RESEARCH

Report No. UT- 08.15

ROADWAY PAVEMENT GRINDING NOISE STUDY

Prepared For:

Utah Department of Transportation
Research Division

Submitted by:

Parsons Brinckerhoff

Authored by:

Steven Wolf
Kevin Keller, AICP
Lani Eggertsen-Goff, MS
Chris Elison, PE

August 2008

UDOT
CONNECTING COMMUNITIES
Utah Department of Transportation - Research Division
4501 South 2700 West, Box 148410 - Salt Lake City, Utah 84114-8410

DISCLAIMER

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
UT- 08-15		

4. Title and Subtitle	5. Report Date
ROADWAY PAVEMENT GRINDING NOISE STUDY	AUGUST 2008
	6. Performing Organization Code
7. Author Steven Wolf; Kevin Keller; Lani Eggertsen-Goff; Chris Elison	8. Performing Organization Report No.
9. Performing Organization Name and Address Parsons Brinckerhoff (PB) 488 East Winchester, #400 Murray, Utah 84107	10. Work Unit No. 8RD0840H 11. Contract or Grant No. 08-9195
12. Sponsoring Agency Name and Address Utah Department of Transportation 4501 South 2700 West Salt Lake City, Utah 84114-8410	13. Type of Report & Period Covered FINAL; 2000-2008 14. Sponsoring Agency Code PROJECT ID CODE (PIC) No. AM07.402

15. Supplementary Notes

Prepared in cooperation with the Utah Department of Transportation or U.S. Department of Transportation, Federal Highway Administration

16. Abstract

High frequency pure tone noise, commonly known as tire whine, is significantly reduced by pavement grinding and could be beneficial for both reducing tire pavement noise levels and muting the tire whine pure tone sound of the older concrete pavement transverse tining texture.

17. Key Words	18. Distribution Statement	23. Registrant's Seal
Pavement Conditions; 2000, 2003 & 2008 Noise Data Analysis; Pre-Grinding & Post Grinding Measurements; Traffic Counts.	UDOT Research Division 4501 South 2700 West Box 148410 Salt Lake City, Utah 84114	LEAVE BLANK

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	19	LEAVE BLANK

ACKNOWLEDGMENTS

Doug Anderson – UDOT Research Division

Russ Scovil – UDOT Systems Planning and Programming

Abdul Wakil – UDOT Research Division

Jerry Chaney – UDOT Environmental

Tim Biel – UDOT Materials Division

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

The purpose of this study was to determine noise difference between pre-concrete and post-concrete grinding. Noise measurements were taken at the same location on I-215 East in eastern Salt Lake Valley in 2000, 2003, and 2008. The measurements were taken prior to grinding of the concrete surface and again after.

The results showed that the concrete grinding provided some reduction of noise levels along this section of I-215. The noise reduction was most notable at closer ranges to the traveled way because of engine noise and truck exhaust stacks. This report outlines the benefits in noise reduction from concrete grinding.

1.0 INTRODUCTION

Texturing of roadway pavement surfaces is necessary to provide adequate resistance to skidding, and to allow water drainage from under tires to minimize hydroplaning. This texturing has been shown to contribute to tire noise on rigid pavements. Large aggregate mixes have also been shown to increase tire noise. Studies have been conducted by other state agencies to evaluate which textures provide the needed safety attributes, while reducing the noise levels or the pure tone frequencies or “whine” that are annoying to the public. Other pavement deficiencies have been shown to contribute to tire noise as well. Joint faulting and other pavement roughness can create increases in pavement noise due to tire slap.

An experimental project, started in November 2000, ground a new texture into a 300-foot section of roadway on I-215 and monitored its performance over a three year period. This report presents the results of noise monitored eight years after the grinding of the roadway. The purpose of this report is to document the effect of the wearing of the ground roadway surface on the wayside noise levels. The results of similar studies performed in other states and in Europe have been provided in a previous report dated November 2000 for comparative purposes.

2.0 PAVEMENT CONDITIONS

The original tining was placed in 1990 during construction and was raked into the plastic concrete in the transverse direction. The tining was 1/8 inch wide, 1/16 inch deep, and spaced 1/2 inch apart. After 10 years of traffic, the tining had been worn down to some degree. Enough of the tining still existed in the wheel-paths to contribute to tire whine.
In 2000 a 300-foot test section was located on the east leg of I-215 at approximately 5000 South (M.P. 4.6) on both the northbound and southbound lanes. The surface texturing was performed by diamond grinding of the plane-jointed concrete pavement. The general condition of the pavement was considered to be good with respect to ride quality, with International Roughness Index (IRI) values, in inches per mile, of 100 IRI for northbound lanes and 93 IRI for southbound lanes. The faulting of the joints was considered minor, with more than 90% of the faults less than 0.1 inch in depth. The diamond grinding gave the surface a 1/16 inch depth longitudinal oriented texture. The purpose of this test section was to try to eliminate tire whine and measure noise with the new longitudinal texture.

In 2003 the entire section received diamond grinding from 4500 South to the bridge decks at 6200 South. This allowed noise measurements to be gathered without any noise from outside of the 300 foot test section.

Noise readings were gathered after five years of wear on the surface texture. Table 1 lists the IRI, joint faulting and skid numbers at the time of these new noise readings.

Table 1 -- Skid, IRI and Faulting Data for I-215 East Bench (2008)

	North Bound	South Bound
	M.P. (4-5)	**M.P. (5-4)**
Skid	32	45
IRI	72	69
Fault (0.1000-0.2000)	7	5
Fault (0.2000-0.3000)	1	2
Fault (0.3000-0.4000)	2	0
Fault (0.4000-1.4000)	0	0

3.0 NOISE MEASUREMENTS

The pre-grinding measurements were conducted on May 9, 2000 at five locations along the northbound lanes of I-215 in Salt Lake City (Figure 1). All measurements were taken during free flow traffic after the AM peak hour. Noise data was recorded for 15-minute periods at each measurement site and digitally stored on a Larson Davison Model 2900 Two-Channel Real Time Sound Analyzer.

