NOVACHIP®

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

Post Construction/Performance Report
Experimental Feature WA01-01

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OBJECTIVE

The purpose of this project is to determine the constructibility, performance and cost effectiveness of NovaChip® for use on low volume roads in Washington State. Koch Pavement Solutions, 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. This report will provide a brief history of NovaChip®, discuss project selection and application, and document the project construction, and performance 22 months after construction. Performance will be evaluated over the next five years or until such time that no further useful information can be obtained. At that time, a final report will be written to document the NovaChip®'s performance, life cycle costs, and implementation procedures (if applicable).

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 (6 to 10 years) of Class G, a more cost effective, durable and maintainable pavement surface is desired. Based on reports from other states, it appears that the NovaChip® process may provide the durability and pavement life WSDOT desires.

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 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, resistance to rutting and wear resistance. Based on the United States and European experience, Koch Pavement Solutions 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 of NovaChip® in one 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 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]. Koch Pavement Solutions recommends specific distress conditions for placing 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. Koch Pavement Solutions reports that New Mexico placed 150,000 square yards in 2000 and increased this quantity to 1 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 1 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 are 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 a 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 existing 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.

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

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 speed. 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 3 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 roadway 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 also best dissipates 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 selected gradation is produced at 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® placement 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 Photo 1 and Figure 1.

Photo 1. Novachip Paving Machine.

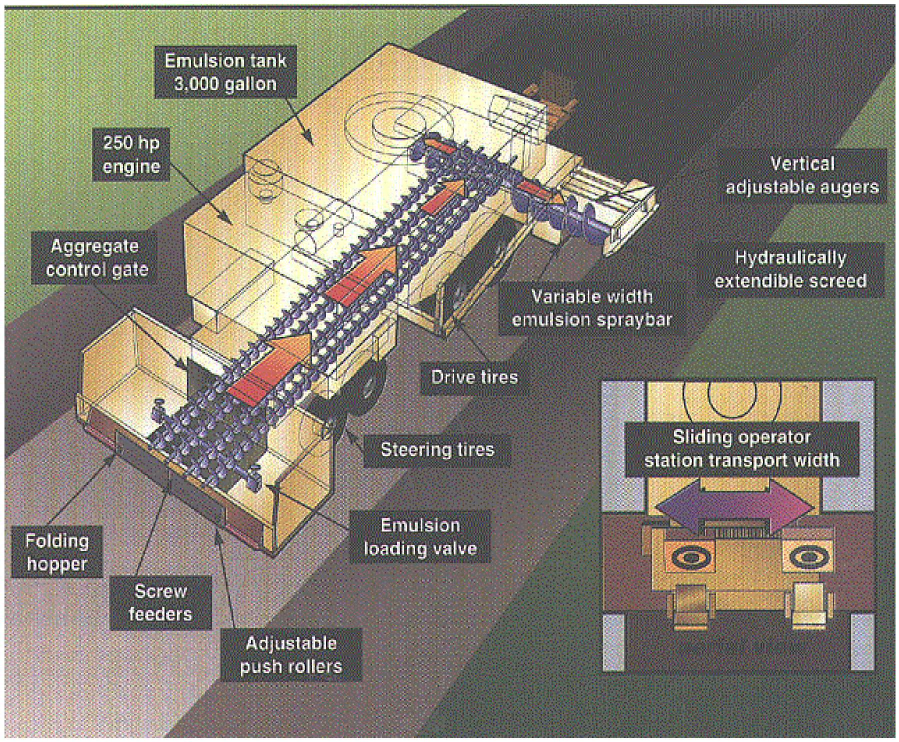

Figure 1. Elements of a NovaChip® Paving Machine.

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 should be started immediately after the NovaChip® placement and 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 10 tons. The process used to compact NovaChip® is to seat the asphalt 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 CONSTRUCTION

Project Background

In the fall of 2000, Koch Pavement Solutions of Spokane, Washington approached WSDOT Headquarters Materials Laboratory and North Central Region Materials with the proposal to provide 15,000 square yards of NovaChip® surfacing as a demonstration project to market their product. North Central Region Program Management, in conjunction with Region Construction, Materials, and Maintenance, identified SR 17 through Soap Lake as the demonstration site location primarily because this section of SR 17 only needed surface restoration. The typical rehabilitation treatment for this roadway would have been Class G, however, NovaChip® was sought as an alternative to provide a more durable pavement (a 2-inch HMA overlay was ruled out due to limited curb height).

WSDOT increased the surfacing amount to 26,000 square yards in order to completely resurface through the City of Soap Lake,. Based on estimated industry costs of $3.00 per square yard, an agreement was made to pay Koch Pavement Solutions a lump sum of $30,000 for the additional 11,000 square yards to be placed. Additional discussion regarding programming and contracting issues are noted in Appendix C.

