RESEARCH REPORT DOCUMENTATION PAGE

1. Report No.	2. Report Date	3. Contract No.	4. Project No.
ND 2011-02	April 2015	N/A	SS-3-015(010)060

5. Title and Subtitle
Warm Mix Asphalt

6. Report Type
- Work Plan ☐
- Construction ☐
- Evaluation ☐
- Final ☒

7. Project No.
SS-3-015(018)073

8. Project No.
SS-4-003(011)159

9. Project No.
SS-4-041(012)057

10. Project No.
SCB-6-032(045)219

11. Author(s)/Principle Investigator(s)
TJ Murphy

12. Performing Organization Name and Address
NDDOT M+R ☒
NDDOT OTHER* ☐
NDSU ☐
UND ☐
UGPTI ☐
OTHER* ☐
*see supplementary notes

North Dakota DOT
Materials and Research Division
300 Airport Road
Bismarck ND 58504-6005

13. Sponsoring Agency Name and Address
North Dakota DOT
Materials and Research Division
300 Airport Road
Bismarck ND 58504-6005

14. Supplementary Notes

15. Abstract

Purpose and Need

WMA techniques work by adding an additive to the asphalt or by injecting water into the asphalt that allows a reduction in the temperatures at which asphalt mixes are produced and placed. This research will use a locally available chemical additive called Evotherm 3G, Advera® WMA, and the foaming process to produce the WMA.

Objective

The objective of this project is to compare the performance of WMA produced using Evotherm 3G, Advera® WMA, and the foamed asphalt process. The density of the WMA produced by the different processes and a control section of Hot Mix Asphalt (HMA) will be compared. The fuel consumption of the plant will be monitored to compare efficiency of the different production processes. Laboratory testing will be performed on both the research and control sections. The testing shall include TSR Lottman test and moisture test.

Scope

This project will use thin lift paving projects to evaluate the WMA production processes using Evotherm 3G and foamed asphalt to provide the viscosity reduction in the asphalt. Five projects have been selected for this research project and they are SS-3-015(010)060, SS-3-015(018)073, SS-4-003(011)159, SS-4-041(012)057, and SCB-6-032(045)219.

Summary

The field performance of WMA and HMA is similar to each other. However the construction differences between the WMA and HMA favor the WMA products. The WMA performs better in the average compaction, TSR Lottman test, and fuel efficiency of the plant than the HMA. The use of WMA should be considered an option for overlay projects.

16. Key Words
Warm Mix Asphalt
Asphalt
Density
Paving

17. Distribution Statement
No restrictions. This document is available from:

North Dakota Department of Transportation
Materials and Research Division:
300 Airport Road
Bismarck ND 58504-6005
Office: (701) 328-6900

18. No. of Pages
42

19. File type
Pdf

NORTH DAKOTA
DEPARTMENT OF TRANSPORTATION

MATERIALS AND RESEARCH DIVISION

Experimental Study

ND 2011-02

Warm Mix Asphalt

Evotherm 3G, Advera WMA and Foamed Asphalt Comparison

January, 2014

Prepared by

NORTH DAKOTA DEPARTMENT OF TRANSPORTATION
BISMARCK, NORTH DAKOTA
www.dot.nd.gov

DIRECTOR
Grant Levi, P.E.

MATERIALS AND RESEARCH DIVISION
Ron Horner, P.E.

Written by: Kyle Evert

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

EXPERIMENTAL PROJECT REPORT

EXPERIMENTAL PROJECT	EXPERIMENTAL PROJECT NO. 1 ND 2011 - 02	CONSTRUCTION PROJ NO SS-3-020(072)069	LOCATION ND 11 - McIntosh County, ND
	EVALUATION FUNDING 48 1 HP&R; 2 CONSTRUCTION; 3 DEMONSTRATION; 4 X IMPLEMENTATION	NEEP NO. 49	PROPRIETARY FEATURE? 51 X Yes; No
SHORT TITLE	TITLE 52 Evotherm 3G, Advera WMA and Foamed		
THIS FORM	DATE 140; MO. June -- YR. 2013	REPORTING 1 INITIAL; 2 x ANNUAL; 3 FINAL	
KEY WORDS	KEY WORD 1 145 Warm Mix Asphalt	KEY WORD 2 167 Hot Mix Asphalt	
	KEY WORD 3 189 Evotherm	KEY WORD 4 211	
	UNIQUE WORD 233	PROPRIETARY FEATURE NAME 255	

CHRONOLOGY	Date Work Plan Approved	Date Feature Constructed:	Evaluation Scheduled Until:	Evaluation Extended Until:	Date Evaluation Terminated:
	277 2011	281 May 2012	285 2012	289 December 2014	293

QUANTITY AND COST	QUANTITY OF UNITS (ROUNDED TO WHOLE NUMBERS)	UNITS	UNIT COST (*Dollars, Cents*)
	297 999	1 LIN. FT; 2 SY; 3 SY-IN; 4 CY; 5 X TON; 6 LBS; 7 EACH; 8 LUMP SUM	306 $651,348

AVAILABLE EVALUATION REPORTS	CONSTRUCTION	PERFORMANCE	FINAL
	315	x	

EVALUATION	CONSTRUCTION PROBLEMS	PERFORMANCE
	318 1 X NONE; 2 SLIGHT; 3 MODERATE	319 1 EXCELLENT; 2 GOOD; 3 X SATISFACTORY; 4 MARGINAL

APPLICATION		
320	1 ADOPTED AS PRIMARY STD.; 2 PERMITTED ALTERNATIVE; 3 ADOPTED CONDITIONALLY	4 X PENDING; 5 REJECTED; 6 NOT CONSTRUCTED

(Explain in remarks if 3, 4, 5, or 6 is checked)

REMARKS

321
The objective of this project is to compare the performance of WMA produced using Evotherm 3G, Advera® WMA, and the foamed asphalt process.

Experimental Study ND 2011-02

Evotherm 3G, Advera WMA and Foamed Asphalt Comparison

Evaluation

January, 2014

Written by
Kyle Evert

Disclaimer

TABLE OF CONTENTS

Construction-Evaluation
ND 2011-02
Evotherm 3G, Advera WMA and Foamed Asphalt Comparison

Purpose and Need

Warm Mix Asphalts, (WMA) are being used in many projects throughout the United States and Europe. The benefits that have been reported are reduced emissions, reduced fuel consumption for the burner, paving aspects, and reduced exposure to workers.

WMA techniques work by adding an additive to the asphalt or by injecting water into the asphalt that allows a reduction in the temperatures at which asphalt mixes are produced and placed. These techniques tend to reduce the viscosity of the asphalt and provide improved aggregate coating at lower temperatures. WMA is produced at temperatures 35-100 °F lower than typical hot mix asphalt (300°F).

This research will use a locally available chemical additive called Evotherm 3G, Advera® WMA, and the foaming process to produce the WMA.

