**RESEARCH REPORT DOCUMENTATION PAGE**

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| ND 2010-02 | May 2013 | N/A | SS-3-020(072)069 |

| 5. Title and Subtitle | 6. Report Type | 7. Project No. |
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| Warm Mix Asphalt | Work Plan ☐<br>Construction ☐<br>Evaluation ☐<br>Final ☒ | 8. Project No.<br>9. Project No.<br>10. Project No. |

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

| 12. Performing Organization Name and Address | 13. Sponsoring Agency Name and Address |
| --- | --- |
| NDDOT M+R ☒<br>NDDOT OTHER* ☐<br>NDSU ☐<br>UND ☐<br>UGPTI ☐<br>OTHER* ☐<br>*see supplementary notes<br><br>North Dakota DOT<br>Materials and Research Division<br>300 Airport Road<br>Bismarck ND 58504-6005 | North Dakota DOT<br>Materials and Research Division<br>300 Airport Road<br>Bismarck ND 58504-6005 |

14. Supplementary Notes

15. Abstract


**Purpose and Need**

This research will use a locally available chemical additive called Evotherm 3G to produce the WMA. Evotherm 3G (Third Generation) – was developed in partnership with Paragon Technical Services and Mathy Technology & Engineering. This water-free form of Evotherm is suitable for introducing additives at the hot mix plant or asphalt terminal. Evotherm 3G generally lowers mix temperatures 60-85°F. The purpose of this research is to evaluate the performance of WMA using Evotherm 3G as an additive on NDDOT asphalt paving projects.

**Objective**

The objective of this project is to compare the compaction density of WMA to the compaction density of typical Hot Mix Asphalt (HMA). The asphalt plant mix temperature will also be monitored to compare fuel consumption for the production of HMA to fuel consumption for the production of WMA using Evotherm 3G as an additive.

**Scope**

This project will use one thin lift paving project to evaluate the WMA using Evotherm 3G to provide the viscosity reduction in the asphalt. The project selected for this research is SS-3-020(072)069. This project is planned to be 8.628 miles in length. The entire project will be paved with WMA for the experimental section. Approximately 5 miles, of project SNH-3-281(093)128 a separate highway, will be used for a control section from RP 130 to RP 135.

**Summary**

The WMA research section and the HMA control section are both performing the same. The materials and methods used to produce WMA provide a lower temperature asphalt mix therefore reducing the emissions, exposure to workers, and fuel consumption. The end product of WMA appears to be the equivalent to HMA. Therefore, it is recommended that use of WMA be an option on thin lift paving projects.


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# NORTH DAKOTA
# DEPARTMENT OF TRANSPORTATION

# MATERIALS AND RESEARCH DIVISION

Experimental Study

ND 2010-02

Warm Mix Asphalt

Construction – Final Evaluation

April 2013

Prepared by


**NORTH DAKOTA DEPARTMENT OF TRANSPORTATION**
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**Ron Horner, P.E.**

Written by: Kyle Evert

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

# EXPERIMENTAL PROJECT REPORT

| | | | |
|---|---|---|---|
| EXPERIMENTAL PROJECT | EXPERIMENTAL PROJECT NO.<br>1 ND 2010 - 02 | CONSTRUCTION PROJ NO<br>SS-3-020(072)069 | LOCATION<br>ND 11 - McIntosh County, ND |
| | EVALUATION FUNDING<br>48 1 HP&R 3 DEMONSTRATION<br>2 CONSTRUCTION 4 X IMPLEMENTATION | NEEP NO.<br>49 | PROPRIETARY FEATURE?<br>51 X Yes<br>No |
| SHORT TITLE | TITLE<br>52 Evaluation of the Rut Resistance Performance of Warm Mix Asphalts in North Dakota | | |
| THIS FORM | DATE 140 MO. April -- YR. 2013 | REPORTING<br>1 INITIAL 2 ANNUAL 3 X FINAL | |
| KEY WORDS | KEY WORD 1<br>145 Warm Mix Asphalt | KEY WORD 2<br>167 Hot Mix Asphalt | |
| | KEY WORD 3<br>189 Evotherm | KEY WORD 4<br>211 | |
| | UNIQUE WORD<br>233 | PROPRIETARY FEATURE NAME<br>255 | |

| CHRONOLOGY | Date Work Plan Approved | Date Feature Constructed: | Evaluation Scheduled Until: | Evaluation Extended Until: | Date Evaluation Terminated: |
|---|---|---|---|---|---|
| | 277 2010 | 281 August 2010 | 285 2012 | 289 December 2012 | 293 |

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

| AVAILABLE EVALUATION REPORTS | CONSTRUCTION | PERFORMANCE | FINAL |
|---|---|---|---|
| | 315 | | X |

| EVALUATION | CONSTRUCTION PROBLEMS | PERFORMANCE |
|---|---|---|
| | 318<br>1 X NONE<br>2 SLIGHT<br>3 MODERATE | 319<br>1 EXCELLENT<br>2 GOOD<br>3 X SATISFACTORY<br>4 MARGINAL |

| APPLICATION | | |
|---|---|---|
| | 320<br>1 ADOPTED AS PRIMARY STD.<br>2 PERMITTED ALTERNATIVE<br>3 ADOPTED CONDITIONALLY | 4 X PENDING<br>5 REJECTED<br>6 NOT CONSTRUCTED<br>*(Explain in remarks if 3, 4, 5, or 6 is checked)* |

| REMARKS | |
|---|---|
| | 321<br>The objective of this project is to compare the compaction density of WMA to the compaction density of typical Hot Mix Asphalt (HMA). The asphalt plant mix temperature will also be monitored to compare fuel consumption for the production of HMA to fuel consumption for the production of WMA using Evotherm 3G as an additive. |

Experimental Study ND 2010-02

# Warm Mix Asphalt

# Construction – Final Evaluation

April 2013

Written by
Kyle Evert

## Disclaimer

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# Work Plan
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## Purpose and Need

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

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

This research will use a locally available chemical additive called Evotherm 3G to produce the WMA. Evotherm 3G (Third Generation) – was developed in partnership with Paragon Technical Services and Mathy Technology & Engineering. This water-free form of Evotherm is suitable for introducing additives at the hot mix plant or asphalt terminal. Evotherm 3G generally lowers mix temperatures 60-85°F. The purpose of this research is to evaluate the performance of WMA using Evotherm 3G as an additive on NDDOT asphalt paving projects.

