Combined Aggregate Gradation as a Method for Mitigating Studded Tire Wear on PCCP

WA-RD 663.2

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Experimental Feature Report

Final Report
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Combined Aggregate Gradation As A Method for Mitigating Studded Tire Wear On PCCP

Contract 5947
I-90
Sprague Avenue Interchange Phase 3
MP 284.41 to 286.38

Washington State
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This study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

16. ABSTRACT
Two sections of pavement were built with different specifications for the gradation of the aggregates, one with the standard gap-graded aggregate specification and one with a combined gradation specification. Equal wear rates for both sections indicated that the combined aggregate gradation had no positive affect on the pavements resistance to studded tire wear.

17. KEY WORDS
Portland cement concrete pavement, combined gradation, pavement wear, studded tires.

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Project Design

The Eastern Region has been experiencing excessive wear in portland cement concrete pavements due to studded tires. Various measures have been tried to mitigate the effect of studded tires on these pavements including higher strength mixes, additives that increase the abrasion resistance and switching from a standard tined finish to a carpet drag finish. One of the ideas also tried was a switch from the standard aggregate gradation specification to a combined gradation specification. The theory was that the near gap grading of the standard specification might be a contributing factor to the increased wear and that a combined gradation with its more uniform grading would help to mitigate this wear.

The portland cement concrete pavement for Sprague Avenue Interchange Phase 2 (Eastbound Milepost 284.36 to 286.65) that was constructed during the summers of 1999 and 2000 used the standard aggregate specification, while the project that constructed the westbound lanes, Sprague Avenue Interchange Phase 3, used the combined gradation specification. This project ran from Milepost 284.42 to 286.38 and was completed in 2001. The contract special provisions called for the aggregate grading to be plotted on a 45-power chart, and as necessary, coarse or fine aggregate added to optimize the aggregate gradation. Figure 1 shows the actual aggregate gradations from the project before and after it was adjusted to more closely fit the 45-power chart.

These two projects provided a prime opportunity for a side-by-side comparison of PCCP constructed with aggregate grading that meets the existing specification to a PCCP constructed with aggregate grading that meets a 45-power chart or combined gradation.

Aggregate Gradations

The aggregate gradations for the two projects are plotted on a 45-power curve chart in Figure 1. The closer fit of the combined gradation to the 45-power curve is evident from this chart.

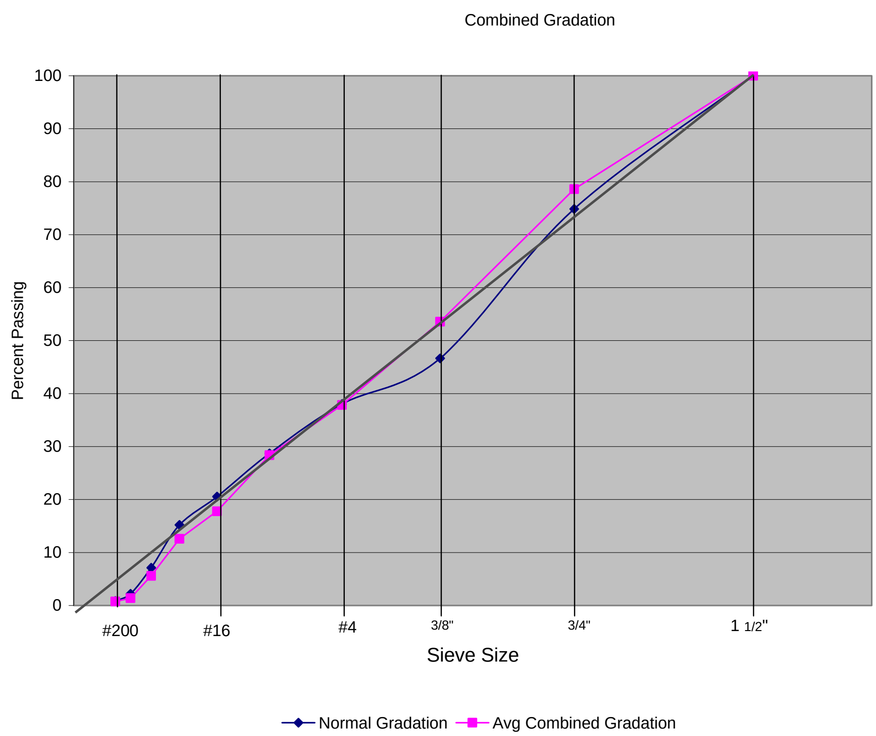

Figure 1. Normal and combined aggregate gradations for the Sprague Avenue Interchange Phase 3.

