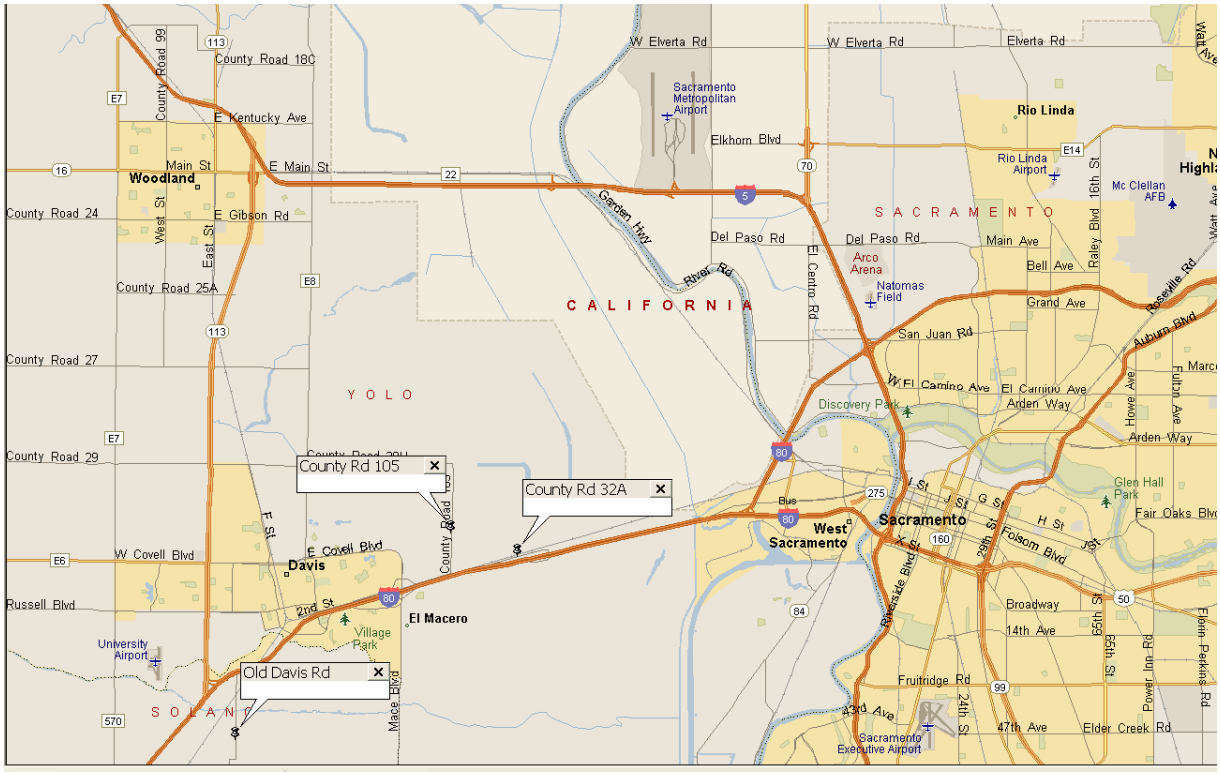
Caltrans County Road 32A Diamond Grooving Experiment
Sacramento, CA

Testing and Report Prepared by Larry Scofield

Draft Report

4/30/07



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Executive Summary

In 1969, what is now Caltrans, evaluated six diamond grooving patterns on County Road 32A near Sacramento, California. The six patterns evaluated were the most commonly considered grooving patterns at the time. The evaluation was conducted to determine if the safety of the motorcyclist was impaired by grooving and if the sensitivity to selected patterns could be determined.

The 1969 study evaluated three aspects of grooving as noted below:

- The effect of groove spacing for the 1/8 inch groove width (e.g. ½", ¾", 1")

The effect of using a narrower groove width than the standard 1/8" (e.g. 0.095")

- The effect of grooving patterns designed to improve roadway friction (e.g. Style A & 15 Patterns)

The results of that study indicated that none of the patterns presented a safety issue to motorcyclists. The 1/8" groove width at ½" and 1" spacing and the Style A pattern resulted in the least overall sensations. The Style 15 resulted in the greatest overall sensitivity.

In 2007, Caltrans conducted an OBSI equipment comparison study on County Road 32A. At that time it was discovered that the 1969 diamond grooving sections still existed, after 28 years in service. County Road 32A was approximately 60 years old at the time. Upon discovering the grooving test sections, ACPA conducted OBSI testing of the six locations to determine if there were differences in the tire/pavement noise levels produced by the respective patterns.

The results of the 2007 study indicated the following:

- The original drag texture was slightly quieter than the grooving patterns suggesting that grooving has no long term benefit for noise reduction
- For the 1/8" pattern, groove spacing had no effect on noise levels produced
- The patterns selected for improved friction did not result in higher overall noise levels.
- The condition of County Road 32A hampers making significant conclusions regarding the surfaces tested.

Follow up activities should include testing the friction levels of each of the patterns to establish the long term benefits, if any, of the Style A and 15 patterns. Additionally, the joint slap effect present on this site should be removed from the acoustic recordings and the effect of the various patterns re-analyzed.

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Caltran's County Road 32A Diamond Grooving Study

Introduction

In 1969 the California Public Works Department, Division of Highways constructed a diamond grooving experiment on an old concrete pavement to determine if the safety of the motorcyclist was impaired by grooving concrete pavement and if the sensitivity to this for selected grooving patterns could be determined[1]. At the time, diamond grooving roadways for safety was increasing in use and there were reports that certain grooving patterns resulted in riding sensations to the motorcyclist which were different from those experienced on ungrooved pavements.

The six test sections were constructed on County Road 32A which was constructed in the 1940s[2]. This section of highway had been replaced by the construction of I-80 in the mid 1960s and the California Public Works Department subsequently relinquished the roadway to the County and it was renamed County Road 32A .

The six grooving patterns selected represented the most commonly used diamond grooving patterns in use in California at the time. The results of that study concluded that there was not a safety issue with any of the patterns.

This section of highway is convenient to Sacramento and had low traffic volumes. This made the roadway well suited for conducting experiments and roadway testing. This is one of the locations that PCA Riedemeters were tested in the old days[2].

Caltrans On-Board Sound Intensity (OBSI) Comparative Testing Experiment

On April 3, 2007 Caltrans conducted an OBSI comparative testing experiment using three of their consultants; Applied Research Associates (ARA), Illingworth and Rokin, Incorporated (I&R), and the University of Davis Pavement Research Center (UC Davis). The objective of the experiment was to evaluate the repeatability and reproducibility of the currently used OBSI systems. A second objective was to develop a calibration site that could be used over time to evaluate system changes and/or to verify system operation.