Project Details

The study site is located on SR 17, MP 75.43 to MP 76.26 through the City of Soap Lake. Soap Lake is located in Grant County approximately 23 miles north of Moses Lake. This roadway has an average daily traffic (ADT) of approximately 4,300 vehicles: approximately 8.5 percent trucks and 15-year equivalent single axle loads (ESAL's) of 1,100,000 eastbound and 660,000 westbound. This roadway section is classified as a rural minor arterial. The roadway has two lanes in each direction with shoulders. The section is curbed through the project limits. Typical views through Soap Lake are shown in photos 2 and 3.

Photo 2. Soap Lake Vicinity – MP 75.54 NB

Photo 3. Soap Lake Vicinity – MP 75.85 SB

Construction History

The construction history for this roadway is shown in Table 5.

Table 5. SR 17 Construction History – MP 75.43 to MP 76.26

Construction Year	Layer Type	Thickness (ft)
1998	BST Class D	0.03
1998	BST Pre Seal	0.02
1990	BST Class B	0.04
1980	HMA Class D or G	0.06
1957 and 1967	HMA Class B	0.21 to 0.25
1957 and 1967	Untreated Base	0.66 to1.50

The roadway has been maintained by the application of bituminous surface treatments. Maintenance reported that occasionally there have been areas where soft subgrades have caused pavement failures. Periodic full depth pavement repairs have been required. Overall, this section of SR 17 has held up well and would have provided several years of additional service if the opportunity to place NovaChip® has not occurred.

Pavement Condition

The major deficiencies on this section were transverse, alligator and longitudinal cracking. The transverse cracks were full width, 1 to 2 inches wide and slightly depressed. The BST placed in 1998 had essentially bridged the transverse cracks. The longitudinal cracking was erratic and was generally low in severity (< ¼ inch wide). Fatigue cracking in the wheel paths was low severity. The typical distresses observed throughout the project limits are listed in Table 6 can be seen in photos 4 to 6. Table 7 lists the Pavement Structural Condition (PSC), rutting and roughness indexes.

Table 6. Specific Distresses Observed on SR 17 through Soap Lake.

Mile Post Limits	Low Severity Cracking [1]			Raveling	Flushing	Patching
	Alligator	Longitudinal	Transverse			
75.43 to 75.50	34	5	1	0	0	0
75.50 to 75.83	28	15	3	0	0	0
75.83 to 76.00	2	41	5	0	0	0
76.00 to 76.07	2	51	6	0	0	0
76.07 to 76.12	10	41	6	0	0	0
76.12 to 76.45	15	11	6	0	0	0

[1] Extent in percent of the section length.

Table 7. Distress Summary.

Mile Post Limits	Pavement Structural Condition (PSC)[1]	International Roughness Index (IRI) (in/mile)	Rutting (mm)
75.43 to 75.50	38	217	5
75.50 to 75.83	44	147	3
75.83 to 76.00	77	149	5
76.00 to 76.07	75	125	5
76.07 to 76.12	66	127	4
76.12 to 76.45	61	136	4

[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).

Photo 4. Typical transverse crack observed on SR 17 in Soap Lake. Repair or crack sealing is not necessary for cracks ¼ inch and less.

Photo 5. Medium to high severity transverse crack seen on SR 17. Cracks of this width should be crack sealed prior to overlay.

Photo 6. Cracks less than ¼ inch observed in Soap Lake. Crack sealing or repair is not necessary.

Pre-Construction Calibration

Prior to paving the project location, Central Washington Asphalt (CWA) personnel received training from Koch. CWA placed NovaChip® at their asphalt production facility to test the system. Koch provided the Novapaver, rented from a California contractor, to place the mix.

Mix Design

Since NovaChip® is a proprietary product, Koch provided the NovaChip® mix design. Koch has basic NovaChip® designs, Type A, B and C, which correspond to a 1/4, 3/8, and 1/2 inch sizes, respectively. In summary, the mix design provided the following:

Type C NovaChip®

- 1/2 inch top aggregate size
- 5.2 percent asphalt content
- 12.7 percent voids in the compacted mix
- PG 64-28 binder
- Aggregate – 1/2 inch

The mix design summary for the Soap Lake project is provided in Appendix D. Test reports for testing performed during the NovaChip® placement are shown in Appendix E. Figure 2 shows a 45-power curve with the job mix formula and production test results.

