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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 H-MDF-2-011(025)035. This project is planned to be 25.210 miles in length. Approximately 5 miles of the project will be paved with WMA for the experimental section and approximately 5 miles of the project will be the control section using a Class 27, PG 58-28 HMA. The research project duration will be three years and will include a construction report and a final report.

Summary

The WMA research section and the HMA control section are both performing the same. The construction method of the WMA provides 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

MR 2010-02

Warm Mix Asphalt

Construction – Final Evaluation

April 2013

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Disclaimer

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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 that have been reported are reduced emissions, reduced fuel consumption for the burner, paving aspects, and reduced emission exposure to workers.

Warm Mix Asphalt 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 reduce the viscosity of the asphalt and provide complete 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 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 mix plant or asphalt terminal. Evotherm 3G generally lowers the mix temperatures approximately 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

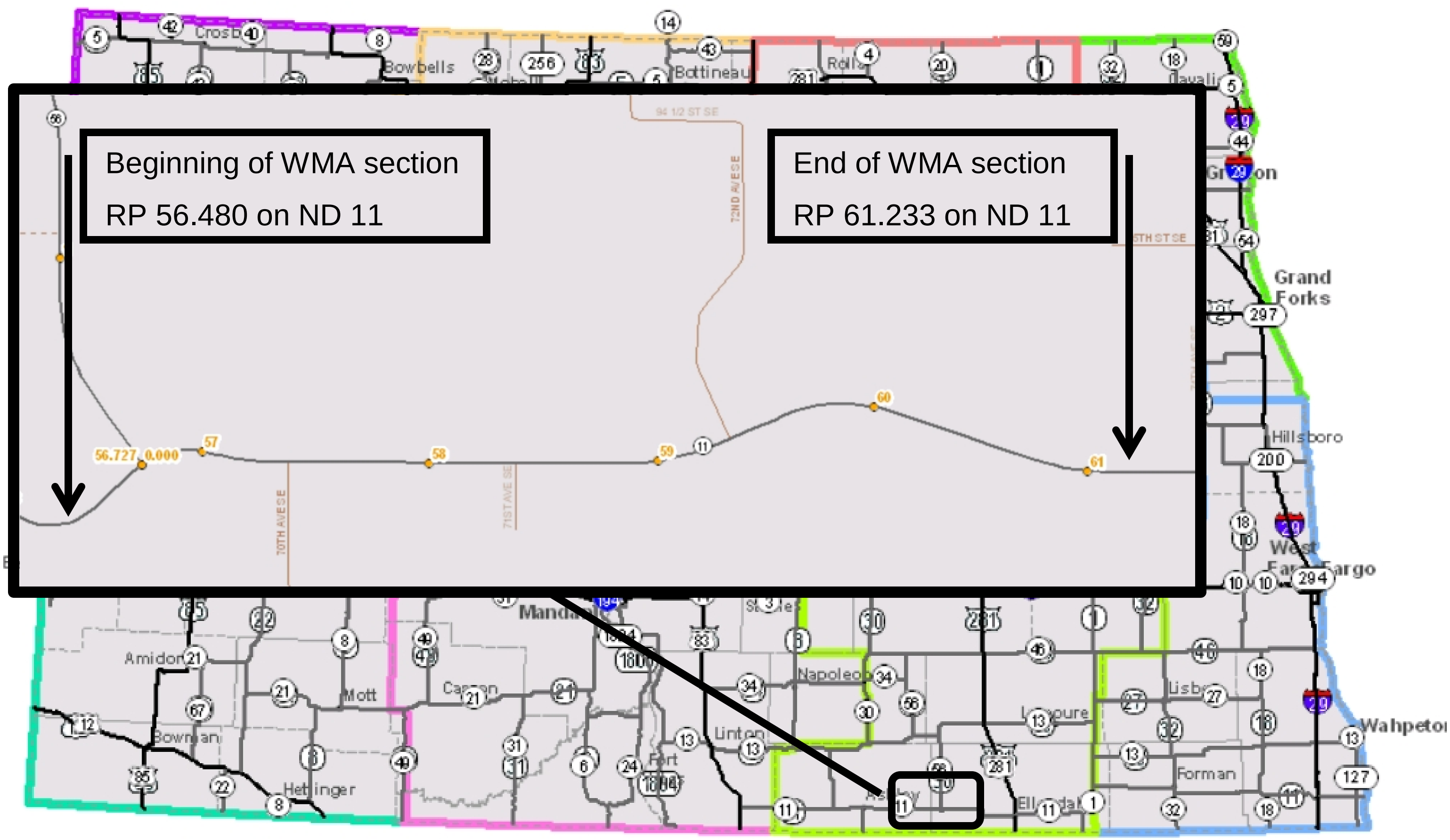
The objective of this project is to compare the compaction density of WMA to the compaction density of typical Hot Mix Asphalt (HMA). Also the asphalt plant settings will be monitored to compare fuel consumption for the production of HMA to fuel consumption for the production of WMA using Evotherm 3G 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 H-MDF-2-011(025)035. This project is planned to be 25.210 miles in length. Approximately 5 miles of the project will be paved with WMA for the experimental section and approximately 5 miles of the project will be the control section using a Class 27, PG 58-28 HMA. The research project duration will be three years and will include a construction report and a final report.