Evotherm 3G (Third Generation) – was developed in partnership with Paragon Technical Services and Mathy Technology & Engineering. Manufacturer's claims:

- This water-free form of Evotherm is suitable for introducing additives at the mix plant or asphalt terminal.
- Evotherm 3G generally lowers mix temperatures 60-85°F.

Advera® WMA – Manufacturer's claim:

- Effective with all paving grades of asphalt liquid, including polymer modified and rubber mixes.
- Added at 0.25% on the weight of the mix, it is easy to use and offers benefits in base, intermediate, and wearing courses.
- This technology allows for the production and placement of asphalt mix at temperatures 50 - 70°F lower than hot mix asphalt.

The foaming process injects water into the hot bitumen resulting in spontaneous foaming. The physical properties of the bitumen are temporarily altered when the injected water, on contact with the hot bitumen, is turned into vapor which is trapped in thousands of tiny bitumen bubbles. However, the foam dissipates in less than a minute and the bitumen resumes its original properties. In order to produce foamed asphalt, the bitumen must be mixed with the aggregates while still in the foam state.

Objective

The objective of this project is to compare the performance of WMA produced using Evotherm 3G, Advera® WMA, and the foamed asphalt process. The density of the WMA produced by the different processes and a control section of Hot Mix Asphalt (HMA) will be compared. The fuel consumption of the plant will be monitored to compare efficiency of the different production processes. Laboratory testing will be performed on both the research and control sections. The testing shall include TSR Lottman test, PG testing of the liquid asphalt mixed with additives before and after the WMA is produced, and moisture test.

Scope

This project will use thin lift paving projects to evaluate the WMA production processes using Evotherm 3G and foamed asphalt to provide the viscosity reduction in the asphalt. Five projects have been selected for this research project and they are SS-3-015(010)060, SS-3-015(018)073, SS-4-003(011)159, SS-4-041(012)057, and SCB-6-032(045)219.

The bid for the ND 15 projects has been awarded to Anderson Western Inc., allowing both projects to be constructed by the same contractor. The ND 15 projects are adjacent to each other for a combined length of 20.581 miles with 7 miles of regular HMA for the beginning section, 7 miles of WMA using Evotherm 3G for the middle section, and 7 miles using foamed asphalt last section. The Evotherm 3G and foamed asphalt WMA will be change ordered onto the project because the WMA test sections were not included in the plans. The estimated additional cost for the Evotherm 3G WMA is $2.89 per ton and the foamed asphalt WMA is $0.57 per ton. Approximately 13,500 tons of asphalt will be used for each test section.

Project SS-4-003(011)159 is 17.849 miles in length. Approximately, 5 miles of the project will be used for the research WMA section produced with Advera® WMA and 5 miles will be used for a control section with HMA. The Advera® WMA will be added to the plans by addendum for the April 15, 2010 Bid Opening.

Project SS-4-041(012)057 is planned to be 16.417 miles in length. Approximately, 5 miles of the project will be used for the research WMA section produced with Advera® WMA and 5 miles will be used for a control section with HMA. The Advera® WMA will be added to the plans by addendum for the April 15, 2010 Bid Opening.

Project SCB-6-032(045)219 is planned to be 17.072 miles in length. This project will use recycled asphalt in the mix design. Approximately 5 miles of the project will be used for the research WMA section produced with Evotherm 3G and 5 miles will be used for a control section with HMA. The Evotherm 3G will be added to the plans by addendum for the May 20, 2010 Bid Opening.

Location

The locations of the project used for the research projects selected are located in Table 1.

Project	Project Limits (RP)		Control Limits (RP)		Evotherm Additive Limits (RP)		Advera Additive Limits (RP)		Foamed Asphalt Limits (RP)	
	Begin	**End**	**Begin**	**End**	**Begin**	**End**	**Begin**	**End**	**Begin**	**End**
SS-3-015(010)060	60.444	73.565	60.444	67.444	67.444	73.565	-	-	-	-
SS-3-015(018)073	73.626	81.086	-	-	73.565	74.444	-	-	74.444	81.086
SS-4-003(011)159	159.341	177.190	164.000	169.000	-	-	159.341	164.000	-	-
SS-4-041(012)057	57.098	74.170	62.000	67.000	-	-	57.098	62.000	-	-
SCB-6-032(045)219	219.556	236.674	224.000	229.000	219.556	224.000	-	-	-	-

Table 1 – Project Locations

Design

The projects chosen for this research are scheduled for a thin lift overlay. The roadway will be overlaid with 2.0” WMA for the research sections and 2.0” HMA for the reminder of the projects. A portion of the HMA will be used as the control section.

The plan notes for the warm mix asphalt by the chemical process Evotherm 3G are as follows:

410 - Notes used for Warm Mix Asphalt Pavement Project (Chemical Process)

The WMA process will be used on this project from RP XX.XXX to RP XX.XXX

Evotherm 3G will be the chemical additive used for this project.

Production and paving temperatures may need to be increased for long haul distances, decreased ambient temperatures, or other WMA project specific conditions.

All requirements in Section 410 for the production and placement of conventional HMA mixtures are to be enforced except as noted in these plan notes.

The contractor will modify the mix design used to produce the Hot Mix Asphalt to meet the Warm Mix Asphalt criteria when produced with Evotherm 3G additive.

The mix design shall meet the requirements of Section 410.04 B of the Standard Specifications. All current mix design criteria will be required when developing the WMA mix design. The mix design will be Contractor developed.

The Warm Mix Asphalt produced will not exceed temperatures greater than 275 ºF. Any WMA over that temperature will not be used.

Place WMA mix on dry, unfrozen surfaces and only when weather conditions allow for proper production, placement, handling and compacting.

The minimum delivery, placement and compaction temperatures that will achieve workability and density requirements will be reviewed and approved by the Project Engineer.

The minimum rolling temperature will be established during the start of mix production.

During WMA production, the contractor will test the temperature of the mix at the point of discharge from the plant. The temperature test will be done once per hour and the results will be recorded with the test time and quantity of mix produced.

The contractor shall provide to the Engineer a daily log of the fuel consumption for the plant operation and a plant production printout. The fuel consumption shall be reported in gallons per day.

The plan notes for the warm mix asphalt by the chemical process Advera are as follows:

410 - Notes used for Warm Mix Asphalt Pavement Project (Chemical Process)

The WMA process will be used on this project from RP XX.XXX to RP XX.XXX

Advera will be the chemical additive used for this project. If Advera is unavailable, Evotherm 3G will be an acceptable alternative.

Production and paving temperatures may need to be increased for long haul distances, decreased ambient temperatures, or other WMA project specific conditions.

All requirements in Section 4XX for the production and placement of conventional HMA mixtures are to be enforced except as noted in these plan notes.

The contractor will modify the mix design used to produce the Hot Mix Asphalt to meet the Warm Mix Asphalt criteria when produced with Advera additive.

The mix design shall meet the requirements of Section 410.04 B of the Standard Specifications. All current mix design criteria will be required when developing the WMA mix design. The mix design will be Contractor developed.