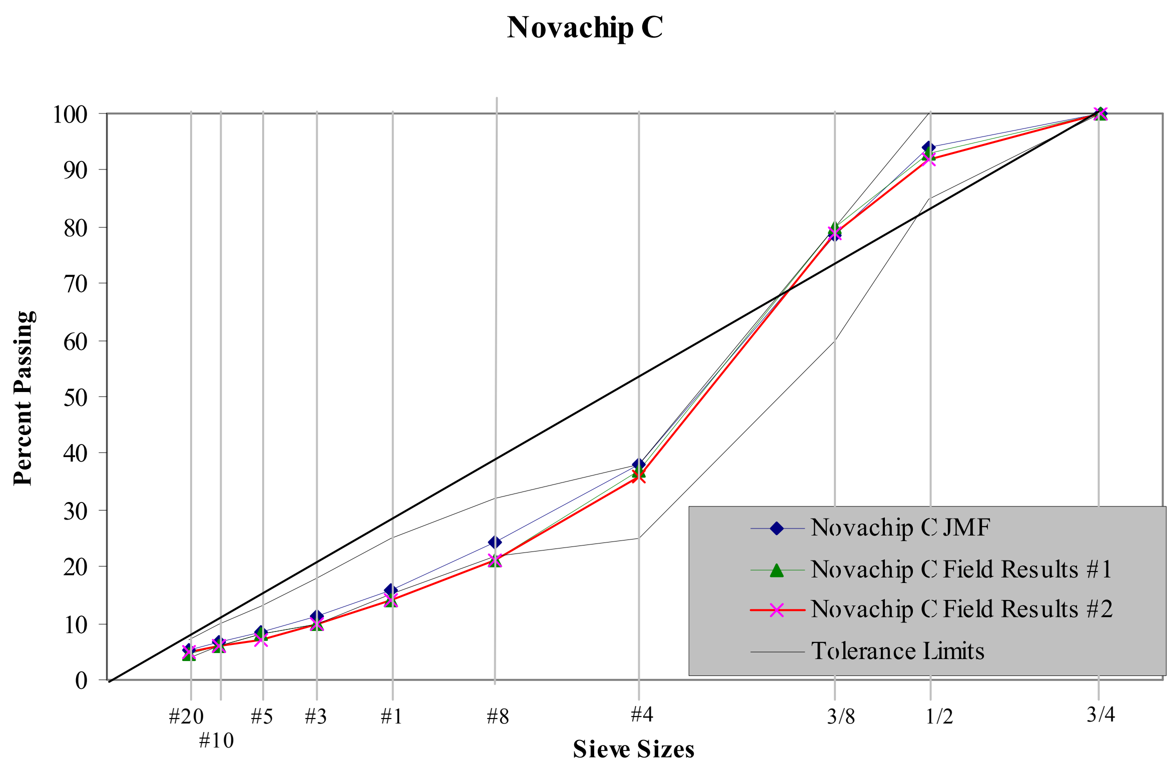

Figure 2. Sieve Sizes 0.45 Power Chart with NovaChip® "C" Job Mix Formula and Production Test Results.

Surface Preparation

WSDOT Maintenance prepared the existing roadway by filling the cracks (typically ¼ inch or greater) and provide minor pavement repairs with a high quality cold patching material. Cracks smaller than ¼ inch were not filled and cracks that had BST placed over them (some of them depressed) were not repaired. Photos 7 to 10 show the degree of existing cracking on this project and the placement of the NovaChip® over them. Prior to placing the NovaChip®, the existing roadway was swept cleaned.

Photo 7. NovaChip® placed over exiting roadway. (The existing low severity cracks were not sealed.)

Photo 8. NovaChip® asphalt placed over existing transverse cracks.

Photo 9. NovaChip® placed over an existing transverse crack (high severity).

Photo 10. NovaChip® asphalt placed over existing cracks. These transverse cracks should have been sealed prior to the NovaChip®.

The existing curb condition through Soap Lake consisted of concrete curb and gutter. The previous BST had been placed adjacent to the concrete gutter causing a build up of asphalt material. The placement of the NovaChip® drastically increased the channel flow condition that previously existed, as is shown in photos 11 and 12. In retrospect, the existing roadway should have been milled so that the overlay would match with the curb and gutter.

Photo 11. NovaChip® asphalt placed adjacent to curb and gutter.

Photo 12. NovaChip® asphalt placed adjacent to curb and gutter. Rotomilling adjacent to the curbing was not done. Previous surfacings and the NovaChip® left a trough in the gutter.

Construction Details

The NovaChip® construction began on August 7th with the intent to complete only the northbound lanes. Progress was good throughout the day and the decision was made to continue. The entire project was completed by 9:00 pm the same day (construction began at 9:00 am and lay down proceeded with only minor difficulties). The asphalt mixture was trucked approximately ten miles from CWA's asphalt plant near Moses Lake. Traffic control was provided by reducing traffic to one lane in each direction, on the opposite side of where the work was being performed. Traffic was shifted to allow one lane in each direction depending upon the lane being paved. Photos 13 to 16 show the paving operation as it occurred in Soap Lake.