Site A – At the edge of pavement of the northbound lanes (25 feet from the traveled way), 150 feet from the start of the 300 foot grind area.

Site B – At the edge of pavement of the northbound lanes (25 feet from the traveled way), 200 feet south of Site A, about 50 feet before the grind area. Noise levels at Sites A and B were recorded simultaneously, only during the May 9, 2000 study.

Site C – Relocated the microphone from Site A to 25 feet back from edge of pavement of the northbound lanes (50 feet from the traveled way), 150 feet from the start of the 300 foot grind area.

Site D – Relocated the microphone from Site B to 25 feet back from edge of pavement of the northbound lanes (50 feet from the traveled way), 200 feet south of Site C, about 50 feet before the grind area. Noise levels at Sites C and D were recorded simultaneously in the May 9, 2000 study.

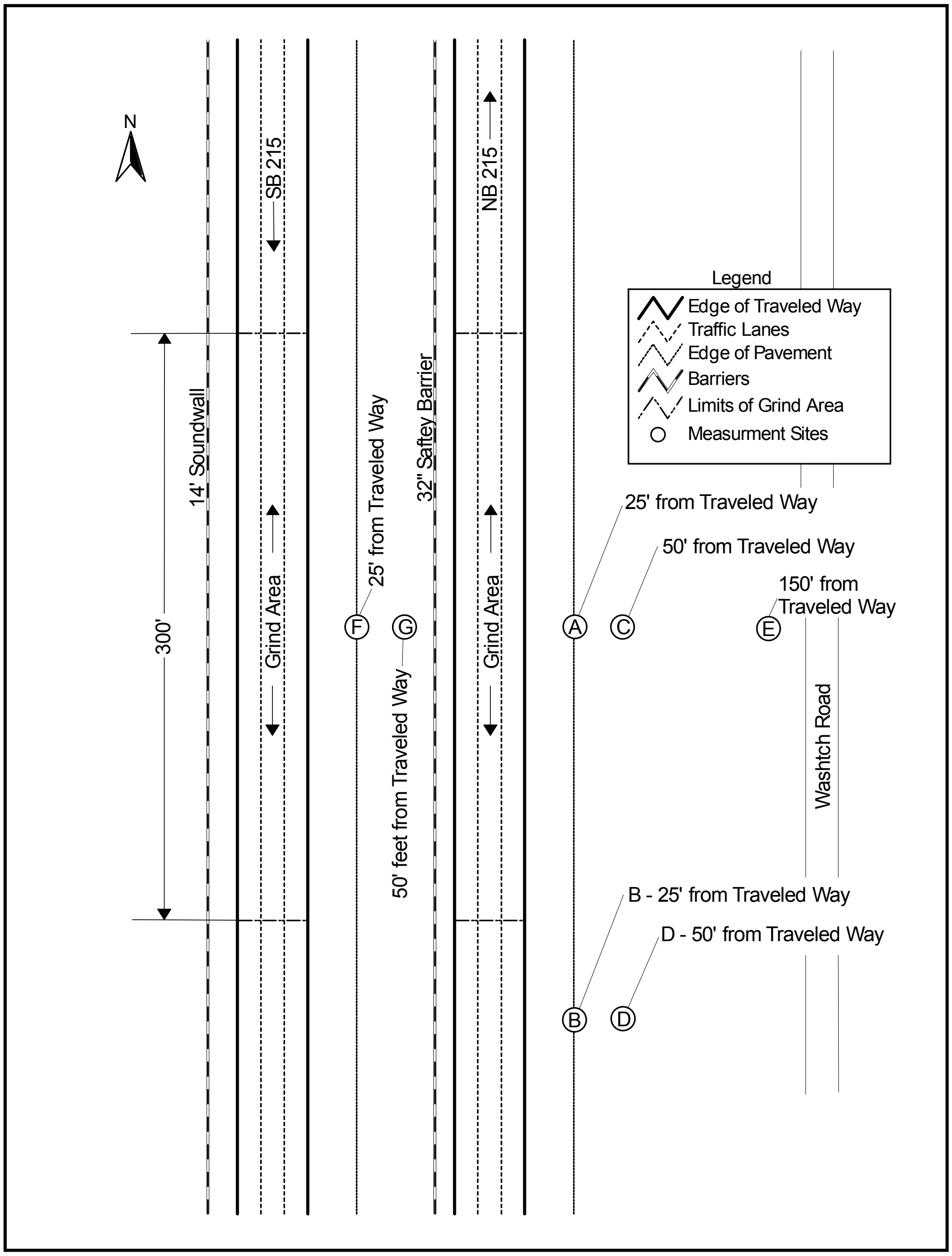
Site E –150 feet from the start of the grind area and 75 feet to the east of Site C, about 100 feet from the edge of pavement of the northbound lanes. Noise levels at Sites C and E were recorded simultaneously.

The post grinding noise measurements were conducted on May 31, 2000 at Sites A, B, C, D and E, and additional measurement sites were included at the request of UDOT, Sites F and G, to measure traffic noise levels from the southbound lanes of I-215.

Site F – At the edge of pavement of the southbound lanes, 150 feet from the start of the grind area.

Site G – 25 feet from the edge of pavement of the southbound lanes, 150 feet from the start of the grind area.

Figure 1 -- Noise Measurement Locations



Noise measurements were conducted again on May 21, 2003, after a larger section of the I-215 was ground. Measurements were conducted at the same locations, except Sites B and D, which were now inside the grind area of pavement and not needed as control sites.

Noise measurements were conducted at Sites A, C, E, F and G again on May 14, 2008.

