Experimental Feature Report

Final Report
Experimental Feature WA 01-01

NovaChip®

SR-17
City of Soap Lake
MP 75.44 to MP 76.15

Washington State Department of Transportation

1. REPORT NO.	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
WA-RD 697.1		

4. TITLE AND SUBTITLE	5. REPORT DATE
NovaChip®	May 2008
	6. PERFORMING ORGANIZATION CODE WA 01-01
7. AUTHOR(S) Mark A. Russell, Linda M. Pierce, Jeff S. Uhlmeyer, and Keith W. Anderson	8. PERFORMING ORGANIZATION REPORT NO.
. PERFORMING ORGANIZATION NAME AND ADDRESS Washington State Department of Transportation Materials Laboratory, MS-47365 Olympia, WA 98504-7365	10. WORK UNIT NO. 11. CONTRACT OR GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS Washington State Department of Transportation Transportation Building, MS 47372 Olympia, Washington 98504-7372 Project Manager: Kim Willoughby, 360-705-7978	13. TYPE OF REPORT AND PERIOD COVERED Final Report 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

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

16. ABSTRACT

An experimental application of NovaChip® was evaluated on a section of SR-17 through the city of Soap Lake, Washington. NovaChip® was investigated as a possible substitute for HMA Class G that is normally specified through cities on routes that only warrant a bituminous surface treatment.

The NovaChip® was placed in the summer of 2001. Pavement condition survey results and visual observations revealed that the NovaChip® was effective in reducing both the frequency and severity of cracking. Ride quality has remained constant throughout the six year evaluation period and wear/rutting has been minimal. Life cycle cost analysis showed that NovaChip® is comparable to HMA Class G when analyzed on a total project cost basis, but not competitive when only the cost of the overlay is considered.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
NovaChip®, BST, chip seal, life cycle cost	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22616

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
None	None	34	

DISCLAIMER

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ACKNOWLEDGEMENT

The authors would like to thank Frank Bonwell and Paul Mahre for providing detailed information about this project. In addition, thanks to Brad Schmitz and Steve Van De Bogert of SemMaterials and the WSDOT North Central Region for making this project possible.

OBJECTIVE

The purpose of this project is to determine the constructability, performance and cost effectiveness of NovaChip® for use on low volume roads in Washington State. SemMaterials*, in conjunction with the North Central Region Program Management Office, Project Engineers Office, Materials Office, and Ephrata Maintenance Office, placed a total of 26,000 square yards of NovaChip® on a curbed portion of SR-17 through Soap Lake in August of 2001. This report documents the performance of NovaChip® five years after completion, compares NovaChip® life cycle cost against other rehabilitation options and provides recommendations for future implementation.

* The NovaChip® in Soap Lake was placed by what was then Koch Pavement Solutions. In 2005 Koch Pavement Solutions was acquired by SemGroup L.P. which operates under SemMaterials L.P. in the United States.

INTRODUCTION

Bituminous surface treatment (BST) or "chip seal" is a common surfacing type on many miles of highways in the eastern half of the state. Normally, the use of BST is limited to sections of highway where the design equivalent single axle loads (ESALs) are less than 500,000 and the average daily traffic (ADT) is less than 2,000. However, the use of BST through cities often results in complaints from city officials and city residents due to its rough texture and the potential for flying chips. To combat this problem, Washington State Department of Transportation (WSDOT) began placing hot mix asphalt (HMA) Class D (open graded friction course) or HMA Class G (fine graded dense asphalt) on state highways that pass through small cities. Due to the raveling problems that WSDOT has experienced with Class D friction courses [1] and the shorter overlay life (six to 10 years) of HMA Class G, a more cost effective, durable and maintainable pavement surface was desired. Based on reports from other states, it appeared that the NovaChip® process could provide the durability and pavement life WSDOT desired.

NOVACHIP® BACKGROUND

Originally developed in France in 1986 [2], NovaChip® is a paving process that places a thin (3/8 to 3/4 inch), gap graded coarse aggregate hot mix asphalt over a Novabond® membrane (polymer modified asphalt emulsion seal coat). NovaChip® is marketed as a pavement rehabilitation, preventive maintenance or surface treatment that has an extremely durable surface with improved skid resistance and is resistant to rutting and wear. Based on the United States and European experience, SemMaterials, the licensed applicator of NovaChip®, anticipates that NovaChip® will provide a service life of approximately 10 to 12 years. The main advantages as reported by Kandhal [2] are:

- Excellent adhesion (no chip loss).
- Reduced rolling noise (urban use).
- Rapid application.
- Quick opening to traffic.

Other advantages as reported in the literature [3] include:

- Placement in a single pass.
- Excellent bond to the underlying surface (delamination from the surface is not a common problem).
- Lower user delay costs during construction.
- Coarse aggregate matrix that has excellent macro texture qualities resulting in good skid resistance and reduced backspray of roadway moisture and hydroplaning.
- Overhead clearances, curbs and drainage profiles are maintained due to the thin lift.