Photo 13. Traffic control in place.

Photo 14. NovaChip® paving operation.

Photo 15. Rolling (seating) the NovaChip® surface.

Photo 16. Compaction of the NovaChip® roadway surface.

The Novabond® membrane emulsion was initially shot at a rate of 0.24 gallons per square yard. This rate was revised to 0.22 gallons per square yard as the Novabond® began to rise though the NovaChip® asphalt to the surface and flushing occurred. The application rate of the Novabond® membrane was also adjusted during the last pass to mitigate the effects of a steep crown to minimize the potential draining towards the curb before setting up. Ideally, the

Novabond® should be embedded in the Novabond® approximately 30 percent. The Novabond® application rate should be adjusted according to the condition of the existing roadway. For instance, a dry, open textured roadway will require a higher application rate.

The typical polymer modified asphalt content of the Novabond® emulsions per Koch Pavement Solutions is 65 to 68 percent. The actual residual asphalt rate falls between 0.0845 gallons per square yard (0.71 pounds) to a probable maximum of 0.184 gallons per square yard (1.55 pounds).

Photo 17 shows the heavy Novabond® membrane shot just prior to the asphalt placement. The spray bar is only 20 inches ahead of the screed. Photo 18 indicates the heavy thickness of Novabond® membrane placed outside the asphalt limits to ensure a full width bond.

Photo 17. Novabond® Membrane being applied prior to the hot mix asphalt.

Photo 18. Novabond® Membrane placed outside the hot mix asphalt indicates its heavy thickness.

As a way to measure the upward absorption of the NovaChip® in the hot mix asphalt, Frank Bonwell, WSDOT project inspector, devised a method where a 6-inch by 6 inch section of roadway was removed and the depth of absorption was measured with a tape measure. With a physical measurement, the adjustment to the proper application rate was easily made.

The placement of the hot mix asphalt was no different than any other paving operation. The paver functions like a typical paving machine, but is much larger and has a 3,000-gallon tank on it that stores the Novabond® emulsion. On the Soap Lake project, the Novabond® emulsion tank required only one refilling 10 hours after beginning the operation. The emulsion tank was also topped off towards the end of the paving operation.

End dumps were used to haul the hot mix asphalt to the project. The contractor chose to tarp all loads as a measure of reducing temperature differentials in the completed mat. Koch cautioned the truck operators to allow the paver to "pick up" trucks, as trucks backing into a NovaChip® paver causes bumps in the unforgiving NovaChip® mix.

The screed of the paver is fully adjustable and is heated electrically. The screed is set to a temperature and maintained with a thermostat control. Typically, the screed is preheated prior to the paving operation. The paver uses a series of augers (Photo 19) that are placed in the hopper of the paver parallel to the centerline of the paver. There did not appear to be segregation in the delivery of the asphalt from the truck to laydown. The NovaChip® paver placed the asphalt at nearly 65 to 75 feet per minute (0.74 to 0.85 lane miles per hour).

Photo 19. Auger system within the Novapaver.

The NovaChip® asphalt was seated into the Novabond® membrane by using one 15-ton roller for the initial breakdown and one 12-ton roller to finish the surface. Rollers were operated only in the static mode as is the recommendation for NovaChip®. Additional rolling occurred to remove remaining roller marks. Koch reported that rolling typically occurs between 195-285°F and is determined by trial and error. In Soap Lake, compaction was attempted immediately after NovaChip® placement, however, rollers “picked” material off the mat. By delaying the initial breakdown rolling until the mat temperature was approximately 230°F (3 to 4 minute delay), picking was not a problem. Cross traffic was allowed on the NovaChip® surface anywhere from 10 to 20 minutes behind initial placement. Compaction photos are shown below.

Photo 20. Rolling directly behind the NovaChip® paver with a 15 ton roller.

Photo 21. Compaction was completed with a 15 ton breakdown roller and 12 ton finish roller.

The initial lay down thickness for several blocks was approximately 1½ inches deep. However, once the crew became familiar with the operation the recommended thickness of ¾ inch NovaChip® was soon met. CWA was not able to maintain thickness through cross streets due to variations in the existing roadway profile. The profile grade was maintained along SR 17 with a laser system, however, the intersection of the two grades resulted in thicker pavement along SR 17 and transitions to cross streets. NovaChip® was feathered as much as possible, however, the transitions from cross streets were abrupt.

Final views of the NovaChip® placement are shown in photos 22 to 25.

