Performance of Concrete Pavements with Longitudinal Tining, Transverse Tining, and Carpet Drag Finish

WA-RD 637.2

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Experimental Feature Report

Final Report
Experimental Features WA 05-02 and 05-05

Performance of Concrete Pavements with Longitudinal Tining, Transverse Tining, and Carpet Drag Finish

Contract 6757
I-5
Federal Way to S. 317th Street HOV Direct Access
MP 143.25 to 144.75
and
Contract 6883
Pierce Co. Line to Tukwila I/C – HOV – Stage 4
MP 139.06 to 144.75




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16. ABSTRACT

This report documents the performance of concrete pavements constructed on I-5 in the vicinity of Federal Way, Washington. The pavements were built using three types of texture; carpet drag, longitudinal tining, and transverse tining. The pavements were monitored for wear, friction resistance, ride, and tire/pavement noise. The purpose of the study was to determine if the carpet drag and longitudinal tining methods of texture were equal to or better than the standard transverse tining used by WSDOT and required by FHWA at the time.

The data showed that the carpet drag and longitudinal tined textures were equal to or better than the transverse tined texture with respect to pavement wear and friction resistance.

Noise levels on the carpet drag and longitudinal tined textured pavements are in the range normally cited for either conventional diamond ground or longitudinal tined pavement.

Additional performance data is reported from three concrete pavement projects located on I-90 in the Spokane urban area that used transverse tined and carpet drag textures. Data showed that neither of the textures will withstand the wear from studded tires. Friction resistance on these projects was adequate despite the quick removal of all texture by studded tire wear. Various mix designs that produced higher flexural strength pavements or pavements with higher cement contents did not prove any more resistant to studded tire wear than pavements built with standard 650 psi mix designs.

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Introduction

Washington State Department of Transportation's (WSDOT) concrete pavement construction program has been relatively small since the completion of the Interstate system in the 1960's and early 1970's. Many of these pavements are now reaching the end of their useful lives and are being programmed for reconstruction. It is essential that the best possible materials and construction practices be used in order to ensure pavement service lives of 50 years or longer. This has led to the development of a number of experimental features that have been incorporated into construction projects to evaluate various innovative materials or construction practices that may provide better performance, especially pavements that are more resistant to studded tire wear. Washington is one of the three states in the western part of the United States that experience a lot of studded tire usage during the winter months, the other two being Oregon and Alaska. This report describes the performance of two projects constructed with carpet drag and longitudinal tined texture used as an alternative to transverse tined texture with the goal of finding a method of texturing that may result in a pavement more resistant to studded tire wear, and equal to or better than transverse tined pavement in frictional properties and tire/pavement noise generation.

Studded Tire Wear

Wear on concrete pavements in the state of Washington is due primarily to studded tires which are legal between November 1 and March 31. The damage from studded tires ranges from a slight dishing of the pavement in the wheel paths to ruts that are over 1/2 inch deep. Figure 1 shows a concrete pavement that was constructed in 1995 on SR 395 just south of Interstate 90 near Ritzville. At the time of this photo, this pavement had been in service for seven years. The traffic on this route is approximately 6,800 vehicles per day. The transverse tining in the wheel paths has been completely worn away due to studded tires (note that the tining is still visible on either side of the wheel paths).

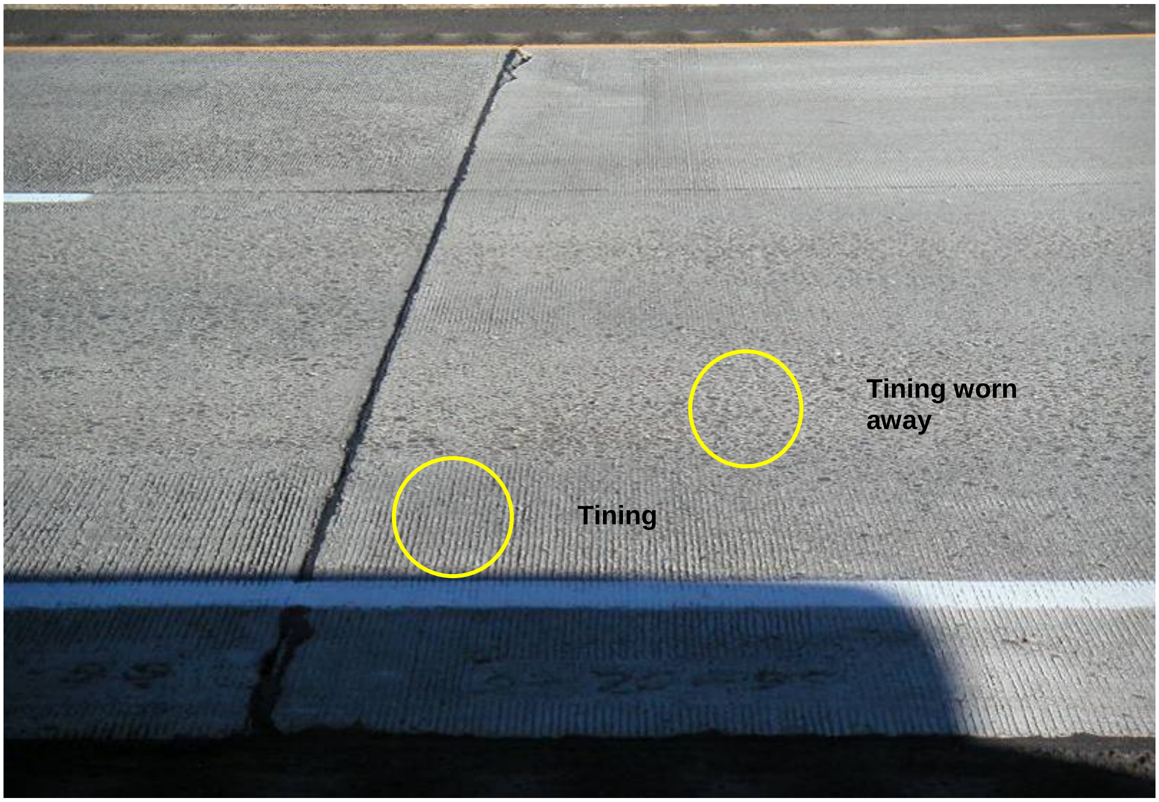

Figure 1. Concrete pavement on SR-395 south of Interstate 90 interchange at Ritzville.

Figure 2 shows a 13 year old concrete pavement located on Interstate 45 in Houston, Texas. Note the clear pattern of tine marks across the entire width of the lane. The traffic on this section is 178,000 vehicles per day. Studded tires are legal in Texas, however, the mild climate in Texas does not typically warrant their use. The damaging effects of studded tires is clearly observable in this comparison which is made even more dramatic when considering that the Texas pavement has received more than 26 times the daily traffic volume (178,000 versus 6,800) and has been in service for almost twice the number of years (thirteen years versus seven years) as the pavement on SR 395.

Figure 2. Concrete pavement on Interstate 45 in Houston, Texas after thirteen years of traffic.

An even more dramatic example of studded tire wear is shown in Figure 3. The wear has formed 1/2 inch deep ruts in the concrete pavement. This type of rutting is especially prevalent in the Spokane urban area, which has the highest use of studded tires in the entire state.

Figure 3. Studded tire wear on a concrete pavement (I-90 Spokane).

Studded Tire Wear Mitigation Projects

A series of experimental features have been built in both Eastern and Western Washington (Table 1) using various strategies to try and reduce the type of wear noted previously. The subject of this report are the two Western Washington projects on I-5, Federal Way to S. 317th Street HOV Direct Access, and Pierce County Line to Tukwila I/C – HOV – Stage 4, hereafter referred to as the Federal Way Project and the Pierce Co. Line Project, respectively. The first project was built using carpet drag instead of transverse tining. The second project used carpet drag in lieu the transverse tining but also incorporated short sections of longitudinal tining and transverse tining.

The performance of the two I-5 projects is contrasted with the performance of three Eastern Washington projects. The projects in Eastern Washington are all on I-90 in the Spokane urban area. The first project is Sprague Avenue I/C Phase III completed in 2001. This project constructed westbound lanes between Milepost (MP) 284.00 and MP 287.00 using a combined aggregate gradation to see if a different aggregate structure would reduce studded tire wear. It is compared to a project constructed a year earlier on the eastbound lanes at the same mileposts using the WSDOT's standard aggregate gradation. The WSDOT 650 psi flexural strength mix design was used for both projects as was transverse tined texture. The study concluded that the combined aggregate gradation provided no measurable improvement in the resistance of the pavement to studded tire wear. This project is hereafter referred to as the Combined Gradation Project.

The second project, Sullivan Road to Idaho State Line, was completed in 2003. Various pavement treatments were installed on an HMA pavement to mitigate deep rutting from studded tires. The pavement treatments included micro/macro resurfacing, modified Class D HMA, whitetopping, and standard Class ½ inch Superpave HMA. The whitetopping was the treatment of interest on this project. Sections with 3-inch, 4-inch, and 5-inch thick fiber reinforced concrete were placed in the westbound travel lane between MP 293.20 and 293.53 with each section about 600 feet in length. The flexural strength requirement for the mix design (see Appendix A) was increased from 650 psi to 800 psi. Polypropylene fibers were incorporated into the mix at the rate of 3 pounds per cubic yard to provide extra strength and hold any cracks together that might form as a result of the much thinner pavement section. The mix design for this project was similar to the 800 psi flexural strength design used on the third project on I-90, Argonne Road to Sullivan Road. The whitetopping was finished with a very light carpet drag texture. The whitetopping sections with the higher flexural strength mix design did not prove to be any more resistant to studded tire wear than our conventional concrete pavement. This project is hereafter referred to as the Whitetopping Project.

The third project, Argonne Road to Sullivan Road, was completed in 2005. This project was built primarily with a higher flexural strength mix but it also included short sections with 650 psi flexural strength mix, 650 psi mix with concrete hardener additive and mix with high cement content, all designed to potentially mitigate studded tire wear. The mixes used were:

- 650 psi flexural strength with both carpet drag and transverse tined texture
- 650 psi flexural strength with Hard-Cem additive with carpet drag texture
- 800 psi flexural strength with both carpet drag and transverse tined texture
- 925 lbs/cy yard cement content with carpet drag texture

The eastbound lanes were opened to traffic in 2004 and the westbound in 2005. The 650 psi mix designs used on the Argonne Road to Sullivan Road project were similar in many ways to the mix designs used on I-5. Carpet drag texture was applied to most of the project with the exception of two short sections of transverse tined texture. The study concluded that higher flexural strength, concrete hardeners, and higher cement contents do not make pavements more resistant to studded tire wear than our conventional 650 psi mix pavements. This project is hereafter referred to as the Argonne to Sullivan Project.

Final or post-construction reports are available for these five projects by clicking on their titles in Table 1. Comparisons of the mix designs and aggregates from the I-5 and I-90 projects are found in Appendix A.

Table 1. Experimental features on mitigation of studded tire wear on concrete pavements.		
Texture Used	**Title**	**Location**
Transverse Tining	**Combined Aggregate Gradation as a Method for Mitigating Studded Tire Wear on PCCP, Final Report**	**I-90, Sprague Ave I/C Phase III, C6947**
Carpet Drag	**Wear Resistant Pavement Study, Final Report**	**I-90, Sullivan Road to Idaho State Line, C6582**
Carpet Drag, Transverse Tining	**Studded Tire Wear Resistance of PCC Pavements**	**I-90, Argonne Road to Sullivan Road, C6620**
Carpet Drag	**Performance of a Portland Cement Concrete Pavement with Carpet Drag Texture, Post-Construction Report**	**I-5, Federal Way to S. 317th Street HOV Direct Access, C6757**
Carpet Drag, Longitudinal and Transverse Tining	**Performance of a Portland Cement Concrete Pavement with Longitudinal Tining, Transverse Tining and Carpet Drag Finish, Post-Construction Report**	**I-5, Pierce Co. Line to Tukwila I/C - Stage 4, C6883**

Studded tire wear mitigation is only one of the issues addressed in this study. Data on friction resistance, pavement smoothness and noise are also collected and analyzed. The Federal Highway Administration required that transverse tining be used on all concrete pavements, unless a State can demonstrate that another texture can provide the frictional properties necessary for safe travel by all vehicles. (FHWA now allows other types of textures if a State can provide the proof as noted previously). Poorly constructed transverse tined texture can be detrimental to the riding quality of a pavement. The projects on I-5 and I-90 will be used to demonstrate that carpet drag and longitudinal tined texture have acceptable friction properties and ride quality as constructed and over time.

Finally, the Federal Highway Administration has a program that would allow states to use quieter pavements as acceptable noise mitigation treatments if the states can demonstrate that the pavement maintains its noise quieting properties over time. Transverse tined texture can be detrimental to the tire/pavement noise level of a newly finished concrete pavement, especially if the texture is too deep or non-uniform. Noise level data from the I-5 projects will be used to develop a database of information on the noise properties of concrete pavements with various surface textures.

In summary, the objectives of this study are to:

- Determine if carpet drag and longitudinal tined textures are more resistant to studded tire wear than transverse tined texture, and to
- Determine if the friction properties of concrete pavement with carpet drag finish and longitudinal tining is equal to or better than pavement with transverse tined texture, and to
- Determine if concrete pavements with carpet drag and longitudinal tined textures have acceptable ride quality and maintain that quality over time.
- Provide tire/pavement noise data for future use in the search for concrete pavements that are quieter than pavements with transverse tined texture.

I-5 Project Descriptions

The two study projects are located adjacent to one another on I-5 in the vicinity of Federal Way, Washington (Figures 4 and 5). The Federal Way Project reconstructed a short section of the southbound lanes (0.61 miles) and added a median side HOV lane in both directions. In addition, the outside 2 lanes of the existing concrete pavement were retrofitted with dowel bars. All lanes of the existing concrete pavement were diamond ground to provide a uniform transverse profile. The Pierce Co. Line Project added an HOV lane in each direction, retrofitted the outside two lanes with dowel bars, and diamond ground the existing concrete pavement to a uniform transverse profile. The configuration of the added lanes and paving limits for both projects are shown in Figure 6.

Figure 4. Vicinity map of Contract 6757, Federal Way to S. 317th Street HOV Direct Access

Figure 5. Vicinity map of Contract 6883, Pierce Co. Line to Tukwila I/C–HOV–Stage 4.

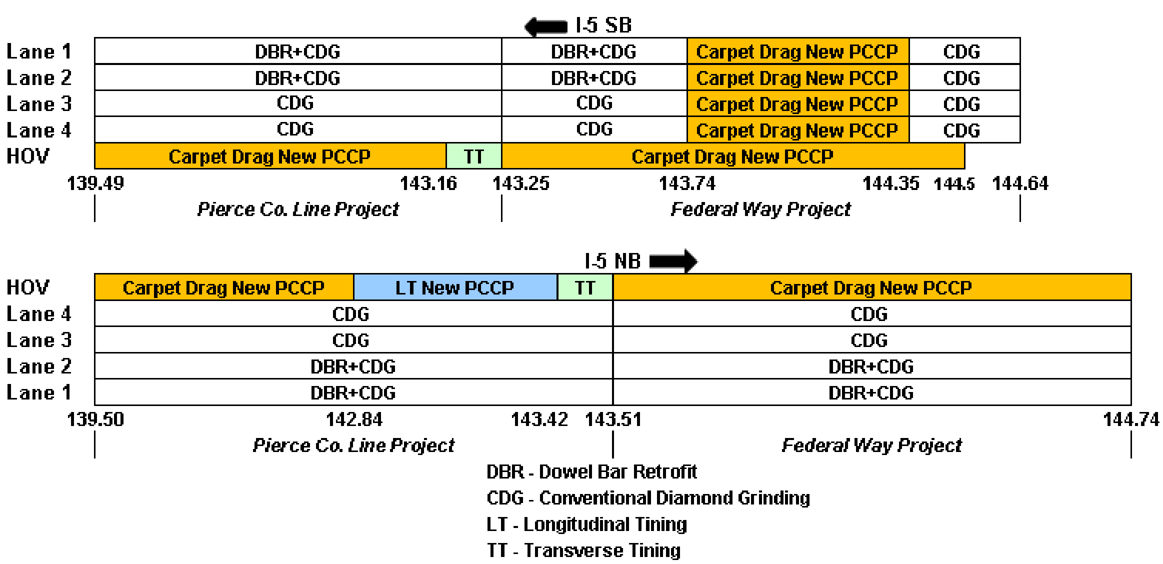

Figure 6. Map of the Pierce County Line and Federal Way projects.

I-5 Projects Construction

Detailed information on the construction of the two I-5 projects is contained in the post-construction reports available by clicking on the links in Table 1. Below is a brief description of the construction process.

Mix Designs

ICON Materials, Tukwila, Washington was the prime contractor on both projects with Salinas Construction of Everett, WA the subcontractor for the concrete paving. The concrete supplier was Miles Sand and Gravel of Auburn, WA. The pavement design called for 13 inches of concrete over 4.2 inches of asphalt base over 4.2 inches of crushed surfacing. The crushed surfacing was produced on the job site by recycling the existing concrete pavement. The concrete mixes used were WSDOT standard specification 650 psi flexural strength designs provided by the Contractor as summarized in Tables 2 and 3.

Table 2. I-5 Federal Way Project mix design 15650AS.