NovaChip® is intended as a surface treatment to be used on structurally sound pavement. It is not designed to bridge weak spots or to cover underlying pavement deficiencies. Adequate pavement repair to address alligator cracking or potholes is necessary to ensure good performance. Non-working cracks, which are less than ¼ inch in width, do not require sealing prior to the placement of NovaChip® due to the heavy application of the Novabond® membrane. Sealing cracks greater than ¼ inch is recommended.

Specific candidates for NovaChip® include roadways that need restoration due to weathering, raveling, and oxidation. NovaChip® can also be used to restore surface smoothness by filling ruts less than ½ inch and smoothing other surface irregularities; however, it is not intended for use as a leveling course or for pavements with more than ½ inch rutting [3]. Prior to selecting NovaChip®, the existing pavement distresses should be quantified according to the WSDOT Pavement Surface Condition Rating Manual [4]. SemMaterials provides guidelines for the type and severity of specific distress condition that can exist prior to the application of NovaChip® (see Appendix A).

NovaChip® use in the United States dates back to 1992, where sections were placed on state highways in Texas and Alabama. Pennsylvania has placed NovaChip® since 1993. Hanson [3] reports the performance has been good to excellent for the three to five year monitoring periods reported. Nationally, upwards of 6.6 million square yards of NovaChip® were placed during 2001. SemMaterials reports that New Mexico placed 150,000 square yards in 2000 and increased this quantity to one million square yards in 2001. California has placed upwards of 1.5

million square yards for state, city and county uses combined. A single contract in California awarded one million square yards for the 2002 construction season. Appendix B lists several states that have used NovaChip® as well as the associated ADT and percent trucks. The literature has not reported ESAL levels on the roadways where NovaChip® has been used.

Twenty six states were scheduled to have NovaChip® projects in 2002. Within Washington State, several cities and counties have expressed interest in placing NovaChip® surfacing on future rehabilitation projects.

NOVACHIP® MATERIALS

NovaChip® consists of an aggregate skeleton made up of coarse aggregate and mastic made from fine aggregate and asphalt binder. Mineral filler is optional and is sometimes necessary to meet the grading requirements. Hydrated lime, fly ash, baghouse fines, and Type 1 Portland Cement are acceptable mineral fillers. Additionally, a Novabond® membrane is used to seal the existing roadway surface and bond the NovaChip® to the roadway.

Aggregates

NovaChip® aggregates must be nearly cubical and very durable. Extensive testing is performed on coarse aggregate (material retained on the #4 sieve), and must meet the requirements shown in Table 1. Requirements for the fine aggregate (material passing the #4 sieve) are listed in Table 2.

Table 1. Coarse aggregate properties.

<table>
<tr><th colspan="2">Tests</th><th>Method</th><th>Limit</th></tr>
<tr><td colspan="2">Los Angeles Abrasion Value, % loss</td><td>AASHTO T 96-94</td><td>35 max</td></tr>
<tr><td rowspan="2">Soundness, % loss</td><td>Magnesium Sulfate or</td><td>AASHTO T 104-94</td><td>18 max</td></tr>
<tr><td>Sodium Sulfate</td><td>AASHTO T 104-94</td><td>12 max</td></tr>
<tr><td colspan="2">Flat & Elongated Ratio, % @ 3:1</td><td>ASTM D 4791</td><td>25 max</td></tr>
<tr><td colspan="2">Percent Crushed, single face</td><td>ASTM D 5821</td><td>95 min</td></tr>
<tr><td colspan="2">Percent Crushed, two or more Mechanically crushed faces</td><td>ASTM D 5821</td><td>85 min</td></tr>
<tr><td colspan="2">Micro-Deval, % loss</td><td>AASHTO TP 58-99</td><td>18 max</td></tr>
</table>

Table 2. Fine aggregate properties.

Tests	Method	Limit
Sand Equivalent	AASHTO T 176-86	45 min
Methylene Blue (on materials passing #200)	AASHTO TP-57-99	10 max
Uncompacted Void Content	AASHTO T 304-96	40 min

The binder selection for the NovaChip® asphalt is based on the climate for a specific geographic location, traffic levels and vehicle speeds. The binder must meet AASHTO MP1 for the Performance Grade (PG) used. Additionally, the binder must meet an elastic recovery requirement with a minimum value of 60 according to ASTM D6084. Hanson [3] reported that both unmodified and modified binders have been used.

Novabond® Membrane

The liquid Novabond® membrane is reported to provide a superior bond between the NovaChip® and the roadway while providing a water proofing membrane. Typically, the Novabond® membrane is shot at a rate of 0.13 to 0.27 gallons per square yard with the actual rate determined by the condition of the existing roadway at the time of construction. The NovaChip® is placed on the Novabond® within three seconds of application on the roadway.