Cylinder Strengths

Compression tests of the PCCP cylinders showed some difference between the two projects. Cylinders from the combined gradation project had a higher average compressive strength, lower standard deviation indicating less variability, and fewer failed specimens. The strength data is included because higher strength mixes may be more resistant to studded tire wear. Higher strength mixes are being evaluated on I-90 on the project Argonne Road to Sullivan Road, report available at http://www.wsdot.wa.gov/biz/mats/pavement/Argonne_SullivanDraftReport.pdf

Table 1. Comparison of cylinder strength data.

Statistic	WSDOT Standard Gradation	Combined Gradation
Total No. of Cylinder Pairs	70	116
No. of Failed Tests	11	6
Percentage of Failed Tests	15.7	5.2
Average Compressive Strength (psi)	4210	4640
Standard Deviation	730	610

Wear Data

The two projects have been monitored for pavement wear since 2004. The WSDOT Pathway Van was used to collect rutting measurements in the spring and fall of 2004, 2005, 2006, 2007, 2008 and the spring of 2009. These wear measurements are listed in Tables 1 and 2 for the center and median lane, respectively. The tables show the increase in wear over the 5-1/2 years of measurement.

Table 2. Wear measurements for center and median lane				
Date	Center Lane		Median Lane	
	Standard Gradation (mm)	Combined Gradation (mm)	Standard Gradation (mm)	Combined Gradation (mm)
Spring 2004	2.4	2.1	1.5	2.4
Fall 2004	5.3	4.1	3.9	3.3
Spring 2005	6.7	5.1	4.8	4.2
Fall 2005	6.4	4.8	4.5	3.5
Spring 2006	7.6	6.0	5.2	3.9
Fall 2006	8.0	5.9	5.7	4.5
Spring 2007	4.6	8.0	6.7	6.0
Fall 2007	8.1	6.8	5.4	4.2
Spring 2008	9.2	7.7	6.0	4.7
Fall 2008	10.3	8.4	7.3	5.9
Spring 2009	11.9	9.8	8.0	5.8