3.1 Results of Measured Noise Data

The measured noise levels were analyzed in 1/3 octave sound pressure levels and are presented in Figures 2 through 6 for the following conditions:

- Figure 2 – The sound pressure level data at Site A, the edge of pavement of the northbound lanes, represents the closest microphone location to the traffic for northbound traffic. This data compares the measurements made on different days during the same time period before and after grinding at the same measurement location.
- Figure 3 – The sound pressure level data at Site C, 25 feet from the edge of pavement of the northbound lanes, compares the measurements made on different days during the same time period before and after grinding at the same measurement location.
- Figure 4 – The sound pressure level data at Site E, 25 feet from the edge of pavement of the northbound lanes, compares the measurements made on different days during the same time period before and after grinding at the same measurement location.
- Figure 5 – The sound pressure level data presented represents simultaneous noise measurements taken of the same traffic at Site A, edge of pavement, next to the pavement area that was ground and Site B, next to the original pavement surface that is directly south of the ground pavement.
- Figure 6 – The sound pressure level data presented represents simultaneous noise measurements taken of the same traffic at Site C, 25 feet from edge of pavement, next to the pavement area that was ground and Site D, 25 feet from edge of pavement, next to the original pavement surface that is directly south of the ground pavement.

The A-scale (dBA) measured noise levels are summarized in Table 2. Data for Sites F and G, requested by UDOT during the post grinding measurements, do not represent the change in traffic noise levels due to the grinding.

Table 2 -- Summary of 2000 Noise Measurements

Measurement Sites	Microphone Location	Pre-Grinding Noise Levels (dBA)	Post Grinding Noise Levels (dBA)	Noise Reduction Due to Pavement Grinding
Site A	Edge of Pavement	84.2	79.2	-5.0
Site C	25 feet from Edge of Pavement	81.2	78.6	-2.6
Site E	125 feet from Edge of Pavement	76.4	76.2	-0.2
Site F	Edge of Pavement - Southbound Lanes	----	79.0	N/A
Site G	25 feet from Edge of Pavement - Southbound Lanes	----	77.9	N/A

Simultaneous Measurement Sites	Microphone Location	Outside of Grind Area	Within Grind Area	Noise Reduction Due to Pavement Grinding
Sites A & B	Edge of Pavement	81.5 (Site B)	79.2 (Site A)	-2.3
Sites C & D	25 feet from Edge of Pavement	79.6 (Site D)	78.6 (Site C)	-1.0

3.2 Data Analysis

Table 2 shows the noise level reduction from pavement grinding from the 2000 noise measurements. The noise reduction from the pavement grinding is highest, 5.0 dBA at Site A, where the microphone location was closest to the traveled lanes. As the measurement location is moved further from the travel lanes the reduction is less, 2.6 dBA at Site C and 0.2 dBA at Site E.

The measured data indicates that the noise contribution from the tire pavement interaction is more predominate at closer distances to the traffic. This effect is lessened at larger distances where the contribution of truck exhaust stack and engine noise is more prevalent. The comparision of the measured A-scale noise levels are presented in Tables 2 through 6:

- Table 3 presents the reduction in noise levels between the 2000 pre-grinding and the 2003 post grinding noise measurements
- Table 4 presents the reduction in noise levels between the 2000 pre-grinding and the 2008 post grinding noise measurements
- Table 5 presents the changes in post grinding noise levels between 2000 and 2003
- Table 6 presents the changes in the post grinding noise levels between 2000 and 2008
- Table 7 presents the changes in noise levels between 2003 and 2008

The other variable in these measured data is the traffic volumes, speed and vehicle mix. The 0.6 to 2.0 dBA reduction in noise levels between 2000 and 2003 is primarily due to the change in the traffic volumes with the additional grinding having a lesser effect. Subsequently the increase in noise levels between 2003 and 2008 are due to a change in traffic volumes and a greater percentage of heavy trucks.

The comparison of the simultaneous measurements at Sites A and B and Sites C and D indicate lower noise reductions than the data taken at these same sites pre and post-grinded.

Table 3 -- Comparison of 2000 Pre-Grinding & 2003 Post Grinding Noise Measurements

Measurement Sites	Microphone Location	Pre-Grinding 2000 Noise Levels (dBA)	Post Grinding 2003 Noise Levels (dBA)	Noise Reduction Due to Pavement Grinding
Site A	Edge of Pavement (EP)	84.2	78.6	-5.6
Site C	25 feet from (EP)	81.2	76.6	-4.6
Site E	125 feet from (EP)	76.4	74.3	-2.1

Table 4 -- Comparison of 2000 Pre-Grinding & 2008 Post Grinding Noise Measurements

Measurement Sites	Microphone Location	Pre-Grinding 2000 Noise Levels (dBA)	Post Grinding 2008 Noise Levels (dBA)	Noise Reduction Due to Pavement Grinding
Site A	Edge of Pavement	84.2	81.6	-2.6
Site C	25 feet from Edge of Pavement	81.2	79.6	-1.6
Site E	125 feet from Edge of Pavement	76.4	75.5	-0.9

Table 5 -- Comparison of 2000 & 2003 Post Grinding Noise Measurements

Measurement Sites	Microphone Location	Post Grinding 2000 Noise Levels (dBA)	Post Grinding 2003 Noise Levels (dBA)	Difference in Noise Levels Due to Changes in Traffic & Additional Grinding
Site A	Edge of Pavement	79.2	78.6	-0.6
Site C	25 feet from Edge of Pavement	78.6	76.6	-2.0
Site E	125 feet from Edge of Pavement	76.2	74.3	-1.9
Site F	Edge of Pavement - Southbound Lanes	79.1	77.8	N/A
Site G	25 feet from Edge of Pavement - Southbound Lanes	77.9	76.3	N/A

Table 6 -- Comparison of 2000 & 2008 Post Grinding Noise Measurements

Measurement Sites	Microphone Location	Post Grinding 2000 Noise Levels (dBA)	Post Grinding 2008 Noise Levels (dBA)	Difference in Noise Levels Due to Changes in Traffic
Site A	Edge of Pavement	79.2	81.6	2.4
Site C	25 feet from Edge of Pavement	78.6	79.6	1.0
Site E	125 feet from Edge of Pavement	76.2	75.5	-0.7
Site F	Edge of Pavement - Southbound Lanes	79.1	81.0	1.9
Site G	25 feet from Edge of Pavement - Southbound Lanes	77.9	79.1	1.2