To conduct the experiment, three roadways were chosen, County Road 32A (Concrete), County Road 105 (asphalt concrete) and Old Davis Road (asphalt concrete). The focus of this report is County Road 32A. The details of the OBSI comparison study can be found in Caltrans report XXXXX[3] and in the ACPA report titled "Caltrans OBSI Comparison Experiment[4].

On April 11, 2007 the ACPA attempted to test the Caltrans OBSI sites to compare against the other units. It had rained the night before and rained that day so OBSI testing could not be accomplished. Therefore, the day was used to establish the locations of the test sites accurately. In doing this, it was observed that six different grooving patterns existed at the County Road 32A location. Only one of the six was included in the Caltrans OBSI experiment. However, ACPA elected to test all six groove sections at the same time as the Caltrans OBSI sites were tested. The six test sections are described in subsequent sections and in Table 2. The groove widths and land widths were measured in the field

with a tape measure and were only meant to be used for descriptive purposes for the noise testing. Upon return to the office a search was conducted to establish the origin of these sections. Therefore the values in Table 2 are slightly different than the test grooving patterns indicated under the section called "Site Conditions."

The between wheelpath location was also used to test the existing burlap drag texture so as to provide a comparison between the grooving patterns and the drag texture.

Table 2 Diamond Grooving Test Sections

Groove Dimensions (inches)	ACPA 1			ACPA 2			05 B		
	LWP	Center	RWP	LWP	Center	RWP	LWP	Center	RWP
Groove Width	¼	Drag	1/8	3/16	Drag	1/8	1/8	Drag	3/16
Land Width	1 1/8	N.A.	3/4	7/8	N.A.	3/8	5/8	N.A.	9/16

Site Conditions

The location of each of the County Road 32A test sites are provided in Table 3 which provides referencing to the exiting Caltrans profiler marking locations.

This stretch of roadway consists of plain jointed concrete pavement with approximate 15 ft non-skewed transverse joints. Joint widths typically ranged from ½ inch to ¾ inch. Vegetation was growing out of both longitudinal and transverse joints regularly at this site. The EB direction was faulted more and had significantly more joint slap than the WB direction. However, both directions had joint slap.

Traffic volumes were low and were predominantly automobile traffic. Most truck traffic consisted of garbage trucks. County Road 32A runs parallel with and adjacent to I-80 WB. The EB direction of 32A appeared to have more of the mortar worn away exposing the aggregate. The top size of the concrete aggregate appeared to be on the order of 1 to 1.5 inches. The EB direction had subsided approximately 1/8 to ¼ inch below the WB direction at the longitudinal joint suggesting the lanes were not tied with longitudinal steel.

Groove depths were highly variable ranging from approximately 1 mm to 4 mm. The exposed aggregate texture (e.g. mortar worn away) produced a 1 mm texture depth. Within each of the grooved test sections, there were areas that had very little groove depth from original construction. This presumably was due to warping and curling of the slabs and/or limited construction control.

This section of roadway was also recently used for a profiler comparison conducted by Caltrans. A one mile section of the concrete was marked with paint stripes every one tenth mile. Those markings are indicated in Figure 1 for both the EB and WB directions. The markings can be used for approximate locations of respective sections. Precise locations (e.g. latitude and longitude) are provided in Table 3. The entire section of concrete roadway appeared to be the same original as-built construction.

Table 3 Approximate Shoulder Marking Locations of Concrete Sections on Rd 32A

Location	**County Road 32 A**				
Texture Type	Drag	Grooved	Drag	Grooved	Grooved
Section Number	05A	05B	05C	ACPA 1	ACPA 2
Shoulder Reference Location (Mile)	0.4	0.3-0.4	0.5	0.6-0.7	0.3-0.2
Direction	EB	WB	WB	WB	WB
Latitude	38.56148N	38.56254N	38.56198N	38.56199N	38.56367N
Longitude	121.65680W	121.65247W	121.65509W	121.65496W	121.64742W

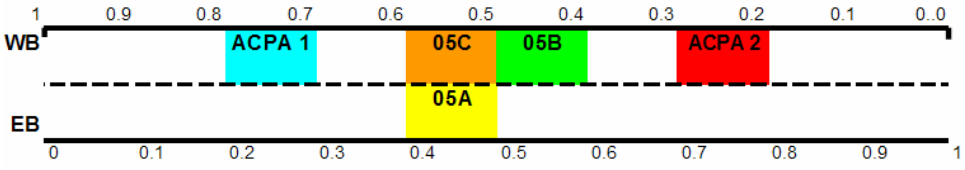

Figure 1 Approximate Test Section Layout on County Road 32

The original layout of these sites is shown in Figure 2 which is from the 1969 report[1]. As evident, each of the sections is 750 in length and separated by 750 ft. The section designations used for the current ACPA OBSI testing are shown on the left of Figure 2 and the original section descriptions are shown on the right. Except for ACPA 2, the left wheelpaths are typically grooved 3 ft wide and the right wheelpaths are grooved 2 ft wide. No explanation as to why the difference in wheelpath groove widths is provided in the 1969 report. For ACPA Site 2, both wheelpaths are approximately the same 2 ft wide groove pattern.

There was considerable wear on the Site 1 patterns and it was difficult in the field to do determine the exact groove/grind pattern. At locations, distinct relic features of the original patterns appeared to be visible. However, at other locations this did not seem to be true. However, it should be remembered that the purpose for the testing was originally not for the groove experiment but rather for the OBSI comparison testing and considerable effort was not expended to ascertain texture features, especially due to the inclement weather on the day the test areas were laid out.

The center of the lane was tested as a third wheelpath at each of these locations. This was done to provide a comparison of the drag texture to that of the grooved pattern to assess any benefit resulting from the grooving pattern. However, one shortcoming to this approach is that there is more wear in the wheel paths and more “armoring of the surface”

(e.g. exposing of the aggregate) and this alone could provide a confounding influence on the noise results.