## Objective

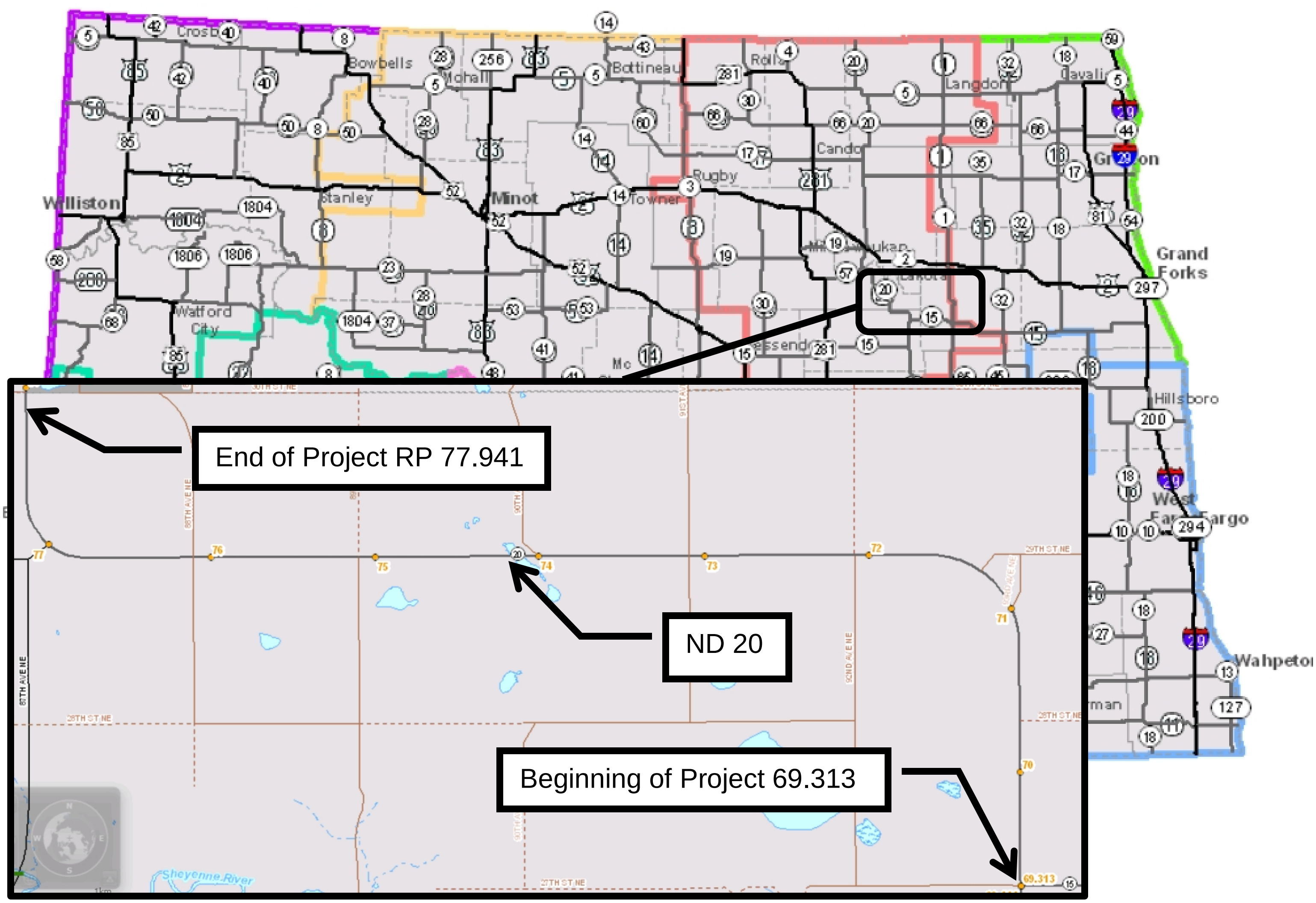
The objective of this project is to compare the compaction density of WMA to the compaction density of typical Hot Mix Asphalt (HMA). The asphalt plant mix temperature will also be monitored to compare fuel consumption for the production of HMA to fuel consumption for the production of WMA using Evotherm 3G as an additive.

## Scope

This project will use one thin lift paving project to evaluate the WMA using Evotherm 3G to provide the viscosity reduction in the asphalt. The project selected for this research is SS-3-020(072)069. This project is planned to be 8.628 miles in length. The entire project will be paved with WMA for the experimental section. Approximately 5 miles, of project SNH-3-281(093)128 a separate highway, will be used for a control section from RP 130 to RP 135.

## Location

The location of the experimental section is the entire roadway on ND 20 from approximately reference point 69.313 to reference point 77.941 and the control section is the entire roadway from RP 130 to RP 135 on US 281.



## Design

The project chosen for this research is scheduled for a thin lift overlay. The roadway will be overlaid with 1.5" of HMA and WMA for both the control and experimental section.

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

*408-P03* *WARM MIX ASPHALT: The warm mix asphalt (WMA) process will be used on this project from approx. RP 69.313 to 77.941.*

*The Evotherm 3G product shall be added to the asphalt binder by the supplier or refiner and have no special handling requirements above and beyond those of the binder itself.*

*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 408 for the production and placement of conventional HMA mixtures are to be enforced except as noted in these plans.*

*The contractor shall modify the mix design used to produce the HMA to meet the WMA criteria when produced with Evotherm 3G additive. All current mix design criteria will be required when developing the WMA mix design. The mix design will be contractor developed.*

*The WMA produced shall not exceed temperatures greater than 275°F. Any WMA over that temperature will not be used. 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 along with the test time and quantity of mix produced. This information will be provided to the Engineer on a daily basis.*

*Place the WMA on dry, unfrozen surfaces and only when weather conditions allow for proper production, placement, handling, and compaction. The minimum delivery, placement and compaction temperatures that will achieve workability and density requirements will be reviewed and approved by the Engineer. The minimum rolling temperature will be established during the start of mix production.*

*All costs for the WMA shall be included in the price bid for 'Hot Bituminous Pavement Cl 29' and 'Warm Mix Modified PG Asphalt'.*

*950-P01* *WARM MIX MODIFIED PG ASPHALT: The Warm Mix Modified PG Asphalt shall consist of PG 58-28 asphalt cement modified with Evotherm 3G.*

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

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 temperature, density, rolling efforts and plant setting will be monitored.