The Warm Mix Asphalt produced will not exceed temperatures greater than 275 ºF. Any WMA over that temperature will not be used.

Place WMA mix on dry, unfrozen surfaces and only when weather conditions allow for proper production, placement, handling and compacting.

The minimum delivery, placement and compaction temperatures that will achieve workability and density requirements will be reviewed and approved by the Project Engineer.

The minimum rolling temperature will be established during the start of mix production.

During WMA production, the contractor will test the temperature of the mix at the point of discharge from the plant. The temperature test will be done once per hour and the results will be recorded with the test time and quantity of mix produced.

The contractor shall provide to the Engineer a daily log of the fuel consumption for the plant operation and a plant production printout. The fuel consumption shall be reported in gallons per day.

The plan notes for the warm mix asphalt by the foamed asphalt process are as follows:

410 - Notes used for Warm Mix Asphalt Pavement Project (Foamed Asphalt Process)

*The WMA Foamed Asphalt Process will be used on this project from RP XX.XXX to RP XX.XXX.**

Modifications to the HMA plant will be necessary to accomplish the WMA foaming procedure. All Manufacturers recommendations for incorporating WMA technology into the mix will be complied with.

Production and paving temperatures may need to be increased for long haul distances, decreased ambient temperatures, or other WMA project specific conditions.

All requirements in Section 4XX for the production and placement of conventional HMA mixtures are to be enforced except as noted in these plan notes.

The mix design shall meet the requirements of Section 410.04 B of the Standard Specifications. All current mix design criteria will be required when developing the WMA mix design. The mix design will be Contractor developed.

Place WMA mix on dry, unfrozen surfaces and only when weather conditions allow for proper production, placement, handling and compacting.

*The minimum delivery, placement and compaction temperatures that will achieve workability and density requirements will be reviewed and approved by the Project Engineer. ***

The minimum rolling temperature will be established during the start of mix production.

The contractor shall provide to the Engineer a daily log of the fuel consumption for the plant operation and a plant production printout. The fuel consumption shall be reported in gallons per day.

**The intent is to have a several mile section of WMA.*

***Recommend setting the minimum mixing temperature at 245° F ± 20° F, and minimum rolling temperature at 140° F. The mix design should be developed at 245° F ± 5° F.*

The density specifications will abide by the North Dakota Standard Specifications for Road and Bridge Construction 408.04 I.3. Specified Density.

Evaluation

The field evaluation for these projects will consist of observing and documenting the construction process of the WMA pavement and an annual inspection of the pavement distresses.

Prior to the construction of these projects an evaluation of the existing distresses will be completed. The evaluation prior to construction and annual inspection will include pavement distresses such as:

- Rutting measurements - will be taken at the beginning and end of the experimental and control section with a straightedge. Measurements will also be taken at every reference point and the midpoint of the reference points.
- Thermal cracks –will be completed by counting the thermal cracks between each reference point.
- Cracking distresses caused by loading and traffic - will be a visual inspection of the pavement distresses due to loading.

The existing distresses for these roadways were very similar to one another. The distresses being measured are rutting, thermal cracking and fatigue cracking. All of the roadways exhibited similar rut values that were less than one sixteenth of an inch.

The transverse cracking for the roadways differed from one another. ND 15 and ND 3 had thermal cracking approximately every ten feet. ND 32 had thermal cracking every fifteen to twenty feet. ND 41 had thermal cracking every thirty five feet approximately.

During the construction of the project the following data will be collected for both the experimental and control section:

- Density – will be determined from the cores taken according the 408.04 I.3 Specified Density requirements.
- Temperature – will be determined by the NDDOT inspector taking random temperatures in the wind row before paving and behind the paver before the breakdown roller.
- Fuel Consumption – The fuel consumption will be monitored during paving operations.

Laboratory testing will be performed for the research and control sections for each project. One sample per mile will be taken from each section. A binder sample will be taken from the tanker for the WMA and HMA sections prior to production. Samples for the Moisture Test will be taken from the loose mix behind the paver. The test will include:

- TSR Lottman Test – will determine the moisture sensitivity of the research and control section.

The research project will last three years with a construction report, an annual evaluation report, and a final report.

Construction

SS-4-003(011)159

Project SS-4-003(011)159 was a thin lift overlay designed and administered by Apex Engineering for the Minot District. The construction of the Superpave 43 WMA section was performed September 1 through September 6, 2011 by Mayo Construction Company, Inc. The control section is a Superpave 43 Hot Bituminous Asphalt (HMA) that was also constructed by Mayo Construction Company, Inc. on September 19 and September 20, 2011.

The process remained the same for the paving of the WMA and HMA. The only difference between the two is the asphalt used for the WMA had an Advera additive added by the contractor at the plant. This additive allowed the WMA to be produced at a lower temperature then the HMA.

SS-3-015(010)060 & SS-3-015(018)073

Both projects SS-3-015(010)060 and SS-3-015(018)073 were a thin lift overlay designed and administered by Devils Lake District. The construction of the Class 29 WMA section was performed May 24, 2012 through June 2, 2012 by Anderson Western Inc. The control section is a Class 29 HMA that was also constructed by Anderson Western Inc. on May 21, 2012 through May 23, 2012.

The WMA used two types of warm mix technologies. The two technologies were a forming process and an Evotherm additive. Both processes were applied at the plant mixing drum.

SCB-6-032(045)219

Project SCB-6-032(045)219 was a 2” mill and fill overlay designed and administered the Grand Forks District. The construction of the Superpave 43 WMA section was performed July 18 through July 20, 2011 by Knife River Corporation. The control section is a Superpave Hot Bituminous Asphalt (HMA) that was also constructed by Knife River Corporation on July 20, 2011.

The process remained the same for the paving of the WMA and HMA. The only difference between the two is the asphalt used for the WMA had an Evotherm additive added by the supplier. This additive allowed the WMA to be produced at a lower temperature then the HMA.

SS-4-041(012)057

Project SS-4-003(011)159 was a thin lift overlay designed and administered by the Minot District. The construction of the WMA section was performed July 14 through July 16, 2011 by Anderson Western Inc. The control section is a Superpave 43 Hot Bituminous Asphalt (HMA) that was also constructed by Anderson Western Inc. on July 18 and July 19, 2011.

The process remained the same for the paving of the WMA and HMA. The only difference between the two is the asphalt used for the WMA had an Advera additive added by the supplier. This additive allowed the WMA to be produced at a lower temperature then the HMA.

Construction Evaluation

The evaluation for this project will consist of observing and documenting the construction process of the WMA pavement and an annual inspection of the pavement distresses. During the construction the compaction, mat temperature, rolling efforts and fuel usage will be monitored.

Compaction

Cores were taken for density requirements in both the experimental and control section. The core mat densities are compared to the maximum theoretical density to develop a percentage of compaction.