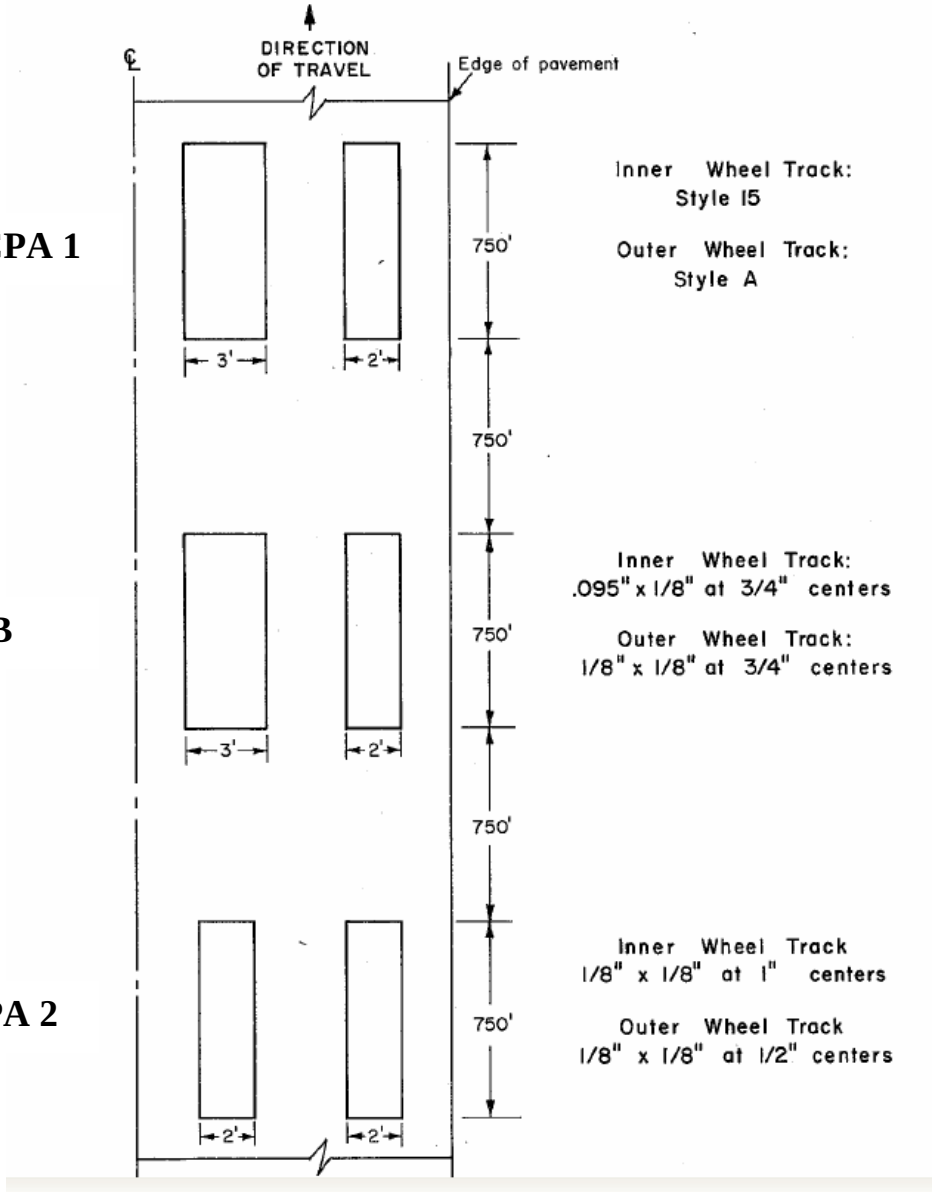

Figure 2 Original Construction Design and Layout[1]

ACPA 1

This site is located to the west of Caltrans Site 05C as shown in Figure 1 on the WB roadway. It consisted of two different groove patterns, one in each wheelpath. Figures 3 & 4 (from the 1969 report) provide photos and schematics of the grooving configurations. The Christensen Diamond Services Company's Style 15, used in the inner

wheelpath (Figure 3), was tested because it had been reported as being superior at increasing the coefficient of friction on smooth pavements [5].

The Style A groove pattern, used in the outer wheelpath (Figure 4), had been used at locations where it was desirable to improve the coefficient of friction a significant amount. This pattern consisted of cuts 0.95" x 1/8" on ¾" centers with two 0.095" grooves equally spaced between those on ¾" centers and not more than 1/16" deep.