NovaChip® Mix Types

NovaChip® wearing courses are placed to compacted depths of approximately ½ inch to ¾ inch thick. Specifications for the three mix designs, Types A, B and C are shown in Table 3. Type A is not commonly used and is reserved for pavements such as airports or areas where a very tight surface is needed. Type A also has the lowest roadway friction numbers. Type B is used for most applications in the United States and has a more open texture and with higher friction numbers than Type A. Type C has the most open texture and is used on the highest traffic areas. Type C provides the best friction numbers and is also the best at dissipating surface water.

Table 3. NovaChip® mixture specifications.

Sieves	Composition by Weight					
	1/4 inch Type A		3/8 inch Type B		1/2 inch Type C	
	Design General Limits (% passing)	Production Tolerance, % (+/-)	Design General Limits (% passing)	Production Tolerance, % (+/-)	Design General Limits (% passing)	Production Tolerance, % (+/-)
3/4 inch					100	
1/2 inch			100		85 - 100	
3/8 inch	100		85 - 100	5	60 - 80	5
#4	40 - 55	4	28 - 38	4	28 - 38	4
#8	22 - 32	3	25 - 32	4	25 - 32	4
#16	15 - 25	3	15 - 23	3	15 - 23	3
#30	10 - 18	3	10 - 18	3	10 - 18	3
#50	8 - 13	3	8 - 13	3	8 - 13	3
#100	6 - 10	2	6 - 10	2	6 - 10	2
#200	4 - 7	2	4 - 7	2	4 - 7	2
Asphalt Content	5.0 - 5.8		4.8 - 5.6		4.6 - 5.6	

NOVACHIP® PROCESS

The NovaChip® process begins at the asphalt production plant where the aggregate and binder are mixed in a batch or drum plant. NovaChip® requires a mixing temperature of 300 to 350° Fahrenheit which is comparable to conventional hot mix asphalt. Since NovaChip® is a gap graded mixture, caution must be used to avoid draindown if asphalt storage silos are used. NovaChip® should not be stored for more than four hours.

NovaChip® application utilizes a single piece of specially designed equipment that places the NovaChip® surfacing and Novabond® membrane in a single pass. The Novapaver and its basic components are shown in Figures 1 and 2.

Figure 1. NovaChip® Paving Machine.

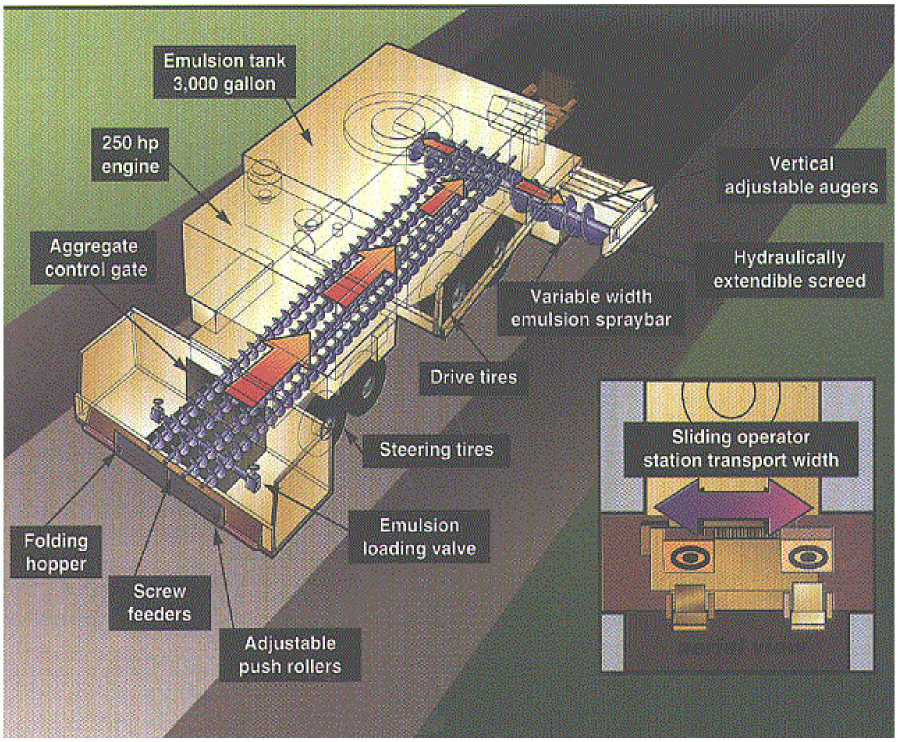

Figure 2. Elements of a NovaChip® Paving Machine.

Following production of the asphalt, conventional haul trucks deliver the hot mix to the paver. Once the asphalt is delivered to the load hopper of the paver, a four-auger system delivers material to the rear of the paver. Conventional augers distribute the asphalt the full width of the roadway. Just seconds before the paver distributes the hot mix to the roadway, the Novabond® membrane is sprayed on the roadway surface.