Location

The location of the experimental section is the entire roadway on ND 11 from reference point 56.480 to reference point 61.233 and the control section is the entire roadway from reference point RP 51.000 to reference point 56.000.



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 56.480 to 61.233.*

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 27' 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 construction, the density, temperature, rolling efforts, and plant setting will be monitored.

Construction

Project H-MDF-2-011(025)035 was a thin lift overlay designed and administered by the Valley City District. The construction of the WMA section was performed July 22 and July 23, 2010 by Central Specialties Inc. (CSI). The control section is a Class 27 Hot Bituminous Asphalt (HMA) that was also constructed by CSI on July 20 and July 21, 2010.

The process remained the same for the paving of the WMA and HMA. The only difference was the Evotherm additive for the WMA which was added at the suppliers manufacturing plant. This additive allowed the WMA to be produced at a lower temperature then the HMA.

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

H-MDF-2-011(025)035				
Asphalt	**Quantity (Tons)**	**Unit Price**	**Total Cost**	**Cost Per Mile**
PG 58-28 Asphalt Cement	2,118	$550	$1,164,900	$55,978
Warm Mix Modified PG Asphalt	544	$610	$331,840	$69,817

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 section by the Valley City district. The core mat densities are compared to the maximum theoretical density to develop a percentage of compaction. Both sections had very similar densities indicating that Evotherm did not have any negative effect on the compaction of the HMA. The average compaction can be seen in Table 2 and the results for all the cores can be found in Appendix A.

H-MDF-2-011(025)035 - Compaction Control - HMA		H-MDF-2-011(025)035 - Compaction Control - WMA	
Date	**Average Compaction**	**Date**	**Average Compaction**
7/19/2010	93.8%	7/21/2010	92.9%
7/20/2010	94.2%	7/22/2010	94.3%
Average	**94.0%**	**Average**	**93.6%**

Table 2 – Average daily densities.

The temperature of the WMA was 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 temperatures for the HMA control section were unable to be collected.

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 rolling patterns did not change from the experimental section to the control section. The temperatures of the pavement before the rollers, behind the paver and the windrow are displayed in the charts below and in Table 3.