Photo 22. Soap Lake – Final NovaChip® surface.

Photo 23. Soap Lake – Final NovaChip® surface.

Photo 24. Soap Lake – Final NovaChip® surface.

Photo 25. Soap Lake – NovaChip® macro-texture.

SOAP LAKE - PERFORMANCE

A field review of the NovaChip® construction was undertaken during May 2003. After 22 months of performance, the NovaChip® surfacing is performing well (Photo 26). However, some cracks are reflecting through the NovaChip® overlay that is likely due to inadequate surface preparation of the pre-existing cracks. Photos 27 and 28 show examples of cracking that have reflected through the NovaChip surfacing from the preexisting transverse and block cracking. The reflective cracks are still tight.

Photo 26. NovaChip® overlay through Soap Lake – May 2003.

Photo 27. Transverse crack reflecting through the NovaChip® overlay.

Photo 28. Block Cracking reflecting through the NovaChip® overlay.

DISCUSSION – NOVACHIP® USE IN WASHINGTON STATE

Koch Pavement Solutions 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 Class G Hot-Mix Asphalt

Within WSDOT, the application of NovaChip® is comparable with WSDOT HMA Class G rehabilitation. Through selected cities that are BST routes, WSDOT often places 1 inch of Class G 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 1 million ESALs (over 15 years). A Class G overlay typically last six to eight years, however, spans of ten years and longer occur. Statewide, Class G asphalt usage is low.

NovaChip® Compared to WSDOT Class A or Superpave Hot-Mix Asphalt

WSDOT typically places HMA such as WSDOT 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 from studded tires on high volume routes such as interstate and 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, because of the effects of studded tire wear on higher volume routes the expected service life of eight years was reduced to less than four years due to excessive rutting. 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.

Average HMA Class A and Superpave Costs

Average construction bid prices for Class A or Superpave hot-mix asphalt summarized by WSDOT's six regions are shown in Table 8. These prices are for asphalt projects greater than

2,500 tons. The average price for Class A HMA in Eastern Washington is about $27.26 per ton and Western Washington is about $32.59 per ton. The average price for ½ inch Superpave HMA experienced in Eastern Washington is 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 Class A asphalt and $2.71 per square yard for ½ inch Superpave asphalt placed 1.8 inches thick. For Western Washington this equates to about $3.35 per square yard for Class A asphalt and $3.51 per square yard for ½ inch Superpave asphalt.

Table 8. WSDOT Average Bid Prices for Asphalt Concrete Class A or ½ inch Superpave.

Eastern Washington			**Western Washington**		
Region	**Asphalt Type[1]**		**Region**	**Asphalt Type[1]**	
	Class A ($/SY)	**½ inch Superpave ($/SY))**		**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 Class G Costs

Likewise, average Class G asphalt prices are shown in Table 9. The prices shown are for projects greater than 1,000 tons. Usage of Class G in two of the Eastern Washington regions is minimal and data was not available. For the Eastern Region, the Class G price per square yard is $2.06. For Western Washington, the average price is $1.71 per square yard.

Table 9. WSDOT Average Bid Prices for Asphalt Concrete 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] Class G usage is low. Insufficient data to calculate a price.

NovaChip® Costs

Since NovaChip® is new to Washington State, prices are based on Koch Materials estimates. Nationwide, Koch reports 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 are 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. Koch Pavement Solutions can only estimate at this time but expects NovaChip® costs for larger projects to be $3.00 to $4.00 per square yard in Washington State. Table 10 summarizes and compares NovaChip® prices to traditional WSDOT asphalts.

Table 10. Summary of Asphalt Costs (Material and Placement).

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

While the preceding table compares asphalt bid prices on a square yard basis, comparing asphalt 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 a 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 is 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 Class A or ½ inch Superpave. For Class G the cost per lane mile is approximately $50,000 or $5.33 per square yard. These costs 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 costs 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 Class A or ½ inch Superpave HMA project and NovaChip® project cost is 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 Class G and HMA overlay. Table 11 illustrates this comparison.

Table 11. Project Costs for Various Rehabilitation Treatments.

Rehabilitation Type[1]	Project Cost ($/Lane Mile)	Project Cost ($/Square Yard)
BST	14,000	1.49
Hot Mix Asphalt (Class G)[2]	50,000	5.33
NovaChip®	58,000	6.18
Hot Mix Asphalt (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] Class G compacted depth is 1.0 inches.
[3] Class A or ½ inch Superpave compacted depth is 1.8 inches.