Compaction is started immediately after the NovaChip® placement and must be completed before the mix reaches 195° F. Compaction is obtained partially by the vibratory screed of the paver and then by one or two double drum rollers used in the static mode with a minimum weight of ten tons. The compaction process is used to seat the aggregate into the Novabond® membrane rather than to obtain density, thus eliminating density specifications. Only one or two static passes from each roller are required to adequately seat the material. The crushing of the NovaChip® aggregate indicates a roller weight that may be too large.

SOAP LAKE – PERFORMANCE

A field review conducted in May of 2007 revealed that the NovaChip® is performing well given its age of nearly six years. The quantity of reflective cracking has increased since the field review in June of 2003, however, the cracks remain tight.

Prior to placing the NovaChip®, major deficiencies in this section consisted of transverse, alligator and longitudinal cracking. Transverse cracks were full width, one to two inches wide and slightly depressed. Longitudinal cracking was erratic and generally of low severity (less than ¼ inch wide).

Figures 3 through 6 show the cracking that was present prior to construction and after construction from the May 2007 review. The photos illustrate a noticeable decrease in the severity of the cracking and the overall improvement in the appearance of the surface of the pavement.

Figure 3. Medium to high severity pre-existing transverse crack.

Figure 4. Pre-existing longitudinal and transverse cracking.

Figure 5. Transverse crack, May 2007.

Figure 6. May 2007 longitudinal and transverse crack.

WSDOT conducts pavement condition surveys on all state highways annually. Tables 4 and 5 list specific distresses observed each year from 1996 through 2006 the last year of data available at the time of this report. Surveys occur in the fall, so the 2001 survey represents the condition of the newly placed NovaChip® overlay.

Table 4 shows a significant reduction in the frequency and severity of the cracking between survey years 1999 and 2000. It is not clear what caused this reduction and it contradicts evidence from pre-construction photos taken in 2001 which clearly show medium to high severity cracking.

Table 4. Specific cracking observed on SR 17 through Soap Lake.									
Survey Year	Low Severity Cracking			Med Severity Cracking			High Severity Cracking		
	Alligator	Longitudinal	Transverse	Alligator	Longitudinal	Transverse	Alligator	Longitudinal	Transverse
1996	2.7	1.1	0.0	0.2	28.9	6.5	0.0	0.0	0.0
1997	4.3	0.0	0.0	0.0	30.0	4.7	0.0	0.0	2.4
1998	26.8	0.0	0.0	0.0	6.3	0.0	0.0	102.5	10.9
BST Class D w/ Pre Seal 1998									
1999	0.0	39.7	0.2	12.4	85.5	2.4	0.2	0.0	3.7
2000	13.1	19.5	4.9	0.0	0.0	0.0	0.0	0.0	0.0
NovaChip® Placement August 2001									
2001	1.2	2.0	.3	0.1	0.0	0.1	0.0	0.0	0.0
2002	0.0	3.3	0.0	0.6	0.0	0.1	0.0	0.0	0.0
2003	0.0	8.0	2.7	0.0	0.0	0.2	0.0	0.0	0.0
2004	3.5	27.8	5.0	0.0	0.0	0.6	0.0	0.0	0.0
2005	0.4	59.7	7.4	0.0	0.0	0.0	0.0	0.0	0.0
2006	4.3	34.1	5.4	0.0	1.6	0.3	0.0	0.0	0.0

As can be seen in Table 4, NovaChip® eliminated the medium and high severity cracking that existed prior to the overlay. A few low severity reflective cracks were apparent soon after the overlay was placed, but significant amounts of cracking did not recur until 2004, three years after application. Even though the 2005 and 2006 low severity cracking data shows inconsistent results, the mid and high severity cracking is still very low.

Survey Year	Low Severity			Medium Severity			High Severity		
	Ravel	Flush	Patch	Ravel	Flush	Patch	Ravel	Flush	Patch
1996	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1997	12.5	0.0	0.0	0.0	2.6	1.6	0.0	0.0	0.0
1998	0.0	19.7	0.0	0.0	5.3	3.2	0.0	0.0	0.0
BST Class D w/ Pre Seal 1998									
1999	0	0	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0	0	0
NovaChip® Placement August 2001									
2001	0	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	0	0

Table 5. Specific raveling, patching and flushing observed on SR 17 through Soap Lake.

Table 5 shows that distress other than cracking was not a problem on this section before or after placement of the NovaChip®.

Table 6 lists the Pavement Structural Condition (PSC), roughness and rutting indexes from the WSPMS. The improvement in PSC after the overlay is a result of the reduction of cracking by the NovaChip® overlay. PSC has steadily decreased since placement but is still above 50, the value at which a rehabilitation of the pavement is due. The data suggests that this pavement may perform another three to four years before rehabilitation is due. If crack severity remains low for this low volume route, crack treatment by maintenance personnel may be able to further extend the pavement life past its due date.

Ride measured in International Roughness Index (IRI) in centimeters per kilometer and rutting show improvements over the previous BST surface and do not appear to be deteriorating significantly.

Table 6. Distress summary.