## Construction

Project SS-3-020(072)069 was a thin lift overlay designed and administered by the Grand Forks district. The project was originally programmed to be administered by the Devils Lake district but was transferred to the Grand Forks district to help reduce work load on the Devils Lake district. The construction of the WMA section was performed August 20 to August 25, 2010 by Knife River Materials. The control section is a Class 29 HMA that was also constructed by Mayo Construction Company Inc. from September 13 to 16, 2010.

The paving process was performed by different paving companies for the WMA and HMA. Also the aggregate used for the jobs came from separate pits.

The cost of the WMA and HMA differed due to the additional cost of the Evotherm additive. The difference can be seen in Table 1 below.

| SS-3-020(072)069 | | | | |
|---|---|---|---|---|
| **Asphalt** | **Quantity (Tons)** | **Unit Price** | **Total Cost** | **Cost Per Mile** |
| Warm Mix Modified PG Asphalt | 999 | $652 | $651,348 | $75,127 |

| SNH-3-281(093)128 | | | | |
|---|---|---|---|---|
| **Asphalt** | **Quantity (Tons)** | **Unit Price** | **Total Cost** | **Cost Per Mile** |
| PG 58-28 Asphalt Cement | 3,073 | $480 | $1,475,040 | $60,696 |

**Table 1 – Cost comparisons between the WMA and HMA taken from contractors bid document.**

Cores were taken for density requirements in both the experimental and control sections by the Grand Forks district. The core mat densities are compared to the maximum theoretical density to develop a percentage of compaction. The WMA had better compaction then the HMA. Both projects exceed compaction requirements. The compaction of the WMA displays that the Evotherm has no detrimental effect to density and workability of the mix. The average compaction can be seen in Table 2 and the results for all the cores can be found in Appendix A.

| SS-3-020(072)069 - Compaction Control - WMA | | SNH-3-281(093)128 - Compaction Control - HMA | |
|---|---|---|---|
| **Date** | **Average Compaction** | **Date** | **Average Compaction** |
| 8/20/2010 | 95.0% | 9/13/2010 | 92.1% |
| 8/21/2010 | 93.9% | 9/14/2010 | 92.9% |
| 8/22/2010 | 93.8% | 9/15/2010 | 92.7% |
| 8/23/2010 | 94.3% | 9/16/2010 | 92.3% |
| **Average** | **94.2%** | **Average** | **92.5%** |

**Table 2 – Average daily densities.**

The temperatures of the WMA and HMA were measured throughout the paving process. Measurements were recorded from the windrow, behind the paver, and again before rolling the WMA. Different mix temperatures were used to observe the performance limits of the Evotherm.

The rolling process used steel drum rollers for the breakdown and intermediate rolling. A vibratory steel drum roller was used for the finish rolling. The number of rollers for each project was the same; however the number of passes each roller completed was not recorded. The temperatures of the pavement immediately before the rollers, behind the paver and the windrow are displayed in the Appendix B. The average temperatures can be seen in Table 3.

| Average WMA and HMA Temperature (F) | Windrow | Behind Paver | Behind Roller | Behind 2nd Roller | Behind 3rd Roller |
|---|---|---|---|---|---|
| SS-3-020(072)069 WMA | 249 | 234 | 228 | 161 | 162 |
| SNH-3-281(093)128 HMA | 283 | 273 | 250 | 224 | 165 |

**Table 3 – Average WMA temperature during different operations of the paving process.**

The plant production rate is being used to measure the efficiency of the WMA. The target temperature is the temperature that 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 drying time and reduces production rate. Table 4 has the target temperature along with the plant production rate for the two days of paving with the WMA. Table 4 also displays the effect of the mix temperature on the efficiency.

This can be seen by how the decreasing mix temperature corresponds with the increasing production rate therefore improving the efficiency of the plant.

| SS-3-020(072)069 WMA | | | SNH-3-281(093)128 HMA | | |
|---|---|---|---|---|---|
| **Date** | **Average Temperature** | **Average Production Rate (TPH)** | **Date** | **Average Temperature** | **Average Production Rate (TPH)** |
| 8/20/2010 | 237 | 388 | 9/13/2010 | 297 | 376 |
| 8/21/2010 | 231 | 408 | 9/14/2010 | 303 | 374 |
| 8/23/2010 | 239 | 427 | 9/15/2010 | 293 | 378 |
| 8/24/2010 | 251 | 428 | 9/16/2010 | 305 | 374 |
| 8/25/2010 | 244 | 423 | | | |
| **Average** | **240** | **415** | **Average** | **300** | **376** |

**Table 4 – Mix temperatures and production rates of the WMA.**

## Field Evaluation – 2011/2012

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 December of 2011 and then again in December 2012. The transverse cracks and rutting measurements were recorded. The rutting was very minimal throughout the research and control section. The rutting was less than 1/16$^{th}$ of an inch throughout both the research section and the control section. The transverse cracking can be seen below in Table 5 and Table 6.

| SS-3-020(072)069 WMA | | |
|---|---|---|
| **Reference Point** | **Transverse Cracks** | |
| | **1st Evaluation 2011** | **2nd Evaluation 2012** |
| 70 | 125 | 142 |
| 71 | 100 | 137 |
| 72 | 83 | 113 |
| 73 | 86 | 118 |
| 74 | 72 | 110 |
| 75 | 103 | 144 |
| 76 | 101 | 132 |
| 77 | 95 | 117 |

**Table 5 - Transverse cracking for both the research section.**

| SNH-3-281(093)128 HMA | | |
|---|---|---|
| **Reference Point** | **Transverse Cracks** | |
| | **1st Evaluation 2011** | **2nd Evaluation 2012** |
| 130 | 136 | 160 |
| 131 | 148 | 152 |
| 132 | 129 | 161 |
| 133 | 140 | 141 |
| 134 | 144 | 162 |

**Table 6 - Transverse cracking for both the control section.**

## Summary

The density, mat temperature, plant temperature, rolling efforts, and plant settings were monitored during the construction of this project. The construction of the WMA was very similar to the HMA. The WMA was paved with no noticeable differences other than production temperature and Evotherm 3G additive.

The density for the HMA was slightly lower than the WMA. The average compaction for the WMA was 94.2% and the HMA was 92.5% of maximum theoretical density. Both projects exceeded the density of 91% minimum from the NDDOT specifications.

The field temperature for the WMA averaged 32° F lower than the HMA behind the roller. WMA showed the ability to achieve densities at a lower temperature then the HMA.