SS-4-003(011)159

The cores were taken by the Apex Engineering. Both sections had very similar densities indicating that Advera and the lower mix temperature did not have any negative effect on the WMA compaction. The average compaction can be seen in Table 2 and the results for all the cores can be found in Appendix A.

ND 3 – Advera WMA Compaction Control			
Date	**Core Density**	**Maximum Theoretical Density**	**Compaction**
Average	142.7	153.7	92.8%
ND 3 - HMA Compaction Control			
Date	**Core Density**	**Maximum Theoretical Density**	**Compaction**
Average	141.7	153.8	92.1%

Table 2 – Average daily densities.

SS-3-015(010)060 & SS-3-015(018)073

The cores were taken by the Devils Lake district. Both sections had very similar densities indicating that Evotherm and the foaming process with lower mix temperatures did not have any negative effect on the WMA compaction. The average compaction can be seen in Table 3 and the results for all the cores can be found in Appendix A.

ND 15 - HMA Compaction Control			
Date	**Core Density**	**Maximum Theoretical Density**	**Compaction**
Average	140.1	150.9	92.8%
ND 15 - WMA - Evotherm Compaction Control			
Date	**Core Density**	**Maximum Theoretical Density**	**Compaction**
Average	139.5	150.7	92.6%
ND 15 - WMA - Foamed Compaction Control			
Date	**Core Density**	**Maximum Theoretical Density**	**Compaction**
Average	139.4	150.7	92.5%

Table 3 - Average daily densities.

SCB-6-032(045)219

The cores were taken by the Grand Forks district. In this section the Evotherm additive was added to a recycled asphalt mix. Both of the WMA and HMA sections compaction percentage is meeting our specification and similar to one another. The average compaction can be seen in Table 4 and the results for all the cores can be found in Appendix A.

ND 32 - WMA Compaction Control				
Date	**Station**	**Core Density**	**Maximum Theoretical Density**	**Compaction**
Average		138.8	150.1	92.5%
ND 32 - HMA Compaction Control				
Date	**Station**	**Core Density**	**Maximum Theoretical Density**	**Compaction**
Average		139.6	150.7	92.6%

Table 4 - Average daily densities.

SS-4-041(012)057

The cores were taken by the Minot district. In this section the Advera additive was used for a WMA agent. The WMA had better compaction than the HMA. The HMA still met the compaction requirements of specification. The average compaction can be seen in Table 5 and the results for all the cores can be found in Appendix A.

ND 41 - WMA Compaction Control			
Date	**Core Density**	**Maximum Theoretical Density**	**Compaction**
Average	142.6	153.0	93.2%
ND 41 - HMA Compaction Control			
Date	**Core Density**	**Maximum Theoretical Density**	**Compaction**
Average	141.2	153.7	91.9%

Table 5 - Average daily densities.

Mat Temperature

The temperature of the WMA was measured throughout the paving process. Measurements were recorded from the windrow, behind the paver prior to the break down roller, intermediate roller, and finish roller. The temperatures for the WMA research section and HMA control section can be seen in the charts below.

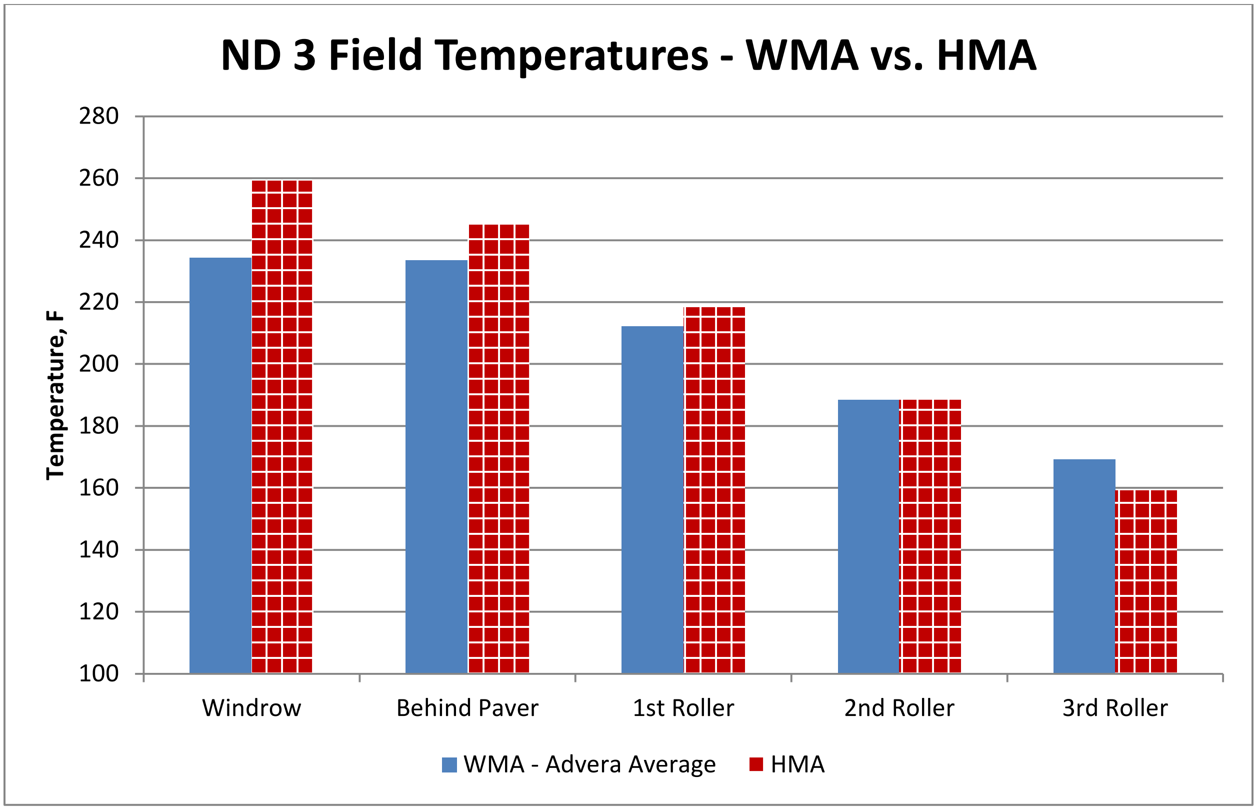

Chart 1 – Field Temperatures for ND 3 WMA and HMA.