Survey Year	Pavement Structural Condition (PSC)[1]	International Roughness Index (cm/km)	Rutting (mm)
1996	63.7	200	5.2
1997	57.9	N/A	N/A
1998	11.3	200	5.5
BST Class D w/ Pre Seal 1998			
1999	32.7	160	3.8
2000	63.6	160	4.5
NovaChip® Placement August 2001			
2001	93.2	130	3.2
2002	92.7	120	3.7
2003	87.2	130	3.8
2004	76.2	120	3.2
2005	72.9	120	2.3
2006	74.0	130	2.8

[1] Pavement Structural Condition (PSC) is the pavement ranking according to those distresses that are related to the pavements structural ability to carry the loads. For asphalt pavements these distress include: transverse, longitudinal, and alligator cracking and patching. This ranking ranges from 100 (best condition) to 0 (worst condition).

DISCUSSION – NOVACHIP® USE IN WASHINGTON STATE

SemMaterials has been marketing NovaChip® in Washington State since 1999. The Soap Lake project has provided a platform to evaluate the capabilities of this product. The questions raised by WSDOT engineers about the use of NovaChip® can be summarized in two categories.

- How does NovaChip® performance compare with similar rehabilitation treatments used by WSDOT?
- What is the cost of NovaChip® compared to other similar WSDOT rehabilitation treatments?

These questions are explored below.

NovaChip® Compared to WSDOT HMA Class G

Within WSDOT, the application of NovaChip® is comparable with a HMA Class G overlay. WSDOT often places one inch of HMA Class G through selected cities that are on BST routes to reduce noise and roughness problems and to eliminate the flying chips that are common with BST treatments. A Class G overlay provides minimal structure and is used to maintain low volume roadways, typically less than one million equivalent single axle loads (ESALs) over 15 years. A HMA Class G overlay typically last six to eight years, however, spans of ten years and longer has been documented. The use of HMA Class G statewide is low.

NovaChip® Compared to WSDOT HMA Class A or Superpave HMA

WSDOT typically places HMA such as Class A or Superpave on Interstate and primary arterials. The typical thickness of HMA overlays placed in Washington is 1.8 inches. On minor arterials, depending on ESALs, both HMA and BST are used.

Where additional pavement structure is not required to rehabilitate a roadway, an asphalt friction course such as NovaChip® would be adequate. However, one limitation with using NovaChip® is its unknown performance on roadways with high usage of studded tires and on high volume routes such as Interstate and primary arterials. WSDOT used open-graded friction courses (Class D) in the 1980's and early 1990's, but the use of these thin surfaces has been suspended due to raveling and rutting mainly caused by studded tires [1].

Similar to NovaChip®, Class D overlays were placed on pavements that were weathered, raveled, or oxidized but were structurally sound. However, the expected service life of eight years was reduced to less than four years due to excessive rutting from studded tires on the higher volume routes. The failure modes of Class D asphalt included raveling (aggregate particles that are dislodged from the pavement) and delamination (loss of bond between pavement layers).

WSDOT is interested in using NovaChip® on low volume roadways, however, depending on future research and the resistance to studded tires, NovaChip® could be used on higher volume routes. At this time, the resistance of NovaChip® to studded tire wear has not been determined.

NovaChip® Cost Comparison

The following section summarizes NovaChip® costs compared to WSDOT Standard HMA mixes Class A, G and Superpave. Note that all costs are in 2001 dollars, the year of construction.

Average HMA Class A and Superpave Costs

Average construction bid prices for HMA Class A or Superpave HMA summarized by WSDOT's six regions are shown in Table 7. These prices are for asphalt projects greater than 2,500 tons. The average price for HMA Class A in Eastern Washington in 2001 was about $27.26 per ton and in Western Washington was about $32.59 per ton. The average price for ½ inch Superpave HMA experienced in Eastern Washington was about $26.38 per ton and Western Washington about $34.12 per ton. For Eastern Washington, this equates to about $2.80 per square yard for HMA Class A and $2.71 per square yard for ½ inch Superpave HMA placed 1.8 inches thick. For Western Washington this equates to about $3.35 per square yard for HMA Class A and $3.51 per square yard for ½ inch Superpave HMA.

Table 7. WSDOT average bid prices in 2001 for asphalt concrete HMA Class A or ½ inch Superpave.					
Eastern Washington			Western Washington		
Region	Asphalt Type[1]		Region	Asphalt Type[1]	
	HMA Class A ($/SY)	½ inch Superpave ($/SY)		HMA Class A ($/SY)	½ inch Superpave ($/SY)
Eastern	2.71	2.50	Northwest	3.29	3.38
North Central	2.85	2.74	Olympic	3.58	4.13
South Central	2.85	2.93	Southwest	3.08	3.41

[1] Asphalt type based on Performance Grade (PG) binders.