Plant temperature versus production was used to measure the efficiency of the plant. As the temperature of the mix decreases the rate that the aggregate and oil pass through the mixing drum increases. As the mix temperature was changed on these projects the plant production rate also changed accordingly. This indicates that a decrease in the plant temperature will increase production.

Transverse cracking has appeared in both the test and control section after one year of service. The second evaluation indicates that transverse cracking is increasing but at decreased rate from the first year of service.

The rutting in the experimental section is very minimal. This is expected since there was very little rutting before due to the low number of traffic ESAL's (30 daily ESAL's) on the research section. The rutting is also low on the control section. The daily ESAL's on this section is 181.

## Recommendation

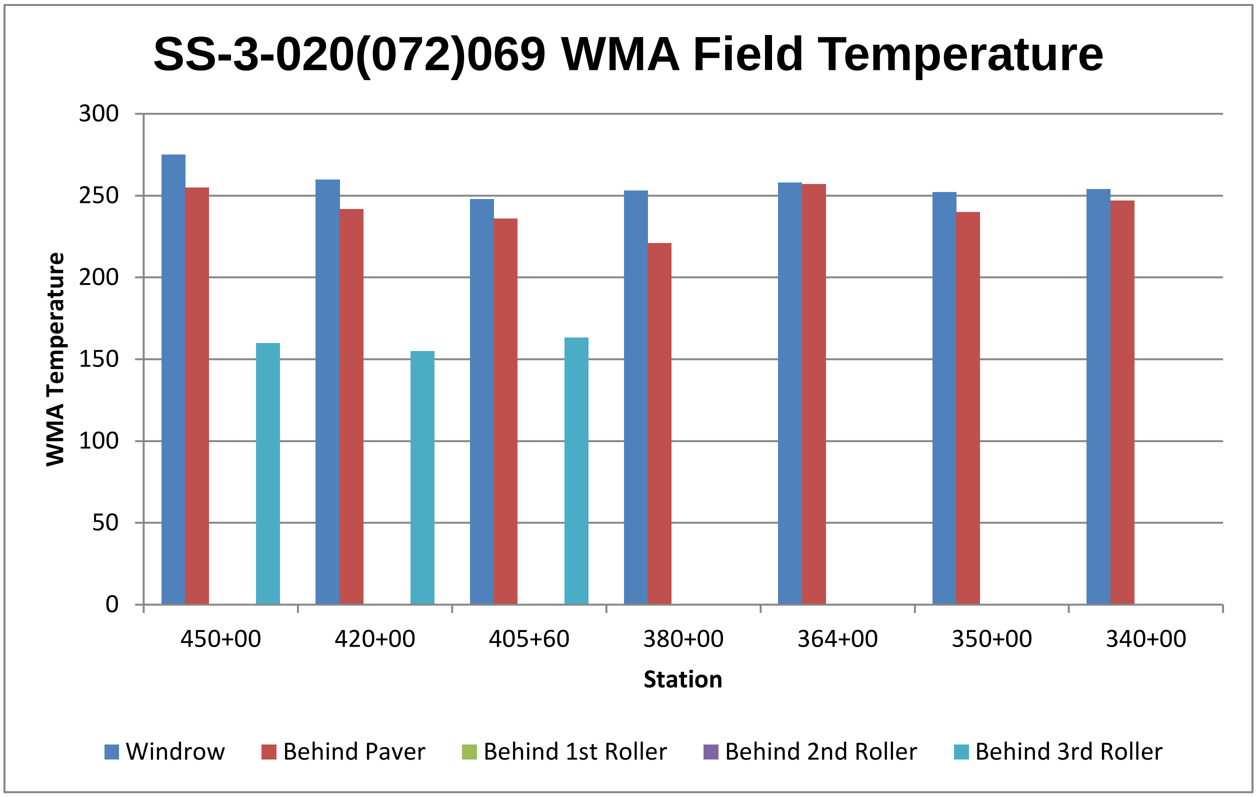
The WMA research section and the HMA control section are both performing the same. The materials and methods used to produce WMA provide a lower temperature asphalt mix therefore reducing the emissions, exposure to workers, and fuel consumption. The end product of WMA appears to be the equivalent to HMA. Therefore, it is recommended that use of WMA be an option on thin lift paving projects.

# Appendix A

| SS-3-020(072)069 WMA - Compaction Control | | | | |
|---|---|---|---|---|
| **Date** | **Station** | **Core Density** | **Maximum Theoretical Density** | **Compaction** |
| 8/20/2010 | 457+77 | 143.3 | 152.1 | 94.2% |
| | 437+77 | 144.4 | 152.1 | 94.9% |
| | 417+77 | 145 | 152.1 | 95.3% |
| | 397+77 | 145.5 | 152.1 | 95.7% |
| | 277+77 | 145.5 | 152.1 | 95.7% |
| | 357+77 | 144.7 | 152.1 | 95.1% |
| | 337+77 | 143.1 | 152.1 | 94.1% |
| 8/21/2010 | 457+77 | 144.6 | 152.7 | 94.7% |
| | 437+77 | 144.7 | 152.7 | 94.8% |
| | 417+77 | 142.8 | 152.7 | 93.5% |
| | 397+77 | 145.7 | 152.7 | 95.4% |
| | 277+77 | 144.1 | 152.7 | 94.4% |
| | 357+77 | 139.8 | 152.7 | 91.6% |
| | 337+77 | 142.2 | 152.7 | 93.1% |
| 8/22/2010 | 317+75 | 142.6 | 152.3 | 93.6% |
| | 297+75 | 142.3 | 152.3 | 93.4% |
| | 277+75 | 143.6 | 152.3 | 94.3% |
| | 257+75 | 142 | 152.3 | 93.2% |
| | 237+75 | 147 | 152.3 | 96.5% |
| | 217+75 | 142.3 | 152.3 | 93.4% |
| | 197+75 | 141.8 | 152.3 | 93.1% |
| | 177+75 | 141.1 | 152.3 | 92.6% |
| 8/23/2010 | 332+28 | 146.5 | 152.5 | 96.1% |
| | 312+28 | 142.3 | 152.5 | 93.3% |
| | 292+28 | 145.4 | 152.5 | 95.3% |
| | 272+28 | 143.8 | 152.5 | 94.3% |
| | 252+28 | 144.7 | 152.5 | 94.9% |
| | 232+28 | 144.6 | 152.5 | 94.8% |
| | 212+28 | 144.5 | 152.5 | 94.8% |
| | 192+28 | 143.3 | 152.5 | 94.0% |
| | 172+28 | 142.7 | 152.5 | 93.6% |
| | 152+28 | 145.5 | 152.5 | 95.4% |
| | 132+28 | 142.2 | 152.5 | 93.2% |
| | 112+28 | 142.2 | 152.5 | 93.2% |
| | 92+28 | 141.8 | 152.5 | 93.0% |
| **Average** | | **143.6** | **152.4** | **94.2%** |