Table 7 -- Comparison of 2003 & 2008 Post Grinding Noise Measurements

Measurement Sites	Microphone Location	Post Grinding 2003 Noise Levels (dBA)	Post Grinding 2008 Noise Levels (dBA)	Difference in Noise Levels due to Changes in Traffic
Site A	Edge of Pavement	78.6	81.6	3.0
Site C	25 feet from Edge of Pavement	76.6	79.6	3.0
Site E	125 feet from Edge of Pavement	74.3	75.6	1.3
Site F	Edge of Pavement - Southbound Lanes	77.8	81.0	3.2
Site G	25 feet from Edge of Pavement - Southbound Lanes	76.3	79.1	2.8

The traffic counts on northbound I-215 taken during the noise measurements are presented in Table 8. Vehicles with less than six tires were defined and counted as cars. Vehicles with six tires, such as small sized delivery trucks or small shuttle vans, were counted as medium trucks (MT) and those with more than six tires were counted as heavy trucks (HT).

Table 8 -- Traffic Counts – Northbound I-215 East

		15 Minute Count				**1 Hour Volume**				**Vehicle Percent**		
		Total	**Cars**	**MT**	**HT**	**Total**	**Cars**	**MT**	**HT**	**Cars**	**MT**	**HT**
Site A	Pre-Grinding 2000	662	628	19	15	2648	2512	76	60	95%	3%	2%
Site A	Post Grinding 2000	664	607	33	24	2656	2428	132	96	91%	5%	4%
Site A	Post Grinding 2003	593	555	26	12	2372	2220	104	48	94%	4%	2%
Site A	Post Grinding 2008	612	551	32	29	2448	2020	80	120	90%	5%	5%
Site C	Pre-Grinding 2000	614	571	26	17	2456	2284	104	68	93%	4%	3%
Site C	Post Grinding 2000	591	538	27	26	2364	2152	108	104	91%	5%	4%
Site C	Post Grinding 2003	556	510	29	17	2224	2040	116	68	92%	5%	3%
Site C	Post Grinding 2008	554	505	20	30	2220	2020	80	120	91%	4%	5%
Site E	Pre-Grinding 2000	562	524	24	14	2248	2096	96	56	93%	4%	2%
Site E	Post Grinding 2000	540	488	19	33	2160	1952	76	132	90%	4%	6%
Site E	Post Grinding 2003	518	481	12	15	2072	1964	48	60	95%	2%	3%
Site E	Post Grinding 2008	554	505	20	30	2220	2020	80	120	91%	4%	5%
Site F and G	Post Grinding 2003	414	383	11	20	1656	1532	44	80	93%	3%	5%
Site F and G	Post Grinding 2008	475	434	11	30	1900	1736	44	120	91%	2%	6%

3.3 Summary and Conclusions

Since traffic noise consists of pavement/tire noise and vehicle engine compartment and engine exhaust noise, the benefits of the pavement grinding is reduced by the noise contribution from heavy truck engine exhaust stack noise and engine compartment noise. At speeds of approximately 60 mph or less, the engine exhaust stack noise of a heavy truck is higher than the tire noise. At lower speeds, the gap in this relationship widens, where the engine stack exhaust noise is the predominate source of truck noise. The maximum noise reduction of the pavement grinding was measured at the edge of pavement and decreased as the distance from the traffic increased. At close distances to the tire/pavement noise, the lower frequency truck engine stack exhaust noise (which is at a source height in the range of 8 to 12 feet above the pavement surface) will diffract over the 5-foot high microphone location. As the distance between the microphone and the traffic increases, the truck engine stack noise becomes more significant.

The potential traffic noise reduction of the pavement grinding to the communities along I-215 would be in the range of 1 dBA to 2 dBA depending on the percentage of heavy trucks and their speed. The higher the percentage of cars and medium trucks (vehicles without a vertical engine exhaust stack) the better the noise reduction.

The basic shape of the frequency spectrum before and after the grinding is similar with the exception that at or about the 1600 Hz 1/3 octave band there is more pronounced reduction in sound pressure level. At measurement Site A (Figures 2 and 5), and Site C (Figure 3) there is a difference in the range of 3 dB to 7 dB at this frequency for the 2000 post grinding measurements.

The 2003 post grinding measurements showed further improvement over the 2000 post grinding level in the frequencies above 1000 Hz, in the range of 1 to 4 dB. This decrease is primarily due to the change in the traffic volumes with the additional grinding having a lesser effect.

The 2008 post grinding measurements showed an increase in noise level in the frequencies above 1000 Hz, of 3 to 6 dB, over the 2003 measurements. This increase is mainly due to the lesser heavy truck traffic during the 2003 measurements, 2 to 3 percent compared to 4 to 5 percent in 2000 and 2008. The 2008 post grinding measurements also showed an increase over the 2000 post grinding level in the frequencies above 1000 Hz, in the range of 1 to 4 dB. This increase may be due to wear of the roadway surface.

The 2008 post grinding measurements do still show an improvement over the 2000 pre-grinding measurements, in frequencies above 1000 Hz, of 1 to 4 dBA.

The pure tone characteristics of the tire noise have been reduced by the pavement grinding. Subjectively, this would contribute to the perception that the post-ground tire noise is lower in noise level than the A-scale difference of 1 to 2 dBA would indicate.
Since the pavement grinding did remove the uniformly spaced transverse tines from the concrete pavement, the high frequency pure tone noise, commonly known as tire whine, has

been significantly reduced. Studies conducted in Minnesota, North Dakota and Wisconsin have found that uniformly spaced transverse tined concrete pavement results in the most irritating tire/pavement noise when compared to other transverse or longitudinal tine concrete pavement textures because of the higher frequency tonal nature of the tire pavement noise better known as “tire whine”.