Average HMA Class G Costs

The average 2001 HMA Class G asphalt prices are shown in Table 8. The prices shown are for projects greater than 1,000 tons. Usage of HMA Class G in two of the Eastern Washington regions is minimal and data was not available. For the Eastern Region, the HMA Class G price per square yard was $2.06. For Western Washington, the average price was $1.71 per square yard.

Table 8. WSDOT average bid prices in 2001 for HMA Class G.			
Eastern Washington		Western Washington	
Region	Average Asphalt Price ($/Square Yard)	Region	Average Asphalt Price ($/Square Yard)
Eastern	2.06	Northwest	1.65
North Central	[1]	Olympic	1.98
South Central	[1]	Southwest	1.86

[1] HMA Class G usage is low. Insufficient data to calculate a price.

NovaChip® Costs

Since NovaChip® was new to Washington State, prices were based on Koch Materials estimates. Nationwide, Koch reported material and placement costs of $4.00 per square yard in the Western United States and $3.50 per square yard in the Eastern United States. These prices were predicated on projects that have 100,000 to 200,000 square yards. As with any paving operation, factors that will influence NovaChip® costs are contractor familiarity and quantity being placed. SemMaterials estimated NovaChip® costs for larger projects would be $3.00 to $4.00 per square yard in Washington State. Table 9 summarizes and compares NovaChip® prices to traditional WSDOT pavement types.

Table 9. Summary of asphalt costs (material and placement) for 2001.

Pavement Type	Cost Range ($/Square Yard)
HMA Class G	1.65 - 2.06
HMA Class A	2.71 - 3.58
½ inch Superpave	2.50 - 4.13
NovaChip®	3.00 - 4.00

While the preceding table compares pavement type bid prices on a square yard basis, comparing pavement types on a project cost may be more reasonable. The reason for this is that individual bid prices do not take into account several factors including traffic control, guardrail adjustments, edge mitigation, and utility adjustments. For instance, on a NovaChip® project there would be minimal traffic control or guardrail adjustments.

To illustrate this difference, consider WSDOT's Preservation Model using an HMA (such as Class A or Superpave) placed 1.8 inches deep and a HMA (such as Class G) placed 1.0 inches deep for a typical rural four-lane highway 64 feet wide. The typical statewide project cost used for budget purposes was about $90,000 per lane mile or $9.59 per square yard to rehabilitate (two 12 foot lanes with 8 foot shoulders in each direction) with HMA Class A or ½ inch Superpave. For HMA Class G, the cost per lane mile was approximately $50,000 or $5.33 per square yard. These figures take into consideration all costs required in a project including mobilization, crack sealing, pavement repair, tack coat, traffic control, asphalt materials and placement, road approaches, shoulder dressing and preliminary and construction engineering.

The NovaChip® project cost for the 26,000 square yards of NovaChip® placed was $58,000 per lane mile (this total was derived from the Soap Lake project costs shown in Appendix C). The ratio between a typical HMA Class A or ½ inch Superpave project and

NovaChip® project cost was 1.6 with the HMA project being more expensive. Since WSDOT has only constructed the one experimental project, this comparison may not reflect true lane-mile costs for NovaChip®. However, it appears the NovaChip® costs, based on a project basis from the costs provided for the SR 17 project, falls between a HMA Class G and a HMA Class A or ½ inch Superpave overlay. Table 10 illustrates this comparison.

Table 10. Project costs for various rehabilitation treatments in 2001.

Pavement Type[1]	Project Cost ($/Lane Mile)	Project Cost ($/Square Yard)
BST	14,000	1.49
HMA Class G[2]	50,000	5.33
NovaChip®	58,000	6.18
HMA Class A or ½ inch Superpave[3]	90,000	9.59

[1] Comparisons are based on two 12-foot lanes with 8-foot shoulder in each direction.
[2] HMA Class G compacted depth is 1.0 inches.
[3] Class A or ½ inch Superpave compacted depth is 1.8 inches

Life Cycle Cost Comparison

In order to do a life cycle cost comparison of NovaChip® to other rehabilitation treatments the lifespan of NovaChip® must be determined. The difficulty is that little information is available on the lifespan of NovaChip®, mainly because it has not been in use long enough for good service life data to be collected. SemMaterials anticipates a service life of approximately 10 to 12 years. Other sources report a lifespan ranging from seven to twelve years [5]. The lifespan of pavement is highly dependant on environmental conditions. WSDOT's experience is that asphalt pavements east of the Cascade crest do not last as long as pavement on the west side. The more severe environmental conditions east of the Cascade crest reduce the service life of asphalt pavements. The more severe environment would most likely also affect the NovaChip® overlay resulting in a service life at the low end of the range.

Another method of predicting the service life of the NovaChip® in Soap Lake is to use Washington State Pavement Management System (WSPMS). WSPMS uses annual pavement survey data to predict when a pavement is due for rehabilitation. Regression equations formulated from the annual distress survey data are used to predict PSC values for future years. Once the calculated PSC value reaches 50 the pavement is due for rehabilitation. A PSC is calculated for each analysis unit (an analysis unit is a length of road used as a reference for analyzing pavement data) within the project. The NovaChip® overlay in Soap Lake consists of seven analysis units. Figure 7 plots the actual pavement survey data and the weighted average of the predicted PSC for the seven analysis units making up the NovaChip® overlay.