Item	Source	Type	Lbs/cy	Specific Gravity
Cement	Lafarge	I-II	423	3.15
Slag	Lafarge	I	141	2.83
Agg. Source 1	B-345	Class 2	1,090	2.65
Agg. Source 2	B-345	1-1/2”	510	2.70
Agg. Source 3	B-345	3/8”	590	2.71
Agg. Source 4	B-345	3/4”	1,075	2.71
Water			233	1.00
W/C Ratio			0.38	
Water Reducer	Master Builders	Polyheed 997	23 oz/cy	
Air Entrainment	Master Builders	MB-AE-90	5-20 oz/cy	

Table 3. I-5 Pierce Co. Line Project mix design 15700AS.				
Item	**Source**	**Type**	**Lbs/cy**	**Specific Gravity**
Cement	Lafarge	I-II	423	3.15
Slag	Lafarge	I	141	2.83
Agg. Source 1	B-345	Class 2	1,150	2.65
Agg. Source 2	B-345	1-1/2	490	2.70
Agg. Source 3	B-345	3/8”	560	2.69
Agg. Source 4	B-345	3/4”	1,050	2.70
Water			233	1.00
W/C Ratio			0.41	
Water Reducer	Degussa	Polyheed 997	23 oz/cy	
Air Entrainment	Degussa	MB-AE-90	5-20 oz/cy	

Paving

The Federal Way Project was paved in late May and early June, 2005 and on the northbound HOV lane in early 2006. The paving on the Pierce Co. Line project started in April of 2006 and was completed in July of that same year. The Federal Way project used carpet drag texture for all of the paving as a result of a change order. The Pierce Co. Line project also used carpet drag on the majority of the pavement but sections of longitudinal and transverse tining were also included, once again, via a change order. A 500 foots section of transverse tining was used on the northern end of each of the NB and SB HOV lanes. The longitudinal tining was used on the NB lane for a distance of 3,000 feet south of the NB transverse tining section.

Carpet Drag Finish

The change orders for the addition of the carpet drag included requirements for depth of texture measurements of the carpet drag finished pavement. The requirement followed Minnesota Department of Transportation specifications which call for a depth of 1.0 mm using the ASTM sand patch test. Testing on the Federal Way project found 78% of the tests passing the 1.0 mm requirement, whereas on the Pierce Co. Line project the passing rate was only 41%. No remedial action was taken due to the absence of a penalty requirement in the change order for not meeting the depth requirement. Post-construction friction measurements averaged 54 for

Federal Way and 48 for Pierce Co. Line indicating the low passing rate of the sand patch test did not pose a safety problem.

It is important to note that the construction of a carpet drag finish is not a fool proof process. The carpet imparting the texture is prone to wearing and clogging which results in variations in the depth of the texture. The amount of weight placed on top of the carpet will also result in variable depths of texture. The wetness or dryness of the concrete mix can also have an influence on how easy or difficult it is for the carpet to imprint the surface with the proper texture. This is not to say that the construction of either a longitudinal or transverse tined texture is a simple process, however, the final product seems to be less prone to construction variables than the carpet drag process.

Post-Construction Testing

Pavement Wear

The most important aspect of this study is to determine if the change in finishing methods had any positive effect on the amount of studded tire wear on the I-5 projects. Secondarily, how does the amount of wear on the I-5 projects compare to the wear experienced on the I-90 Spokane urban area projects?

I-5 Federal Way Project

Wear measurements from the I-5 Federal Way Project are summarized in Table 4 and shown graphically in Figure 7. The wear readings in Table 4 support the conclusion that there is very little, if any; wear occurring on any of the lanes on the project. There is a trend of higher readings from Fall 2005 to Spring 2007, then some low readings for Fall 2007 and Spring 2008, and then rather stable readings from there to the last reading in the Spring of 2011. The initial higher reading might be the result of the measurement equipment reading the carpet drag texture as wear. The two lower readings might be attributed to some problems with the measurement equipment since they occur in every lane for both sets of readings. In both cases it is pure speculation to assign a cause for the seemingly anomalous readings. The greatest amount of wear is being shown in outside Lanes 2 and 3 and the least amount in the inside HOV lanes

This may also be an indication of the amount of traffic in each lane, or it may be the way the lanes were constructed since the rut depth measurement does not change over time for any of the lanes. The important fact is that the amount of wear in any of the lanes (end rut depth minus beginning rut depth) is less than 1.0 mm over the five to six year measurement period. The maximum rut depth ranges from 1.8 to 2.8 mm for all of the lanes with an average of 2.2 mm (a little over a 16th of an inch).

Table 4. Wear measurements for the I-5 Federal Way Project.

Dir/ Lane	Wear (mm)											
	F 2005	S 2006	F 2006	F 2007	S 2008	F 2008	S 2009	F 2009	S 2010	F 2010	S 2011	F 2011
SB L2	3.7	2.5	2.2	2.1	2.1	2.7	2.6	2.5	2.5	2.6	2.7	2.6
SB L3	2.9	2.4	2.4	1.9	1.9	3.1	2.7	2.4	2.7	2.7	2.8	2.8
SB L4	2.4	2.6	2.6	1.7	1.5	2.4	2.0	1.8	1.9	1.8	1.9	2.0
SB HOV	2.3	2.3	2.3	1.6	1.8	2.1	1.9	2.0	1.9	2.0	1.9	2.0
Age (yr.)	0.3	0.8	1.3	2.3	2.8	3.3	3.8	4.4	4.9	5.3	5.8	6.3
NB HOV	-	-	-	1.5	1.5	2.0	1.9	1.7	1.8	1.8	1.8	1.8
Age (yr.)	-	-	-	1.3	1.8	2.3	2.8	3.4	3.9	4.3	4.8	5.3

Note: F is Fall, S is Spring. The colors of the sections in the table match the colors in the Figure 7 bar chart. Lane 1 was not included in the study because construction traffic control inhibited data collection throughout the early years of the study period.

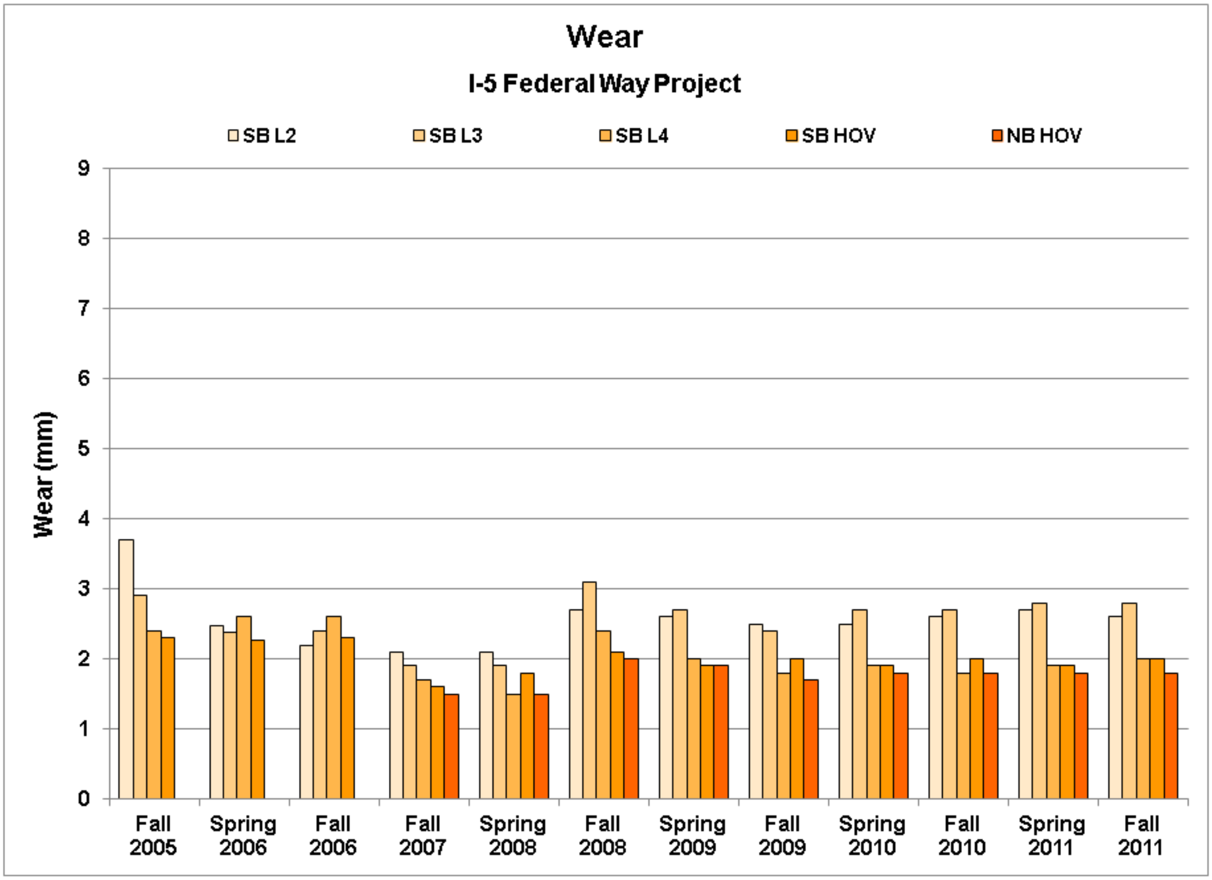

Figure 7. Wear measurement for the I-5 Federal Way Project.

I-5 Pierce Co. Line Project

Wear measurements for the Pierce Co. Line Project are summarized in Table 5 and shown graphically in Figure 8. The various finishing types show very little or no wear after five years of traffic. As with the Federal Way Project, some of the initial readings go up and down, but from the Spring 2009 readings to the Fall 2011 there is virtually no change in wear for any of the sections. The amount of wear over the five year evaluation (F 2011 rut depth minus F 2006 rut depth) is less than 1.0 mm for all of the lanes. The maximum depth of rutting ranges from 2.0 to 2.8 mm with an average of 2.5 mm (3/32 inch) at the end of the evaluation.

Table 5. Wear measurements for the I-5 Pierce Co. Line Project.

Section	Wear (mm)										
	F 2006	S 2007	F 2007	S 2008	F 2008	S 2009	F 2009	S 2010	F 2010	S 2011	F 2011
Transverse Tining NB	1.8	1.5	1.4	1.7	2.1	2.0	1.9	2.1	2.0	1.7	2.0
Longitudinal Tining NB	1.7	1.6	1.7	1.7	2.4	2.2	2.1	2.2	2.1	2.1	2.4
Carpet Drag NB	2.7	2.3	2.3	2.4	3.3	1.9	2.7	2.9	2.8	2.9	2.7
Transverse Tining SB	2.5	1.9	2.3	2.4	2.8	2.8	2.7	2.8	3.0	3.0	2.8
Carpet Drag SB	2.0	2.3	2.0	2.2	2.9	2.7	2.4	2.6	2.6	2.8	2.7
Age (yr.)	0.2	0.8	1.2	1.6	2.2	2.6	3.2	3.7	4.1	4.6	5.1

Note: F is Fall, S is Spring. The colors of the sections in the table match the bars in Figure 8.

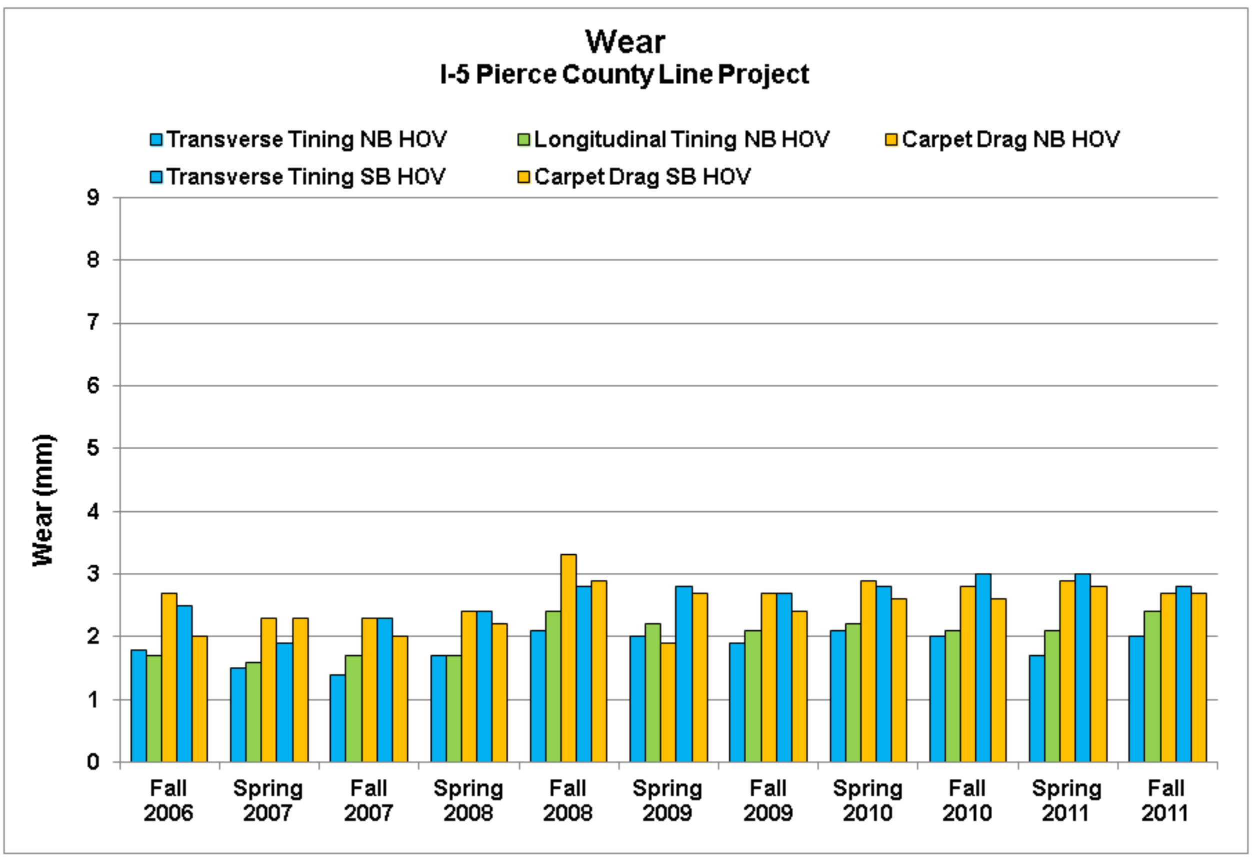

Figure 8. Wear measurements for the I-5 Pierce Co. Line Project.

I-90 Combined Aggregate Project

The pavement wear data is much different for the Spokane I-90 projects. The wear measurements for the Combined Aggregate project are listed in Table 6 and shown graphically in Figure 9. The measurements on the combined gradation lanes which are one year newer than the standard lanes have been adjusted by moving the combined gradation data so that the ages of the two sections are equal. The increased wear with age is very evident for both the standard and combined aggregate gradation lanes. It is also evident that Lane 2 (dark yellow and dark green cells) receives more traffic than Lane 3 (light yellow and light green cells). The amount of wear recorded in the monitoring period ranged from 1.6 to 6.8 mm (year 8 rut depth minus year 4 rut depth). The total rut depth ranged from 5.8 to 9.2 mm with the average being 7.7 mm (about 5/16 inch). This is an average wear rate of one millimeter per year. Data for the older standard gradation section was collected up to the ninth year after construction. The ninth year data showed rut depths of 8.0 mm for Lane 3 and 11.9 mm for Lane 2, again indicating increased wear with age.

Table 6. Wear measurements for I-90 Combined Gradation Project.

Section	Rut Depth (mm)								
Standard Lane 2	2.4	5.3	6.7	6.4	7.6	8.0	4.6	8.1	9.2
Standard Lane 3	1.5	3.9	4.8	4.5	5.2	5.7	6.7	5.4	6.0
Combined Lane 2	5.1	4.8	6.0	5.9	8.0	6.8	7.7	8.4	9.8
Combined Lane 3	4.2	3.5	3.9	4.5	6.0	4.2	4.7	5.9	5.8
Age (yr.)	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0

Note: The colors of the sections in the table match the bars in Figure 9.

Figure 9. Wear measurements for the I-90 Combined Gradation Project.

I-90 Whitetopping Project

The pavement wear data for the Whitetopping Project are listed in Table 7 and shown graphically in Figure 10. The increase in wear over the seven year evaluation period is very noticeable for all of the whitetopping sections. The amount of wear (S 2010 rut depth minus S 2004 rut depth) ranged from 5.2 to 7.6 mm for the seven-year monitoring period. The total rut depth ranges from 8.9 to 9.5 mm at the end of the evaluation with an average of 9.2 mm (about 3/8 inch).

Table 7. Wear measurements for I-90 Whitetopping Project.

Section	S 2004	F 2004	S 2005	S 2006	F 2006	F 2007	S 2008	F 2008	S 2009	S 2010
3-Inch	2.4	3.4	4.1	4.7	5.0	7.6	6.9	7.9	9.1	9.5
4-Inch	1.8	2.9	3.6	3.9	4.4	5.0	6.2	6.8	8.1	9.4
5-Inch	3.7	2.9	3.5	3.9	4.1	5.4	5.7	6.8	7.8	8.9
Age (yr.)	0.75	1.25	1.92	2.75	3.26	4.25	4.75	5.25	5.75	7.00

Note: F is Fall, S is Spring. The colors of the sections in the table match the bars in Figure 10.