The expected reduction of removing the uniformly spaced transverse tined pavement texture would be approximately 3 dB to 5 dB at the pure tone frequencies that generate the tire whine noise. At closer distances to the travel lanes reductions in these same frequencies may be as much as 7 dB.

The use of pavement grinding as a traffic noise abatement measure for I-215 could be beneficial for both reducing tire pavement noise levels and muting the tire whine pure tone sound of the older concrete pavement transverse tining texture.

Figure 2 - Comparison of Roadway Grinding at Edge of Pavement
Measurement Site A

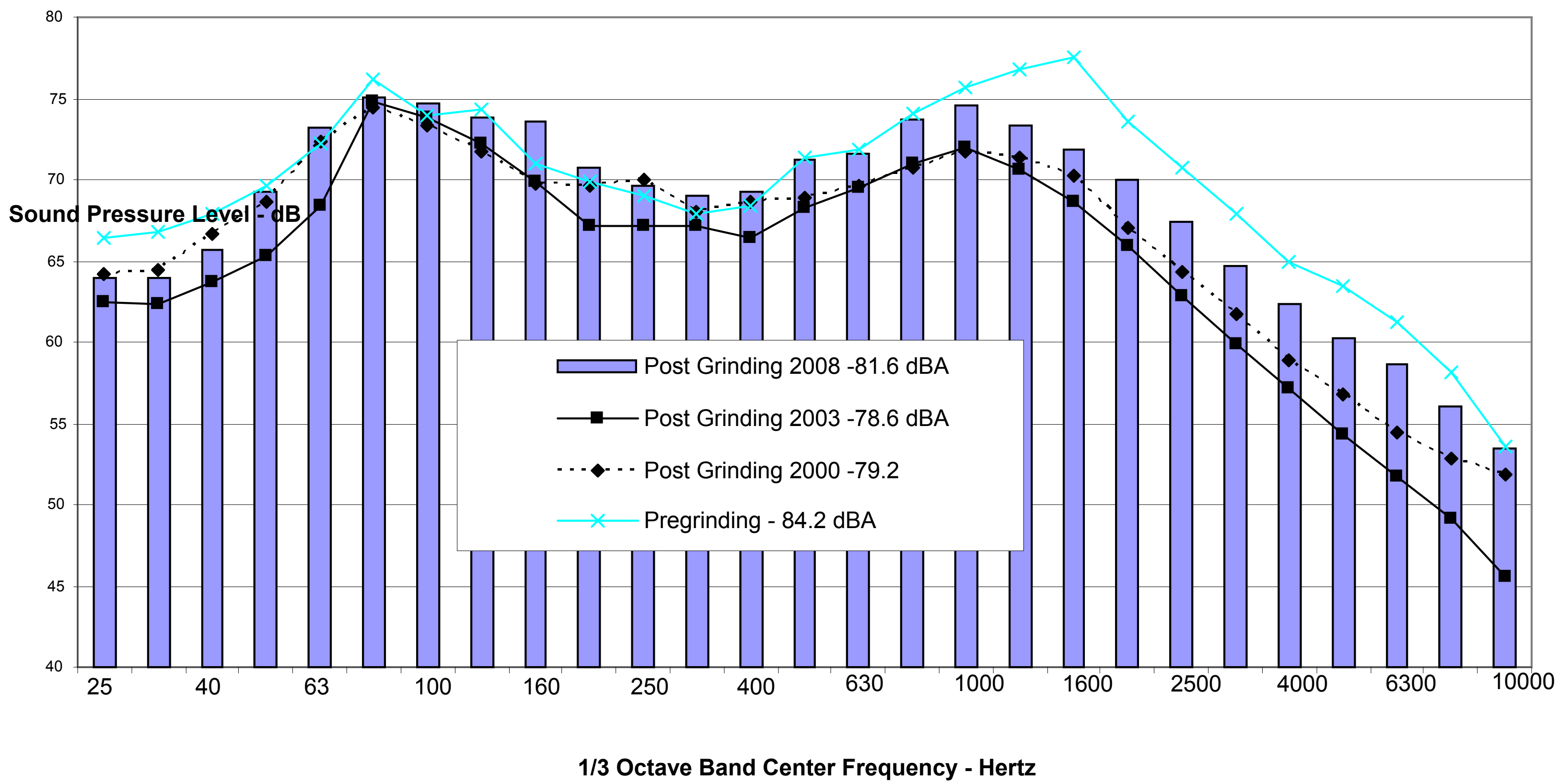


Figure 3 - Comparison of Roadway Grinding at 25 feet from Edge of Pavement
Measurement Site C

