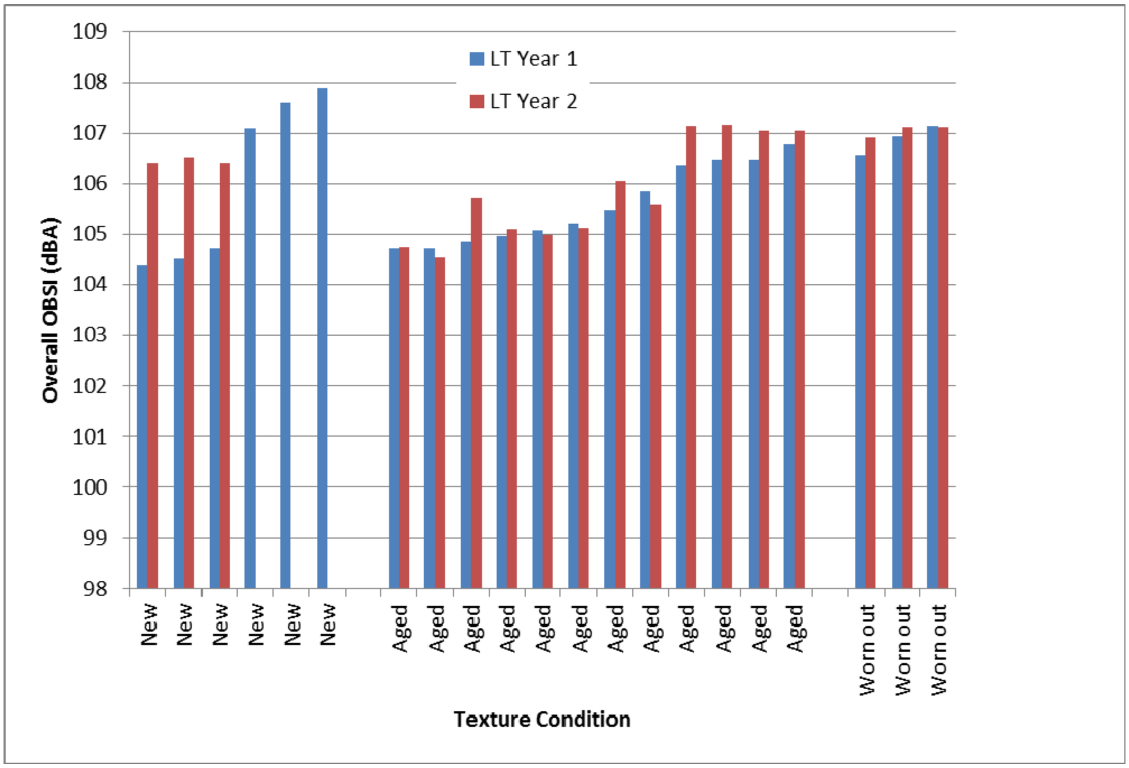


Figure E.8: Compare with Figure 3.38: Longitudinally tined Year 1 and Year 2 results for all texture conditions *(new, aged, worn out).*