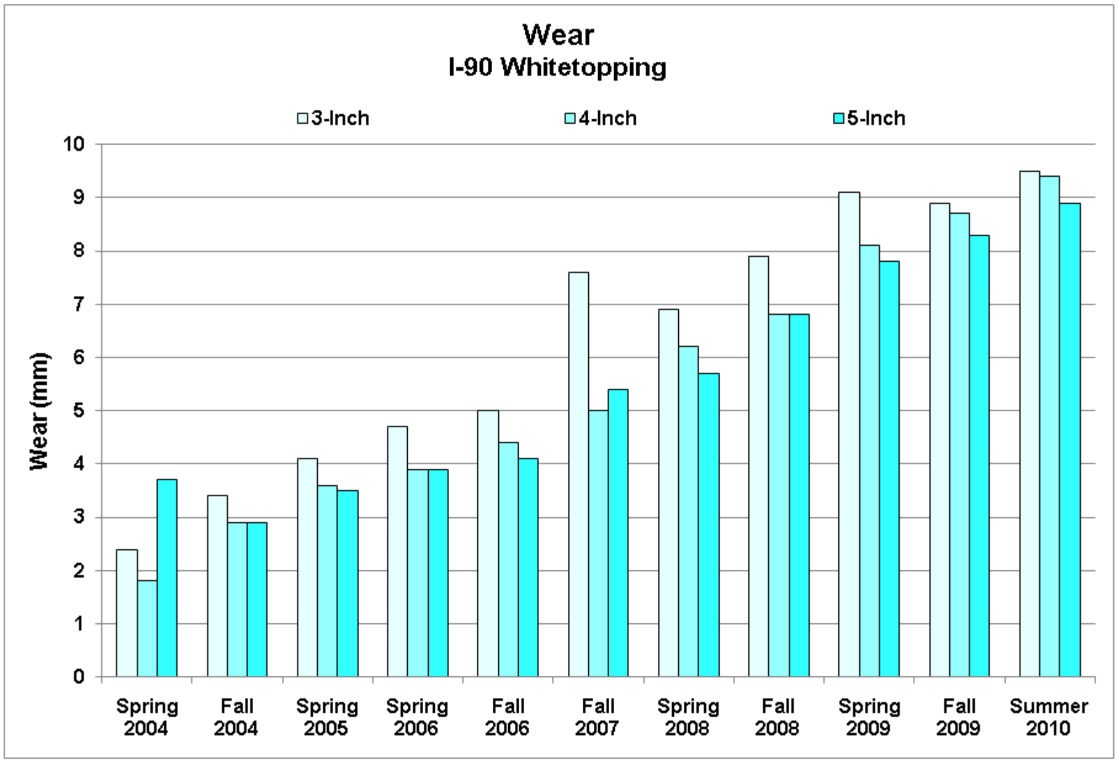

Figure 10. Wear measurement for the I-90 Whitetopping Project.

Two asphalt sections were also constructed along with the whitetopping that were intended to provide some mitigation for studded tire wear. They including micro/macro resurfacing and modified Class D HMA. The modified Class D was installed in the passing lane next to the whitetopping section. The micro/macro surfacing was installed on both of the westbound lanes a short distance east of the whitetopping and Modified Class D HMA installation. The remainder of the project was paved with standard Class 1/2 inch HMA. Final average rut depths for the Spring 2009 measurements* were:

1. Micro/macro resurfacing - 27.6 mm (over 1 inch)
2. Modified Class D HMA - 11.1 mm (7/16 inch)
3. Class 1/2 inch HMA – 11.1 mm (7/16 inch)

The whitetopping at an average rut depth of 9.2 mm outperformed the asphalt alternatives although at a much higher cost.

* Spring 2009 was the last measurement that included all of the asphalt and whitetopping sections.

I-90 Argonne To Sullivan Project

The pavement wear for Argonne Road to Sullivan Road are listed in Table 8 and shown graphically in Figure 11. The initial wear measurements are in the same range as the I-5 projects with values from 2.4 to 3.5 mm (Table 4 and 5). The three sections with 650 mix designs all had 4.8 mm of wear at the most recent measurement in April of 2011. The higher flexural strength sections and the section with 925 lbs/cy cement content showed the most wear. The short sections with tined texture did not have any more or any less wear than the sections with carpet drag texture. The amount of wear (S 2011 reading minus S 2006 reading) for all of the sections ranged from 1.7 to 2.6 millimeters for the five to six year monitoring period. At the end of the period, the total wear ranged from 4.7 to 5.3 mm with an average of 5.0 mm (about 3/16 inch).

Table 8. Wear measurements for the I-90 Argonne to Sullivan Project.

Section	Wear (mm)									
	S 2006	F 2006	F 2007	S 2008	F 2008	S 2009	F 2009	S 2010	F 2010	S 2011
650 psi CD	2.4	2.8	2.5	2.7	3.2	3.9	3.6	4.4	3.8	4.8
650 psi HC CD	2.4	2.5	2.1	2.6	3.2	3.8	3.6	4.4	4.1	4.8
650 psi TT	3.1	3.7	2.3	2.9	3.2	3.4	3.8	4.2	3.2	4.8
800 psi CD	2.6	2.5	2.3	2.9	3.3	3.9	3.9	4.1	4.1	4.7
800 psi TT	3.5	2.9	4.6	5.0	6.0	7.4	7.0	8.0	6.5	5.1
Age (yr.)	1.5	2.0	3.0	3.5	4.0	4.5	5.1	5.6	6.1	6.5
800 psi CD	3.2	3.1	2.9	3.4	3.9	4.4	4.5	5.0	5.0	5.3
925 lbs/cy CD	2.7	2.6	3.2	3.5	4.2	4.6	5.0	5.1	5.5	5.3
Age (yr.)	0.4	0.9	1.9	2.4	2.9	3.4	4.0	4.5	5.0	5.4

Note: F is Fall, S is Spring, CD is carpet drag, HC is Hard-Cem, TT is transverse tined. The colors of the sections in the table match the bars in Figure 11.

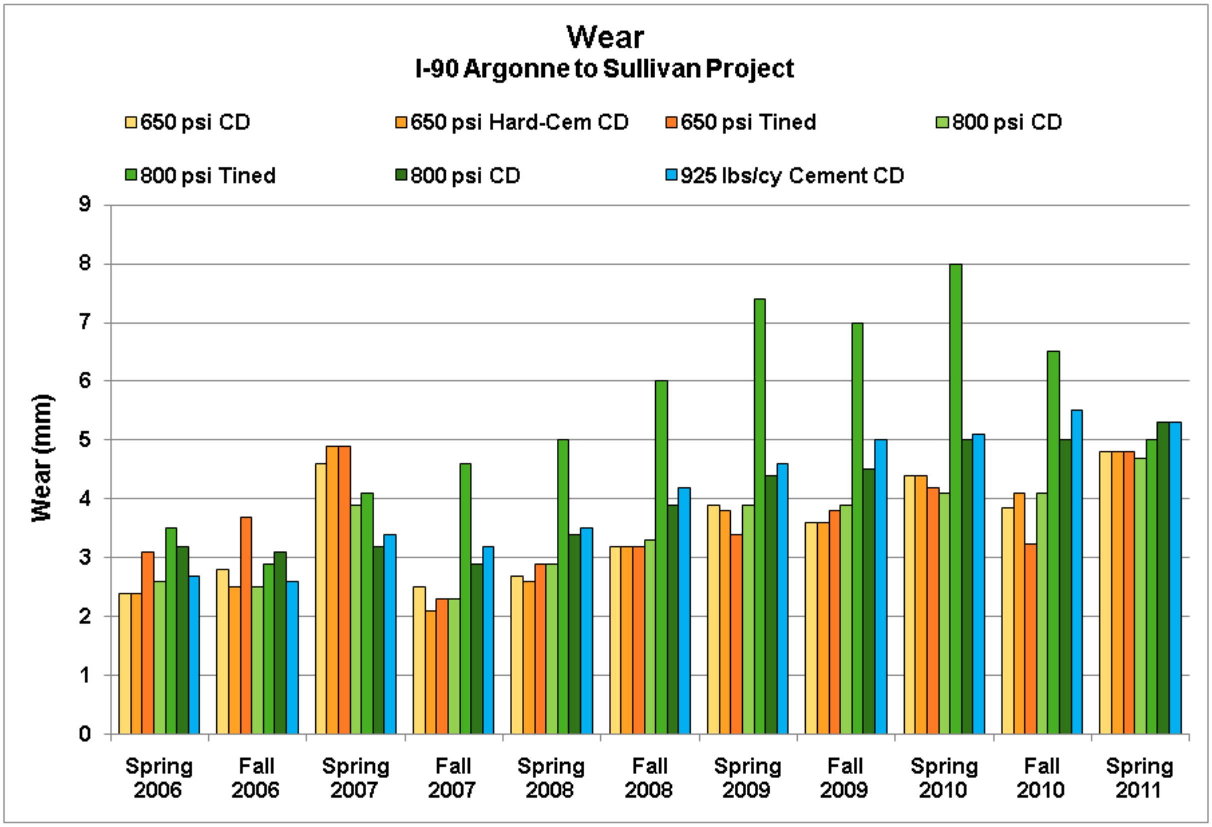

Figure 11. Wear measurements for the I-90 Argonne to Sullivan Project.

Discussion of Pavement Wear

Table 9 summarizes the pavement wear measurements and Figure 12 is a plot of the average depth of wear over time for each of the five projects. The table shows the amount of wear, range of rutting depth, and average depth of rutting at a pavement age of five years for each of the projects. The wear per section or lane for the two I-5 projects is less than one millimeter at the age of five years. The depth of rutting for both projects at the end five years ranged between 1.8 and 2.8 mm with an average of 2.2 to 2.5 mm. The absence of wear for the two I-5 projects is demonstrated by the flat lines (green and brown) in Figure 12

The I-90 projects show a far different picture. After the first two years the readings gradually increase each measurement period. At the end of their evaluation periods the amount of wear at five years ranged from 0.0 to 5.5 mm. The depth of rutting for each of the three projects ranged from 3.6 mm (1/8 inch) to 7.0 mm (9/32 inch). The rutting is also increasing over time for each I-90 project as shown in Figure 12 (red, purple and blue lines).

Table 9. Summary of wear measurements from all projects.

Project	Study (years)	Wear Per Section or Lane (mm)	Rutting Depth Per Section or Lane (mm)	Average Depth of Rutting (mm)
I-5, Federal Way to S. 317th Street	5	0.0 to 0.8	1.8 to 2.7	2.2
I-5, Pierce Co. Line to Tukwila	5	0.0 to 0.7	2.0 to 2.8	2.5
I-90, Combined Gradation Project	5	0.0 to 4.3	3.9 to 6.7	5.4
I-90, Whitetopping Project	5	3.1 to 5.5	6.8 to 4.9	7.2
I-90, Argonne Rd. to Sullivan Rd.	5	0.7 to 3.5	3.6 to 7.0	4.6

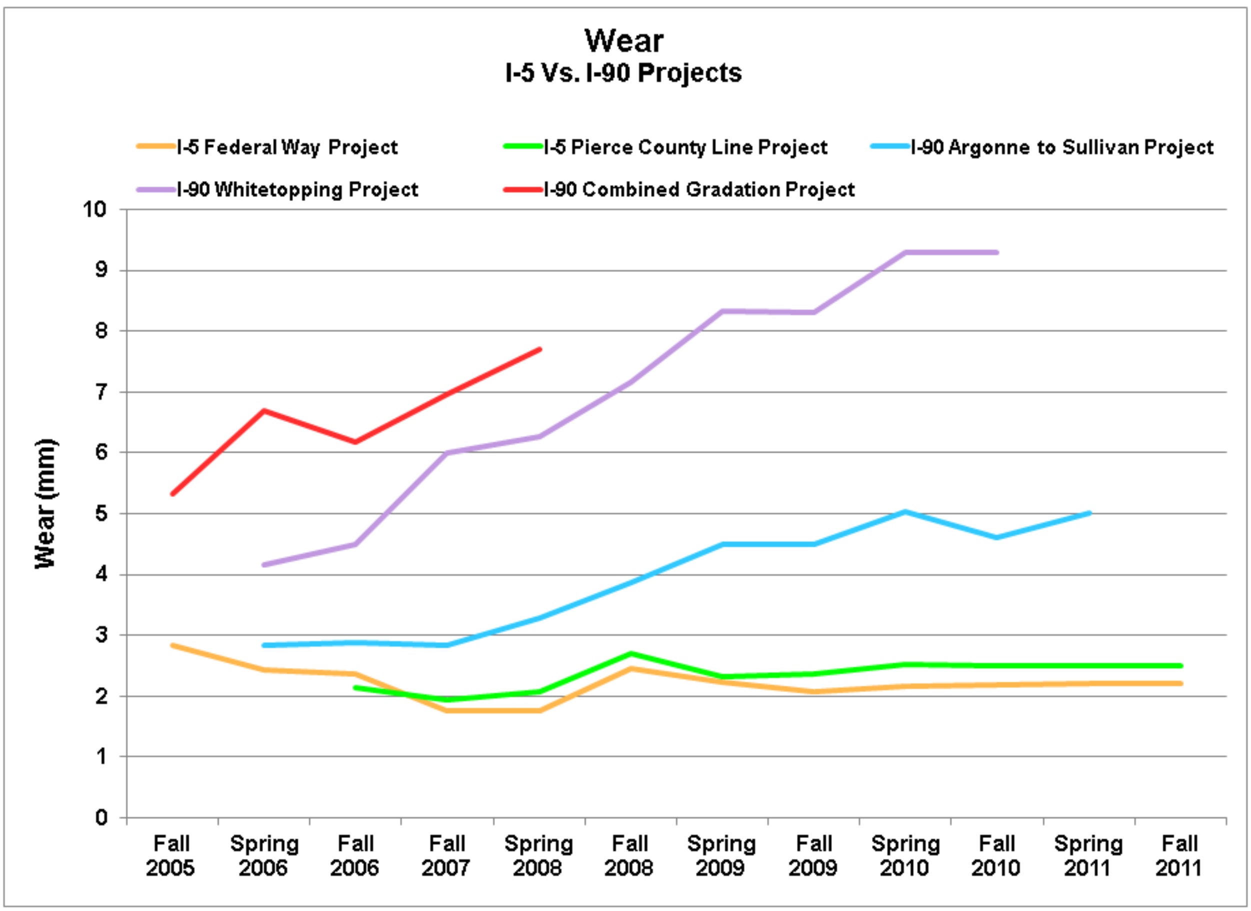

Figure 12. Wear measurements for the I-5 and I-90 projects.

The average daily traffic on I-5 is double the traffic on I-90 which would lead one to believe that the I-5 project would have the higher amount of wear in the same five year time period. However, the higher percentage of vehicles using studded tires in the Spokane area (see excerpt below from a WSDOT whitepaper on studded tire wear) completely changes the wear patterns for those projects located in the Spokane urban area. This is old data and therefore the actual percentages of vehicles using studded tires is most likely inaccurate, however, it is believed that Eastern Washington and especially the Spokane urban area still has a much higher percentage of vehicles using studded tires than the Federal Way area.

> *A survey conducted by WSDOT during the winter of 1996-1997 revealed that, on average, 10 percent of passenger vehicles use studded tires in Western Washington and 32 percent of the vehicles use them in Eastern Washington. Of these locations, the survey indicated highest stud usage was observed in Spokane (56 percent), the lowest in Puyallup (6 percent).*

There are also differences in the materials used for the I-90 and I-5 projects. The quality of the aggregates in the Puget Sound urban area has always been regarded as superior to most aggregates found anywhere. The aggregates in the Spokane urban area are good, but do not match the quality of the aggregates from Puget Sound. There are also probably some differences in the quality of the portland cement used on the projects, however, these differences may not be as important to the wearing quality of the pavement as are the aggregates which take the brunt of the studded tire wear once surface cement is worn away.

In summary, the longitudinal tining and carpet drag finish textures are no better or no worse than transverse tining texture with respect to wear from traffic that includes vehicles with studded tires in either high concentrations (I-90) or low concentrations (I-5). In the case of I-90 it does not matter what type of texture is used because studded tires remove the texture within a very short time (see Figures 13 and 14). In the case of the I-5 projects, all of the textures seem to provide an equal resistance to the type of wear experienced on Western Washington pavements.

Figure 13. Example of rapid wear from studded tires on a longitudinal tined pavement on I-90, Sullivan to Barker, paved in 2011. Photo taken on 4/11/2012 after one winter of traffic.

Figure 14. Example of rapid wear from studded tires on a longitudinal tined pavement on I-90 near Cle Elum. Photo taken after one winter of wear.

Friction Resistance

Friction resistance is the next topic under consideration. The goal is to determine if the friction resistance of the pavements with carpet drag and longitudinal tining is adequate and comparable to pavements with transverse tined texture. The two I-5 projects will be examined first followed by the three I-90 projects.