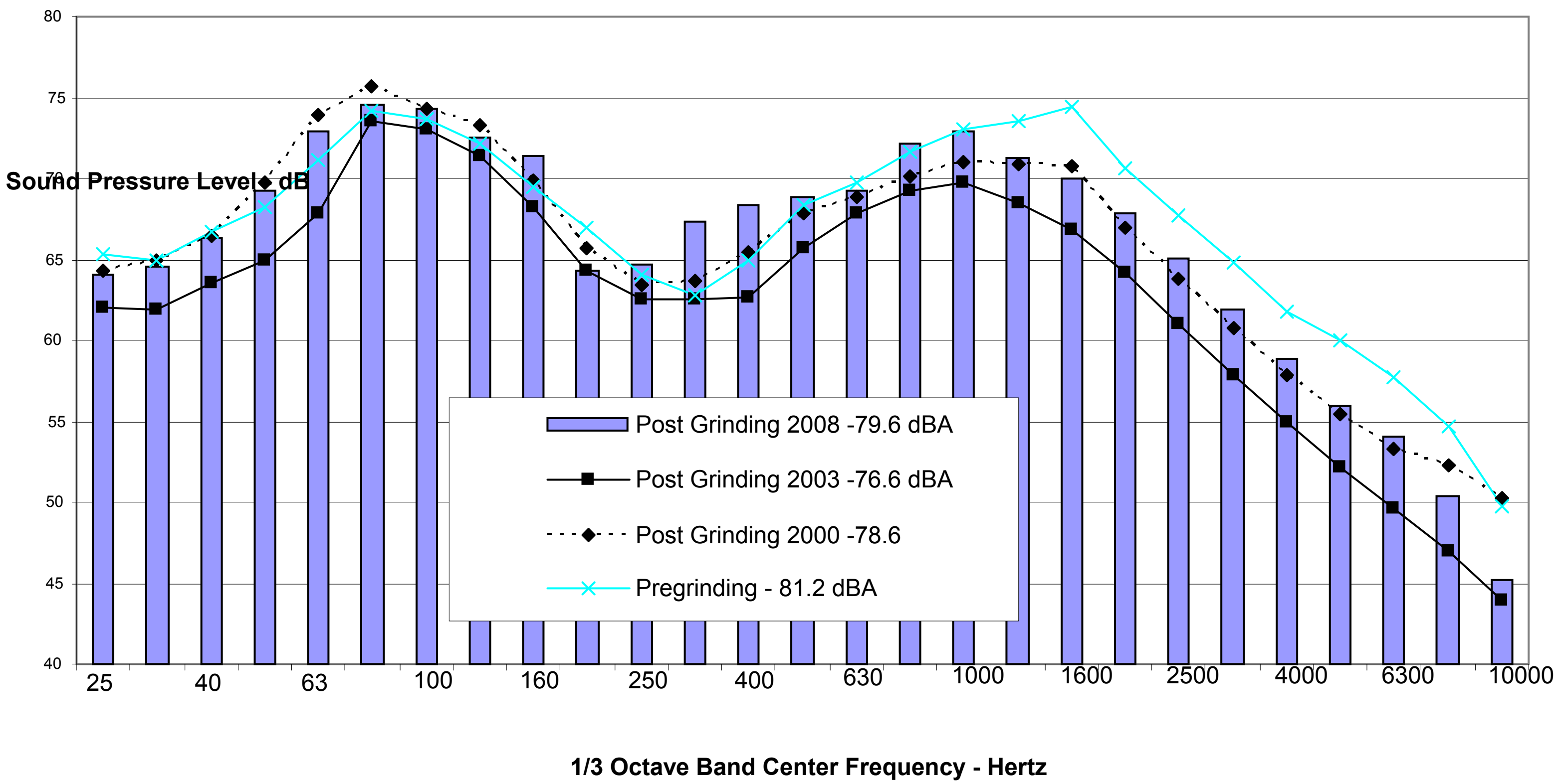


Figure 4 - Comparison of Roadway Grinding at 125 feet from Edge of Pavement
Measurement Site E

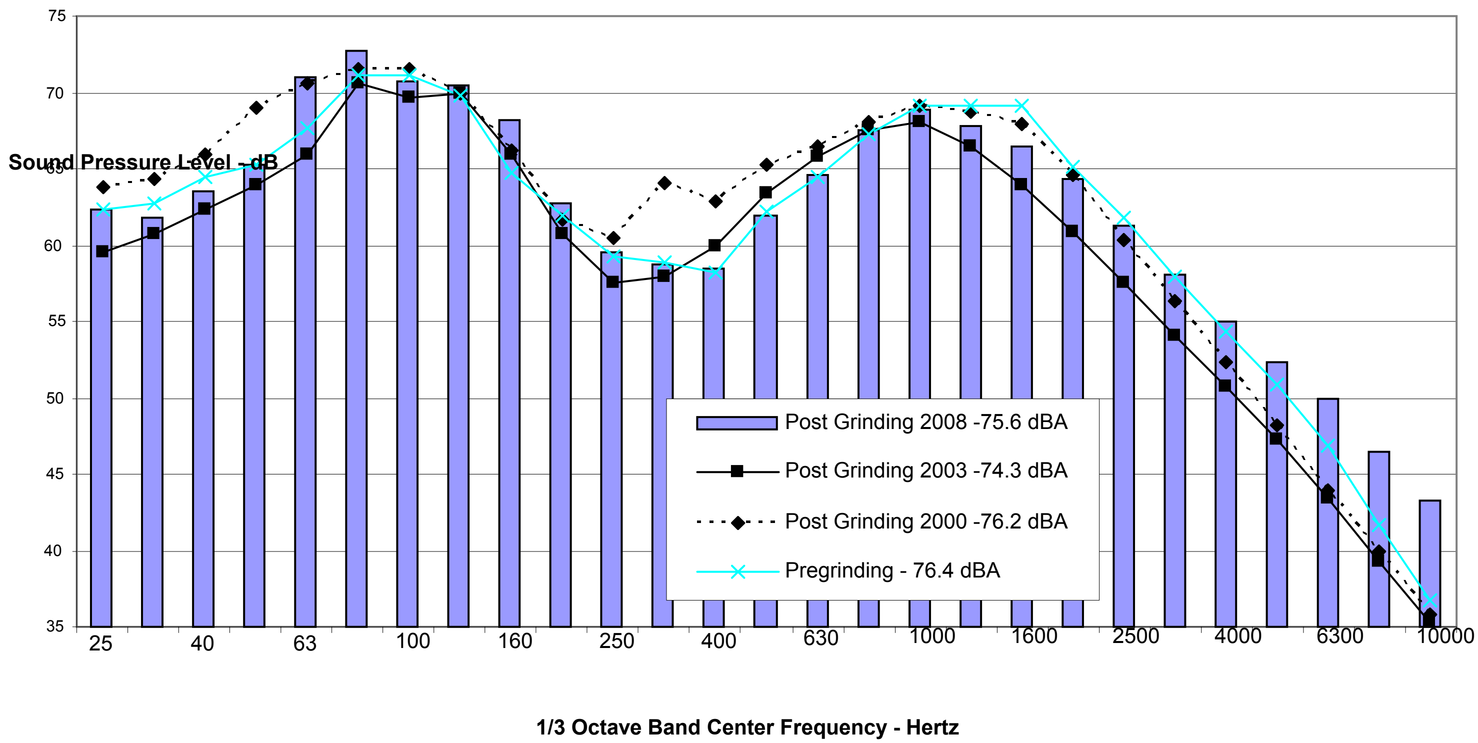


Figure 5 - Comparison of Roadway Grinding at Edge of Pavement
Simultaneous Measurement Site A and B