| SNH-3-281(093)128 HMA- Compaction Control | | | | |
|---|---|---|---|---|
| Date | Station | Core Density | Maximum Theoretical Density | Compaction |
| 9/13/2010 | 351+36 | 142.8 | 153.6 | 93.0% |
| | 331+36 | 143.2 | 153.6 | 93.2% |
| | 311+36 | 141.6 | 153.6 | 92.2% |
| | 291+36 | 138.4 | 153.6 | 90.1% |
| | 271+36 | 142.5 | 153.6 | 92.8% |
| | 251+36 | 140.8 | 153.6 | 91.7% |
| | 231+36 | 139.8 | 153.6 | 91.0% |
| | 211+36 | 141.8 | 153.6 | 92.3% |
| | 191+36 | 142.7 | 153.6 | 92.9% |
| 9/14/2010 | 349+84 | 144.3 | 153.5 | 94.0% |
| | 329+84 | 143 | 153.5 | 93.2% |
| | 309+84 | 140.3 | 153.5 | 91.4% |
| | 289+84 | 141 | 153.5 | 91.9% |
| | 269+84 | 143.4 | 153.5 | 93.4% |
| | 249+84 | 143.4 | 153.5 | 93.4% |
| | 229+84 | 142.7 | 153.5 | 93.0% |
| | 209+84 | 142.5 | 153.5 | 92.8% |
| 9/15/2010 | 181+58 | 142.8 | 154.0 | 92.7% |
| | 161+58 | 142.7 | 154.0 | 92.7% |
| | 141+58 | 142.1 | 154.0 | 92.3% |
| | 121+58 | 144.4 | 154.0 | 93.8% |
| | 101+58 | 143.2 | 154.0 | 93.0% |
| | 81+58 | 143.1 | 154.0 | 92.9% |
| | 61+58 | 140.7 | 154.0 | 91.4% |
| 9/16/2010 | 190+75 | 143.3 | 154.2 | 92.9% |
| | 170+75 | 141.8 | 154.2 | 92.0% |
| | 150+75 | 141.5 | 154.2 | 91.8% |
| | 130+75 | 143.0 | 154.2 | 92.7% |
| | 110+75 | 143.1 | 154.2 | 92.8% |
| | 90+75 | 142.6 | 154.2 | 92.5% |
| | 70+75 | 141.4 | 154.2 | 91.7% |
| **Average** | | **142.3** | **153.8** | **92.5%** |