I-5 Federal Way Project

Friction resistance values for the Federal Way project are listed in Table 10 and shown graphically in Figure 15. The initial average friction number (FN) for the carpet drag finish right after construction was 53.3 with a range of values from 50.2 to 55.9. The friction numbers start out in the low to middle 50's and then drop off to the low to middle 40's for most of the evaluation period (Figure 15). The final measurements made in the spring of 2011 are lower than previous measurements, but are still in the middle to upper 30's and low 40's (concern for low friction numbers begins when they fall below 30 as marked on the bar chart with a red line). The Federal Way project friction numbers are not of concern at present with only the occasional value approaching the 30 threshold. Figure 16 is a photo taken during construction of the carpet drag texture.

Table 10. Friction results for the I-5 Federal Way Project.

Dir/Lane	Friction (FN)										
	F 2005	F 2006*	S 2007	F 2007	S 2008	F 2008	S 2009	F 2009	F 2010	S 2011	F 2011
SB L2	56	30	47	39	42	32	38	41	41	34	31
SB L3	52	34	45	43	40	35	42	43	47	38	38
SB L4	50	39	44	43	41	41	42	44	43	37	38
SB HOV	56	41	43	47	40	41	44	46	49	40	42
NB HOV	-	-	47	48	43	43	46	46	49	41	44
Average	54	36	45	44	41	38	42	44	46	38	39

Note: F is for Fall and S is for Spring. The colors of the sections in the table match the bars in Figure 13. * The readings for Fall 2006 are suspect due to problems with the testing equipment.

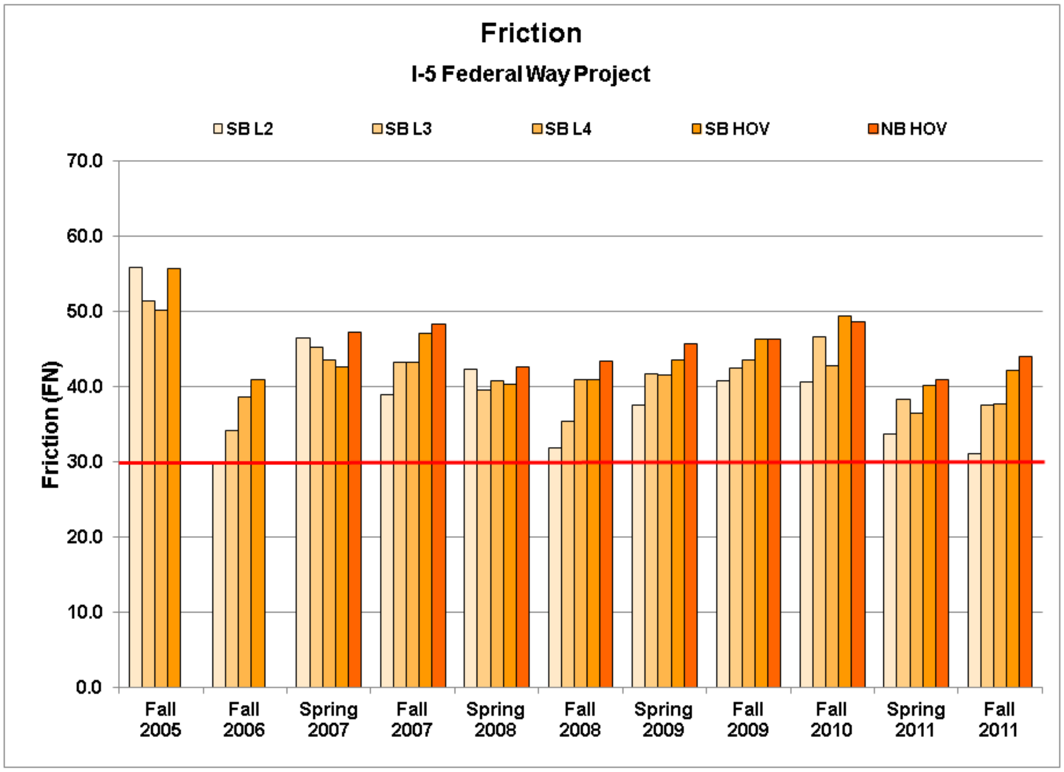

Figure 15. Friction resistance data for I-5 Federal Way Project.

Figure 16. Carpet drag texture on the I-5 Federal Way Project immediately after construction.

I-5 Pierce Co. Line Project

The friction numbers for the Pierce Co. Line project are listed in Table 11 and shown graphically in Figure 17. The values range from the low 40's to low 50's after construction to their present values in the upper 40's and low 50's. None of the results approached the FN 30 red line in spite of the fact that only 41% (see page 10 of this report) of the sand patch tests achieved the desired 1.0 mm depth of texture. There also was not a lot of change in the values throughout the evaluation period. The longitudinal tined section has generally the highest friction number for each measurement period, although the values for each type of finishing method go up and down throughout the 5-year evaluation period. Figure 18 is a photo of the carpet drag finish and Figures 19 and 20 the longitudinal tining texture immediately after construction.

Table 11. Friction resistance data for Pierce Co. Line Project.

Section	Friction Resistance (FN)									
	F 2006	S 2007	F 2007	S 2008	F 2008	S 2009	F 2009	F 2010	S 2011	F 2011
Transverse Tining NB	44	44	50	48	45	51	54	56	45	48
Longitudinal Tining NB	43	53	52	51	49	53	53	53	50	51
Carpet Drag NB	51	49	49	49	46	52	52	52	50	50
Transverse Tining SB	51	50	52	45	47	49	52	51	46	45
Carpet Drag SB	50	50	51	49	47	54	51	50	47	49
Average	48	49	51	48	47	52	52	52	48	49

Note: F is for Fall, S for Spring. The colors of the sections in the table match the bars in Figure 15.

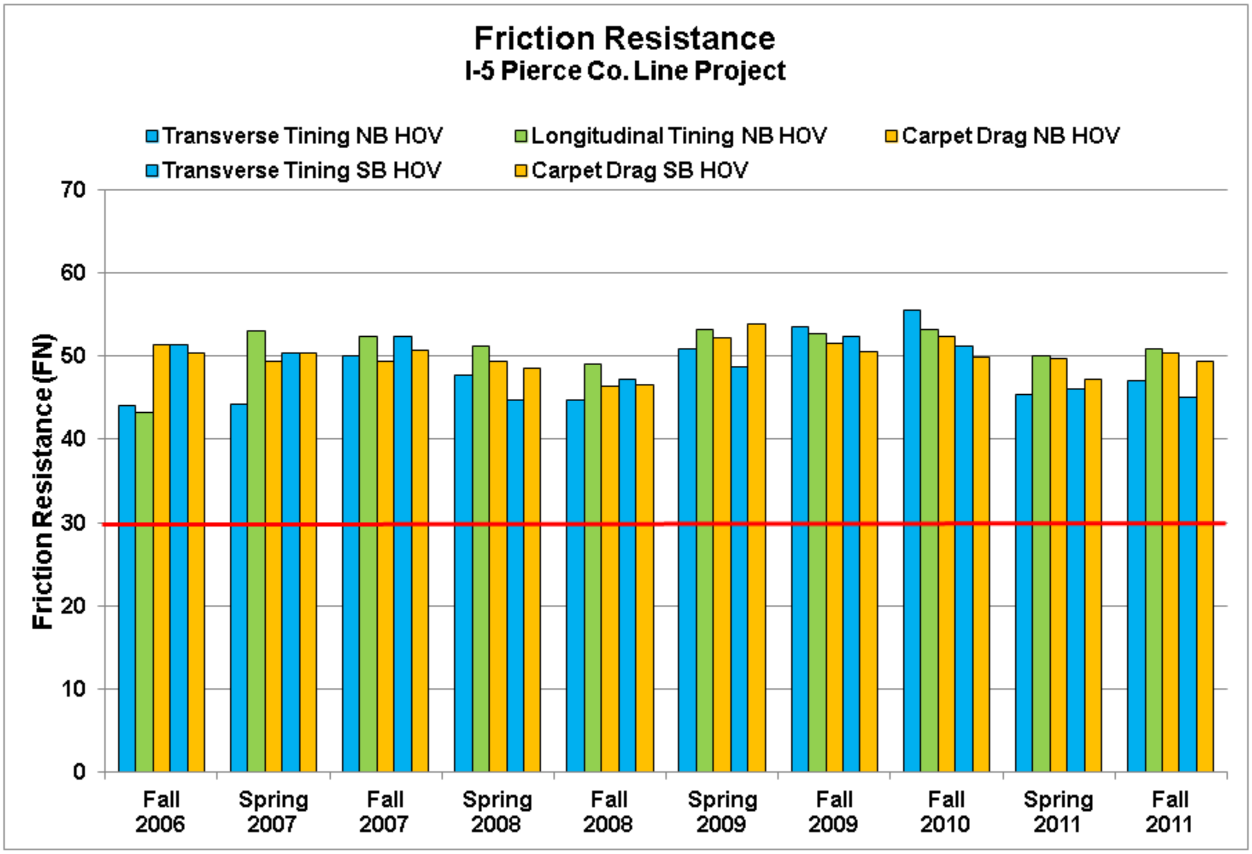

Figure 17. Friction resistance data for I-5 Pierce Co. Line Project.

Figure 18. Carpet drag texture on the I-5 Pierce Co. Line Project.

Figure 19. Longitudinal tining on the I-5 Pierce Co. Line Project.

Figure 20. Close-up of the longitudinal tining on the I-5 Pierce Co. Line Project.

In summary, the friction data from both I-5 projects indicates that the carpet drag and longitudinal tined texture do not pose any risk with regard to providing sufficient friction resistance for vehicles. The sections with carpet drag and transverse tining tended to have somewhat lower friction numbers then the longitudinal tined section.

I-90 Combined Gradation Project

The friction data for the I-90 Combined Gradation project is listed in Table 12 and shown graphically in Figure 21. Friction data was not collected immediately after construction on these sections which were built in 2000 and 2001. It is assumed that by the Spring 2005 measurement all of the transverse tined texture would have been removed from the wheel paths given the history of heavy studded tire use in the Spokane area. The data reflects a pavement with no texture and the friction numbers are very good with no individual values even approaching the level (FN 30) below which there is a safety concern. Figure 22 is a photo of the center lane showing the absence of texture and the rutting from studded tires.

Table 12. Friction resistance data for I-90 Combined Gradation Project with transverse tined texture.

Section	Friction Resistance (FN)							
	S 2005	S 2006	F 2006	S 2007	F 2007	S 2008	F 2008	S 2009
Standard Gradation Lane 2	39	38	35	43	36	44	36	42
Standard Gradation Lane 3	38	39	38	42	39	43	39	42
Combined Gradation Lane 2	41	38	35	43	37	44	37	43
Combined Gradation Lane 3	42	41	38	43	39	44	40	45
Average	40	39	37	43	38	44	38	43

Note: F is for Fall, S for Spring. The colors of the sections in the table match the bars in Figure 19.

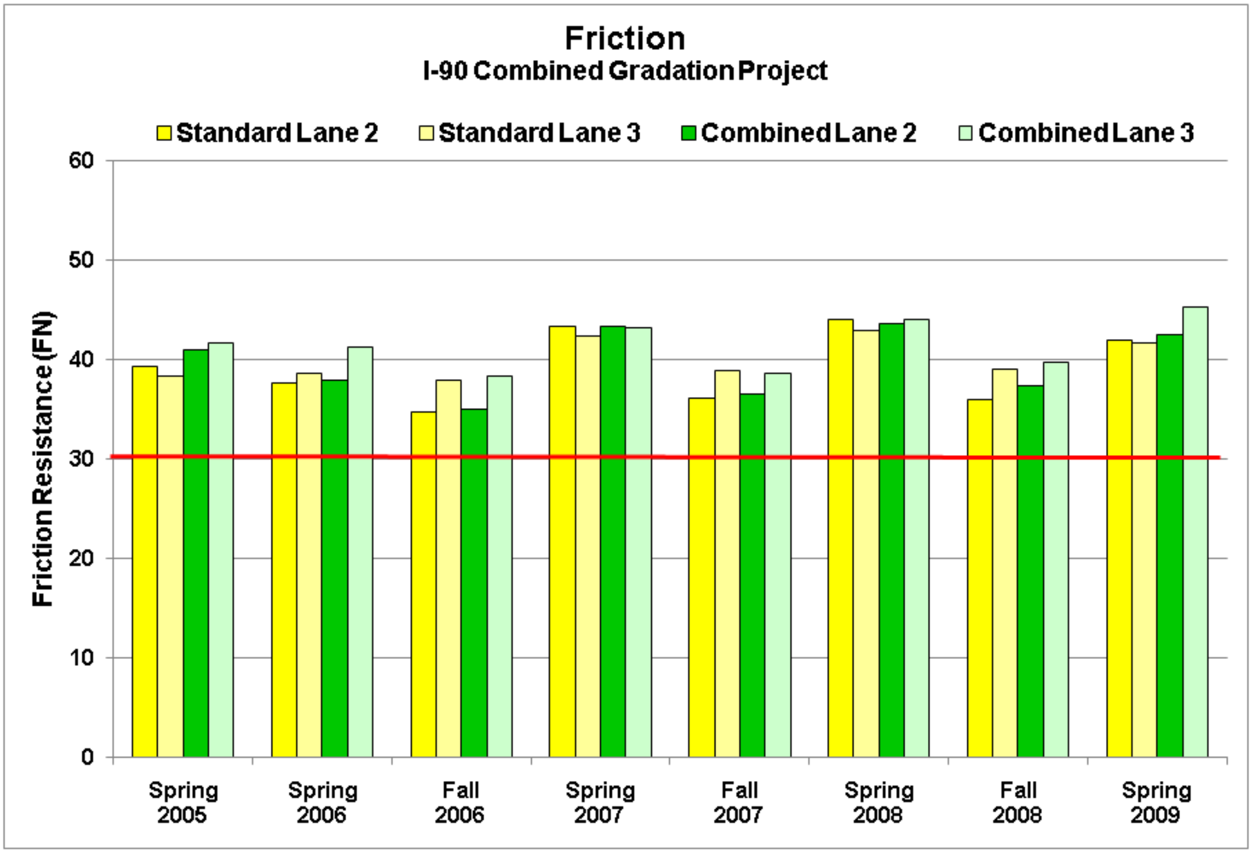

Figure 21. Friction resistance data for the I-90 Combined Gradation Project.

Figure 22. I-90 Combined Gradation project.

I-90 Whitetopping Project

The friction data for the I-90 Whitetopping Project is listed in Table 13 and shown graphically in Figure 23. There was no testing of the project right after construction, however, the photos from the construction of the pavement (Figures 24 and 25) show that the carpet drag texture was not very deep. The data that was collected beginning in 2006 do not indicate that friction resistance is an issue on this project. The friction numbers range from the low 30's to the middle 40's with only a few values falling below 30.

Table 13. Friction resistance data for I-90 Whitetopping Project with carpet drag texture.

Section	Friction Resistance (FN)									
	S 2004	F 2004	S 2005	S 2006	F 2006	F 2007	S 2008	F 2008	S 2009	S 2010
3-Inch	-	-	-	37	32	45	36	44	32	46
4-Inch	-	-	-	36	30	46	35	43	32	44
5-Inch	-	-	-	38	31	45	35	52	32	43
Average	-	-	-	37	31	45	35	46	32	44

Note: F is for Fall, S for Spring. The colors of the sections in the table match the bars in Figure 21.

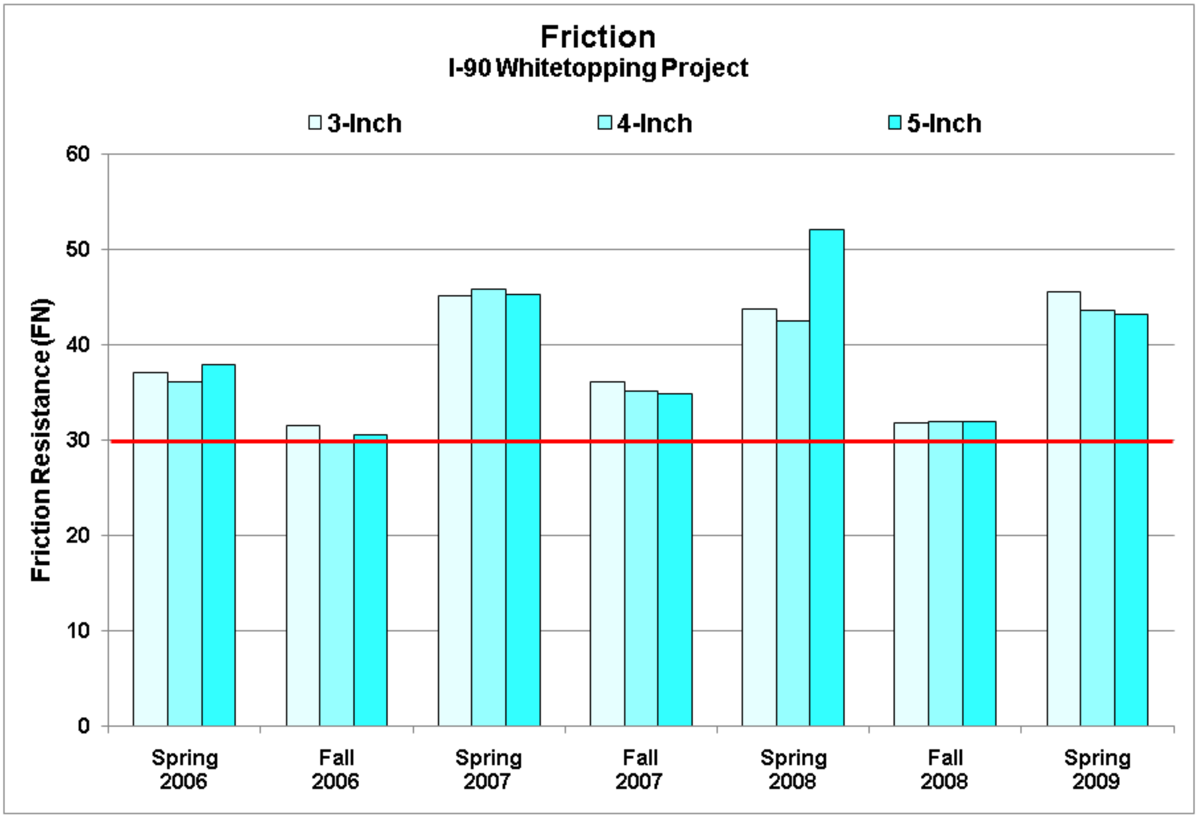

Figure 23. Friction resistance data for the I-90 Whitetopping Project.

