R&T UPDATE
Concrete Pavement Research & Technology

Caltrans Diamond Grooving Experiment – 38 Years Later

1969 California Grooving Experiment

In 1969, what is now Caltrans evaluated six diamond grooving patterns (Figure 1) on County Road 32A near Sacramento, California[1]. The six patterns evaluated were the most commonly considered longitudinal grooving patterns at the time. The evaluation was conducted to determine if the safety of motorcyclists was impaired by grooving and if the sensitivity of the motorcyclist to selected patterns could be determined.

The 1969 study aimed to evaluate three aspects of grooving:[1]

- The effect of groove spacing for the standard 1/8 in. (3.2 mm) groove width.
- The effect of using a narrower groove width than the standard 1/8 in. (3.2 mm).
- The effects of grooving patterns that are designed to improve roadway friction.

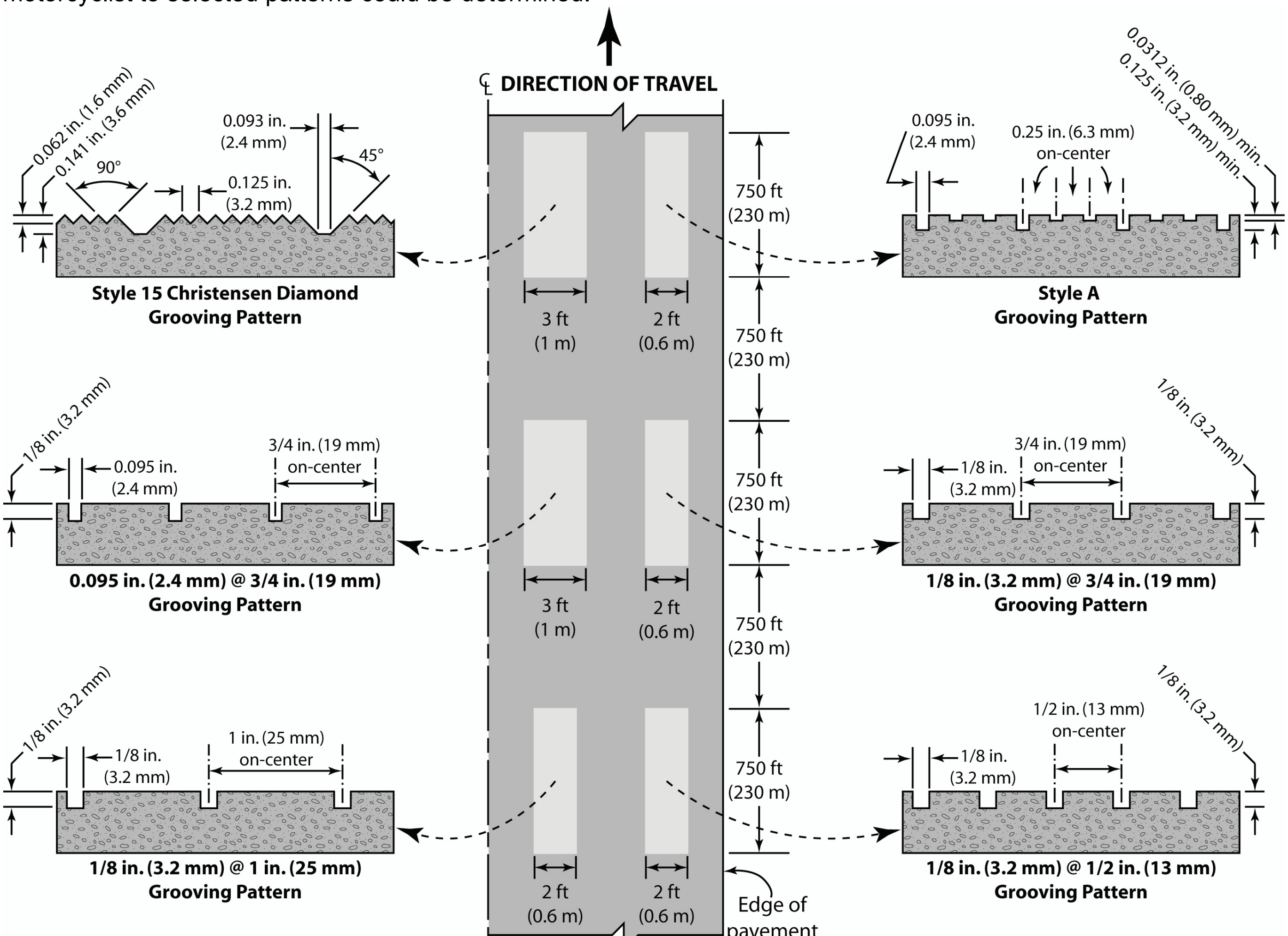

***Figure 1**. Layout and grooving patterns for the six diamond grooving test sections in the 1969 Caltrans diamond grooving experiment on County Road 32A.*

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As is illustrated in Figure 1, the experiment evaluated the 1/8 in. (3.2 mm) groove pattern at three locations and at three different groove spacings (3/4 in. [19 mm], ½ in. [13 mm] and 1 in. [25 mm] on center); the narrower groove pattern at one location (width of 0.095 in. [2.4 mm] at ¾ in. [19 mm] on center); and two frictional improvement surfaces (Style A and Style 15).