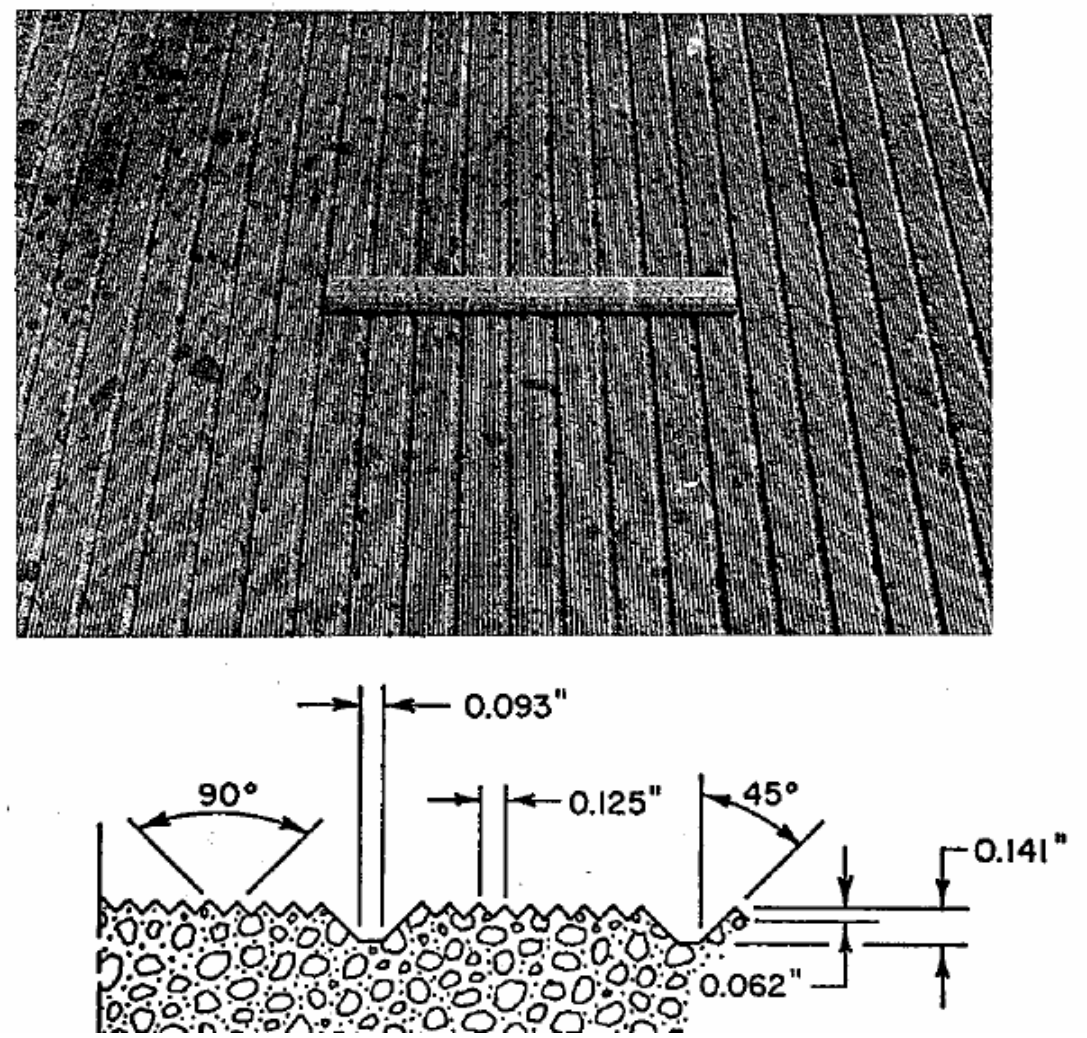

Figure 3 LWP Christensen Diamond Services Company Style 15 Grooving Pattern[1]

Photos, taken on April 30, 2007, are shown in Figure 5. As evident, much of the original pattern has worn away in the last 28 years.

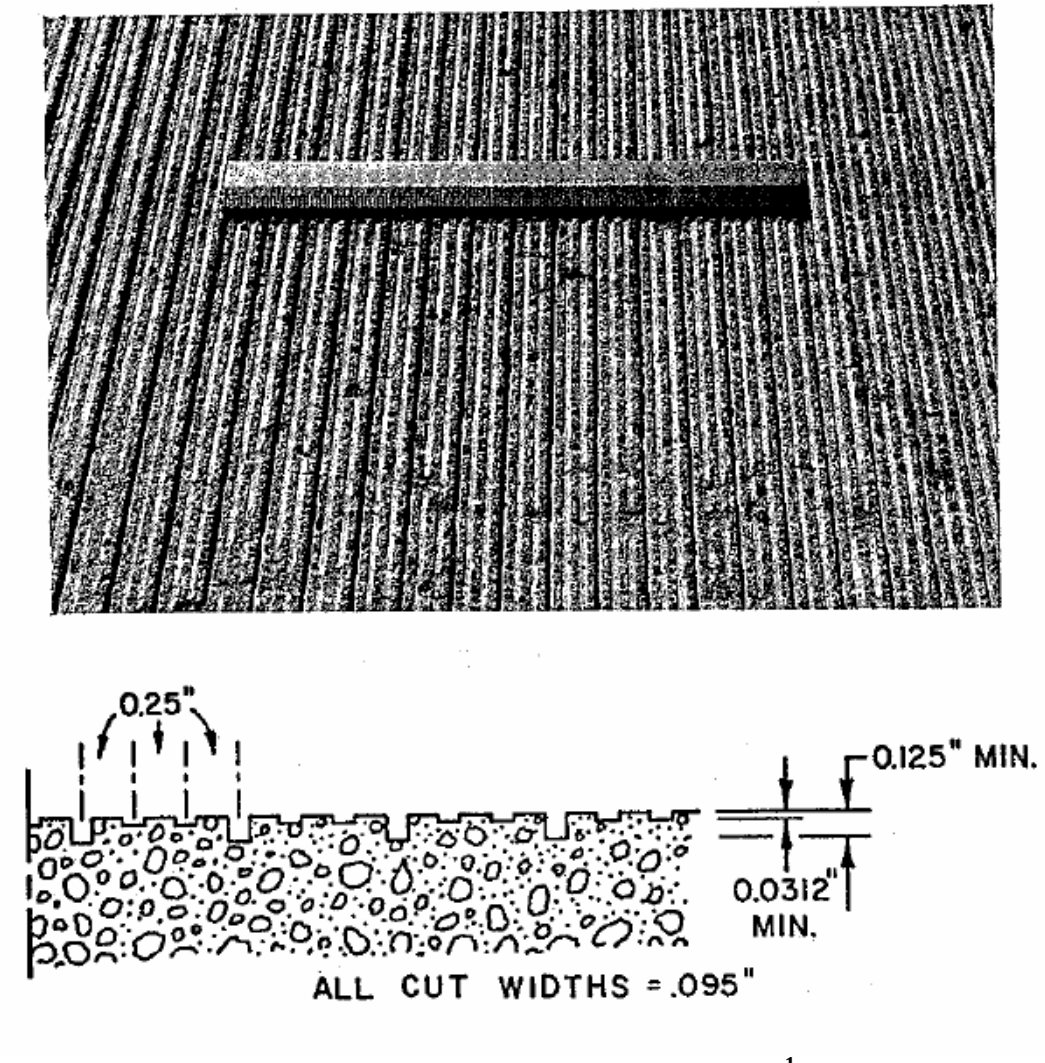

Figure 4 RWP Style A Groove Pattern[1]

Christensen Style 15 Groove Pattern	Style A Groove Pattern

Figure 5 Current Photos of ACPA Site 1 Groove Patterns at 28 Years of Age

ACPA Site 2

This site is located east of all the other 32A sites as indicated in Figure 1 on the WB roadway. It consisted of two different groove patterns, one in each wheelpath. Both wheelpaths were approximately two feet in width at this location, unlike the other locations that used different widths between the left and right wheelpaths. The center of the roadway (e.g. between the wheelpaths) was the original drag texture.

The left wheelpath (See Figure 6) consisted of 1/8" X 1/8" grooves spaced on 1" centers while the right wheelpath (See Figure 7) consisted of 1/8" X 1/8" grooves spaced on ½" centers. The 1/8" by 1/8" groove pattern appears to have been considered the standard groove width for this experiment and the effect of varying the groove spacing was determined. In the original experiment, this groove configuration was evaluated at spacings of ½", ¾" and 1". The ¾" spacing was tested at Site 05B.

Figures 6 and 7 are from the 1969 report while Figure 8 indicates photos taken on April 30, 2007.