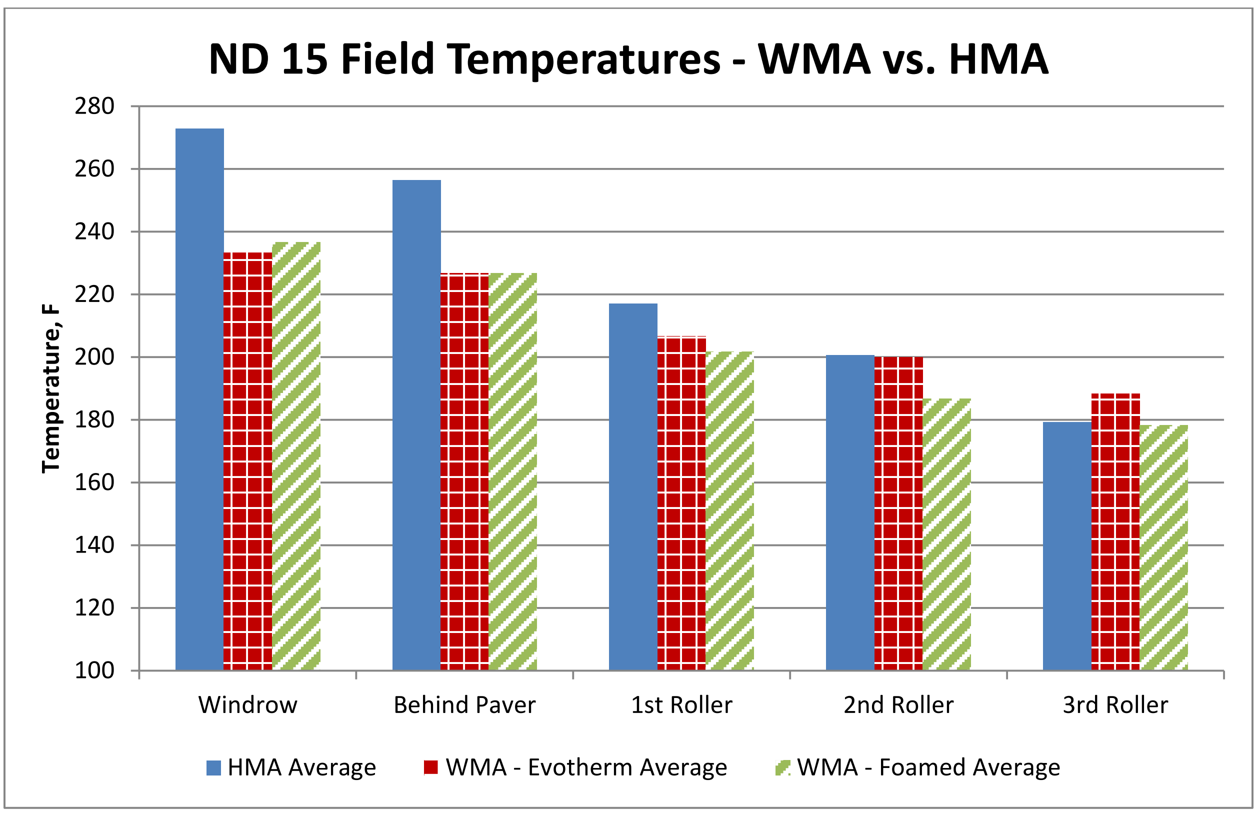

Chart 2 – Field Temperatures for ND 15 WMA and HMA.

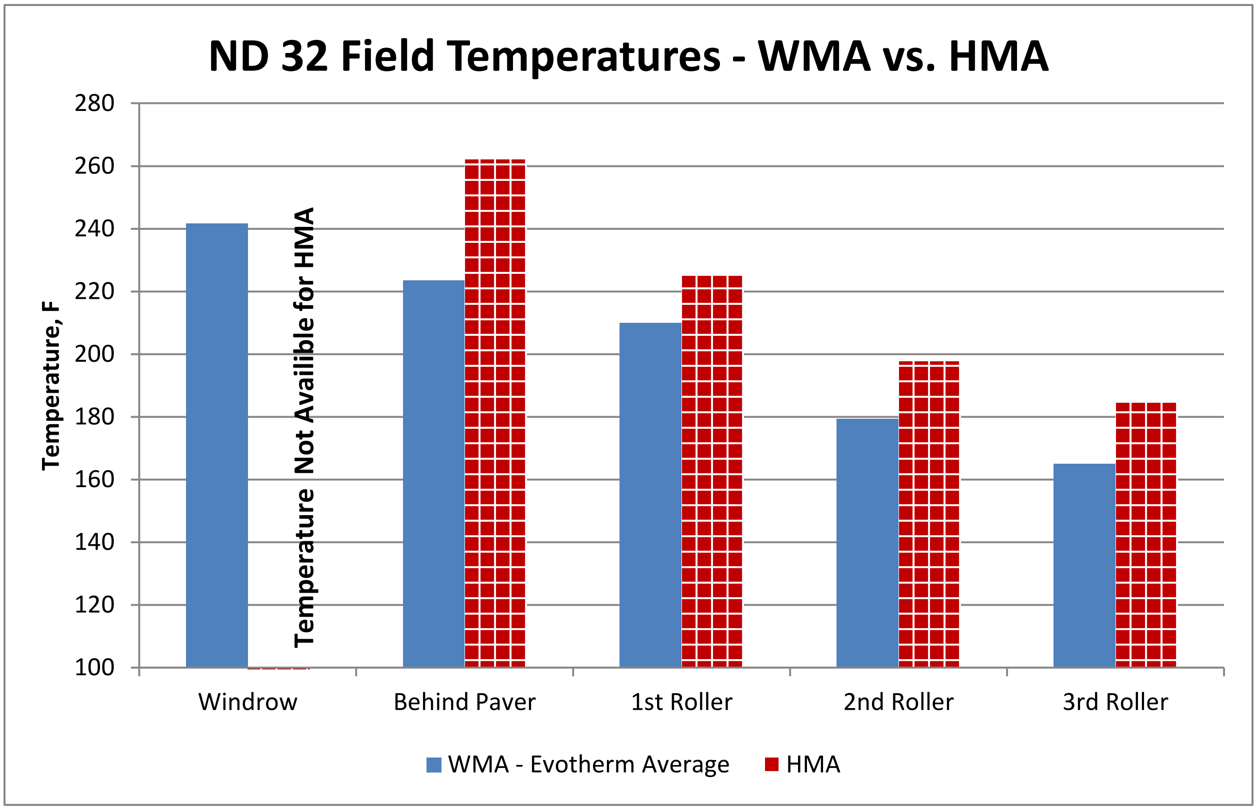

Chart 3 – Field Temperatures for ND 32 WMA and HMA.