## Appendix B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WMA Temperature
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420+00
405+60
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350+00
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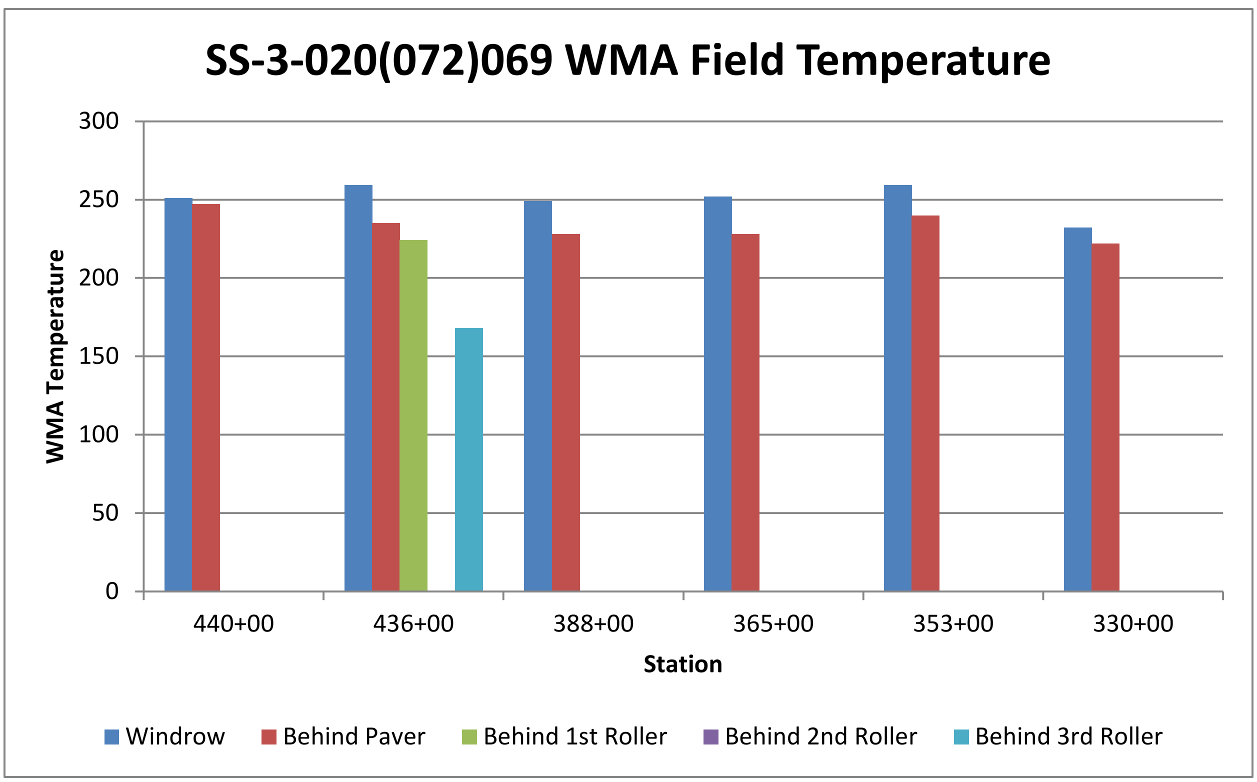
Station
Windrow
Behind Paver
Behind 1st Roller
Behind 2nd Roller
Behind 3rd Roller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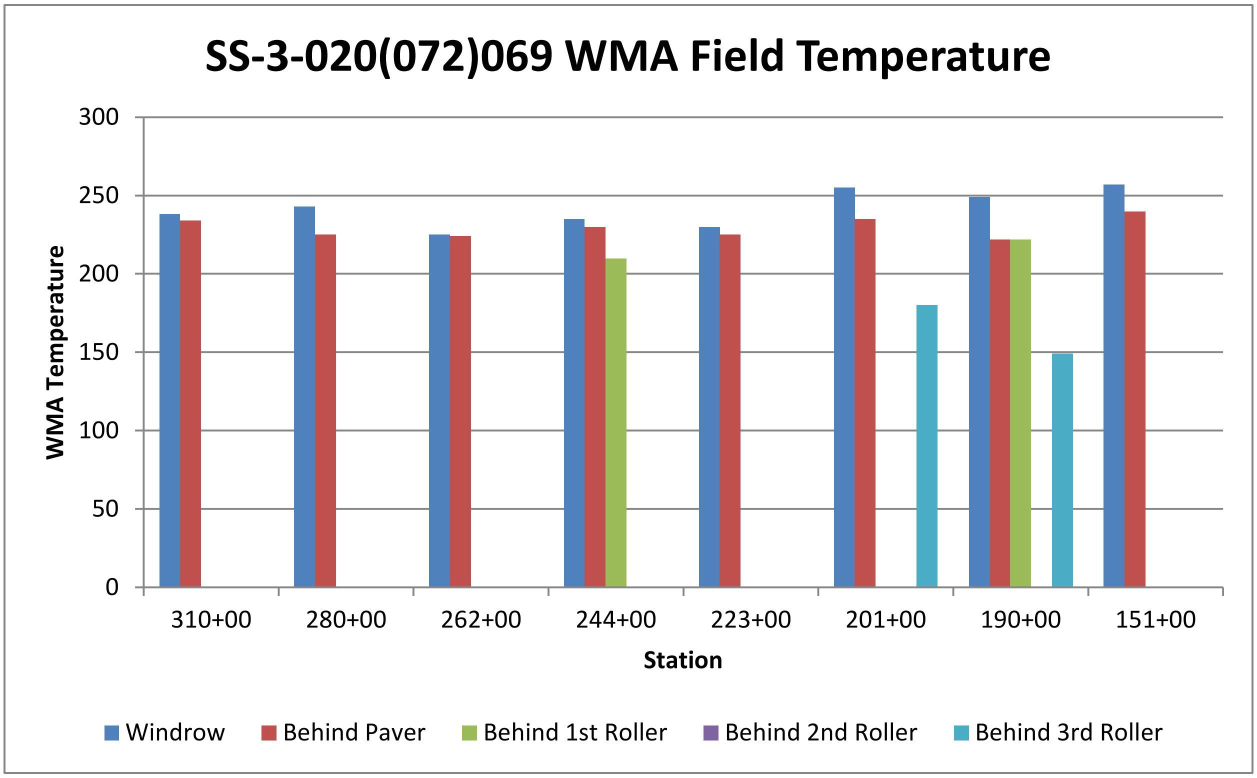
Behind 2nd Roller