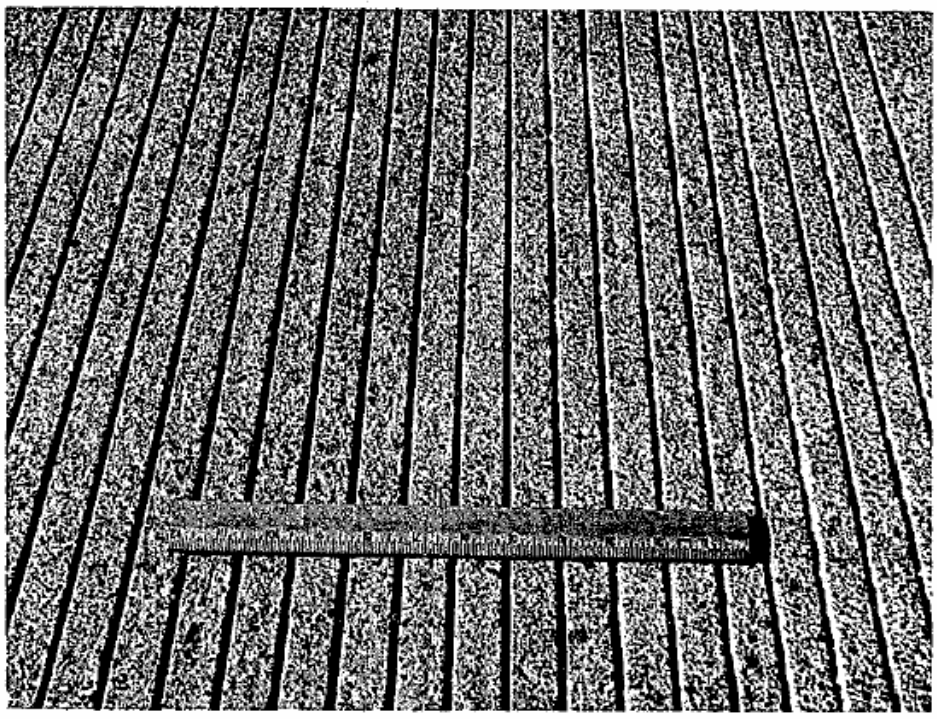

Figure 6 LWP 1/8" X 1/8" at 1" Centers Grooving Pattern[1]

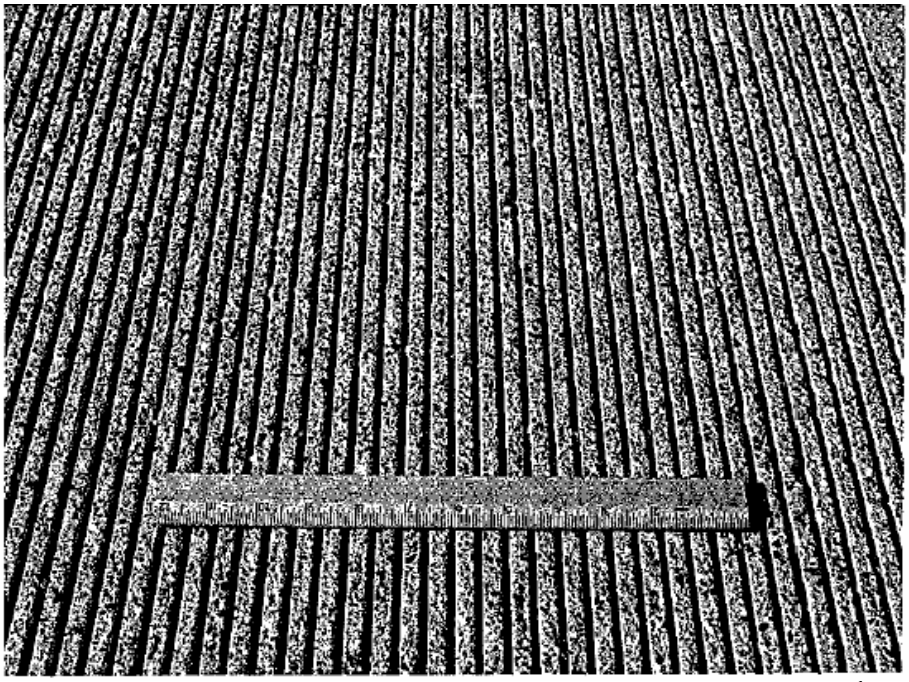

Figure 7 RWP 1/8" X 1/8" at ½" Centers Grooving Pattern[1]

LWP 1/8"X1/8" on 1" Centers	**RWP 1/8" X 1/8" on ½" Centers**

Figure 8 Photos of ACPA Site 2 Taken on April 30,2007 After 28 Years in Service

Site 05B

This site is located east of site 05C and is approximately in the middle of the one mile long profiler test section as indicated in Figure 1. It consisted of two different groove patterns, one in each wheelpath. The left wheel path, approximately 3 ft in width, consisted of 0.095" X 1/8" grooves spaced at ¾" centers (see Figure 9). The right wheel path, approximately 2 ft in width, consisted of 1/8" X 1/8" grooves also spaced at ¾" centers (See Figure 10). The center of the roadway (e.g. between the wheelpaths) was the original drag texture. At the time of the 1969 experiment, the California Public Works Department, Highways Division was evaluating the narrower 0.095" groove width against the commonly used 1/8" X 1/8" groove width. It was believed the 0.095" groove width imparted less roadway sensation to the cyclists[6].

Figures 9 and 10 are from the 1969 report while Figure 11 indicates photos taken on April 30, 2007.

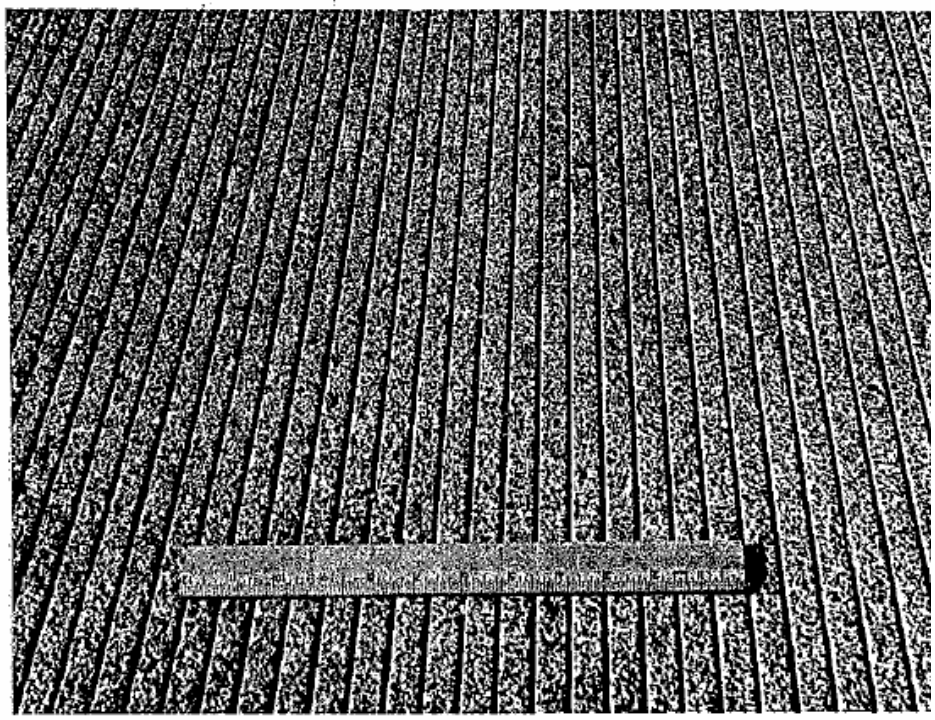

Figure 9 LWP 0.095" X 1/8" at ¾" Centers Grooving Pattern[1]