Caltrans selected the Style A groove pattern for the outer wheelpath, based on their experience with it at locations where it was desirable to improve the coefficient of friction significantly. Style A consisted of a series of 0.095 in. (2.4 mm) wide cuts at the spacing and depths indicated in Figure 1.

Caltrans selected Style 15 from Christensen Diamond Services Co., for the inner wheelpath, because it had been reported as being superior at increasing the coefficient of friction on smooth pavements[4]. Figure 1 describes the complex geometry of the Style 15 groove pattern.

1969 Friction Study Results

As part of the motorcycle sensitivity study, the friction of each test section was measured prior to and after the diamond grooving. The friction testing was conducted at 50 mph (80 kph), with a smooth tire under wet test conditions. As is evident in Table 1, the two friction improvement patterns were superior to the standard grooving patterns of the time. It should be noted that, at the time of the pre-grooving testing, the existing roadway was over 30 years old.

Table 1. *Coefficient of Friction Values for Various Groove Patterns*

Pattern	Before Grooving	After Grooving	Percent Improvement
1/8 in. (3.2 mm) @ ½ in. (13 mm)	0.37	0.38	3
1/8 in. (3.2 mm) @ ¾ in. (19 mm)	0.38	0.39	3
1/8 in. (3.2 mm) @ 1 in. (25 mm)	0.36	0.36	0
0.095 in. (2.4 mm) @ ¾ in. (19 mm)	0.38	0.39	3
Style A	0.40	0.44	*9*
Style 15	0.39	0.45	*13*

Other results of that 1969 Caltrans study indicated that none of the diamond grooving patterns in the test presented a safety issue to motorcyclists. The 1/8 in. (3.2 mm) groove width at ½ in. (13 mm) and 1 in. (25 mm) spacing and the Style A pattern resulted in the least overall sensations to the motorcyclist[1]. The Style 15 resulted in the greatest overall sensitivity[1].

2007 OBSI Test and Results

In 2007, Caltrans conducted an On Board Sound Intensity (OBSI) equipment comparison study on County Road 32A[2]. At that time, it was discovered that the 1969 diamond grooving sections still existed, after 38 years of post-grinding service; County Road 32A, itself, was approximately 60 years old[3]. Upon discovering that the 1969 Friction Study test sections still existed, ACPA also conducted OBSI testing of the six locations to determine if there were differences in the tire/pavement noise levels produced by the respective patterns.

Because the pavement was over 60 years old, the roadway exhibited 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.

Also, comparison of the between-wheelpath and actual wheelpath (where all diamond grooving was applied) locations tends to confound results because of the “armoring effect” that occurs as the mortar is worn away, exposing more and more aggregate.

OBSI testing consisted of three repeat runs for each section in each wheelpath. Testing was conducted at 60 mph (97 kph) using the ACPA dual probe OBSI system and an ASTM Standard Reference Test Tire (SRTT). The data was collected and analyzed using a B&K Model 3560B analyzer and Pulse software. The influence of joint slap was not removed for the analysis.

Center-of-Lane versus Wheelpath

Figure 2 provides a comparison between the center-of-lane (Center) results and the right wheelpath (RWP) results for the OBSI overall A-weighted results at different locations. It does not appear that there is a significant difference between the test locations or that the armoring effect is significantly different between locations.

Burlap Drag Texture versus Diamond Grooving

Figure 3 shows the results for the existing 60+ year old drag texture and the various 38+ year old grooved test sections. Although all test results are within approximately 2 dBA, it appears that the drag texture is slightly quieter than any grooved section. This suggests that grooving may not provide a long term benefit for noise reduction.

Effect of Groove Spacing Width for 1/8 in. (3.2 mm) Grooves

From Figure 3, there does not appear to be a significant difference in overall OBSI levels for the three 1/8 in. (3.2 mm) sections at the groove spacings (e.g. ½ in. [13 mm], ¾ in. [19 mm], and 1 in. [25 mm]) tested in the 1969 experiment; all three results are within one dBA.