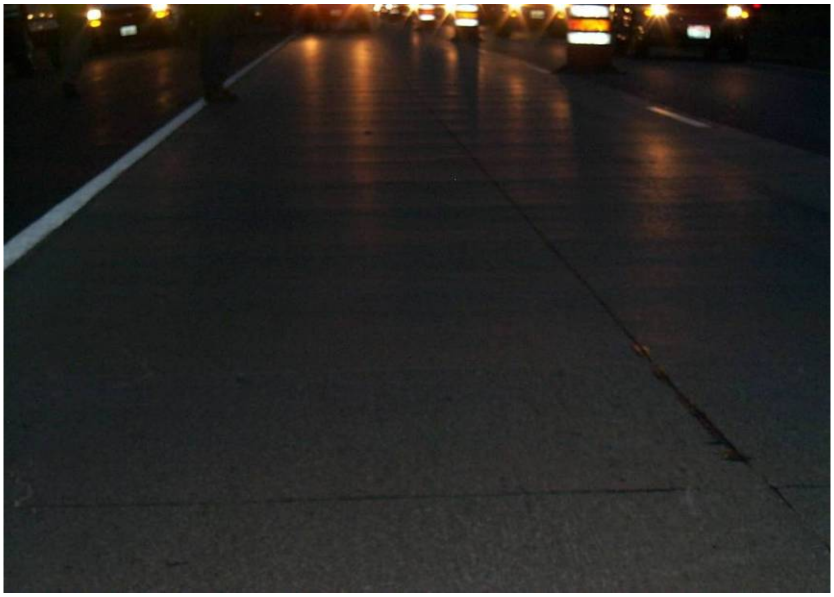

Figure 24. I-90 Whitetopping Project night photo of 3-inch section showing the absence of texture.

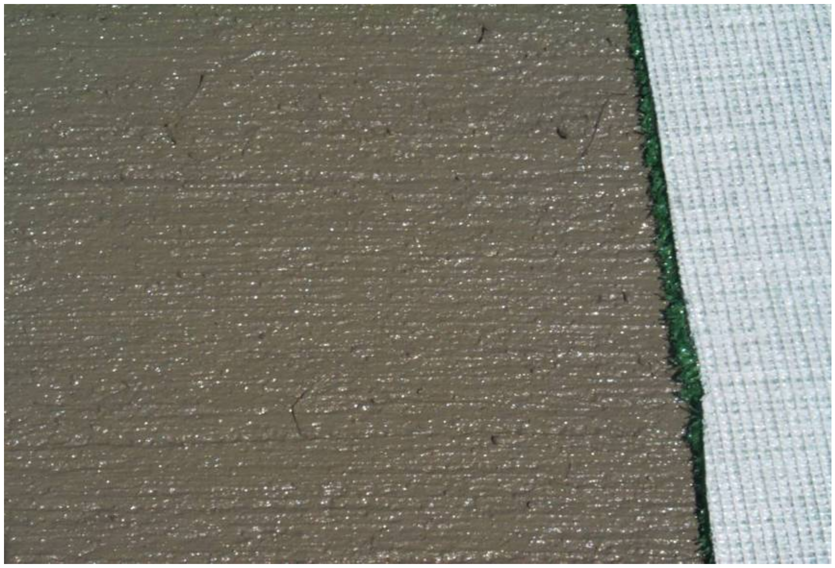

Figure 25. Carpet drag construction on the I-90 Whitetopping Project.

I-90 Argonne to Sullivan Project

The friction data for the Argonne to Sullivan project are listed in Table 14 and shown graphically in Figure 26. The contract specifications for this project did not specify a depth of texture or require any sand patch testing; however, informational sand patch testing was performed. None of the tests approach the 1.0 mm depth as specified on the two I-5 projects (see post-construction report links on page 6, Table 1). The lack of suitable texture on the project is shown in the Figure 27. This accounts for the lower readings right after construction. However, studded tire wear roughens the surface sufficiently to raise the friction values. After the initial few years, the friction values consistently range in the middle 30’s to middle 40’s. There does not appear to be a problem with friction on any of the I-90 projects which used both transverse tining and carpet drag as a finishing method.

Table 14. Friction resistance data for I-90 Argonne to Sullivan Project.

Section	Friction Resistance (FN)										
	S 2006	F 2006	S 2007	F 2007	S 2008	F 2008	S 2009	F 2009	S 2010	F 2010	S 2011
650 psi CD	32	35	40	33	36	35	49	38	39	40	40
650 psi HC CD	31	33	35	32	37	33	43	37	38	39	39
650 psi TT	37	39	36	36	39	35	49	39	41	42	41
800 psi CD	35	37	40	35	40	35	42	39	39	40	39
800 psi TT	36	42	46	38	41	38	43	40	42	41	39
800 psi CD	33	35	39	34	39	35	40	39	37	38	38
925 lbs/cy CD	30	30	33	30	35	31	35	35	34	37	35
Average	33	36	38	34	38	35	43	38	39	40	39

Note: F is Fall, S is Spring, CD is carpet drag, HC is Hard-Cem, TT is transverse tined. The colors of the sections in the table match the bars in Figure 24.

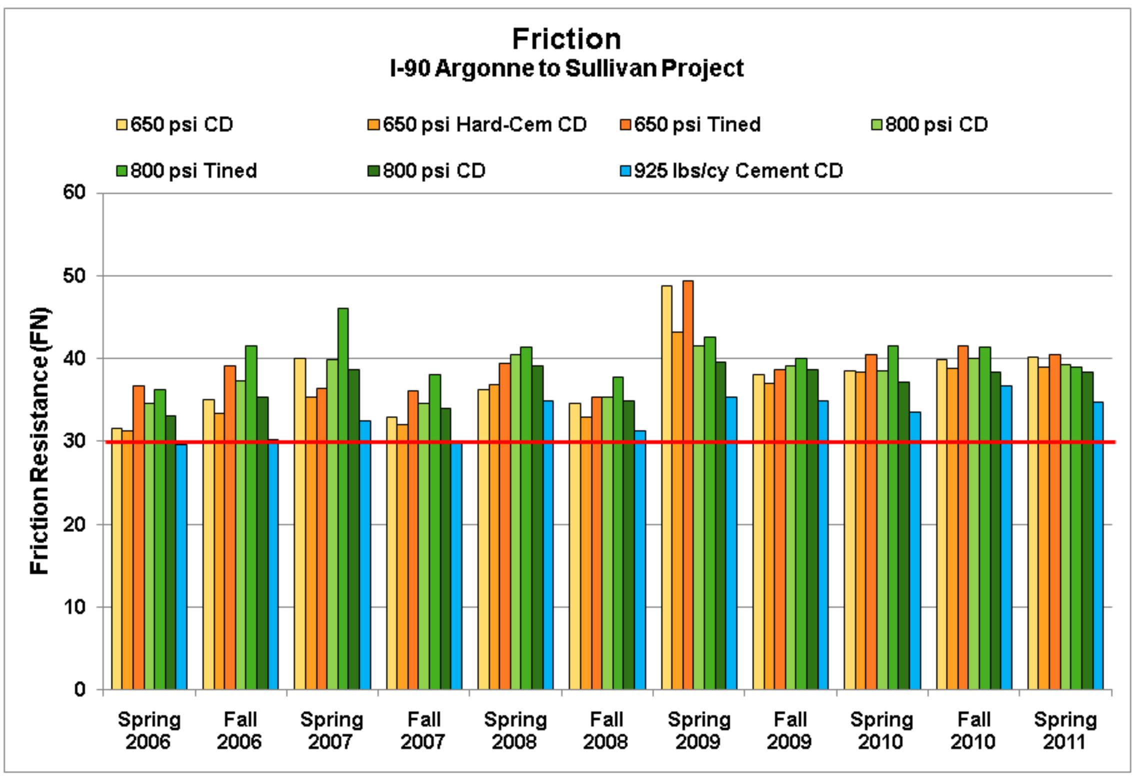

Figure 26. Friction resistance data for the I-90 Argonne to Sullivan Project.

Figure 27. Transverse tining on the left and carpet drag finish on the right from the Argonne to Sullivan Project.

Ride

Pavement riding characteristics or smoothness is one of the issues of interest for the carpet drag and longitudinal tined sections of the I-5 projects. The ride quality will be evaluated using the Washington State Pavement Management System (WSPMS) rating scale noted in Table 15. International Roughness Index (IRI) is a standardized roughness measurement developed by the World Bank in the 1980s. IRI is a measurement of the longitudinal profile of a roadway based on a quarter-car model.

Table 15. WSDOT WSPMS ride rating scale.

Rating	IRI (inches/mile)
Very Good	<= 95
Good	95 – 170
Fair	170 - 220
Poor	220 - 320
Very Poor	>320

I-5 Federal Way Project

The ride measurements for the Federal Way project are listed in Table 15 and plotted in Figure 28. The ride values are very consistent for each lane throughout the five year monitoring period. The three mainline lane values range from the high 70's to low 90's (Table 16) which puts them in the "very good" range of the WSPMS rating scale. The HOV lane values are somewhat higher with a range in values from the high 90's to low 110's putting them in the "good" rating category. The ride values are relatively static as would be expected in a concrete pavement. The poorer ride on the HOV lanes is the result of difficulties experienced by the contractor in paving a median side HOV lane with limited room and adequate support for the paving equipment. In addition, some of the pavement was placed by hand due to overhead clearance issues that did not allow the use of a paving machine.

Table 16. Ride data for the I-5 Federal Way Project.

Dir/ Lane	Ride IRI (inches/mile)												
	F	S	F	S	F	S	F	S	F	S	F	S	F
	2005	2006		2007		2008		2009		2010		2011	
SB L2	-	83	75	82	84	90	78	83	85	80	84	88	86
SB L3	92	87	78	82	85	90	84	87	87	86	88	89	87
SB L4	84	83	77	77	82	85	80	81	79	81	81	81	81
SB HOV	92	103	99	101	102	107	100	102	101	103	102	103	102
NB HOV	-	-	-	-	110	115	109	110	103	111	115	114	103

Note: F is for Fall, S for Spring. The colors of the sections in the table match the bars in Figure 26.

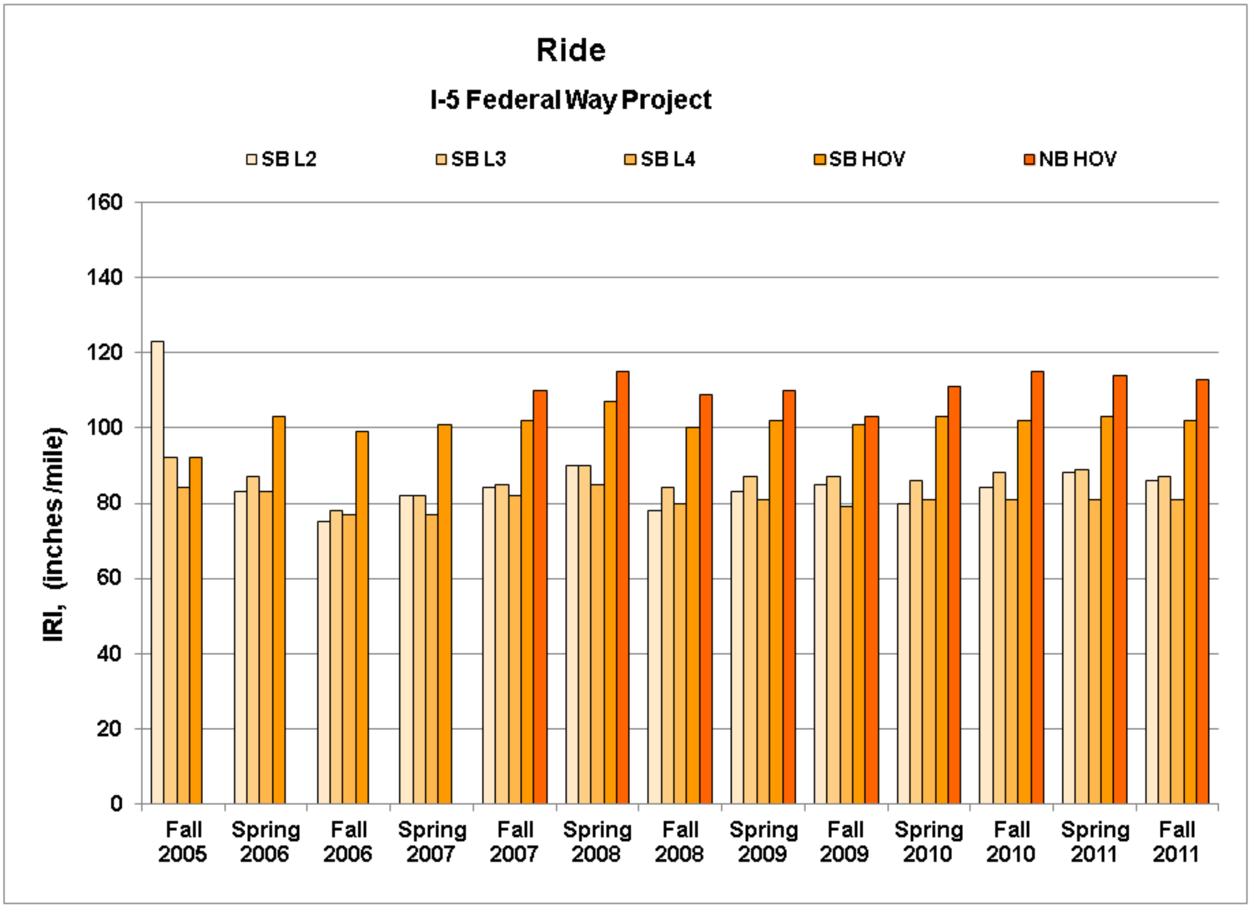

Figure 28. Ride measurements for the I-5 Federal Way Project.

I-5 Pierce Co. Line Project

The ride values for the Pierce Co. Line project are higher than the first project as shown in Table 17 and Figure 29. The values are very consistent for each section throughout the monitoring period. The transverse tined sections had the highest values (SB HOV) and lowest values (NB HOV) with the other sections occupying the middle range of values. All of the sections were in the "good" rating category. Again the ride values change very little over time.

Table 17. Ride data for the I-5 Pierce Co. Line Project.											
Section	Ride IRI (inches/mile)										
	F 2006	S 2007	F 2007	S 2008	F 2008	S 2009	F 2009	S 2010	F 2010	S 2011	F 2011
Transverse Tining NB	107	101	108	113	109	114	108	110	111	106	110
Longitudinal Tining NB	126	123	124	126	123	121	121	123	127	126	121
Carpet Drag NB	115	114	120	122	117	110	120	120	122	122	122
Transverse Tining SB	144	133	136	131	125	133	135	141	145	143	129
Carpet Drag SB	112	114	118	120	115	118	117	119	121	122	120

Note: F is for Fall, S for Spring. The colors of the sections in the table match the bars in Figure 27.