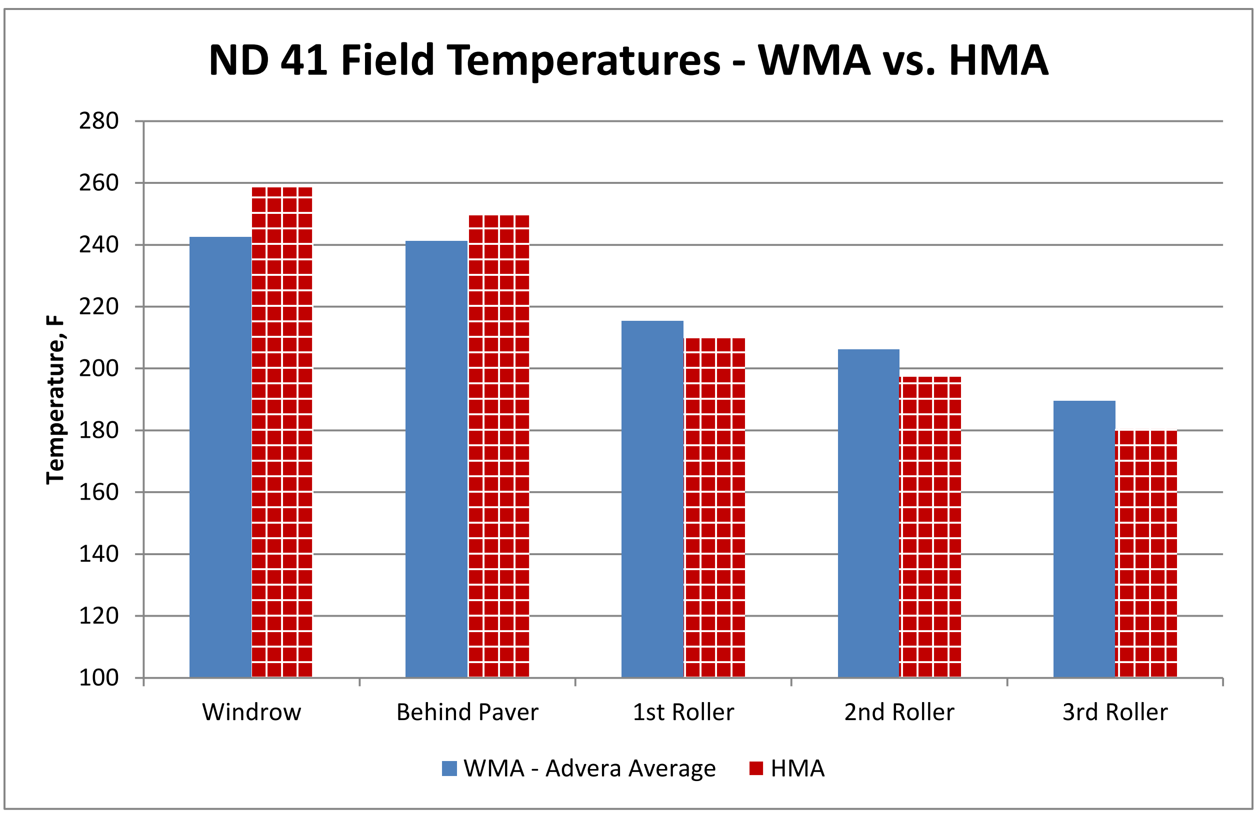

Chart 4 – Field Temperatures for ND 41 WMA and HMA.

Fuel Usage

The target temperature is the temperature the asphalt is produced at the plant. To change the target temperature the rate of the aggregate and the oil passing through the mixing drum increases or decreases depending on the temperature desired. Moisture in the aggregate will also affect the production rate. Increased moisture in the aggregate requires more time drying and reduces efficiency of the plant. The efficiency of the plant will be measured by the ratio of burner fuel to the tons of mix produced in a day. These results can be seen in the tables below.

ND 3 – Advera WMA Fuel Consumption			
Type	**Gallons**	**Total Tons**	**Gal/Ton**
Total/Average	13,168	9,467	1.38
ND 3 - HMA Fuel Consumption			
Type	**Gallons**	**Total Tons**	**Gal/Ton**
Total/Average	14,473	8,861	1.63

Table 6 – ND 3 fuel usage for WMA and HMA.

ND 15 – WMA Foamed Fuel Consumption			
Type	**Gallons**	**Total Tons**	**Gal/Ton**
Total/Average	15,868	12,840	1.22
ND 15 - WMA Evotherm Fuel Consumption			
Type	**Gallons**	**Total Tons**	**Gal/Ton**
Total/Average	16,603	13,620	1.15
ND 15 - HMA Fuel Consumption			
Total/Average	22,259	15,280	1.46

Table 7 – ND 15 fuel usage for WMA and HMA.

ND 32 – Evotherm WMA Fuel Consumption			
Type	**Gallons**	**Total Tons**	**Gal/Ton**
Total/Average	11,652	7,429	1.62
ND 32 - HMA Fuel Consumption			
Type	**Gallons**	**Total Tons**	**Gal/Ton**
Total/Average	15,232	8,958	1.72

Table 8 – ND 32 fuel usage for WMA and HMA.

ND 41 - WMA Fuel Consumption			
Type	**Gallons**	**Total Tons**	**Gal/Ton**
Total/Average	13,564	9,674	1.39
ND 41 - HMA Fuel Consumption			
Type	**Gallons**	**Total Tons**	**Gal/Ton**
Total/Average	17,315	11,995	1.44

Table 9 – ND 32 fuel usage for WMA and HMA.

Tensile Strength Ratio (TSR) Lottman Test

The TSR Lottman test is a moisture sensitivity test. Hot Mix Asphalt, Evotherm – Warm Mix Asphalt, and Foamed - Warm Mix Asphalt samples were taken from ND 15 projects. From these samples the Lottman tests was performed by the Materials and Research Division. The results can be viewed in Table 10. NDDOT specifies a TSR value of 70 or higher.

TSR Lottman Test			
Mix Type	**Wet Tensile Strength/ Dry Tensile Strength Ratio**		**Average**
WMA - Evotherm	110.1	102.3	**106.2**
WMA - Foamed	107.9	107.1	**107.5**
HMA	103.7	88.5	**96.1**

Table 10 – ND 15 TSR Lottman Tests Results.

Performance Evaluation

The field evaluation includes transverse crack counts, rut measurements, and an evaluation of pavement distresses caused by loading and traffic.

The first evaluation took place in January of 2013 and then again in November 2013. The transverse cracks and rutting measurements were recorded. The rutting was very minimal throughout the research and control section. The rutting was less than 1/16th of an inch throughout both the research and the control sections. The transverse cracking can be seen in Tables 11 through 14.

ND 3					
Section	Reference Point		Thermal/Reflective Cracks	Thermal/Reflective Cracks	Comments
	Begin	End	1/1/2013	11/18/2013	
Experimental - Advera WMA	160	161	121	133	2 small patches
	161	162	159	161	4 patches
	162	163	155	163	5 patches
	163	164	101	104	4 patches
Control - HMA	164	165	93	114	1850 -3900ft grade raise, 5 patches
	165	166	155	194	4 patches
	166	167	90	140	4 patches
	167	168	164	209	9 patches
	168	169	178	233	1 patches

Table 11 – ND 3 thermal cracking for experimental Advera WMA and control HMA sections.