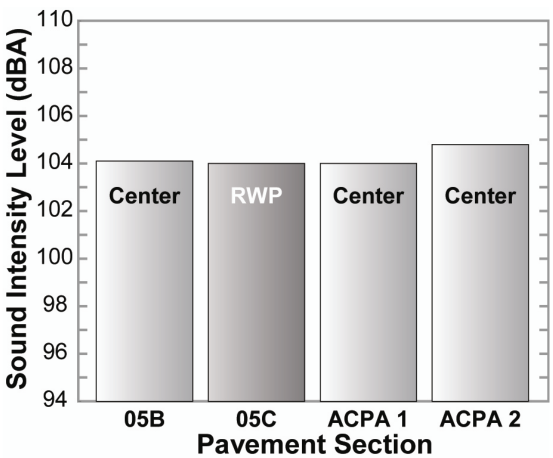

***Figure 2.** Comparison of OBSI test results for drag texture in the right wheelpath (RWP) and between wheel paths (Center). Detailed information on the test section locations is available in reference 2.*

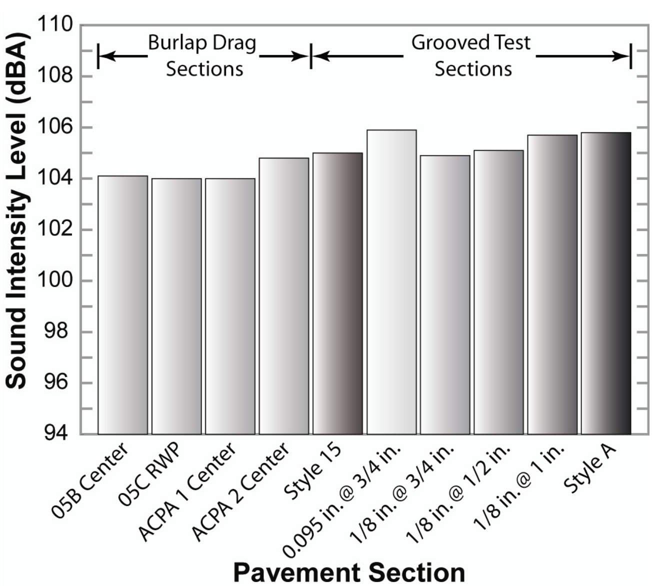

***Figure 3.** Comparison of OBSI test results for the burlap drag textures and all six grooved sections.*

Figure 4 indicates the spectral plot for the 1/8 in. (3.2 mm) groove at the three spacings. As before, there does not seem to be a significant difference between the results for these three spacings, although there does appear to be a slight difference at the 800 -1000 Hz centerband frequencies. Thus, although the overall sound levels are practically identical, there was a notable difference in the sound intensity level spectrums in this frequency range.

0.095 in. (2.4 mm) Groove Width versus 1/8 in. (3.2 mm) Groove Width

In the Los Angeles area during the 1960s, the 0.095 in. (2.4 mm) groove width had been placed in experimental sections because it was felt that this provided less of an annoyance to motorcycles[5]. The 1969 study did not confirm this belief. The 2007 OBSI testing also did not indicate any noise advantage to the narrower groove widths. In fact, the study showed that the 0.095 in. (2.4 mm) section was slightly louder than the 1/8 in. (3.2 mm) section at the same spacing (3/4 in. [19 mm]) after 38+ years of service.

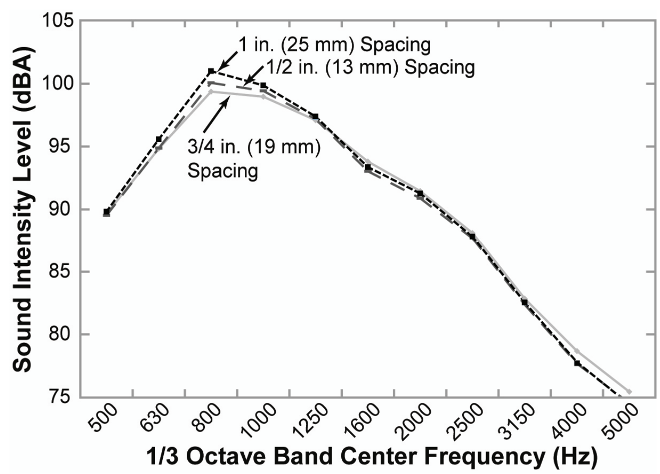

***Figure 4.** Evaluation of groove spacing effect on OBSI spectral plots for a 1/8 in. (3.2 mm) standard groove at various spacings.*

Friction Grooving Patterns versus 1/8 in. (3.2 mm) Groove Width Patterns

The results presented in Figure 3 do not indicate that either of the friction improvement surfaces resulted in an increased noise level after 38+ years in service. Thus, both frictional grooving patterns should be considered equivalent to the standard 1/8 in. (3.2 mm) groove width spaced at a ¾ in. (19 mm) from a tire/pavement noise perspective.