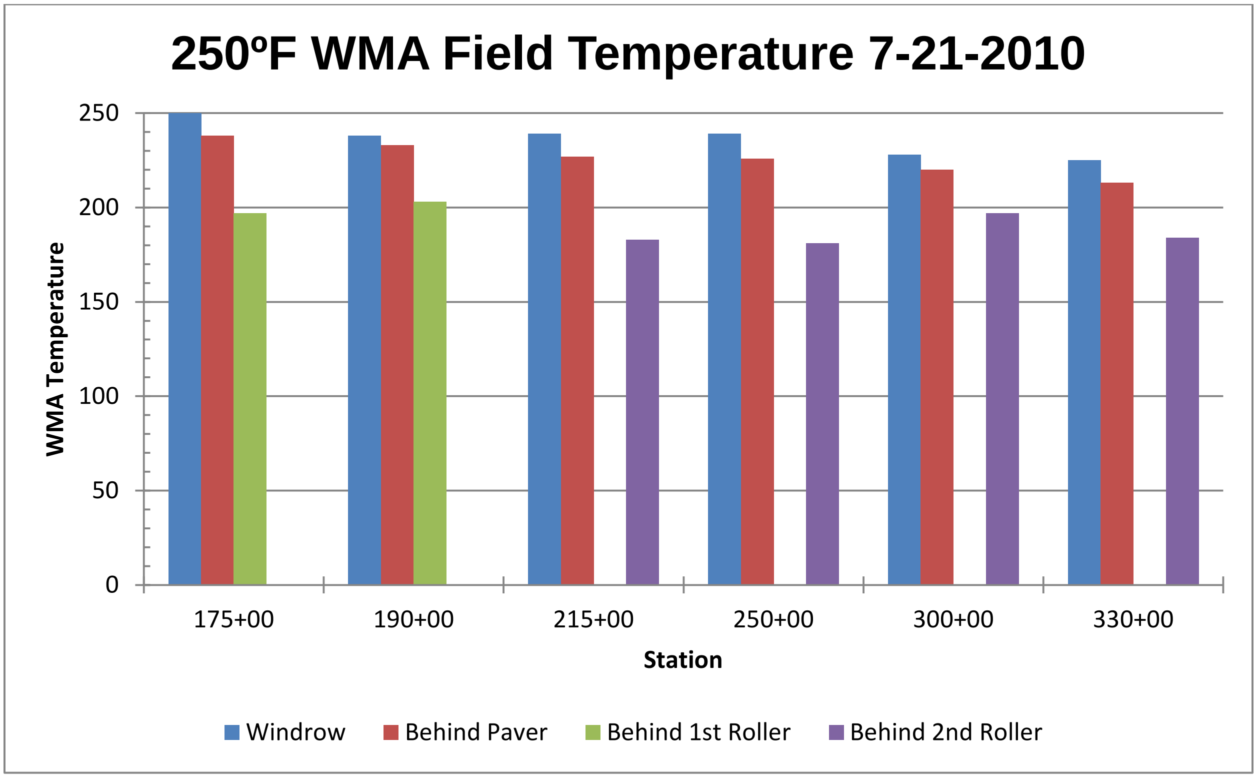


Chart 1 – Field temperatures recorded on 7-21-10 for the WMA.