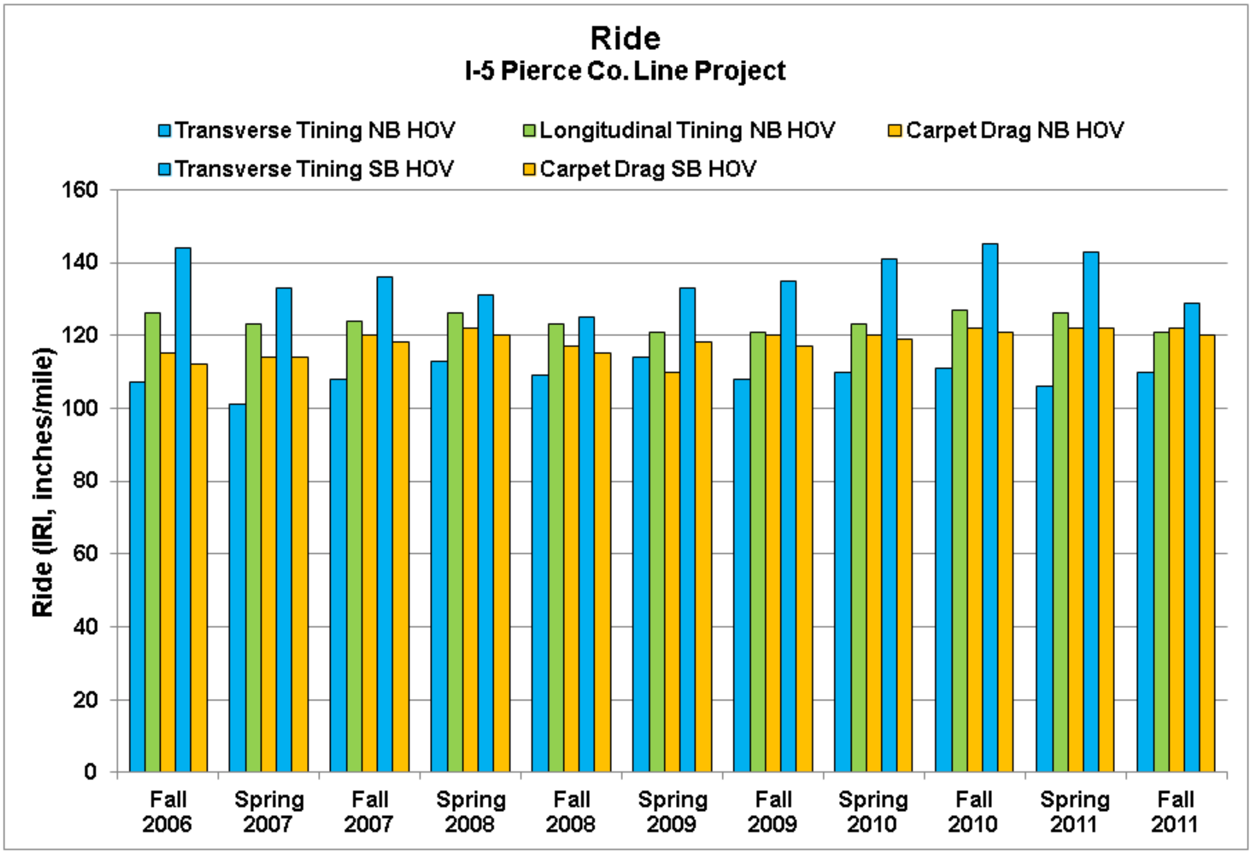

Figure 29. Ride data for the I-5 Pierce Co. Line Project.

I-90 Combined Gradation Project

The ride values for the Combined Gradation project are in the same range as the I-5 Pierce Co. Line project as shown in Table 18 and Figure 30. The values are very consistent for each lane throughout the monitoring period. All of the lanes were in the "good" rating category. Again the ride values change very little over time.

Table 18. Ride data for the Combined Gradation Project.

Section	Ride IRI (inches/mile)										
	S 2004	F 2004	S 2005	F 2005	S 2006	F 2006	S 2007	F 2007	S 2008	F 2008	S 2009
Standard Grad. L2	96	101	94	92	96	99	97	100	103	102	110
Standard Grad. L3	96	100	95	93	95	95	95	96	101	99	104
Combined Grad. L2	101	108	103	100	104	102	101	105	109	104	112
Combined Grad. L3	123	118	107	105	108	106	104	107	113	107	111
Average	104	107	100	98	101	101	99	102	107	103	109

Note: F is for Fall, S for Spring. The colors of the sections in the table match the bars in Figure 28.

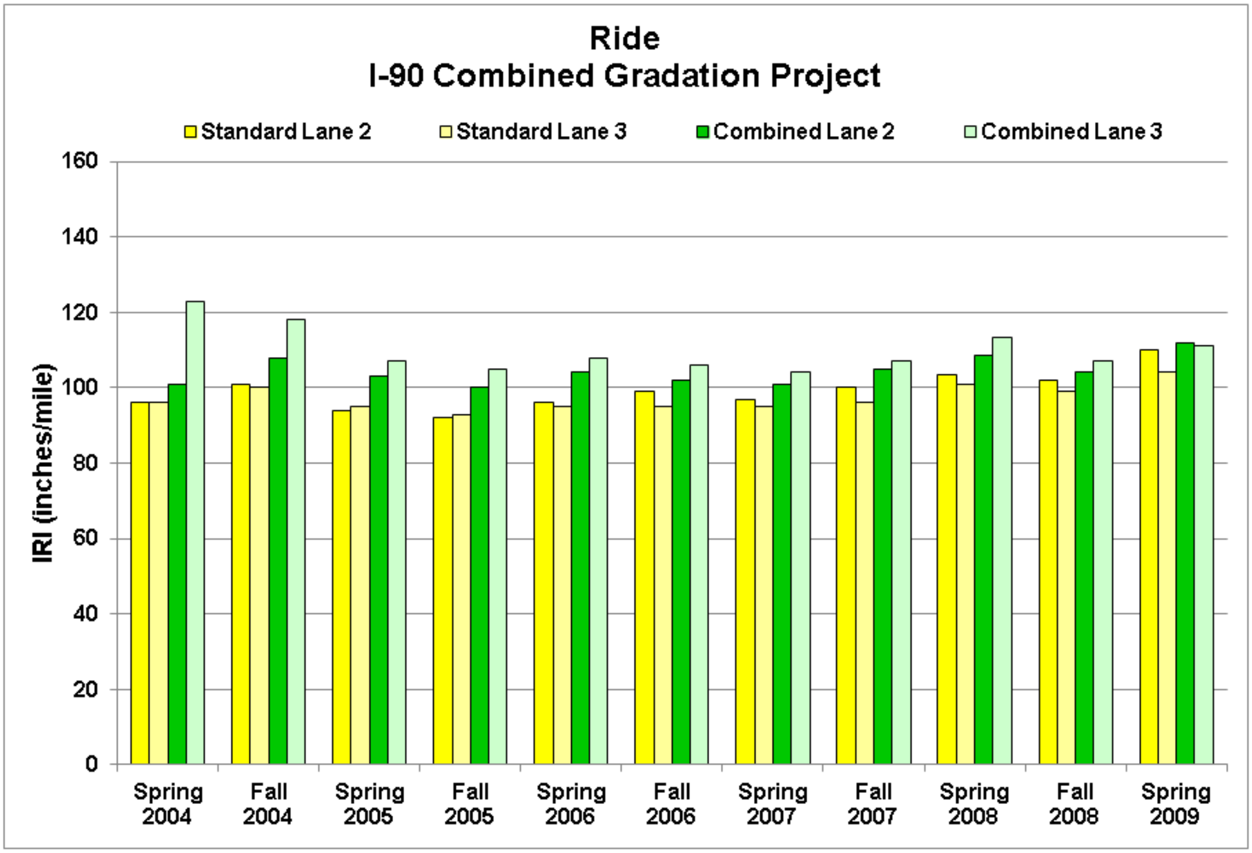

Figure 30. Ride data for the I-90 Combined Gradation Project.

I-90 Whitetopping Project

The ride values for the Whitetopping vary depending on the thickness of the section as shown in Table 19 and Figure 31. It is interesting that the section with the thickest concrete has the highest ride values and the most variation from measurement period to measurement period. This project shows more variation over time than any other project. Warping and curling of the thin concrete sections may be a contributing factor to this variation. The values for all three sections range from the "very good" (3-inch) to the "good" (4 and 5-inch) rating category. One additional note, the values for Spring 2004 do not appear to be valid, possibly due to problems with the measurement equipment.

Table 19. Ride data for the I-90 Whitetopping Project.										
Section	Ride IRI (inches/mile)									
	S 2004	F 2004	S 2005	S 2006	F 2006	F 2007	S 2008	F 2008	S 2009	Sum 2010
3-Inch	45	83	84	74	95	92	70	90	83	86
4-Inch	44	86	82	72	101	80	78	102	80	98
5-Inch	46	101	100	107	142	119	119	148	123	140
Average	45	90	89	84	113	97	89	113	92	108

Note: F is for Fall, S for Spring except for 2010. The colors of the sections in the table match the bars in Figure 29.

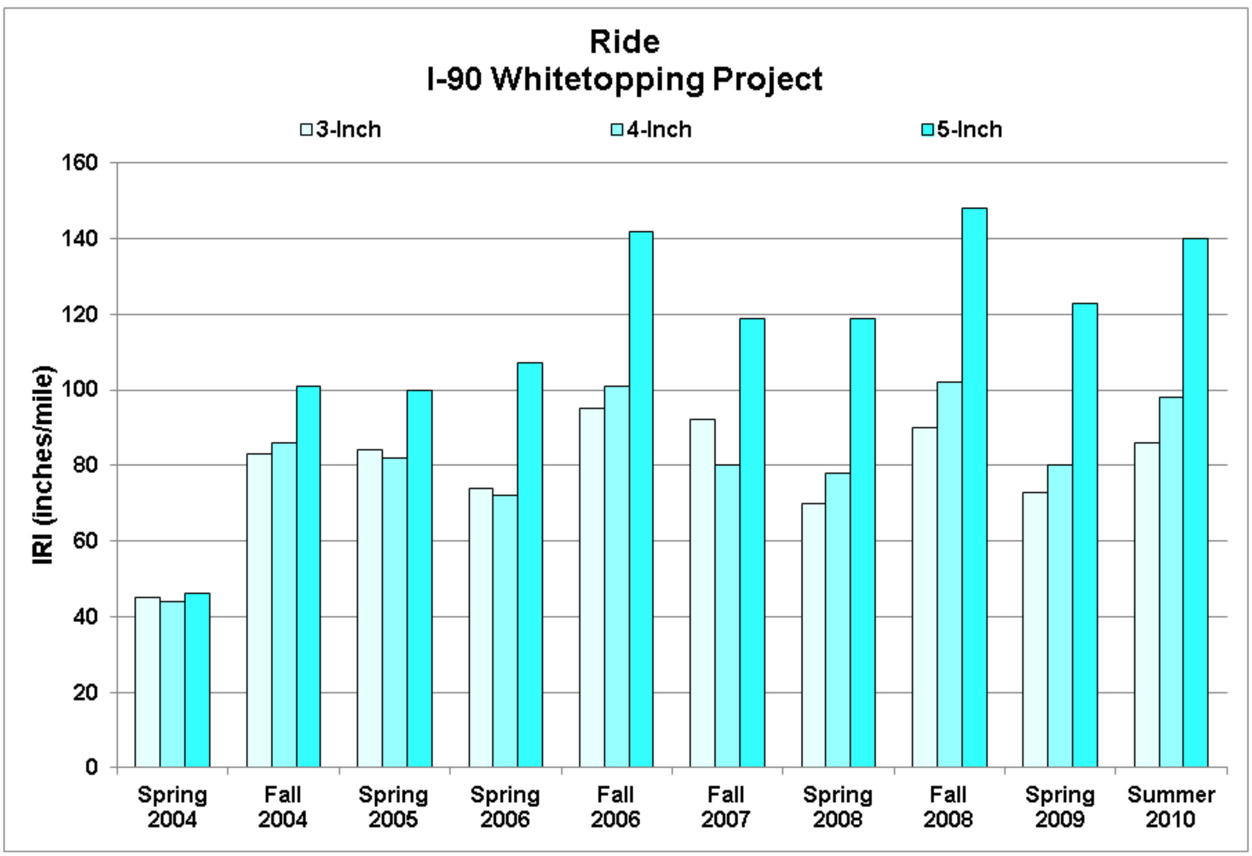

Figure 31. Ride data for the I-90 Whitetopping Project.

I-90 Argonne to Sullivan Project

The ride values for the Argonne to Sullivan project vary between the low 80's and low 140's as shown in Table 20 and Figure 32. The ride values for each section are fairly consistent from one measurement period to the next indicating that the ride is not changing over time. The bar chart confirms this observation as each colored bar varies slightly from one period to the next, but staying are relatively the same level from Spring 2006 to Spring 2011. Four of the sections were in the "very good" category (650 psi CD, 650 psi Hard-Cem, 650 psi Tined, and 800 psi CD) with the remaining three in the "good" category (800 psi Tined, 800 psi CD, and 925 lbs/cy CD).

Table 20. Ride data for the I-90 Argonne to Sullivan Project.

Section	Ride IRI (inches/mile)										
	S 2006	F 2006	S 2007	F 2007	S 2008	F 2008	S 2009	F 2009	S 2010	F 2010	S 2011
650 psi CD	92	87	82	85	89	84	84	81	88	91	90
650 psi HC CD	90	93	90	91	98	87	96	90	96	96	83
650 psi TT	82	81	82	83	92	82	88	78	85	81	100
800 psi CD	94	93	91	93	97	90	93	90	93	93	95
800 psi TT	128	122	125	111	132	121	129	125	132	128	141
800 psi CD	107	99	98	99	109	97	93	98	99	101	102
925 lbs/cy CD	104	95	100	87	112	100	101	95	97	102	106
Average	100	96	95	93	104	94	98	94	99	99	102

Note: F is Fall, S is Spring, CD is carpet drag, HC is Hard-Cem, TT is transverse tined. The colors of the sections in the table match the bars in Figure 30.

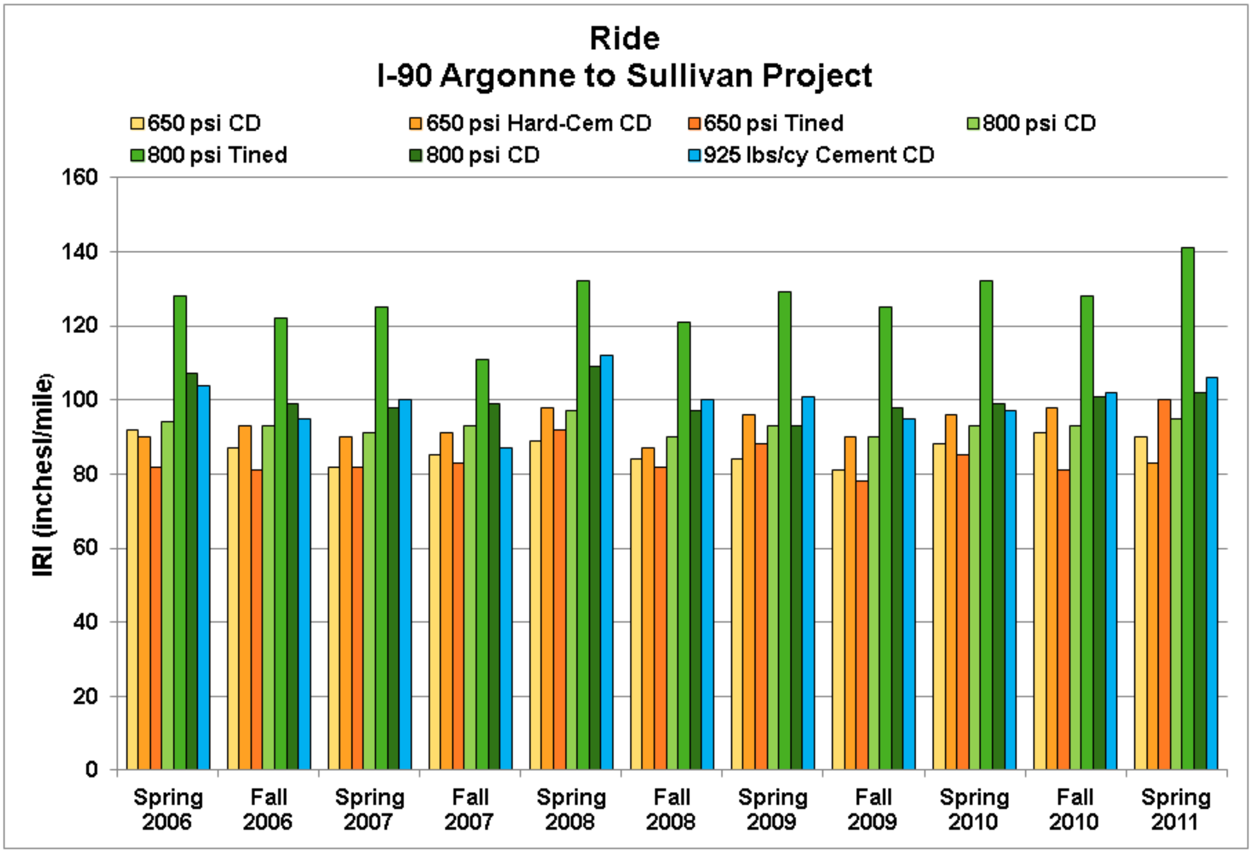

Figure 32. Ride data for the I-90 Argonne to Sullivan Project.

In summary, the ride data indicates that the projects on I-5 are in the “good” to “very good” range and are not deteriorating over the 5-year evaluation period. The three I-90 projects also ranked in the “good” to “very good” category and are not deteriorating over the evaluation period of each project.