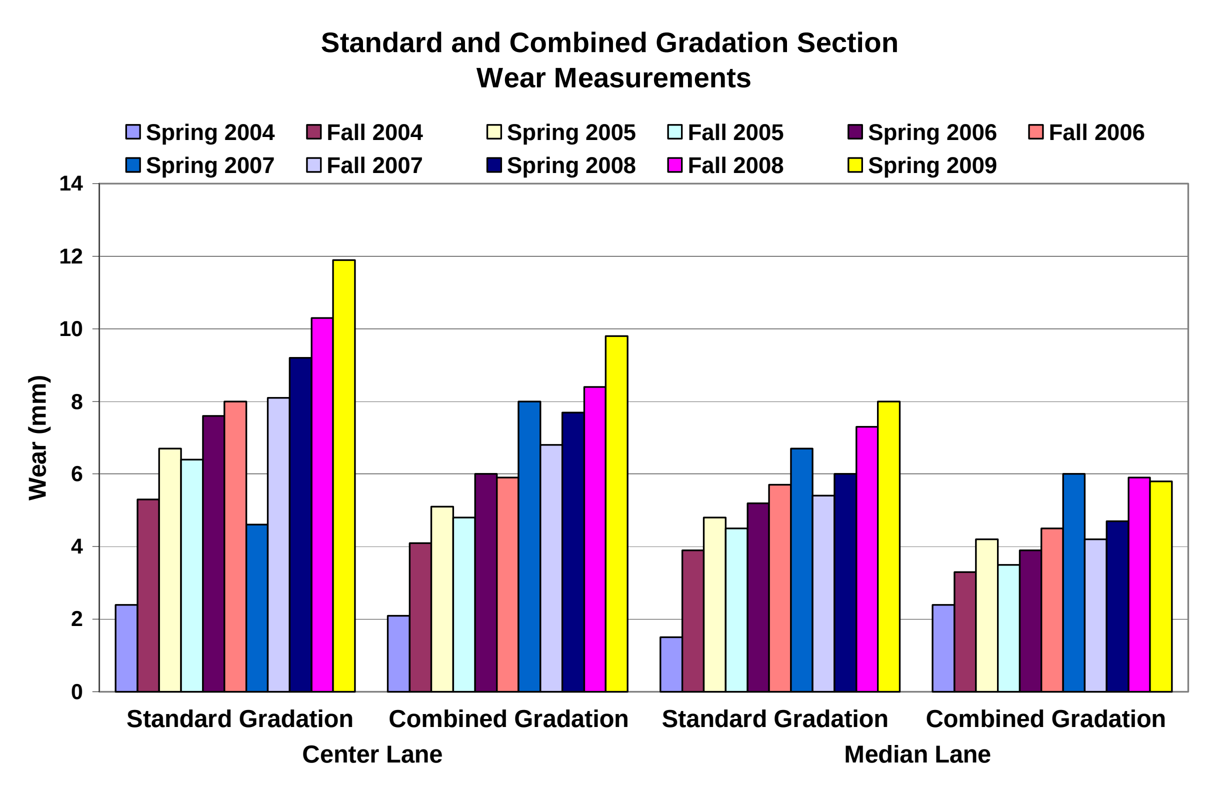

Figure 2. Spring and fall wear measurements for standard and combined gradation sections.

A direct one to one comparison cannot be made between the sections because they are not the same age and have not experienced the same amount of traffic. Two rate of wear calculations can be made, one based on the age of the sections and one based on the traffic experienced by both sections. The section with the standard aggregate gradation was built in 2000 and the section with the combined gradation one year later. Table 3 summarized the rate of wear for each section based on the age of the pavement. The rate of wear is calculated by dividing the average wear for both lanes by the age of the section. The age based rate of wear calculations indicates very little difference between the two sections with a difference of only 0.04 mm per year in favor of the combined gradation.

Table 3. Rates of wear based on age.

Standard Gradation	Center Lane Wear (mm)	Median Lane Wear (mm)	Average (mm)	Rate of Wear (mm/yr)
Fall 2004	5.3	3.9	4.6	1.15
Fall 2005	6.4	4.5	5.5	1.09
Fall 2006	8.0	5.7	6.9	1.14
Fall 2007	8.1	5.4	6.8	0.96
Fall 2008	10.3	7.3	8.8	1.10
			Average	1.09
Combined Gradation	**Center Lane Wear (mm)**	**Median Lane Wear (mm)**	**Average (mm)**	**Rate of Wear (mm/yr)**
Fall 2004	4.1	3.3	3.7	1.23
Fall 2005	4.8	3.5	4.2	1.04
Fall 2006	5.9	4.5	5.2	1.04
Fall 2007	6.8	4.2	5.5	.92
Fall 2008	8.4	5.9	7.2	10.2
			Average	1.05

The rate of wear adjusted for traffic is a little more complicated. Traffic data was collected from the WSPMS in 2006 for the mileposts included in each section. The total traffic for one year was then estimated based on the average daily traffic. A ratio was then determined to correct the greater amount of traffic experience by the standard gradation section that was paved one year earlier. The average daily traffic (ADT) from the 2006 survey for the eastbound lanes was 48,161 and the westbound 43,919. The total traffic for the 6 years (year 2000 to year 2006) experienced by the eastbound lanes was 105,472,765 (48,161 x 365 x 6) vehicles and for the five years the westbound has been in existence is 80,152,175. The ratio between the two directions of travel is 1.316, that is, the westbound wear readings must be multiplied by 1.316 to adjust for the added traffic experience by the older eastbound lanes. For example, the corrected amount of wear on combined gradation section for fall 2006 is 6.8 mm (5.2 mm x 1.316). The corrected wear readings and rates of wear for fall 2006 and fall 2008 are shown in Table 4. The rates of wear for both sections are basically equal with the combined gradation rate of wear are slightly lower in 2006 and slightly higher in 2008 than the wear rates for the standard gradation. The rates of wear calculated using traffic are also slightly higher than those calculated using the age difference only, but all of the rates are very similar, about 1.1 millimeters per year for the average of both lanes..