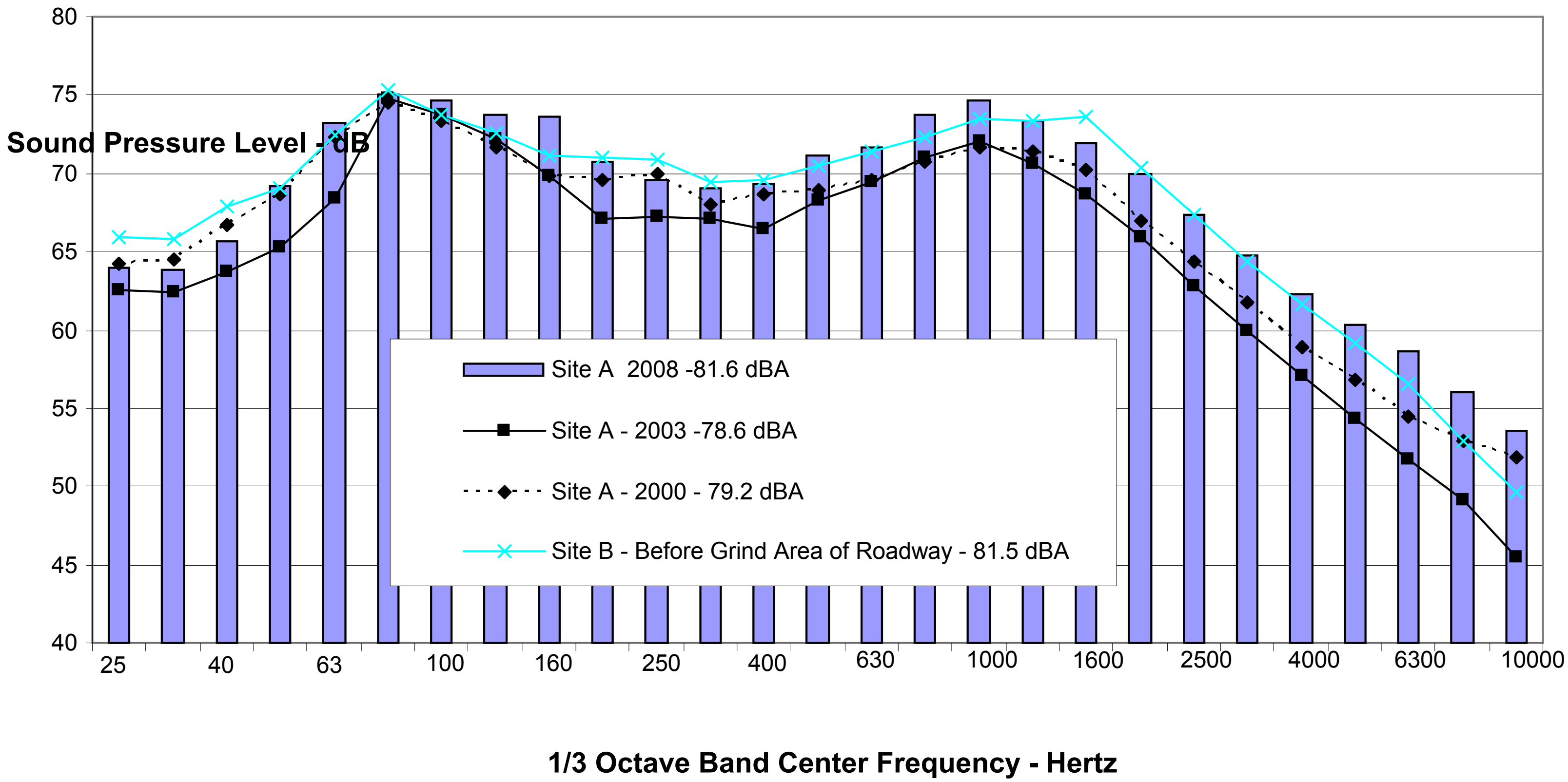
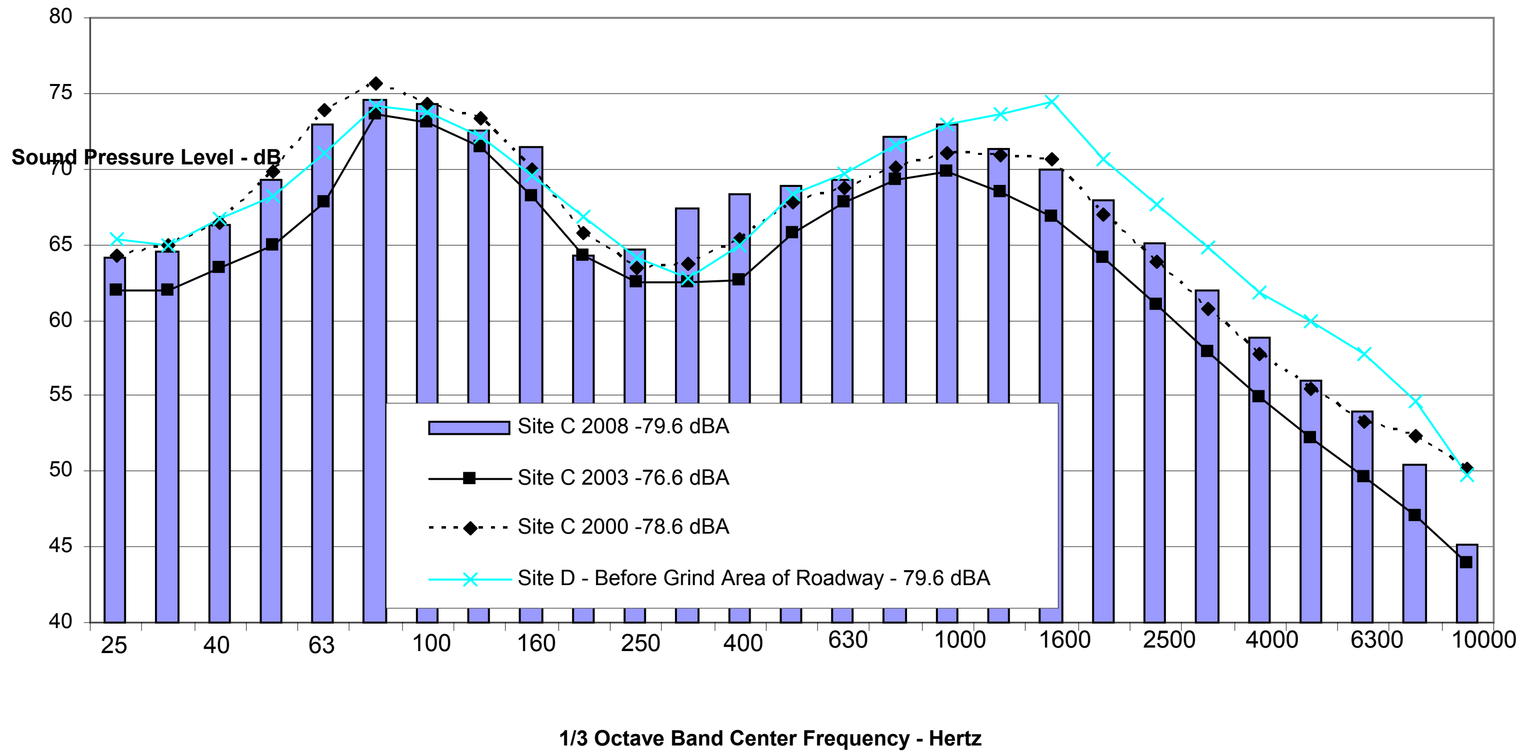