ND 15				
Section	**Reference Point**		**Thermal Cracks**	**Comments**
	Begin	**End**	**11/18/2013**	
Control - HMA	61	62	109	
	62	63	108	
	63	64	118	
	64	65	149	
	65	66	172	
Experimental - Evotherm WMA	68	69	115	
	69	70	124	
	70	71	106	
	71	72	140	
	72	73	126	
Experimental - Foamed WMA	76	77	206	
	77	78	203	
	78	79	193	
	79	80	227	
	80	81	233	

Table 12 – ND 15 thermal cracking for experimental Evotherm, foamed WMA sections and control HMA sections.

ND 32					
Section	Reference Point		Thermal Cracks		Comments
	Begin	End	1/7/2013	11/19/2013	
Experimental - Evotherm WMA	220	221	96	142	
	221	222	80	121	
	222	223	103	144	
	223	224	75	127	
Control - HMA	224	225	71	124	
	225	226	86	141	
	226	227	98	153	
	227	228	100	152	
	228	229	124	183	

Table 13 – ND 32 thermal cracking for experimental Evotherm WMA and control HMA sections.

ND 41					
Section	Reference Point		Thermal Cracks		Comments
	Begin	End	1/7/2013	11/18/2013	
Experimental - Advera WMA	58	59	109	118	
	59	60	100	117	
	60	61	114	130	
	61	62	105	116	
Control - HMA	62	63	105	119	
	63	64	107	118	
	64	65	110	116	
	65	66	115	129	
	66	67	95	109	

Table 13 – ND 41 thermal cracking for experimental Advera WMA and control HMA sections.

Summary

The pavements are performing as expected for a thin lift overlay. The cracking has reflected through the overlay in both the research and control section. The rutting is very minimal with less than 1/16th for both the research and control sections.

Appendix A

ND 3 - WMA Compaction Control				
Date	**Station**	**Core Density**	**Maximum Theoretical Density**	**Compaction**
9/1/2011	5+20	141.9	153.5	92.4%
	29+80	141.4	153.5	92.1%
	59+20	141.1	153.5	91.9%
	78+80	142.4	153.5	92.8%
	82+00	142.1	153.5	92.6%
	105+60	142.8	153.5	93.0%
	121+40	141.8	153.5	92.4%
	142+16	145.7	153.5	94.9%
9/2/2011	18+14	144.5	153.9	93.9%
	36+12	141.5	153.9	91.9%
	47+50	142.1	153.9	92.3%
	76+50	141.4	153.9	91.9%
	93+96	141.6	153.9	92.0%
	116.42	140.7	153.9	91.4%
	122+64	142.8	153.9	92.8%
	145+44	141.2	153.9	91.7%
9/6/2011	178+80	143.4	153.7	93.3%
	200+44	142.8	153.7	92.9%
	222+20	142.1	153.7	92.5%
	228+28	144.9	153.7	94.3%
	179+32	143.5	153.7	93.4%
	198+18	142.6	153.7	92.8%
	217+34	144.9	153.7	94.3%
	234+54	144.4	153.7	93.9%
Average		**142.7**	**153.7**	**92.8%**

ND 3 - HMA Compaction Control				
Date	**Station**	**Core Density**	**Maximum Theoretical Density**	**Compaction**
9/19/2011	273+24	142.0	153.6	92.4%
	294+52	143.5	153.6	93.4%
	311+58	141.2	153.6	91.9%
	317+76	140.2	153.6	91.3%
	349+84	139.2	153.6	90.6%
	369+32	144.1	153.6	93.8%
	383+10	144.0	153.6	93.8%
	408+80	142.5	153.6	92.8%
	424+76	140.9	153.6	91.7%
	438+64	140.0	153.6	91.1%
	482+06	141.6	153.6	92.2%
9/21/2011	272+84	140.0	154.0	90.9%
	288+10	141.2	154.0	91.7%
	312+96	141.0	154.0	91.6%
	324+30	141.2	154.0	91.7%
	341+68	142.1	154.0	92.3%
	373+44	142.5	154.0	92.5%
	383+10	142.5	154.0	92.5%
Average		**141.7**	**153.8**	**92.1%**

ND 15 - HMA Compaction Control				
Date	**Station**	**Core Density**	**Maximum Theoretical Density**	**Compaction**
5/21/2012	38480	138.0	150.8	91.5%
	36130	141.6	150.8	93.9%
	33338	142.0	150.8	94.2%
	32342	144.1	150.8	95.6%
	30278	141.1	150.8	93.6%
	28178	139.5	150.8	92.5%
	26880	140.9	150.8	93.4%
	24100	139.2	150.8	92.3%
	21704	143.3	150.8	95.0%
	20862	141.4	150.8	93.8%
	19310	140.0	150.8	92.8%
	17058	139.4	150.8	92.4%
5/22/2012	38280	140.6	150.9	93.2%
	36438	140.5	150.9	93.1%
	33700	138.4	150.9	91.7%
	33098	139.1	150.9	92.2%
	30980	141.2	150.9	93.6%
	27780	140.1	150.9	92.8%
	25600	140.6	150.9	93.2%
	21722	139.0	150.9	92.1%
	20438	138.8	150.9	92.0%
	18190	139.5	150.9	92.4%
	16702	140.2	150.9	92.9%
	14534	140.7	150.9	93.2%
	12118	141.5	150.9	93.8%
5/23/2012	14040	138.5	151.0	91.7%
	12620	139.2	151.0	92.2%
	10320	139.3	151.0	92.3%
	7900	140.9	151.0	93.3%
	6360	140.6	151.0	93.1%
	3980	137.5	151.0	91.1%
	3060	140.4	151.0	93.0%
	320	139.6	151.0	92.5%
	9260	139.9	151.0	92.6%
	7120	139.2	151.0	92.2%
	6460	137.4	151.0	91.0%
	4360	138.0	151.0	91.4%
	980	141.5	151.0	93.7%
Average		**140.1**	**150.9**	**92.8%**

ND 15 - WMA - Evotherm Compaction Control				
Date	**Station**	**Core Density**	**Maximum Theoretical Density**	**Compaction**
5/24/2012	68040	138.2	151.0	91.5%
	66780	139.9	151.0	92.6%
	62980	139.4	151.0	92.3%
	61260	140.5	151.0	93.0%
	60740	140.2	151.0	92.8%
	58600	139.6	151.0	92.5%
	56680	140.5	151.0	93.0%
	54340	139.7	151.0	92.5%
	52080	139.3	151.0	92.3%
	49100	139.2	151.0	92.2%
	48300	138.1	151.0	91.5%
5/25/2012	68000	137.7	150.6	91.4%
	66520	138.8	150.6	92.2%
	63020	138.6	150.6	92.0%
	61400	139.9	150.6	92.9%
	59060	140.8	150.6	93.5%
	57460	140.3	150.6	93.2%
	56120	138.8	150.6	92.2%
	53980	137.6	150.6	91.4%
	51760	139.5	150.6	92.6%
	49140	140.6	150.6	93.4%
	47480	140.2	150.6	93.1%
5/30/2012	44080	141.1	150.5	93.8%
	42560	140.5	150.5	93.4%
	39880	138.9	150.5	92.3%
	37980	140.5	150.5	93.4%
5/31/2012	44682	137.7	150.6	91.4%
	42480	138.4	150.6	91.9%
	41334	140.2	150.6	93.1%
	38284	140.7	150.6	93.4%
Average		**139.5**	**150.7**	**92.6%**