Figure 10 RWP 1/8" X 1/8" at ¾" Centers Grooving Pattern[1]

LWP 0.095"X1/8" on 3/4" Centers	**RWP 1/8"X1/8" on 3/4" Centers**

Figure 11 Photos of Site 05B Taken on April 30,2007 After 28 Years in Service

Sites 05A & 05C

These two sites are located as indicated in Figure 1. Both sites represent worn burlap drag textures. They were included to provide a comparison to the groove textures. Since both of these sections are a drag texture across the entire lane, the effect of surface wear within the wheelpath can be evaluated. Unfortunately, at the time of the OBSI testing, only the right wheelpath location was tested at these sites. However, this provided a drag texture wheelpath condition to be compared to the grooved wheelpath conditions.

Results of 1969 Groove Pattern Sensitivity Study

The 1969 study evaluated six of the most commonly considered grooving patterns in California for their influence on motorcycle driver sensation. The results of that testing indicated that none of the patterns presented a safety issue to motorcycle riders[1]. The 1/8" groove width at ½" and 1" spacings and the Style A patterns resulted in the least overall sensations to the cyclists[1]. The two 1/8" wide groove patterns spaced at ¾" centers provided the greatest sensation to the cyclists[1] for the lighter motorcycles. The Style 15 resulted in the greatest overall sensitivity to the cyclsists[1].

Wet, lock-wheeled friction testing conducted with a smooth tire at 50 mph for the 1969 study resulted in the friction results indicated in Table 4. As evident in Table 4, the two patterns used/considered for friction improvement did improve the existing friction over the original condition. The more common patterns did not appear to provide a significant benefit.

Table 4 Coefficient of Friction Values for Various Groove Patterns

Pattern	Before Grooving	After Grooving	Percent Improvement
1/8" X 1/8" @1/2"	0.37	0.38	3
1/8" X 1/8" @1"	0.36	0.36	0
1/8" X 1/8" @3/4"	0.38	0.39	3
0.095" X 1/8" @3/4"	0.38	0.39	3
Style A	0.40	0.44	9
Style 15	0.39	0.45	13

Results of OBSI Testing

OBSI testing of the each of the sections consisted of three repeat runs for each wheelpath indicated at each site. Testing was conducted at 60 mph using the ACPA dual probe OBSI system and an ASTM SRTT test tire. The data was collected and analyzed using a B&K Model 3560B analyzer and Pulse software.

For comparison purposes Site 0BA has been excluded since the faulting/joint slap at that location is worse than the other sites. This suggests that the traffic/loadings in the EB direction are different from the WB direction and could confound the results further. Therefore, pattern comparisons will be made with data from the WB direction only.

This comparison is being made after the diamond grooving patterns have been in service for approximately 28 years and the WB roadway has been in service approximately 60 years. As such, the roadway currently exhibits wide joints and some faulting. Both of these conditions lead to joint slap which confounds the ability to determine the effect of grooving on the tire/pavement noise level. Similarly, by comparing the between wheel path and traveled wheelpath locations tends to confound the results since the "armoring effect" that was previously described. Therefore it is a bit of a leap in faith to draw meaningful conclusions from these sections, but an attempt will be made to describe the differences, if any between sections. The effect of joint slap has not been removed for this analysis.

One additional factor that should be considered when viewing the results is that it is that the center-of-lane and left wheelpath testing require additional care in driving the vehicle. Since the driver was collecting the data and positioning the vehicle at the same time, there is always a possibility that the vehicle did not stay true to the grooving pattern. The author believes that the test tire was accurately positioned during all testing but there is no way to verify this. Each of the wheelpaths is fairly narrow when compared to normal driving/testing.

It should be noted that the legends used in the following graphs are in accordance with the descriptions used in Table 2 which were developed from the ACPA field review and not the 1969 groove pattern definitions.

Center of Lane Vs Wheelpath Results

Figure 12 provides a comparison of the center-of-lane to the right wheelpath results for the OBSI overall A-weighted results. From this figure it does not appear that there is a significant difference between the two test locations. Note that 05A is not being considered since it is in the EB direction and has more joint slap included.

Figure 13 indicates the spectral plots for these same surfaces. As before, there does not seem to be a significant difference between the two wheel placement locations. The RWP data points are shown in red and tend to envelope the center-of-lane results shown in blue.

Burlap Drag Texture Vs Diamond Grooving Results

Figure 14 indicates the results for both the drag textures and the various groove patterns. Although all test results are within approximately 2 dBA, it appears that the drag textures are slightly quieter than the grooved sections. This would tend to suggest that grooving does not provide a long term benefit for noise reduction.

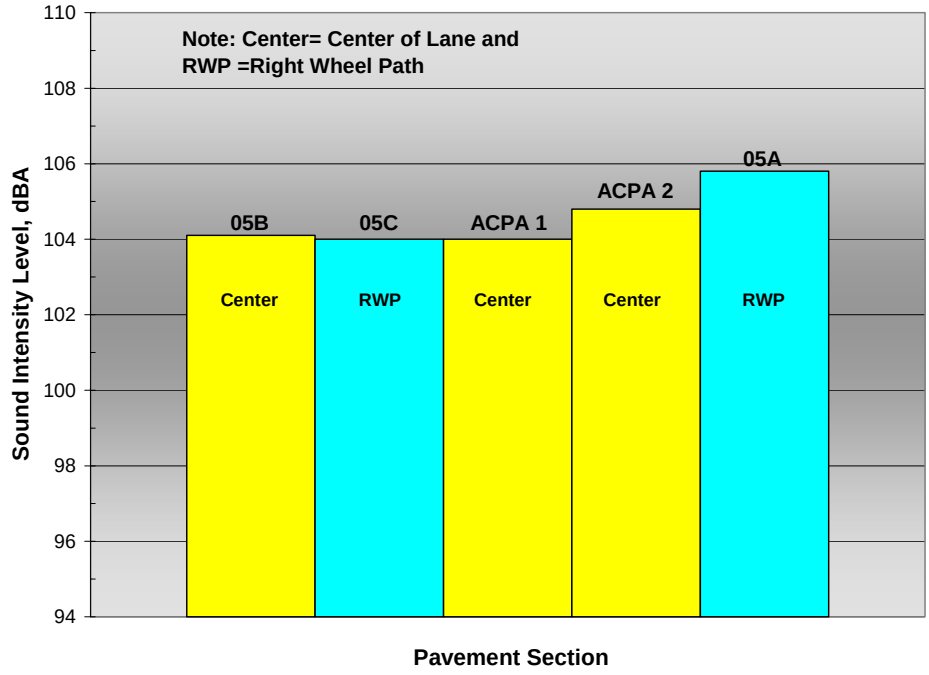

Figure 12 Comparison of Center of Lane to Right Wheelpath Drag Texture OBSI Overall Results