Additional Diamond Grooving Research

In 2002, Caltrans completed a pavement rehabilitation project on I-280 in San Mateo County. On that project, test sections were included that compared a conventional diamond ground surface to an experimental "texture grind" (Figure 5) [6]. The texture grind was produced by making a second pass with a different grinding head over the conventionally ground surface and it is interesting to note the similarities in geometry between the texture grind of 2002 and the old Style 15 texture grind from the 1960s.

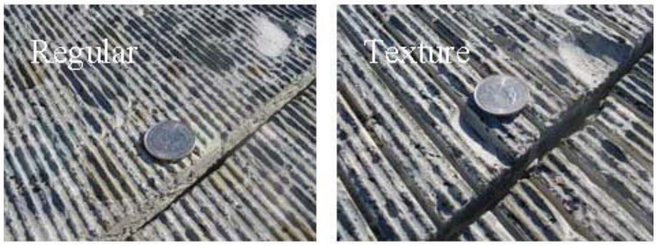

***Figure 5.** California I-280 conventional diamond grinding versus texture grinding[6].*

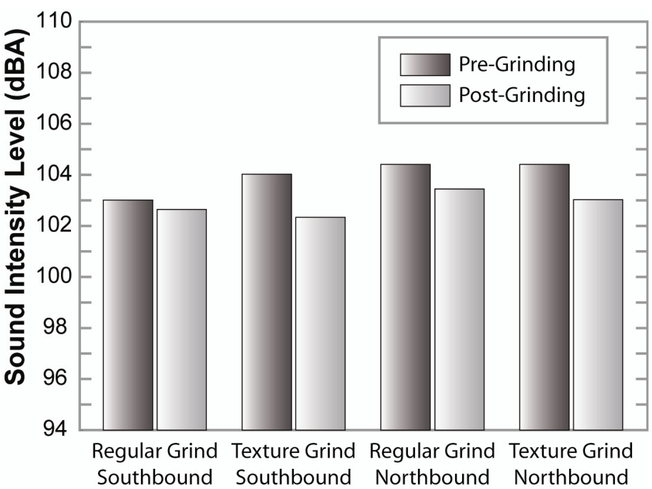

***Figure 6.** Comparison of overall OBSI levels for sections with original and two types of diamond ground textures[6].*

OBSI testing of these surfaces indicated that essentially no benefit was observed from an acoustical perspective for the experimental texture grind. In fact, as is evident in Figure 6, the experimental texture grind resulted in slightly lower noise levels (ranging between ¼ and ½ dBA lower) than the regular grind[6].

Conclusions

OBSI testing conducted on two California projects suggests that diamond grooving is not effective from an acoustic standpoint for noise mitigation purposes. This new conclusion adds another "rule-of-thumb" assertion to those reported in ACPA R&T Update 7.06.

It should be remembered however, that grooving has never been applied for noise mitigation but, instead, for lateral stability and improved friction. Both of these improvements are attainable by grooving without sacrificing noise qualities.

The results of ACPA's 2007 OBSI study indicate the following:

- The original drag texture (60+ years old) was slightly quieter than the grooved patterns (38+ years old), suggesting that grooving has no long-term benefit for noise reduction.
- For the 1/8 in. (3.2 mm) pattern, groove spacing had no effect on the overall noise levels produced.
- The patterns selected for improved friction did not result in higher overall noise levels.
- The condition of California's 60+ year old County Road 32A hampers making significant conclusions regarding the surfaces tested.

References

1. Sherman, G.B., Skog, J.B., and Johnson, M.H., "Effect of Pavement Grooving on Motorcycle Rideability", California Department of Public Works-Highways Division, November 1969.
2. Scofield, L., "Caltrans OBSI Comparison Experiment, Sacramento, CA", ACPA, April 2007, Draft Report.
3. Woodstrom, J., Personal communication with Larry Scofield.
4. Zube, E., Skog, J.B., and Munday, H.A., "Coefficient of Friction of Various Grooving Patterns on PCC Pavement", California Department of Public Works, Division of Highways, Materials and Research Department, Research Report 633126-4, July 1968.
5. Beaton, J.L., "Slippery Pavements", California Division of Highways, presented to the 39th Annual Meeting of the Institute of Traffic Engineering, Los Angeles, CA, August 25-28, 1969.
6. Donavan, P., "Quieting of Portland Cement Concrete Highway Surfaces with Texture Modifications", Proceedings of NOISE-CON 2005, Minneapolis, Minnesota, October 17-19, 2005.
7. "Rules of Thumb on Pavement Noise", Research and Technology Update 7.06, ACPA, 2006.

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