Figure 6 - Comparison of Roadway Grinding at 25 feet from Edge of Pavement Measurement Site C and D



REFERENCES

Federal Highway Administration (FHWA); *Highway Construction Noise: Measurement, Prediction, and Mitigation*, 1976

Federal Highway Administration (FHWA); *Procedures for Abatement of Highway Traffic and Construction Noise*, Code of Federal Regulations 23CFR 772, April 1994.

Federal Highway Administration (FHWA); Memorandum: *Highway Traffic Noise Analysis and Abatement - Policy and Guidance*, June 1995.

R. E. Franklin, D. G. Harland, and M. Nelson, *Road Surfaces and Traffic Noise*, TRRL Report 896, Transport and Road Research Laboratory, Crowthorne, Berkshire, England, 1979, 33 pp.

P. M. Nelson, G. J. Harris, and B. J. Robinson, *An Examination of the Relationship Between Tire Noise and Safety Performance*, Project Report PR/ENV/047/93, Transport Research Laboratory Unpublished Report, Crowthorne, Berkshire, England, 1993.

Highway Traffic Noise Guidance and Policies and Written Noise Policies, Tony Kane's June 12, 1995, memorandum to FHWA Regional Administrators, 86 pp.

J. D. Chalupnik and D. S. Anderson, *The Effect of Roadway Wear on Tire Noise*, Washington State Transportation Center (TRAC), University of Washington, Seattle, Washington, August 1992, 33 pp.

Guidelines for Skid Resistant Pavement Design, American Association of State Highway and Transportation Officials, AASHTO, 1976, 20 pp.

Guide on Evaluation and Abatement of Traffic Noise, American Association of State Highway and Transportation Officials, AASHTO, 1993, 40 pp.

Neal, B. F., et al., *Surface Textures for PCC Pavements, Report No. FHWA-CA-TL-78-14*, California Department of Transportation, Sacramento, CA, 1978, 63 pp.

Report of the 1992 U.S. Tour of European Concrete Highways, FHWA-SA-93-012, FHWA, December 1992, pp. 113-116.

Jofre, C., *Spanish Practice and Experience with Concrete Pavements*, Paper presented to the U.S. TECH Study Tour, June 1992.

R. I. Aberola, J. Quereda, J. M. Lozano, and A. Medrano, *Modern Construction of Concrete Pavements for Expressways in Concrete Roads*, Madrid, Spain (CEMBUREAU-Brussels), October 1990, pp. 29-39.

Guidelines for Skid Resistant Pavement Design, American Association of State Highway and Transportation Officials, AASHTO, 1976, 20 pp.

P. G. Dierstein, *A Study of PCC Pavement Texturing Characteristics in Illinois*, Final Report, FHWA/IL/PR-095, Illinois Department of Transportation, Springfield, IL, 1982, 54 pp.

R. A. Scarr, Transverse Texturing With Metal Tines, *Highway Focus*, April 1976, Volume 8, No. 2, FHWA, pp. 9-17.

E. E. Rugenstein, Summary and Evaluation of Concrete Pavement Texturing Practices, *Proceedings, International Conference on Concrete Pavement Design*, Purdue University, U.S., 1977, pp. 557-563.

D. A. Kuemmel, J. J. Jaeckel, A. Satanovsky, S. F. Shober, and M. Dobersek, *Noise Characteristics of Pavement Surface Texture in Wisconsin*, Draft TRB Paper, March 1996, 37 pp.

PCCP Texturing Methods, Technical Report, Ahmad Ardani, Colorado DOT, February 1995.

Guide on Evaluation and Abatement of Traffic Noise, AASHTO, 1993, 40 pp.

S. H. Dahir and J. J. Henry, *Alternatives for the Optimization of Aggregate and Pavement Properties Related to Friction and Wear Resistance*, FHWA-RD-78-209, Final Report, FHWA, April 1978, 295 pp.

Fifth International Conference on Concrete Pavement Design and Rehabilitation, Volumes I and II, Purdue University, April 1993, 700 pp.

NCHRP Synthesis 268, Relationship Between Pavement Surface Texture and Highway Traffic Noise, TRB, 1998.