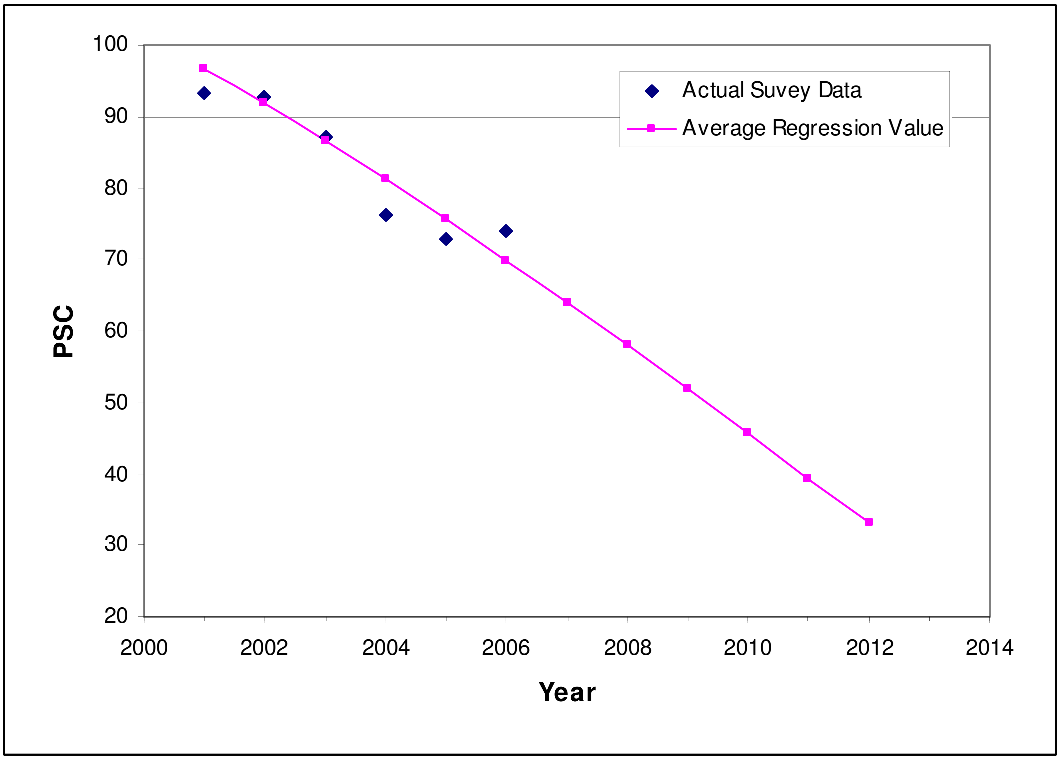

Figure 7. Soap Lake overlay PSC regression curves.

The plot in Figure 7 indicates that the overlay in Soap Lake will be due for replacement between 2009 and 2010 depending on the segment. This means that rehabilitation would have to occur during the eight to nine years after placement. Eight to nine years is at the lower end of the predicted service life range of seven to twelve years which seems reasonable given the shorter lifespan of pavement east of the Cascade crest.

HMA Class G and NovaChip® are compared using annual worth analysis in Table 12. As mentioned earlier Class G typically lasts six to eight years so an average life of seven years for class G is used in the analysis.

Table 11. Annual worth of various rehabilitation treatments.

Rehabilitation Type[1]	Estimated Time Between Treatments (yrs)	Annual Worth ($/Lane Mile)	Annual Worth ($/Square Yard)
BST	6	2,700	0.28
HMA Class G[2]	7	8,300	0.89
NovaChip®	8-9	7,800 - 8,600	0.83 - 0.92
HMA Class A or ½ inch Superpave[3]	10	11,100	1.18

[1] Comparisons are based on two 12-foot lanes with 8-foot shoulder in each direction.
[2] HMA Class G compacted depth is 1.0 inches.
[3] Class A or ½ inch Superpave compacted depth is 1.8 inches.

Annual worth analysis predicts the cost of NovaChip® to be comparable to HMA Class G. This suggests that NovaChip® could be a suitable alternative to HMA Class G, however, NovaChip® is not comparable to HMA Class G on all projects. When only the cost of the pavement is considered, the base cost for placing NovaChip® is twice that of HMA Class G (see Table 9). When other project cost such as traffic control, utility adjustments, edge mitigation and guardrail adjustments are considered, NovaChip® project cost is only 16 percent higher than HMA Class G (see Table 10). So a large part of the reason that NovaChip® is comparable in price is that other project costs associated with placing a HMA Class G overlay are much higher. This could make NovaChip® a good alternative when the other costs associated with a thicker rehabilitation treatment such as HMA Class G are high. However, if the cost associated with placing a thicker rehabilitation treatment is low, HMA Class G would be the less costly alternative. A comparison of total project cost should be made before selecting NovaChip® over a HMA Class G overlay.