CONCLUSIONS

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

- NovaChip® can be placed very quickly through a city with many road approaches and cross streets. Traffic was allowed to cross the new mat ten minutes after placement.
- NovaChip® is easily produced at a hot mix asphalt facility and placed on a project location with little difficulty.
- The curbline through Soap Lake should have been milled to account for the additional thickness of the NovaChip® overlay. A channel has formed along the curbline due to the NovaChip® 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.
- The cost for NovaChip®, on a lane mile basis, falls between that of Class G and HMA such as Class A or Superpave.
- After 22 months of service, the NovaChip® surfacing is performing well. Existing transverse and block cracks are reflecting through the NovaChip®, however, the cracks are tight.

WSDOT will evaluate the Soap Lake NovaChip® project on a yearly basis over the next five years or until such time that no further useful information can be obtained. At that time, a final report will be written to document the NovaChip's® performance, life cycle costs, and implementation procedures (if applicable).

REFERENCES

1. Uhlmeyer, Jeff S., Performance of Class D Overlays in Washington State – A White Paper. Washington State Department of Transportation, June 1996.

2. Kandhal, Prithvi S. and Lockett, Larry., Construction and Performance of Ultrathin Asphalt Friction Course, NCAT Report 97-5, National Center for Asphalt Technology, Auburn University, September 1997.

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.

APPENDIX A – NOVACHIP® DESIGN CRITERIA

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

<u>Cracking</u>

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.

<u>Patching and Potholes</u>

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.

<u>Surface Deformation</u>

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®.

<u>Surface Defects</u>

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. Also shown is the average daily traffic and percent trucks. ESAls for the individual roadways were not provided.

Table B-1. Summary of NovaChip® Projects Constructed by Various Agencies across the United States. (This project list was provided by Koch Pavement Solutions)

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%

APPENDIX C – NOVACHIP® CONTRACTING ISSUES

Programming Issues

The Headquarters (HQ) Program Management and Materials Laboratory approved the concept of the demonstration project. The HQ Materials Laboratory prepared an Experimental Feature Work Plan that was approved by the Federal Highway Administration on April 2, 2001.

Because this project did not exist in the approved 2001-2003 WSDOT Construction Program, a special project needed to be programmed. The region proposed this project to the Screening Board on May 1, 2001. The Screening Board approved the estimated $65,000 to $85,000 expenditure on May 3, 2001 which covered traffic control, striping and iron adjustment items as well as the additional NovaChip® requested.

Contracting Issues

The Soap Lake NovaChip® project did not follow the normal competitive bid process that WSDOT typically uses to administer construction contracts. To perform the work, a North Central Region Project Engineers Office provided the inspection and some traffic control for design and maintenance preparation. The construction portion of the work was administered in two phases under a maintenance contract. In order to administer the project in this manner a legal issue had to be resolved.

Washington State law under the Revised Code of Washington (RCW) 47.28.050 requires a competitive bid process for work over $7,500. In addition, RCW 47.28.030 places a $50,000 limit on the work that can be done by State Forces. RCW 47.28.030 would have been violated in both aspects because there was no competitive bid and State Forces are not allowed to perform work that exceeds the $50,000 limit.

To overcome this obstacle, WSDOT contacted the Attorney Generals Office and was advised that they were within the law if they could declare Koch Pavement Solutions the sole source of the NovaChip® surfacing. WSDOT filed appropriate documentation received from Koch Pavement Solutions stating that they were a sole source provider.

The contracts set up on this project included two maintenance contracts under a single work order and support engineering and maintenance under a separate construction work order. One maintenance contract reimbursed Koch for the additional 11,000 square yards of NovaChip® (26,000 total square yards were placed). The second maintenance contract paid for the removal of existing traffic items and replacement. Competitive bids were received for this portion of the work. The construction contract covered construction inspection, traffic control and surveying. A summary of the contracts necessary to complete the work is shown in Table C-1.

Table C-1. Summary of NovaChip® Contract Items and Costs.

Work Order	Contract Item	Estimated Cost ($)	Final Cost ($)
MS 4244	Koch Oil	30,000	30,000
XL 1446	State Force (Inspection, flagging, surveying, adjustments for manholes and inlets)	10,000	10,254
MS 4244	Apply-A-Line (Striping – removal, striping placement and traffic control)	25,000	22,134
Total Expenditures		65,000	62,388

In order to compare NovaChip® costs to other rehabilitation methods, WSDOT determined a project cost for the Soap Lake project based on an estimated industry cost of $4.00 per square yard for NovaChip® materials and placement. WSDOT determined a total project cost by including the other cost items such as project inspection, flagging, surveying, adjustments for manholes and inlets and striping items. Table C-2 shows the estimated project cost, based on the available information, to rehabilitate the 2.84 lane miles through Soap Lake. Based on a total estimated cost of $163,665, the cost per lane mile is approximately $58,000.