ND 15 - WMA - Foamed Compaction Control				
Date	**Station**	**Core Density**	**Maximum Theoretical Density**	**Compaction**
5/30/2012	36840	142.1	150.5	94.4%
	34380	138.5	150.5	92.0%
	31940	139.1	150.5	92.4%
	29860	139.5	150.5	92.7%
	28680	141.5	150.5	94.0%
5/31/2012	37228	140.6	150.6	93.4%
	33924	138.9	150.6	92.2%
	32880	137.8	150.6	91.5%
	30536	138.4	150.6	91.9%
	29038	139.4	150.6	92.6%
	27100	141.2	150.6	93.8%
	24284	138.3	150.6	91.8%
	22478	138.7	150.6	92.1%
	21434	139.0	150.6	92.3%
	19504	139.7	150.6	92.8%
	17124	138.2	150.6	91.8%
	14938	136.3	150.6	90.5%
6/2/2012		137.9	150.7	91.5%
		137.7	150.7	91.4%
		138.5	150.7	91.9%
		137.6	150.7	91.3%
		138.5	150.7	91.9%
		140.6	150.7	93.3%
		139.1	150.7	92.3%
		138.9	150.7	92.2%
		140.0	150.7	92.9%
		139.6	150.7	92.6%
		142.2	150.7	94.4%
		141.4	150.7	93.8%
		141.6	150.7	94.0%
		141.1	150.7	93.6%
5/30/2012	13512	138.0	150.8	91.5%
	12334	138.5	150.8	91.8%
	9882	140.2	150.8	93.0%
	8234	138.8	150.8	92.0%
	5106	138.5	150.8	91.8%
	3812	141.3	150.8	93.7%
	2138	138.3	150.8	91.7%
Average		**139.4**	**150.7**	**92.5%**

ND 32 - HMA Compaction Control				
Date	**Station**	**Core Density**	**Maximum Theoretical Density**	**Compaction**
7/21/2011	180	136.4	150.9	90.4%
	200	138.5	150.9	91.8%
	220	137	150.9	90.8%
	240	138.3	150.9	91.7%
	260	137.8	150.9	91.3%
	280	139	150.9	92.1%
	300	138.5	150.9	91.8%
	320	140.4	150.9	93.0%
	340	141.2	150.9	93.6%
	360	139.2	150.9	92.2%
	380	140.4	150.9	93.0%
	400	139.1	150.9	92.2%
	420	140.9	150.9	93.4%
7/25/2011	470.64	138.2	150.4	91.9%
	490	142.3	150.4	94.6%
	510	140.8	150.4	93.6%
	530	144.3	150.4	95.9%
	550	138.2	150.4	91.9%
	570	138.6	150.4	92.2%
	590	139.1	150.4	92.5%
	610	143.2	150.4	95.2%
Average		**139.6**	**150.7**	**92.6%**

ND 32 - WMA Compaction Control				
Date	**Station**	**Core Density**	**Maximum Theoretical Density**	**Compaction**
7/18/2011	1700	138.4	151.2	91.5%
	480	139.7	151.2	92.4%
	1380	138.1	151.2	91.3%
	1860	137.1	151.2	90.7%
7/19/2011	920	139.9	150.3	93.1%
	2020	141.1	150.3	93.9%
	1720	140.1	150.3	93.2%
	1520	140.5	150.3	93.5%
	1300	142.6	150.3	94.9%
	540	143	150.3	95.1%
	1900	134.1	150.3	89.2%
	1520	136.6	150.3	90.9%
	1720	139.9	150.3	93.1%
7/20/2011	601	140.1	149.3	93.8%
	1740	140.3	149.3	94.0%
	1220	138.7	149.3	92.9%
	380	139.1	149.3	93.2%
	880	138.8	149.3	93.0%
	660	136.6	149.3	91.5%
	1880	137.3	149.3	92.0%
	920	135.7	149.3	90.9%
	1060	136.3	149.3	91.3%
Average		**138.8**	**150.1**	**92.5%**

ND 41 - HMA Compaction Control				
Date	**Station**	**Core Density**	**Maximum Theoretical Density**	**Compaction**
7/18/2011	26985	142.1	154.0	92.3%
	29265	140.5	154.0	91.2%
	30965	140.1	154.0	91.0%
	33905	144.8	154.0	94.0%
	35325	143.6	154.0	93.2%
	37045	143.7	154.0	93.3%
	39445	142.7	154.0	92.7%
	42485	142.9	154.0	92.8%
	43525	140.4	154.0	91.2%
	45605	141.2	154.0	91.7%
	48505	143.5	154.0	93.2%
	49265	139.9	154.0	90.8%
	51007	138.8	154.0	90.1%
7/19/2011	33655	139.3	153.7	90.6%
	36515	141.7	153.7	92.2%
	38035	143.3	153.7	93.2%
	39575	140.3	153.7	91.3%
	41915	140.9	153.7	91.7%
	43895	139.3	153.7	90.6%
	45575	137.8	153.7	89.7%
	47855	136.5	153.7	88.8%
	50715	141.4	153.7	92.0%
	51435	139.9	153.7	91.0%
7/20/2011	54088	142.6	153.2	93.1%
	56108	139.8	153.2	91.3%
	58168	141.6	153.2	92.4%
	60088	143.3	153.2	93.5%
	62568	142.9	153.2	93.3%
	64108	142.2	153.2	92.8%
	66028	142.7	153.2	93.1%
	68388	140.4	153.2	91.6%
	69768	142.2	153.2	92.8%
	72185	138.6	153.2	90.5%
Average		**141.2**	**153.7**	**91.9%**

ND 41 - WMA Compaction Control				
Date	**Station**	**Core Density**	**Maximum Theoretical Density**	**Compaction**
7/13/2011	2+63	141	152.6	92.4%
	22+63	137.9	152.6	90.4%
	42+63	145.4	152.6	95.3%
7/15/2011		142.5	153.0	93.1%
		146	153.0	95.4%
		144	153.0	94.1%
		143.1	153.0	93.5%
		144.3	153.0	94.3%
		144.1	153.0	94.2%
		142.7	153.0	93.3%
		144.8	153.0	94.6%
		141.7	153.0	92.6%
		141.8	153.0	92.7%
7/16/2011	751+95	141.9	153.1	92.7%
	768+75	138.4	153.1	90.4%
	790+15	144.3	153.1	94.3%
	810+55	142.5	153.1	93.1%
	822+95	143.1	153.1	93.5%
	848+25	140.3	153.1	91.6%
	819+18	143.0	153.1	93.4%
	845+21	141.8	153.1	92.6%
Average		**142.6**	**153.0**	**93.2%**