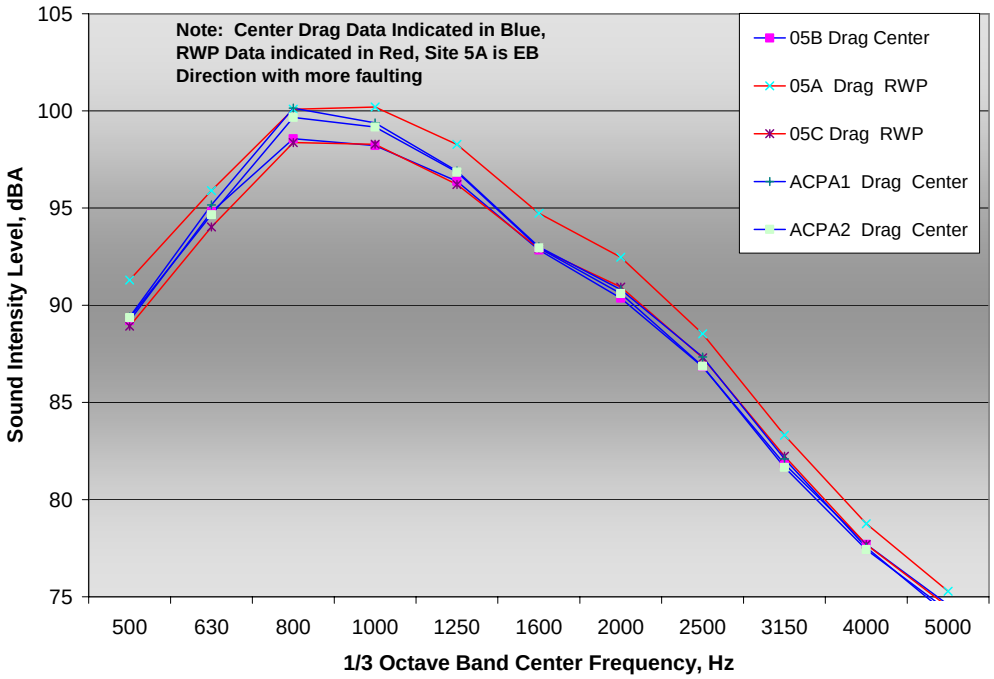

Figure 13 Spectral Plots Comparing Center-of Lane to Right Wheelpath Drag Texture OBSI Results

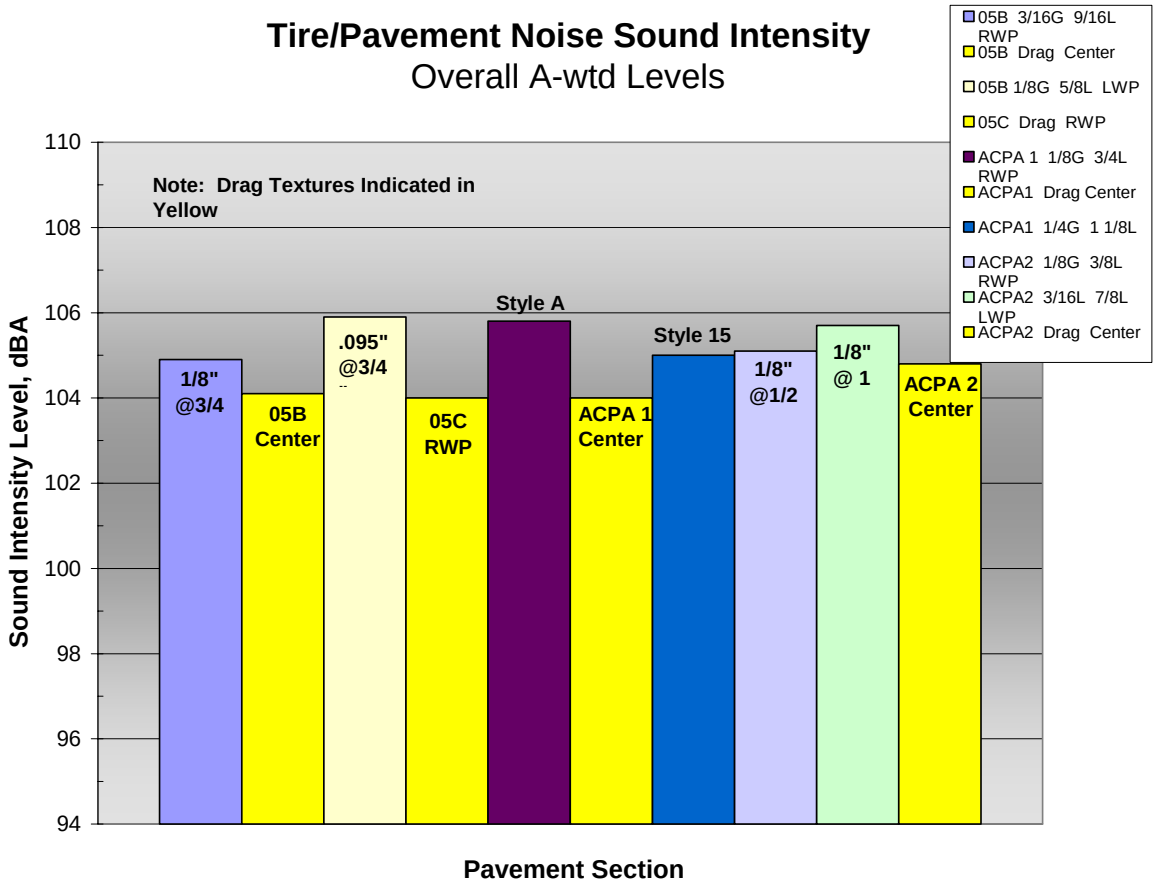

Figure 14 Overall OBSI Level of Drag and Diamond Grooved Test Sections

Effect of Groove Spacing Width for 1/8" Grooves

Figure 15 indicates the overall OBSI levels for the three groove spacings (e.g. ½", ¾", and 1") constructed in the 1969 experiment. As indicated in Figure 15, there does not appear to be a significant difference resulting from the spacing effect. All three results are within one dBA.