Table C-2. Estimated Project Cost for NovaChip® Placement.

Contract Item	**Quantity**	**Unit**	**Unit Cost ($)**	**Project Cost ($)**
Koch Oil – NovaChip® materials and placement	26,000[1]	Square Yard	4.00	104,000.00
State Force (Inspection, flagging, surveying)	1	Lump Sum	10,254.00	10,254.00
Apply-A-Line (Striping – removal, striping placement and traffic control)	1	Lump Sum	25,000.00	22,134.00
Subtotal				136,388.00
Engineering (20 percent)				27,278.00
Total Cost				163,665.00

[1] The roadway consisted of two 12-foot lanes with 8-foot shoulders in each direction. The project length was 0.71 miles (3,748 feet) long.

APPENDIX D – NOVACHIP® MIX DESIGN

NOVACHIP MIX DESIGN SHEET

KOCH MATERIALS LABORATORY 415 NORTH 10th STREET TERRE HAUTE, INDIANA 47807 PHONE (812) 232-0421 FAX (812) 235-1144

PROJECT - Soap Lake
CONTRACTOR - Central Washington
BINDER - PG 64-28 G_b = 1.025
SUPPLIER - KMC
SALESMAN - Brad Schmitz

W.O. W WA NC 2001.92
Date completed: 16-Jul-01
Technician: Hulett
Design # 2001.092
Lab Costs: $1,500.00

AGGREGATE GRADATIONS - INDIVIDUAL AND BLEND

		AGG 1	AGG 2	AGG 3	AGG 4	AGG 5	AGG 6		
	KMC Lab No.	Coarse	G Mix						
	Source	292	206						
	% in Blend	57.0	43.0		0.0	0.0	0.0		NovaChip C
SIEVE								Blend	Specs
1 "	25.00 mm	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100
3/4 "	19.00 mm	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100
1/2"	12.50 mm	89.6	100.0	100.0	100.0	100.0	100.0	94.1	85 - 100
3/8 "	9.50 mm	62.1	100.0	100.0	100.0	100.0	100.0	78.4	60 - 80
#4	4.75 mm	6.5	80.0	100.0	100.0	100.0	100.0	38.1	25 - 38
#8	2.36 mm	4.0	51.4	100.0	100.0	100.0	100.0	24.4	22 - 32
#16	1.18 mm	3.0	32.9	100.0	100.0	100.0	100.0	15.8	15 - 23
#30	0.600 mm	3.0	22.3	100.0	100.0	100.0	100.0	11.3	10 - 18
#50	0.300 mm	3.0	15.6	100.0	100.0	100.0	100.0	8.4	8 - 13
#100	0.150 mm	3.0	11.4	100.0	100.0	100.0	100.0	6.6	6 - 10
#200	0.075 mm	2.9	8.6	100.0	100.0	100.0	100.0	5.4	4 - 7
Agg. Gsb (T85-91 & T84-95)		2.829	2.802	1.000	1.000	1.000	1.000		
FAA (TP33)								47.4	
Sand Equivalency (T176-86)			79.6						
Meth. Blue (TP57-99)			1.5						
F & E (D4791-95)		20.0	19.0						
Micro-Deval (TP58-99)		4.2							
LA. Abrasion (T96-99)		13.0							
Water Absorption (T255-92)		1.46	1.48					*Producer's Historical Data	

Mixing Temperature 157 C
Compaction Temperature 149 C
Compaction Method Gyratory (TP4)
Number of Blows/Gyrations 100

P_b	G_{mb} T269-97	G_{mm} T209-94	% Air Voids	Gsb %VMA	Gsb %VFA	Gse %VMA	Gse %VFA	Surface Area	Film Thickness
5.2	2.259	2.589	12.7			24.2	47.3	4.4	11.6

G_{se} = 2.825
Nominal Mixture Size = 0.500

Effective Binder Content = 5.0 %
% Absorbed Asphalt = 0.18 %
D/A = 1.1

COMMENTS
Draindown % (T305-97) = 0.017 %
TSR % (T283-89) = 95.20 %
Recommended max. emulsion shot rate = 0.28 gal/yd^2
Recommended min. emulsion shot rate = 0.20 gal/yd^2

Approved

Test data reported herein has been secured by reliable testing procedures. As we have no knowledge of, or control over, the conditions that may affect the use of material from which the samples were taken, we assume no responsibility in furnishing this data other than to warrant that they represent reliable measurements of the properties of the sample received and tested.

APPENDIX E – NOVACHIP® TEST REPORTS

The following test reports were obtained from Western Pacific Engineering, Inc., Moses Lake Washington, who performed the independent testing for the NovaChip® project.