Behind 3rd Roller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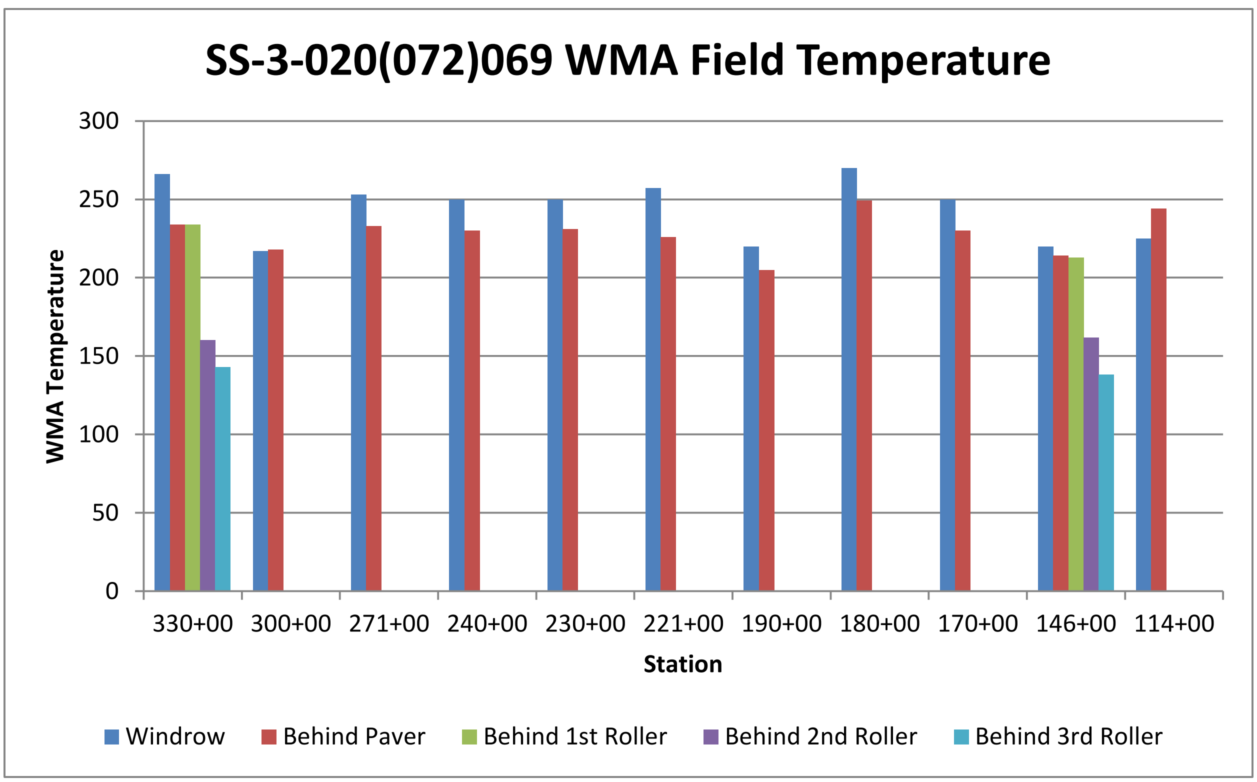
Behind 2nd Roller
Behind 3rd Roller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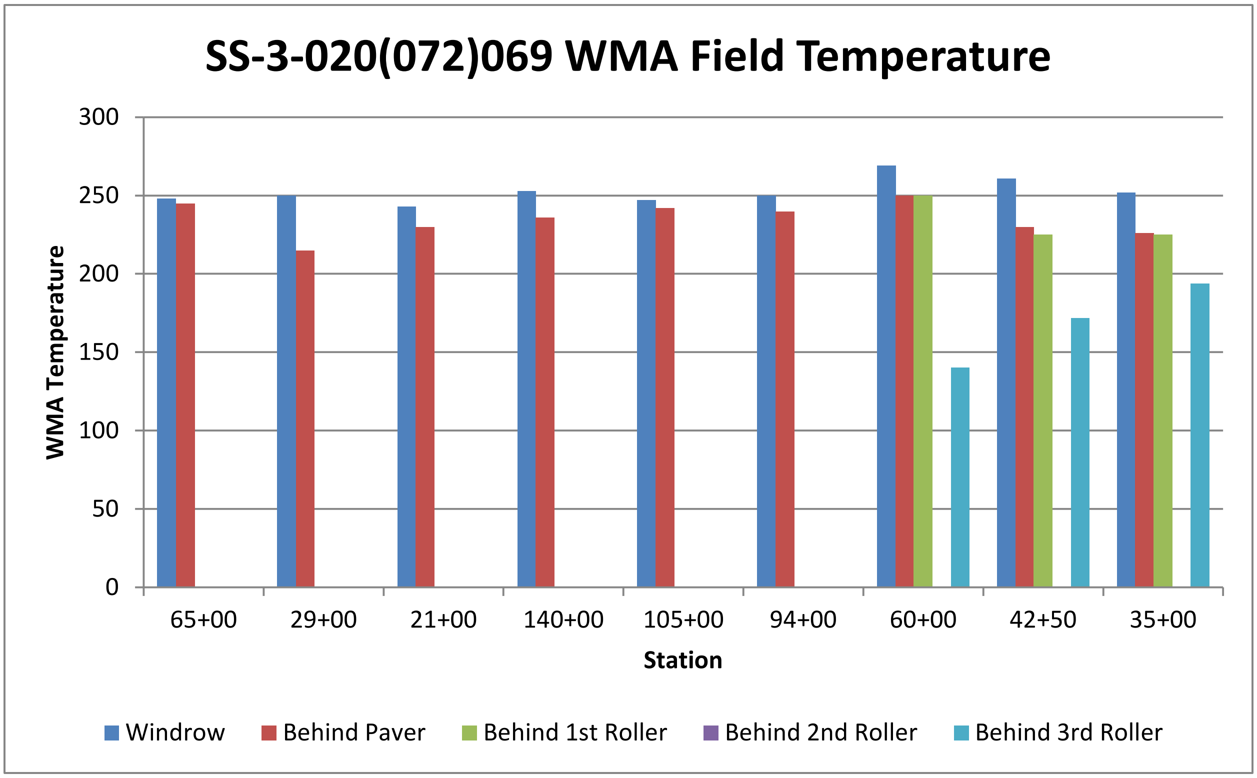
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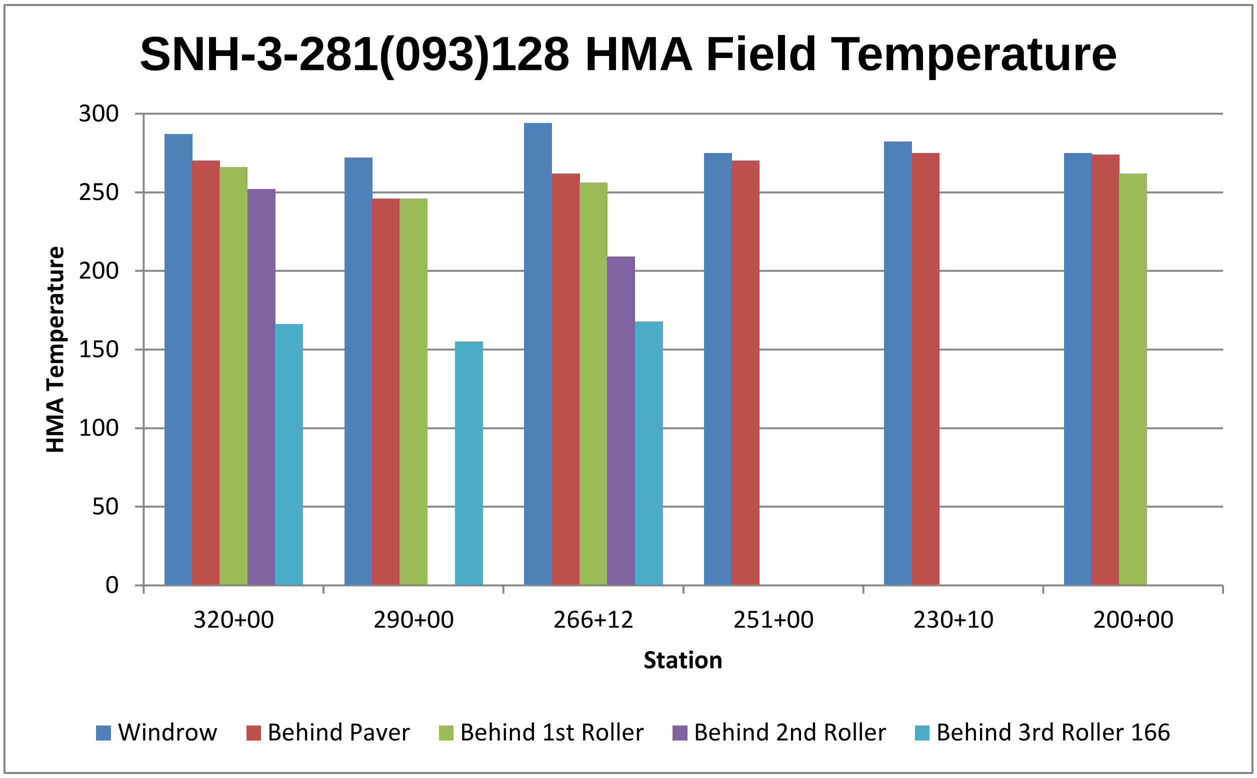
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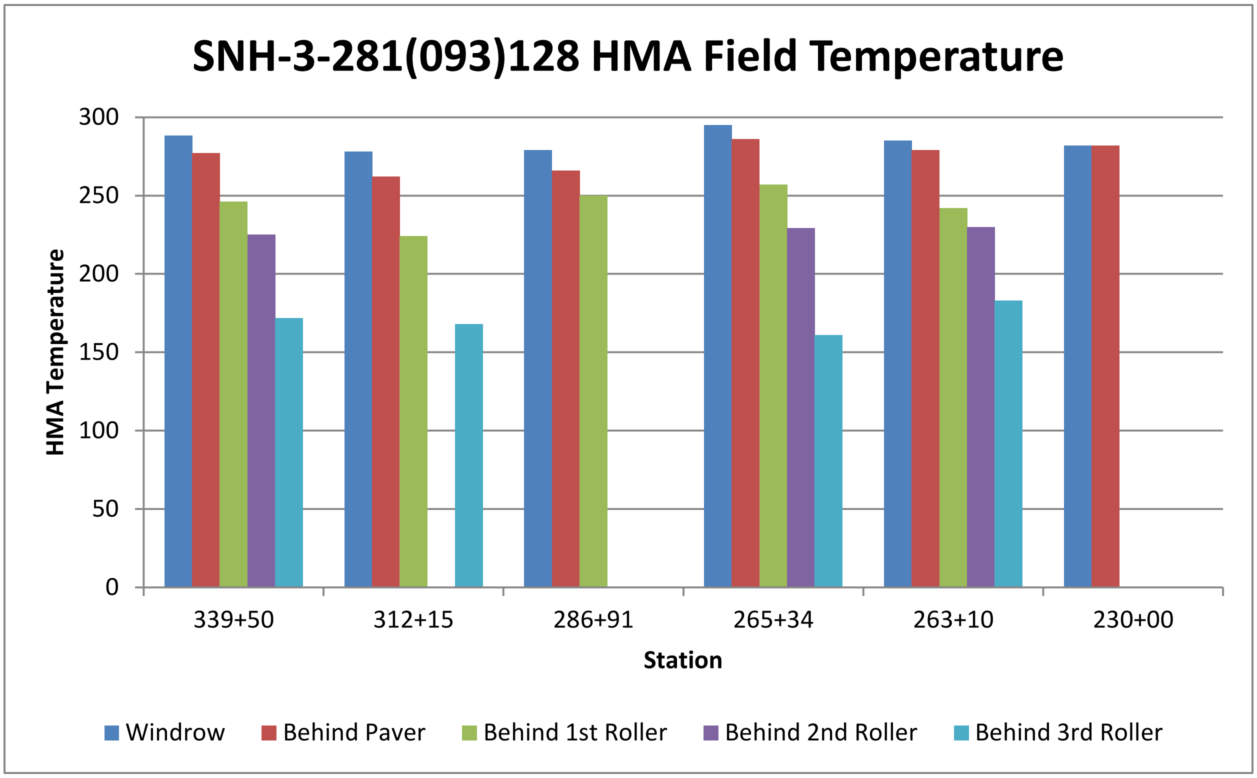
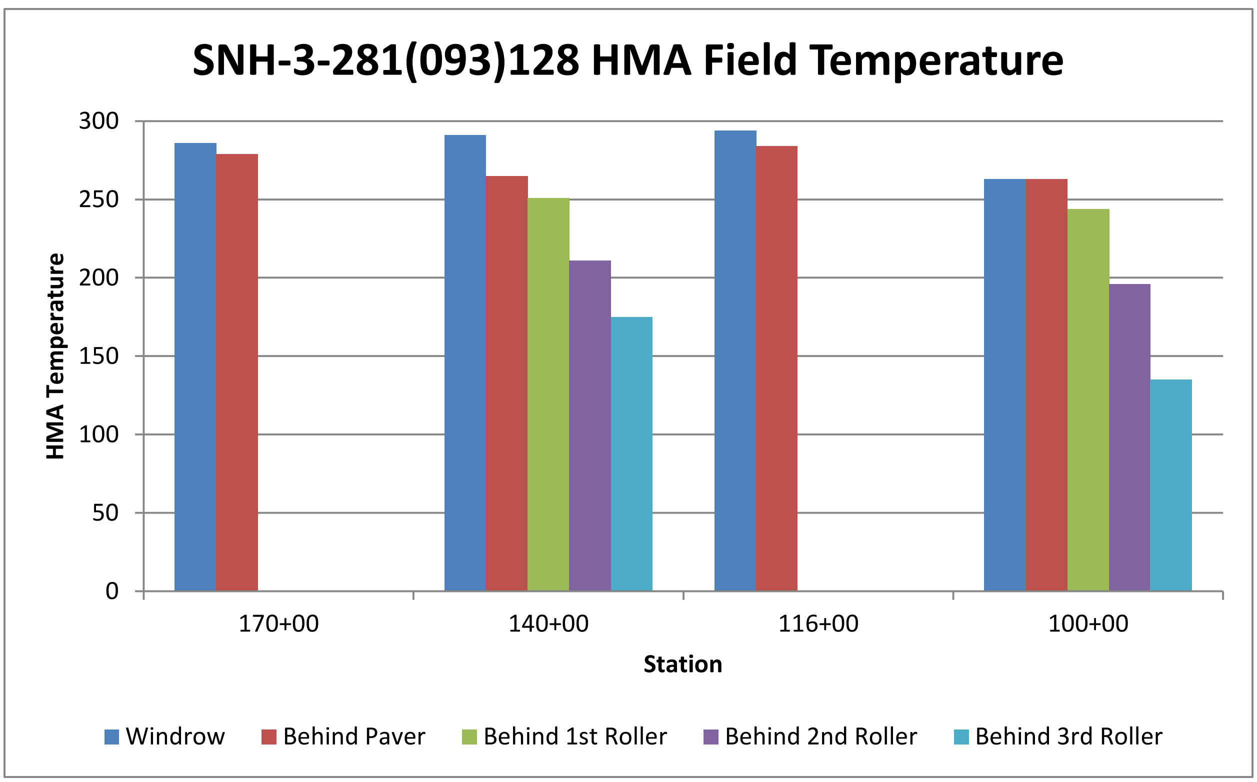
320+00
290+00
266+12
251+00
230+10
200+00
Station
Windrow
Behind Paver
Behind 1st Roller
Behind 2nd Roller
Behind 3rd Roller 166


SNH-3-281(093)128 HMA Field Temperature
300
250
200
150
100
50
0
HMA Temperature
339+50
312+15
286+91
265+34
263+10
230+00
Station
Windrow
Behind Paver
Behind 1st Roller
Behind 2nd Roller
Behind 3rd Roller


SNH-3-281(093)128 HMA Field Temperature
300
250
200
150
100
50
0
HMA Temperature
170+00
140+00
116+00
100+00
Station
Windrow
Behind Paver
Behind 1st Roller
Behind 2nd Roller
Behind 3rd Roller