Figure 16 indicates the spectral plots for these same surfaces representing the 1/8" groove width constructed at three spacings; ½", ¾" and 1". As before, there does not seem to be a significant difference between the spacing. However, at the 800 -1000 Hz centerband frequencies there does appear to be a slight difference.

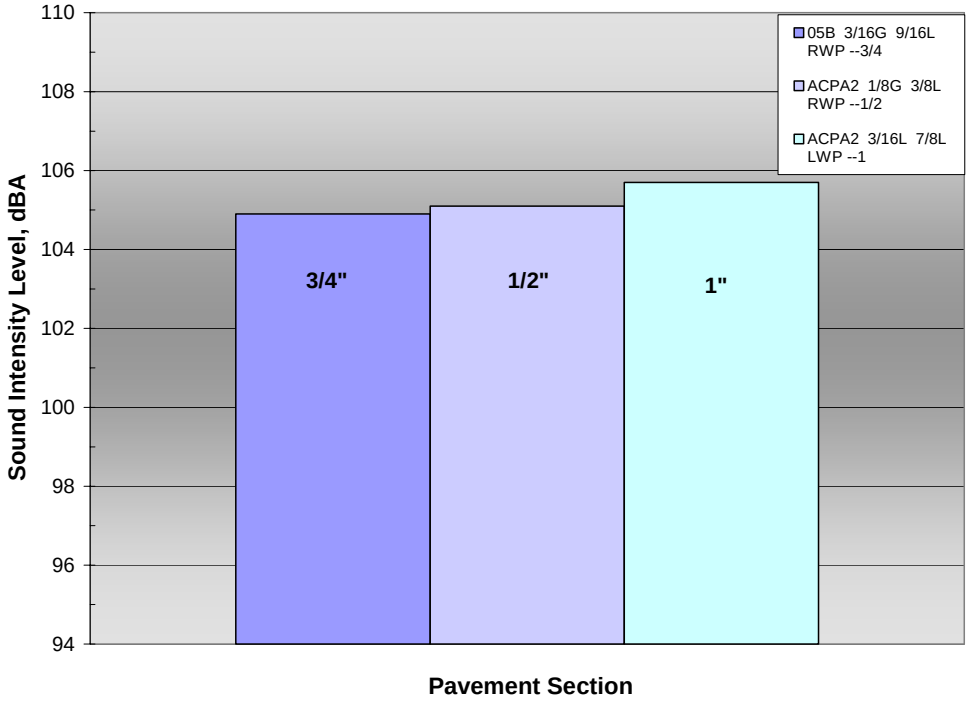

Figure 15 Indicates the Overall OBSI Levels for the 1/8” Groove Width for Different Spacings

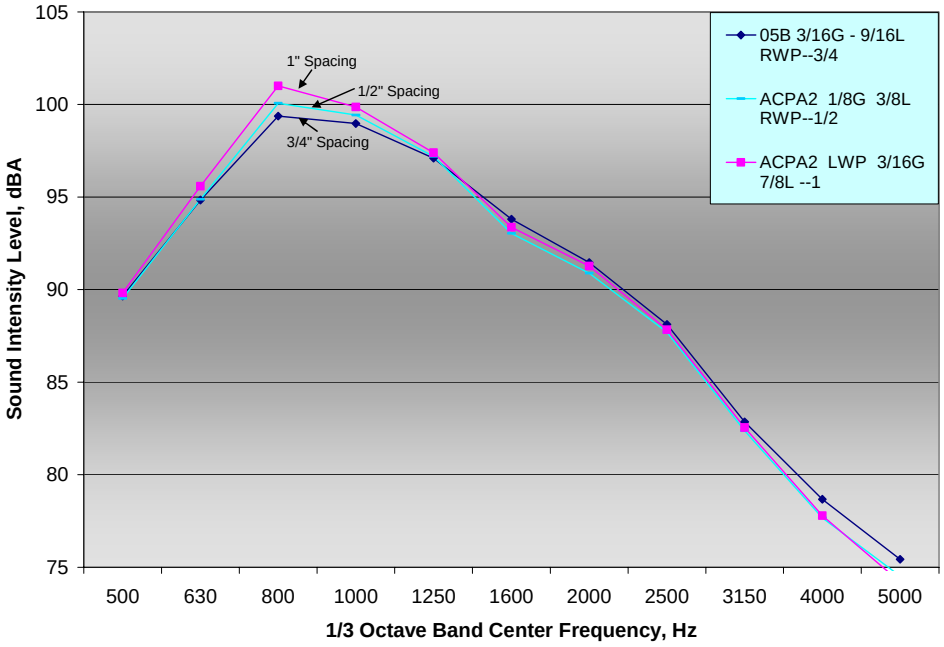

Figure 16 OBSI Spectral Plots Indicating the Effect of Spacing Width on 1/8” Groove Patterns (1/2”, 3/4”, 1”)

Comparison of 0.095" Groove Width to 1/8" Groove Width

Figure 14 indicates that the two patterns are within one dBA of each other and that this is probably too close to be considered significant. It should probably be assumed that no difference exists.

Comparison of Friction Improvement Patterns to 1/8" Groove Width

The results presented in Figure 14 do not indicate that either of the friction improvement surfaces resulted in an increased noise level after 28 years.

Conclusions

It should be reiterated that this testing was conducted on treatments that were placed 28 years ago and on a roadway that is approximately 60 years old. As such, the joint slap affects and armoring that occurs as a result of traffic over the years makes it tenuous at best to draw significant conclusions. These results should help form the basis for "rules of thumb" if supported by other, more rigorous work.

- Grooving does not appear to provide a noise benefit in the long term. On the contrary, the drag texture performed slightly better.
- The textures used to provide improved friction properties did not resolve in an increase in noise levels in the long term.
- For the three groove spacings evaluated (e.g. ½:, ¾", 1") there did not appear to be any difference. They all performed similarly. Therefore it appears groove spacing is not significant.

Follow Up Activities

1. Get friction measurements on the surfaces to see if the textures resulted in long term effects.
2. Remove the joint slap effects from the acoustic recordings and reanalyze the data to see if this effect was confounding the grooving effects.
3. Get additional OBSI measurements on Sites 05A and 05C to better evaluate the armoring effect in the wheelpath (e.g. center versus wheelpath location). Long term noise levels may better be a function of the armoring effect and the aggregate size of the armoring.

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