REPORT TO: Koch Pavement Solutions
N. 4327 Thor St.
Spokane, WA 99217-0904
Attn: Brad Schmitz

DATE: August 8, 2001
PROJECT NO: 01651
WPE SAMPLE #: 067

PROJECT: Soap Lake Street Improvements, Soap Lake, Washington.

SAMPLE IDENTIFICATION:

On August 8, 2001, client delivered one sample of Asphaltic Concrete produced by Asphalt producer for the above referenced project. At your request, we performed an Extraction, Gradation in accordance with ASTM D6307. The moisture content of the asphalt was determined in accordance with WSDOT test method no. 713.

Mix Design: Nova Chip "C"
Location Sampled: Batch Plant

TEST RESULTS

Ignition Furnace Correction Factor: 0.63
Moisture Content of Sample: .02%
Mass of Oven Dried Asphalt Sample Before Ignition: 1503.4
Mass of Asphalt Sample After Ignition: 1413.3

Measured Asphalt Content: 5.34

Sieve Size	Percent Passing	Nova Chip "C" Spec. Specified Limits
1"	100	100
3/4"	100	100
1/2"	93	85-100
3/8"	80	60-80
No. 4	37	25-38
No. 8	21	22-32
No. 16	14	15-23
No. 30	10	10-18
No. 50	8	8-13
No. 100	6	6-10
No. 200	4.7	4-7

REPORT TO: Koch Pavement Solutions
N. 4327 Thor St.
Spokane, WA 99217-0904
Attn: Brad Schmitz

DATE: August 9, 2001
PROJECT NO: 01651
WPE SAMPLE #: 070

PROJECT: Soap Lake Street Improvements, Soap Lake, Washington.

SAMPLE IDENTIFICATION:

On August 8, 2001, client delivered one sample of Asphaltic Concrete produced by Asphalt producer for the above referenced project. At your request, we performed an Extraction, Gradation in accordance with ASTM D6307. The moisture content of the asphalt was determined in accordance with WSDOT test method no. 713.

Mix Design: Nova Chip "C"
Location Sampled: Batch Plant

TEST RESULTS

Ignition Furnace Correction Factor: 0.63
Moisture Content of Sample: .00%
Mass of Oven Dried Asphalt Sample Before Ignition: 1508.0
Mass of Asphalt Sample After Ignition: 1420.6

Measured Asphalt Content: 5.17

Sieve Size	Percent Passing	Nova Chip "C" Spec. Specified Limits
1"	100	100
3/4"	100	100
1/2"	92	85-100
3/8"	79	60-80
No. 4	36	25-38
No. 8	21	22-32
No. 16	14	15-23
No. 30	10	10-18
No. 50	7	8-13
No. 100	6	6-10
No. 200	4.9	4-7

REPORT TO:	Koch Pavement Solutions N. 4327 Thor St. Spokane, WA 99217-0904 Attn: Brad Schmitz	DATE: August 8, 2001 PROJECT NO: 01651 SAMPLE NO.: 068

PROJECT: **Soap Lake Street Improvements, Soap Lake, Washington.**

Date Sampled: August 8, 2001
Sample Location: Central Washington Asphalt Batch Plant Cold Feed

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On August 8, 2001, client delivered one (1) sample of Nova Chip "C" Asphalt aggregate. At your request, we performed sieve analysis, in accordance with the ASTM C117.

The test results are as follows:

Sieve Size	Percent Passing	Nova Chip "C" Specified Limits
1"	100	100
3/4"	100	100
1/2"	87	85-100
3/8"	72	60-80
No. 4	32	25-38
No. 8	18	22-32
No. 16	12	15-23
No. 30	8	10-18
No. 50	6	8-13
No. 100	5	6-10
No. 200	3.7	4-7

REPORT TO:	Koch Pavement Solutions N. 4327 Thor St. Spokane, WA 99217-0904 Attn: Brad Schmitz	DATE: August 9, 2001 PROJECT NO: 01651 SAMPLE NO.: 071

PROJECT: **Soap Lake Street Improvements, Soap Lake, Washington.**

Date Sampled: August 8, 2001
Sample Location: Central Washington Asphalt Batch Plant Cold Feed

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On August 8, 2001, client delivered one (1) sample of Nova Chip "C" Asphalt aggregate. At your request, we performed sieve analysis, in accordance with the ASTM C117.

The test results are as follows:

Sieve Size	Percent Passing	Nova Chip "C" Specified Limits
1"	100	100
3/4"	100	100
1/2"	90	85-100
3/8"	72	60-80
No. 4	34	25-38
No. 8	20	22-32
No. 16	13	15-23
No. 30	9	10-18
No. 50	6	8-13
No. 100	4	6-10
No. 200	3.3	4-7