Noise

Noise measurements were taken on both of the projects to provide data to compare to other projects within the state and nationally. On-Board Sound Intensity (OBSI) measurements for the carpet drag textured new concrete and the conventional diamond ground (CDG) existing concrete for the Federal Way Project are shown in Figure 33. The value shown in the bar chart for the carpet drag section is the average of three measurements which ranged from 102.1 to

102.9. The reading for the CDG concrete is also the average of three readings that ranged from 104.7 to 105.3 decibels.

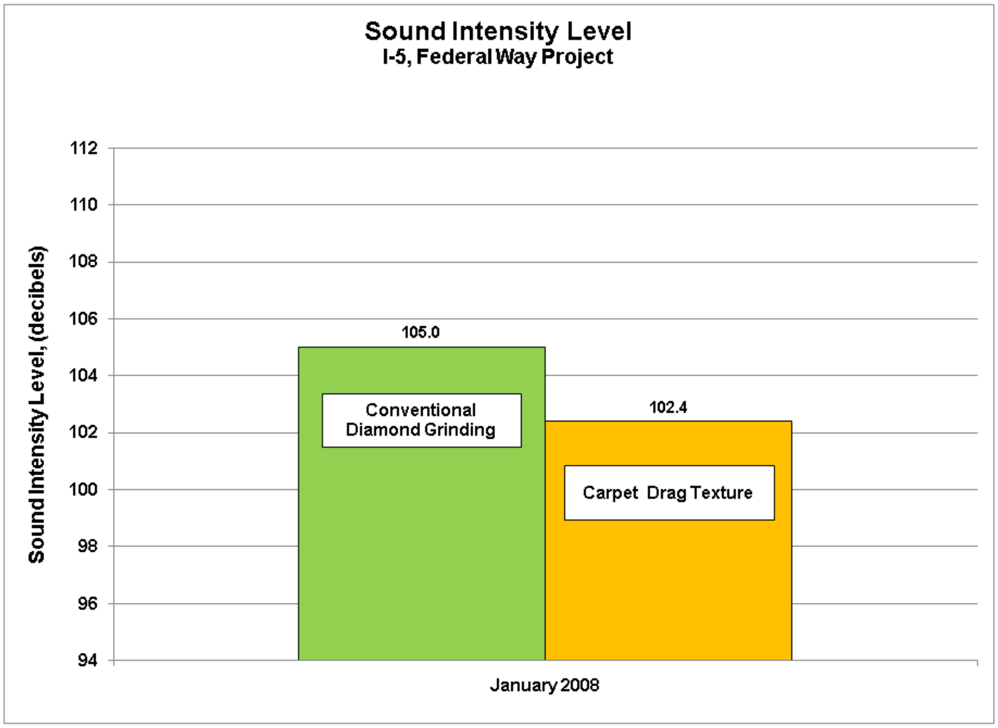

Figure 33. Noise measurements for the carpet drag textured lanes and the conventional diamond ground existing pavement on the I-5 Federal Way Project.

These results are similar to the noise measurements made on the Pierce County Line project where the carpet drag texture readings ranged from 102.6 to 102.9 decibels (Figure 34). The longitudinal and transverse tined sections had results in the same range (102.7 to 102.9 decibels).

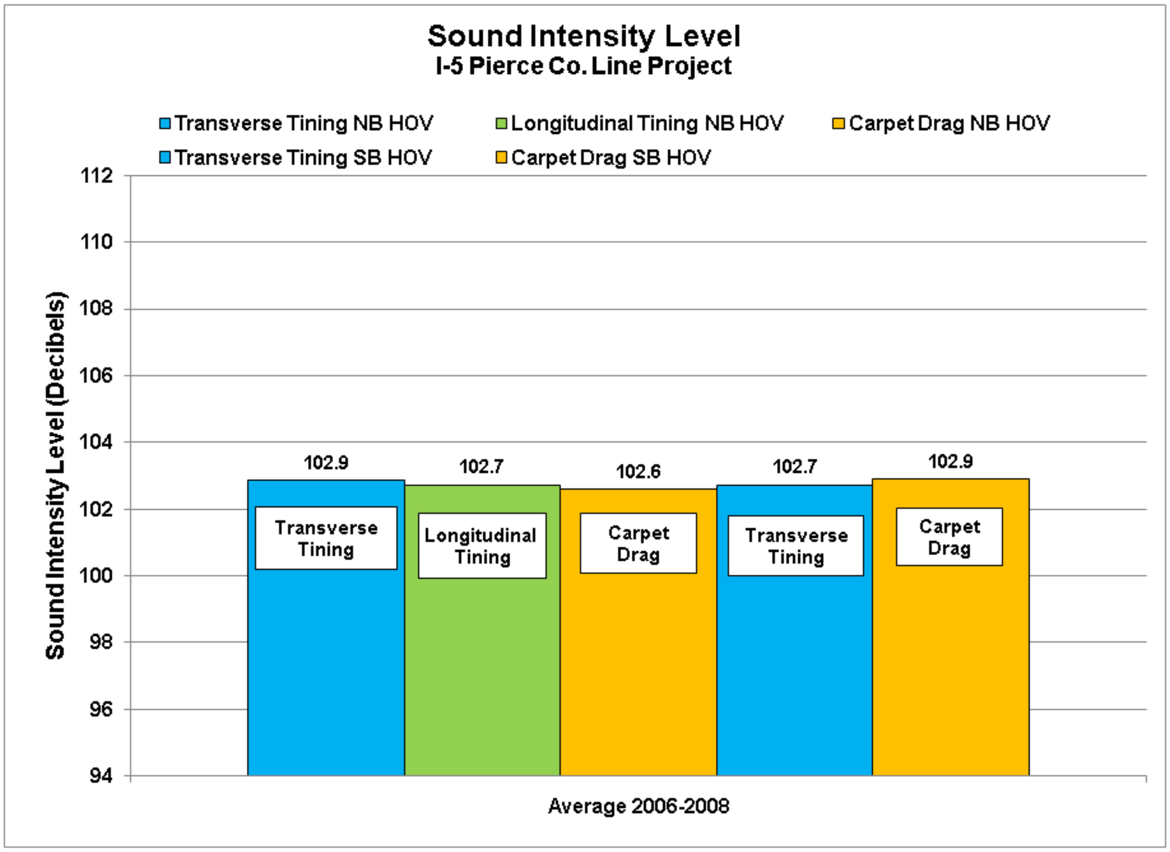

Figure 34. Sound intensity level data for I-5 Pierce Co. Line Project.

The noise readings on both projects are encouraging based on the values reported in the literature published by the American Concrete Paving Association (ACPA) (Table 21, Scofield 2009). The range of values for the three textures (102.4 to 102.9 decibel) measured by WSDOT are consistent with ACPA's longitudinal tining measurements and just below their quietest transversely tined concrete measurements. The carpet drag texture was not measured by ACPA but WSDOT measurements were within the range of ACPA's longitudinal tining and conventional diamond grinding measurements and quieter than their transversely tined concrete.

Table 21. Range of noise measurement readings for various concrete surface textures. (Scofield 2009)	
Texture	**Range of OBSI Readings (Decibels, dBA)**
Transverse Tining	**103-110**
Longitudinal Tining	**101-106**
Conventional Diamond Grinding	**100-104**
Next Generation Concrete Surface	**99-101**

Summary

The most interesting aspect of the two I-5 projects is the almost non-existence of wear on the pavement no matter what type of texture was applied to the concrete. This is in stark contrast to projects constructed on I-90 in Spokane with both carpet drag and transverse tined textures. The Spokane projects have a range of five to almost ten mm ruts from studded tire wear. The following facts can be stated concerning the performance of the five projects.

- The pavement wear (final rut measurement minus initial rut measurement) on the two I-5 projects is less than one millimeter for the five to six year monitoring period.
- The friction numbers on the two I-5 projects are very good and have remained at the same level over the monitoring period.
- The ride on the two I-5 projects and three I-90 projects is "good" to "very good" and has not deteriorated over the various monitoring periods.
- The noise measurements on the carpet drag texture are in the range normally cited for either conventional diamond ground or longitudinal tined pavements.
- The pavement wear (final rut measurement minus initial rut measurement) on the three I-90 projects ranged from 1.6 to 7.6 mm for the five to seven year monitoring period.
- The transverse tining and carpet drag textured concrete pavement was equally susceptible to studded tire wear on the three I-90 projects.

Conclusions

The following conclusions can be drawn from the study:

- Carpet drag and longitudinal tining are acceptable alternatives methods of texturing to transverse tining for concrete pavements based on wear resistance, friction resistance, riding quality and acceptable noise level.
- There are no texturing techniques or mix designs that will produce a concrete pavement that is resistant to wear from traffic with a high percentage of studded tires.

References

Scofield, Larry (2009) "Transportation Noise and Concrete Pavements – Using Concrete Pavements as the Noise Solution", American Concrete Paving Association, May 2009.

Appendix A

I-5 and I-90 Mix Designs

This is a summary of the mix designs used on the two I-5 projects and the two I-90 projects discussed in this report. A discussion of the hardness characteristics of the aggregates used on the four projects follows the mix design information.

I-5 Federal Way Project

Only one mix design was used for all of the paving on the first project, Federal Way to S.317th Street HOV Direct Access project on I-5.

Mix design 15650AS.				
Item	**Source**	**Type**	**Lbs/cy**	**Specific Gravity**
Cement	Lafarge	I-II	423	3.15
Slag	Lafarge	I	141	2.83
Agg. Source 1	B-345	Class 2	1,090	2.65
Agg. Source 2	B-345	1-1/2”	510	2.70
Agg. Source 3	B-345	3/8”	590	2.71
Agg. Source 4	B-345	¾”	1,075	2.71
Water			233	1.00
W/C Ratio			0.38	
Water Reducer	Master Builders	Polyheed 997	23 oz/cy	
Air Entrainment	Master Builders	MB-AE-90	5-20 oz/cy	

I-5 Pierce Co. Line Project

Only one mix design was used for the second project, Pierce County Line to Tukwila I/C – HOV - Stage 4. The only change from the first project was in the amounts of the various aggregates.

Mix design 15700AS.				
Item	**Source**	**Type**	**Lbs/cy**	**Specific Gravity**
Cement	Lafarge	I-II	423	3.15
Slag	Lafarge	I	141	2.83
Agg. Source 1	B-345	Class 2	1,150	2.65
Agg. Source 2	B-345	1-½”	490	2.70
Agg. Source 3	B-345	3/8”	560	2.69
Agg. Source 4	B-345	¾”	1,050	2.70
Water			233	1.00
W/C Ratio			0.41	
Water Reducer	Degussa	Polyheed 997	23 oz/cy	
Air Entrainment	Degussa	MB-AE 90	5-20 oz/cy	

I-90 Combined Gradation Project

The 650 psi mix design for both the combined and standard aggregate gradation mixes were almost identical except for the aggregate gradations and the amount of water.

Standard aggregate gradation 650 mix design.			
Item	Type	Standard lbs/cy	Combined lbs/cy
Cement	I-II	452	452
Fly Ash	Class F	113	113
	1 1/2 -3/4	823	672
	3/4 - 3/8	941	785
	3/8 - #4	271	494
	#4 - #8	299	298
	#9 - #16	268	333
	#16 - #30	178	163
	#30 - #50	265	220
	#50 - #100	153	132
	#100 - #200	45	20
Water		215	230

I-90 Whitetopping Project

A single mix design was used for all three sections of whitetopping. It was a fly ash mix with polypropylene fibers added to increase the strength of the very thin concrete and prevent any cracks from opening. Not a lot of similarity to the other Argonne Road to Sullivan Road project 800 psi mix designs although both used the same sources for the aggregates.

Whitetopping 800 psi mix design.				
Item	Source	Type	Lbs/cy	Specific Gravity
Cement	Lafarge	I-II	650	3.15
Fly Ash	ISG Resources, Inc.	Class F	160	
Agg. Source 1	C-173	1 ½ - ¾	834	2.66
Agg. Source 2	C-173	¾ - #4	701	2.67
Agg. Source 3	C-173	Coarse Sand	692	2.64
Agg. Source 4	C-297	Fine Sand	555	2.64
Water			260	1.00
W/C			0.33	
Water Reducer	W. R. Grace & Co.	WRDA=64, Type A	28-36 oz/cy	
Air Entrainment	W. R. Grace & Co.	Daravair	6-10 oz/cy	
Reinforcement	Poly Fiber	Polypropylene	3	

I-90 Argonne to Sullivan Project

The first I-90 project discussed in this report, Argonne Road to Sullivan Road, used six mix designs over a period of two years. The eastbound lanes were constructed in 2004 and the westbound the following year. In 2004 the standard mix design for the 800 psi flexural strength used throughout the project was 6620-02. A variation of 6620-02 with minor changes in aggregate gradation, 6620-02R, was also used in 2004. All of the mix designed used a combined gradation for the aggregates. All of the cement in 2004 was MaxCem which is a combination of 20-25% Ground Granulated Blast Furnace Slag (GGBFS) and portland cement.

Mix design 6620-02 with 800 psi flexural strength used for the majority of the paving in 2004.

Item	Source	Type	Lbs/cy	Specific Gravity
Cement	Lafarge	I-SM	660	3.15
Agg. Source 1	C-173	1 ½ - ¾	629	2.69
Agg. Source 2	C-173	3/4 - #4	599	2.68
Agg. Source 3	C-173	3/8	329	2.67
Agg. Source 4	C-173	5/8	421	2.69
Agg. Source 5	C-107	Coarse Sand	680	2.64
Agg. Source 6	C-297	Fine Sand	463	2.64
Water			217.8	1.00
W/C Ratio			0.33	
Water Reducer	Master Builders	Master Pave A&D	40-60 oz/cy	
Air Entrainment	Master Builders	MBAE 90	6-12 oz/cy	

Mix design 6620-02R with 800 psi flexural strength also used in 2004.

Item	Source	Type	Lbs/cy	Specific Gravity
Cement	Lafarge	I-SM	660	3.15
Agg. Source 1	C-173	1 ½ - ¾	470	2.69
Agg. Source 2	C-173	¾ - #4	1,314	2.68
Agg. Source 3	C-107	Coarse Sand	862	2.64
Agg. Source 4	C-297	Fine Sand	462	2.64
Water			212	1.00
W/C Ratio			0.33	
Water Reducer	Master Builders	Master Pave A&D	40-60 oz/cy	
Air Entrainment	Master Builders	MBAE 90	6-12 oz/cy	

A 650 psi flexural strength mix was used in 2004 on a short section of pavement to act as a control section of WSDOT's standard specification mix.

Mix design 6620-03 with 650 psi flexural strength used for the control section.				
Item	**Source**	**Type**	**Lbs/cy**	**Specific Gravity**
Cement	Lafarge (MaxCem)	I-SM	565	3.15
Agg. Source 1	C-173	1 ½ - ¾	631	2.69
Agg. Source 2	C-173	¾ - #4	1,354	2.68
Agg. Source 3	C-107	Coarse Sand	682	2.64
Agg. Source 4	C-297	Fine Sand	464	2.64
Water			237	1.00
W/C Ratio			0.42	
Water Reducer	Master Builders	Master Pave A&D	40-60 oz/cy	
Air Entrainment	Master Builders	MBAE 90	6-12 oz/cy	

The fourth mix design used in 2004 was a 650 psi flexural strength mix to which Hard-Cem was added. Hard-Cem is an integral concrete hardener manufactured by Cementec Industries, Inc. According to Cementec Industries, Hard-Cem is a functional filler additive and not a chemical admixture and claims it can be added to any concrete mix with no effect on the concrete qualities such as air-entrainment. Hard-Cem is a fine powder that is handled similar to cement, is added during the batching process, and affects the entire mix, not just the surface of the pavement. This mix design is identical to the 650 psi flexural strength design used for the control section except for the substitution of 67 lbs/cy of Hard-Cem for the same amount of Type I-SM cement. The addition of the Hard-Cem lowered the water cement ratio from 0.42 to 0.38.

Mix design 6620-04 with 650 psi flexural strength and Hard-Cem additive.				
Item	**Source**	**Type**	**Lbs/cy**	**Specific Gravity**
Cement	Lafarge	I-SM	565	3.15
Hard-Cem	Cementec Ind.		67	3.15
Agg. Source 1	C-173	1 1/2 - ¾	631	2.69
Agg. Source 2	C-173	¾ - #4	1,354	2.68
Agg. Source 3	C-107	Coarse Sand	670	2.64
Agg. Source 4	C-297	Fine Sand	428	2.64
Water			237	1.00
W/C Ratio			0.38	
Water Reducer	Master Builders	Master Pave A&D	20-30 oz/cy	
Air Entrainment	Master Builders	MBAE 90	6-12 oz/cy	

A new mix design, 6620-05, was developed in 2005 for the 800 psi flexural strength concrete. Mix design 6620-02R was also used extensively in 2005 depending upon which source of cement was available at the time. When slag cement was not available they used 6620-02R, otherwise they use the new mix design 6620-05. Approximately 50% of the 2005 paving was constructed with each of the two mix designs.

Mix design 6620-05 with 800 psi flexural strength.				
Item	**Source**	**Type**	**Lbs/cy**	**Specific Gravity**
Cement	Lafarge	I-SM	495	3.15
Slag	Lafarge	New Cem	165	2.83
Agg. Source 1	C-173	1 ½ - ¾	627	2.69
Agg. Source 2	C-173	¾ - #4	1,345	2.68
Agg. Source 3	C-107	Coarse Sand	688	2.64
Agg. Source 4	C-297	Fine Sand	459	2.64
Water			218	1.00
W/C Ratio			0.33	
Water Reducer	Master Builders	Master Pave A&D	40-60 oz/cy	
Air Entrainment	Master Builders	MBAE 90	6-12 oz/cy	

The final mix design on the project was the one with high cement content. This design was added to see concrete with higher cement content would have more resistance to wear from studded tires.