CONCLUSIONS

The NovaChip® project in Soap Lake has demonstrated the following:

- NovaChip® was effective in reducing both the frequency and severity of cracking. The cracks that did reappear tended to be tighter and the overall appearance of the roadway was improved.
- Ride quality improved after the placement of the NovaChip® overlay and has remained constant for the four years after the overlay.
- NovaChip® reduced the rutting of the existing pavement and only a slight increase in rutting was present four years after the overlay.
- The long-term performance of NovaChip® on high volume arterials with significant studded tire use in Washington State is uncertain at this time. More research on this issue is needed and may be a limiting factor for use of NovaChip® in Washington State.
- Life cycle cost on NovaChip® is comparable to HMA Class G when analyzed on a project cost basis. However, when only the cost to place the overlay is considered, the cost to place HMA Class G is significantly less. An analysis of the total project cost is necessary to determine if NovaChip® is a cost effective alternative to HMA Class G.

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3. Hanson, Douglas I., Construction and Performance of Ultra-Thin Bonded HMA Wearing Courses, Transportation Research Record 1749, TRB, National Research Council, Washington D.C., 2001, pp 53-59.

4. Pavement Surface Condition Rating Manual, Washington State Department of Transportation, March 1992.

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APPENDIX A

NOVACHIP® DESIGN CRITERIA

Roadways that are potential candidates for NovaChip® should exhibit satisfactory structural condition with uniform crown and the following characteristics:

Cracking

1. Longitudinal and transverse cracking should not exceed medium severity.
2. Block cracking should not exceed moderate severity.
3. Edge cracking should not exceed moderate severity.
4. Reflection cracking at joints should not exceed moderate severity.

Cracks that are less than ¼ inch will be adequately sealed by the Novabond® membrane. Cracks greater than ¼ inch should be cleaned or routed and sealed flush with an approved crack sealing material. Cracks should not be overfilled.

Patching and Potholes

1. Patches should not exceed moderate severity.
2. Potholes should not exceed moderate severity.

In both cases, potholes and patches should be properly repaired prior to the NovaChip® surfacing.

Surface Deformation

Rutting should not exceed ½ inch. Where rutting exceeds ½ inch, the ruts should be milled or leveled with suitable material prior to the placement of NovaChip®.

Surface Defects

1. Bleeding should not exceed moderate severity.
2. Polished aggregate is acceptable.
3. Raveling may be severe.

APPENDIX B

NOVACHIP® PROJECT SUMMARY

The following list shows NovaChip® projects that have been completed across the United States the average daily traffic (ADT) and the percent trucks. ESALs were not provided.

Table 12. Summary of NovaChip® projects constructed by various agencies across the United States (list provided by SemMaterials).

State	Road	ADT	Percent Trucks
Alabama	I-65, Cullman	60,000	
Alabama	I-29, Birmingham	165,000	
Arkansas	Ironton Road, Bingham Road, Pulaski County	1,600	10%
Arkansas	Lawson Road, Pulaski County	1,600	40%
Colorado	6th St., Glenwood Springs	23,000	
Illinois	16th Street, York Twp. (Lombard)	1000	<1%
Illinois	19th Avenue, Brookfield Twp. (Morris)	1000	<1%
Iowa	I-69, Ames	8000	
Louisiana	Calcasieu Parish Project No. 2000-11	3500	
Maryland	Route 12	17,000	
Maryland	Route 80	5000	
Michigan	17½ Mile Road, Calhoun County	1,500	1%
Michigan	McDevitt Dr., Jackson County	13,500	10%
Michigan	State Park Dr., Bay County	11,000	6%
Michigan	Tittabawassee Road, Saginaw County	30,000	15%
Michigan	Tittabawassee Road/ Adams Dr., Saginaw County	5,000	5%
Michigan	West River Dr., Kent County	25,000	5-10%
Minnesota	I-35, Minneapolis-St. Paul Metro area	35,000	15%
Minnesota	TH 169, Princeton, MN	14,477	4%
New Jersey	Garden State Parkway	150,000	
New York	I-95	145,000	
New York	New York Thruway	80,000	
North Carolina	I-440	60,000	
Ohio	SR14	30,000	20%
Ohio	SR261	10,000	10%
Ohio	I-76	60,000	25%
Ohio	SR124	10,000	40%
Ohio	Mahoning Intersections	10-20,000	10%/ 25%
Pennsylvania	I-95, Philadelphia	85,000	
Pennsylvania	Route 100	100,000	
Pennsylvania	Rt. 422, Reading	50,000	
South Dakota	I-29	27,500	12%
Texas	US 380 (near Denton)	15-20,000	35%
Wisconsin	Field St., Muskogee	500	10%
Wisconsin	Hwy 18	5000	20%