Table 4. Rates of wear for the fall 2006 and fall 2008 measurements corrected for traffic.

Date	Section	Average for Both Lanes (mm)	Corrected for Traffic Average for Both Lanes (mm)	Rate of Wear (mm/yr)
Fall 2006	Standard Gradation	6.9	6.9	1.15
	Combined Gradation	5.2	6.85	1.14
Fall 2008	Standard Gradation	8.8	8.80	1.10
	Combined Gradation	7.2	9.47	1.18

Conclusion

The following conclusions are made based on the data.

- The use of a combined aggregate gradation did not result did not improve the studded tire resistance of the pavement.

- The project built with the combined aggregate gradation had higher compressive strengths and a lower standard deviation than the project built with the standard aggregate gradation.

Recommendations

The following recommendation is made based on the data from this study.

- The use of combined aggregate gradations should be continued, but not to provide any additional resistance to the pavement against studded tire wear.

- Additional research should be conducted to determine if the higher strength provided by the combined aggregate gradation and lower standard deviations holds true for other projects.

APPENDIX A

Experimental Feature Work Plan

Washington State Department of Transportation

WORK PLAN

Combined Aggregate Gradation for Concrete Pavements

I-90, Contract 5947
Sprague Avenue Interchange Phase 3

Milepost 284.41 to Milepost 286.38

Prepared by

Bob L. Hilmes, P.E.
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Washington State Department of Transportation

January 2001

Introduction

The present contract utilizes WSDOT standard specifications in the determination and analysis of aggregate components. In summary, WSDOT standard specifications tests the coarse and fine aggregate constituents of PCCP individually for adherence to gradations without considering combined affects.

The eastbound lanes parallel to this section were built during the summer of 2000 under a separate contract and utilized these current standards. Premature wear of the pavement as a result of studded tires is being seen. The wear may be caused by the gap grading allowed by the aggregate gradations in the present standard specifications.

Plan of Study

Under this proposal the individual components will be analyzed as previously but these results will then be mathematically and proportionally recombined. These results will then be plotted on a 45-power chart to determine if aggregate (coarse and fine) should be added or proportioned to attain a better distribution of aggregate and possibly a more durable mixture.

This is a prime opportunity for a side-by-side comparison of PCCP constructed during the summer of 2000 with aggregate grading that meets the existing specification and PCCP constructed with aggregate grading that meets a 45-power chart.

Scope

This project will place approximately 41,000 cubic yards of Cement Concrete Pavement on the westbound lanes of SR 90 and associated ramps.

Layout

The PCCP construction will be in the westbound lanes fro MP 284.41 to MP 286.38 as well as the on and off ramps in this section.

Staffing

This research project will be constructed as part of a larger rehabilitation project. Therefore the Region Project office will coordinate and manage all construction aspects.

Representatives from Inland Asphalt Company and WSDOT Materials Laboratory (1 to 3 persons) will also be involved with the process.

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Testing

No additional testing will be required.

Reporting

An "End of Construction" report will be written following completion of the test section. This report will include construction details of the test section, construction test results, and other details concerning the overall process. Annual summaries will conducted over the next 5 years. At the end of the five-year period, a final report will be written which summarizes performance characteristics and recommendations for the use of this process.

Cost Estimate

Construction Costs

Description	Quantity	Unit Cost	Unit	Total Price
Gradation Adjustment	40,869	$1.06	CY	$43,321.14
Total				**$43,321.14**

Testing Costs

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

Walking Profiler – 6- surveys (2 hours each) requires traffic control = $2,000

Report Writing Costs

Initial Report – 20 hours = $1,300

Annual Report – 5 hours (2 hour each) = $500

Final Report – 10 hours = $1,000

TOTAL COST = $48,121.14

Schedule

Construction Date: June and July 2001

Date	Condition Survey	End of Construction Report	Annual Report	Final Report
August 2001		X		
August 2002	X		X	
August 2003	X		X	
August 2004	X		X	
August 2005	X		X	
August 2006	X		X	X