Mix design 6620-08 with 925 lbs/cy of cementitious material.				
Item	**Source**	**Type**	**Lbs/cy**	**Specific Gravity**
Cement	Lafarge	I-SM	925	3.15
Agg. Source 1	C-173	1 ½ - ¾	595	2.69
Agg. Source 2	C-173	¾ - #4	1,278	2.68
Agg. Source 3	C-107	Coarse Sand	475	2.64
Agg. Source 4	C-297	Fine Sand	317	2.64
Water			305	1.00
W/C			0.33	
Water Reducer	Master Builders	Master Pave A&D	40-60 oz/cy	
Air Entrainment	Master Builders	MBAE 90	6-12 oz/cy	

Concrete Aggregate Comparison I-5 vs. I-90 Projects

The table below is a comparison of the quality of the aggregates used to produce the concrete for the two I-5 projects versus the three I-90 projects. The aggregate source for the I-5 projects was the same (B-345) as was the aggregate source for the I-90 projects (C-173); both are glacial gravel sources, so a comparison can be made. The aggregates used on the two projects are very similar in quality with the I-5 aggregates having the same LA abrasion number, but the I-90 aggregates a slightly better degradation number. Data was not available for the third I-90 project (Combined Gradation)

Concrete aggregate comparison between I-5 and I-90 projects.			
Use	**Test**	**I-5 Projects**	**I-90 Projects**
Portland Cement Concrete Aggregates	ASR-14 Days	0.52	0.38
	ASR-One year	0.02	0.04
	CCA Absorption	1.1	1.0
	CCA Sp. G.	2.7	2.7
	FCA Absorption	1.6	2.0
	FCA Organics	2.0	1.0
	FCA Sp. G.	2.65	2.61
	LA Abrasion	15	15
	Degradation	73	76

Appendix B

Experimental Feature Work Plan
I-5 Federal Way Project

Washington State Department of Transportation

WORK PLAN

PCCP Features

(Surface Smoothness and Noise)

I-5, Federal Way – South 317th Street HOV Direct Access
Milepost 143.25 to Milepost 144.74

Prepared by

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February 2005

Introduction

Washington State Department of Transportation's (WSDOT) Portland Cement Concrete Pavement (PCCP) construction program has been relatively small since the construction of the Interstate system in the 1960's and early 70's. As many of these early pavements deteriorate and require reconstruction, the best possible construction practices will be essential in order to provide pavements that will last 50 years or longer.

One of the challenges facing WSDOT is to reduce the excessive wear concrete pavements received from studded tires. An Experimental Feature "Combined Aggregate Gradation for Concrete Pavements" is under study and is investigating the use of a combined aggregate gradation to curb the effects of studded tire wear. An additional WSDOT study involves the rates of stud wear on the Specific Pavement Studies (SPS) located on SR 395 south of Ritzville. To date there is definitely less wear due to studded tires in the 900-psi section as compared to the lower strength sections. Further, the tine grooves are still apparent in the high strength sections and are, in essence, gone from the lower strength ones. While these observations are far from conclusive, WSDOT wishes to explore the effects of higher strength PCCP mixes.

Another challenge observed with WSDOT PCCP construction has been with providing smooth riding surfaces, particularly in urban areas. WSDOT has built several pavements in recent years where bonuses have been paid to contractors for satisfying the smoothness specifications, however, in some cases the roadway is still perceived rough. WSDOT's current smoothness requirement is based on a 0.20 inch blanking band with an allowable daily profile index of 7.0 inches per mile or less.

A current experimental feature, I-90, Argonne to Sullivan Experimental Feature, MP 287.98 to MP 292.16, is underway in the Eastern Region to consider PCCP features beyond the 2002 WSDOT Standard Specifications. The eastbound lanes of this feature were paved in the summer of 2004. Included in this study is the use of a carpet drag finish, increasing the flexural strength of the PCCP, and providing a zero blanking band for measuring surface smoothness. Following construction of the PCCP, the influences from the carpet drag finish and increased flexural strength specification on the pavement will be monitored to determine its ability to resist surface abrasion. Additionally, the results of using a zero blanking band to determine smoothness will be analyzed and compared with profilogragh results using the 0.20-inch blanking band.

I-5, Federal Way – South 317th Street HOV Direct Access

Since the approval of the I-90, Argonne to Sullivan Experimental feature, the Federal Highway Administration has changed its noise policy to allow states to take into consideration the effects of quiet pavements as noise mitigation with enough supporting data. The process for state DOT's to utilize pavement type to mitigate noise is found in the January 19, 2005 Memorandum titled "Highway Traffic Noise – guidance on Quiet Pavement Pilot Programs (QPPP) and Tire/Pavement Noise Research."
(http://www.fhwa.dot.gov/environment/noise/qpppeml.htm)

The QPPP is intended to demonstrate the effectiveness of quiet pavement strategies and to evaluate any changes in their noise mitigation properties over time. Current knowledge on changes over time is extremely limited. Thus, the programs will collect data and information for at least a 5-10 year period, after which the FHWA will determine if policy changes to a State DOT(s) noise program are warranted.

The intent of this experimental section is to allow the placement of a carpet drag surface in Western Washington and monitor both rutting/friction and noise over time. Currently, WSDOT does not have a means for collecting noise information, however, there is discussion between the Materials Laboratory and Environmental Noise Quality to purchase equipment. The key item for WSDOT is to place a concrete pavement in Western Washington to compliment the work being performed on I-90 in Spokane. The rutting and friction information will be valuable information as WSDOT begins a QPPP.

Scope

This project involves the reconstruction and rehabilitation of 1.49 miles of southbound I-5. The reconstruction portion of the contract is 0.60 miles long and places full width 13 inches (1.08’) of PCCP over 4.2 inches (0.35’) of asphalt concrete over 4.2 inches (0.35’) of crushed surfacing. The total 50-year design ESALs for the single direction traffic are approximately 200 million. The experimental features will be incorporated over one half of the project length.

Carpet Drag

The final pavement surface will be obtained by drawing a carpet drag longitudinally along the pavement before the concrete has taken its initial set. The carpet drag will be a single piece of carpet of sufficient length to span the full width of the pavement being placed and adjustable to allow up to 4 feet longitudinal length in contact with the concrete being finished. The target depth of the carpet drag will be about 1 millimeter.

Initial WSDOT analysis shows that the carpet drag finish provides an equal or better skid resistance than normal WSDOT transverse tined pavements. This is significant considering studded tire wear normally removes transverse tining 3 to 4 years after placing PCCP.

Mix Design

The mix design requirements will utilize PCCP concrete that has a 14-day target flexural strength of 650 psi as specified in Section 5-05 of the 2004 WSDOT Standard Specifications.

Test Section

Approximately one half of the project will utilize the carpet drag finish. The exact location has not been specified, however, it is likely the northern half of the southbound lanes will receive the carpet drag. The carpet drag will be placed on all lanes, starting and stopping at the same locations. The remainder of the project will receive a tined finish.

Construction

Concrete will be placed by a slip form paver. Except as indicated, 2004 WSDOT Standard Specifications will apply.

Staffing

The Region Project office will coordinate and manage all construction aspects. Representatives from WSDOT Materials Laboratory (one or two persons) will also be involved with documenting the construction.

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Testing

The completed PCCP will be skid tested to determine friction values. The friction values will be measured twice a year on each of the test sections for the duration of the experiment. Specific tests for determining pavement surface wear will also be taken before and after the allowance of studded tires.

Reporting

An "End of Construction" report will be written following completion of the project. This report will include construction details, material test results, and other details concerning the overall process. Annual summaries will also be conducted over the next five years. At the end of the five-year period, a final report will be written which summarizes performance characteristics and future recommendations for use of this process.

Cost Estimate

Construction Costs

This contract is currently under construction. The concrete contractor has agreed to provide the carpet drag at no cost to WSDOT.

Testing Costs

Condition Survey – will be conducted as part of statewide annual survey, no cost.

Rut Measurements – 10- surveys (2 hours each) requires traffic control = $12,000

Friction Measurements – 10 surveys done in conjunction with annual new pavement friction testing, no cost.

Noise Surveys – WSDOT is currently pursuing purchasing noise-monitoring equipment. The cost of this equipment is not included in this experimental feature, as this equipment will be used throughout Washington State once noise monitoring on a regular basis begins.

However, about $5,000 is anticipated for funds necessary to monitoring noise for periodic surveys on this section of I-5.

Report Writing Costs

Initial Report – 20 hours = $1,500
Annual Report – 5 hours (1 hour each) = $500
Final Report – 10 hours = $1,000

Total Cost = $20,000

Schedule

Construction Date: Southbound lanes – June 2005

Date	Condition Survey (Annual)	Rut & Friction Measurements (Annual)	End of Construction Report	Annual Report	Final Report
April 2005		X	X		
Fall 2005	X	X		X	
Spring 2006	X	X		X	
Fall 2006	X	X		X	
Spring 2007	X	X		X	
Fall 2007	X	X		X	
Spring 2008	X	X		X	
Fall 2008	X	X		X	
Spring 2009	X	X		X	
Fall 2009	X	X		X	X

Appendix C

Experimental Feature Work Plan
I-5 Pierce Co. Line Project

Washington State Department of Transportation

WORK PLAN

PCCP Features

(Surface Smoothness and Noise)

I-5, Pierce County Line to Tukwila I/C – HOV - Stage 4
Milepost 139.06 to Milepost 144.75

Prepared by

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October 2005

Introduction

Washington State Department of Transportation's (WSDOT) Portland Cement Concrete Pavement (PCCP) construction program has been relatively small since the construction of the Interstate system in the 1960's and early 70's. As many of these early pavements deteriorate and require reconstruction, the best possible construction practices will be essential in order to provide pavements that will last 50 years or longer.

One of the challenges facing WSDOT is to reduce the excessive wear concrete pavements received from studded tires. An Experimental Feature "Combined Aggregate Gradation for Concrete Pavements" is under study and is investigating the use of a combined aggregate gradation to curb the effects of studded tire wear. An additional WSDOT study involves the rates of stud wear on the Specific Pavement Studies (SPS) located on SR 395 south of Ritzville. To date there is definitely less wear due to studded tires in the 900-psi section as compared to the lower strength sections. Further, the tine grooves are still apparent in the high strength sections and are, in essence, gone from the lower strength ones. While these observations are far from conclusive, WSDOT wishes to explore the effects of higher strength PCCP mixes.

Another challenge observed with WSDOT PCCP construction has been with providing smooth riding surfaces, particularly in urban areas. WSDOT has built several pavements in recent years where bonuses have been paid to contractors for satisfying the smoothness specifications, however, in some cases the roadway is still perceived rough. WSDOT's current smoothness requirement is based on a 0.20 inch blanking band with an allowable daily profile index of 7.0 inches per mile or less.

The following sections highlight WSDOT current research efforts:

I-90 – Argonne to Sullivan

An experimental feature, I-90 - Argonne to Sullivan Experimental Feature, MP 287.98 to MP 292.16, is underway in the Eastern Region to consider PCCP features beyond the 2002 WSDOT Standard Specifications. The eastbound lanes of this feature were paved in the summer of 2004. Included in this study is the use of a carpet drag finish, increasing the flexural strength of the PCCP, and providing a zero blanking band for measuring surface smoothness. Following construction of the PCCP, the influences from the carpet drag finish and increased flexural strength specification on the pavement will be monitored to determine its ability to resist surface abrasion. Additionally, the results of using a zero blanking band to determine smoothness will be analyzed and compared with profilogragh results using the 0.20-inch blanking band.

I-5, Federal Way – South 317th Street HOV Direct Access

The I-5, Federal Way – South 317th Street HOV Direct Access project investigates the use of a carpet drag finish placed in Western Washington. This project reconstructed and rehabilitated 1.49 miles of southbound I-5. The reconstruction portion of the contract is 0.60 miles long and places full width 13 inches (1.08') of PCCP over 4.2 inches (0.35') of asphalt concrete over 4.2 inches (0.35') of crushed surfacing. The total 50-year design ESALs for the single direction traffic are approximately 200 million. The experimental features, constructed during the summer 2005 incorporated the carpet drag texture on the entire mainline pavement. Preliminary results indicate that a smooth PCCP surface with good frictional characteristics was obtained.

Quiet Pavement Pilot Programs

The Federal Highway Administration has changed its noise policy to allow states to take into consideration the effects of quiet pavements as noise mitigation with enough supporting data. The process for state DOT's to utilize pavement type to mitigate noise is found in the January 19, 2005 Memorandum (http://www.fhwa.dot.gov/environment/noise/qpppeml.htm) titled "Highway Traffic Noise – guidance on Quiet Pavement Pilot Programs (QPPP) and Tire/Pavement Noise Research."

The QPPP is intended to demonstrate the effectiveness of quiet pavement strategies and to evaluate any changes in their noise mitigation properties over time. Current knowledge on changes over time is extremely limited. Thus, the programs will collect data and information for at least a 5-10 year period, after which the FHWA will determine if policy changes to a State DOT(s) noise program are warranted.

The intent of the proposed experimental section is to allow the additional placement of a carpet drag and longitudinal tined surfaces in Western Washington. Rutting/friction and noise measurements will be taken over time. Currently, WSDOT does not have a means for collecting noise information, however, there is discussion between the Materials Laboratory and Environmental Noise Quality to purchase equipment. The key item for WSDOT is to place a concrete pavement in Western Washington to compliment the work being performed on I-90 in Spokane. The rutting and friction data will be valuable information as WSDOT begins a QPPP.

Scope

This project involves the construction of HOV lanes and the rehabilitation of 5.69 miles of north and southbound I-5. The pavement section for the HOV lanes will consist of 13 inches

(1.08’) of PCCP over 4.2 inches (0.35’) of asphalt concrete over 4.2 inches (0.35’) of crushed surfacing. The total 50-year design ESALs for the single direction traffic are approximately 200 million. The experimental features will be incorporated over the project length.

Carpet Drag and Longitudinal Tining

The final pavement surface texture will be obtained by drawing a carpet drag or longitudinal tines longitudinally along the pavement before the concrete has taken its initial set. The carpet drag will be a single piece of carpet of sufficient length to span the full width of the pavement being placed and adjustable to allow up to 4 feet longitudinal length in contact with the concrete being finished. The target depth of the carpet drag will be a minimum of 1.0 millimeter. Sand patch tests will be conducted by Materials Laboratory personnel to verify the texture depth of the carpet drag sections. The longitudinal tines will be uniformed spaced metal tines. ACPA is currently researching the specification that promises to provide the quietest surface. This specification will be provided to the Contractor as soon as it is obtained.

Initial WSDOT analysis shows that the carpet drag finish provides an equal or better skid resistance than normal WSDOT transverse tined pavements. This is significant considering studded tire wear normally removes transverse tining 3 to 4 years after placing PCCP.

Mix Design

The mix design requirements will utilize PCCP concrete that has a 14-day target flexural strength of 650 psi as specified in Section 5-05 of the 2004 WSDOT Standard Specifications.

Test Section

Approximately one half of the HOV lane in each direction will utilize the carpet drag finish and the other half will receive the longitudinal tining finish.

Control Section

A minimum of 300 feet of each HOV lane in each direction will be constructed with a transverse tined finish to serve as a control section for the longitudinal tining and carpet drag finished test sections**.** WSDOT Standard Specifications will be followed for the depth and spacing of the tines.

Construction

Concrete will be placed by a slip form paver. Except as indicated, 2004 WSDOT Standard Specifications will apply.

Staffing

The Region Project office will coordinate and manage all construction aspects. Representatives from WSDOT Materials Laboratory (one or two persons) will also be involved with documenting the construction.

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Testing

The completed PCCP will be skid tested to determine friction values. The friction values will be measured twice a year on each of the test sections for the duration of the experiment. Pavement condition survey results will be collected on an annual basis as well as rutting and ride measurements. These tests will measure any changes in performance of the pavement with time as a result of studded tire wear.

Reporting

An "End of Construction" report will be written following completion of the project. This report will include construction details, material test results, and other details concerning the overall process. Annual summaries will also be conducted over the next five years. At the end of the five-year period, a final report will be written which summarizes performance characteristics and future recommendations for use of this process.

Cost Estimate

Construction Costs

This contract is currently under construction. The concrete contractor has agreed to provide the carpet drag at no cost to WSDOT.

Testing Costs

Condition Survey – will be conducted as part of statewide annual survey, no cost.

Rut Measurements – 10- surveys (2 hours each) requires traffic control = $12,000

Friction Measurements – 10 surveys done in conjunction with annual new pavement friction testing, no cost.

Noise Surveys – WSDOT is currently pursuing purchasing noise-monitoring equipment. The cost of this equipment is not included in this experimental feature, as this equipment will be used throughout Washington State once noise monitoring on a regular basis begins. However, about $5,000 is anticipated for funds necessary to monitoring noise for periodic surveys on this section of I-5.

Report Writing Costs

Initial Report – 20 hours = $1,500
Annual Report – 5 hours (1 hour each) = $500
Final Report – 10 hours = $1,000

Total Cost = $20,000

Schedule

Construction Date: October 2005

Date	Condition Survey (Annual)	Rut & Friction Measurements (Annual)	End of Construction Report	Annual Report	Final Report
October 2005		X	X		
Spring 2006	X	X		X	
Fall 2006	X	X		X	
Spring 2007	X	X		X	
Fall 2007	X	X		X	
Spring 2008	X	X		X	
Fall 2008	X	X		X	
Spring 2009	X	X		X	
Fall 2009	X	X		X	X