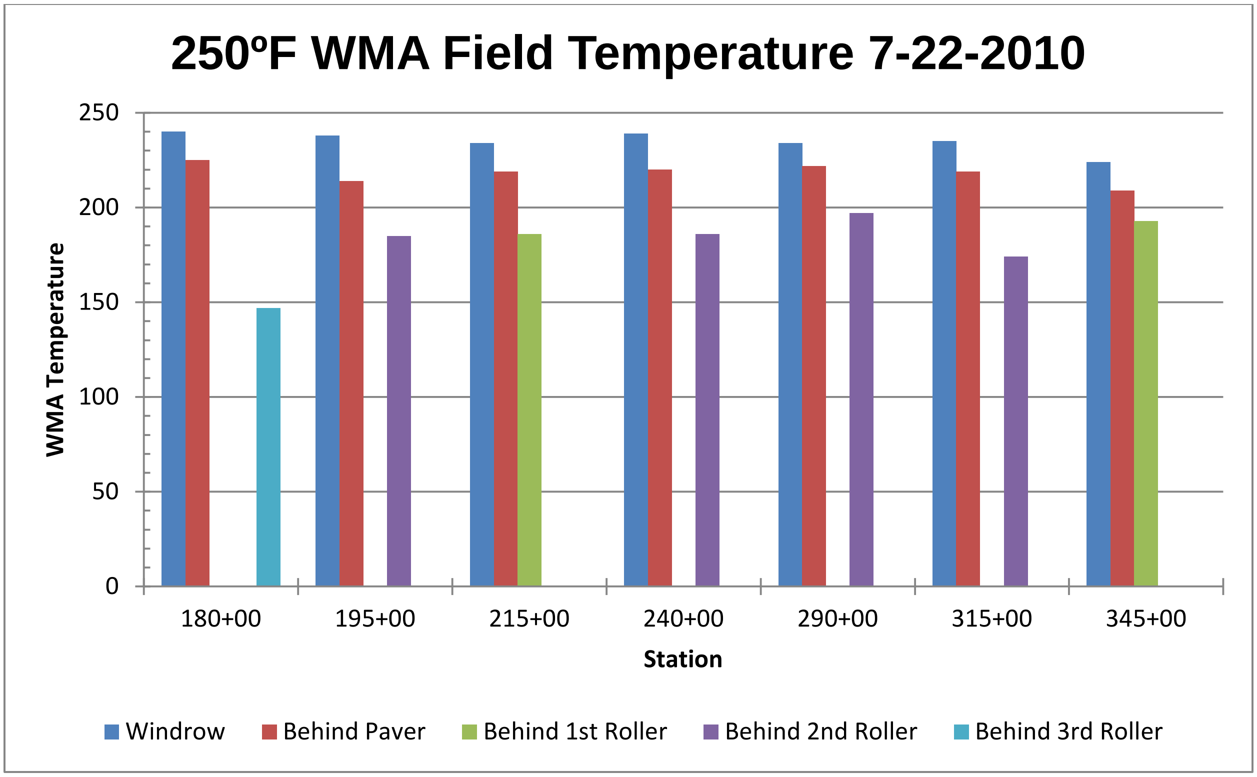


Chart 2 - Field temperatures recorded on 7-22-10 for the WMA. Mix temperature was 250ºF.

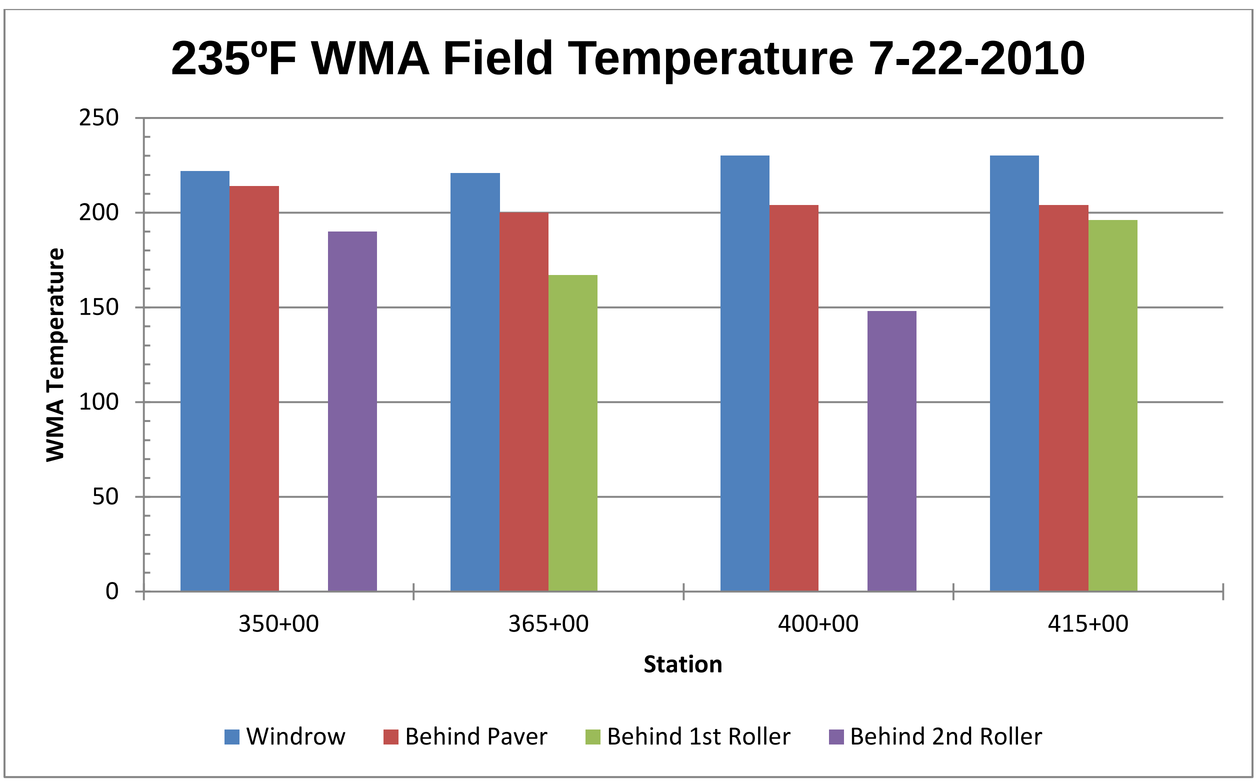


Chart 3 - Field temperatures recorded on 7-22-10 for the WMA. Mix temperature was 235ºF

Average WMA Temperature (F)	Windrow	Behind Paver	Behind Roller	Behind 2nd Roller	Behind 3rd Roller
	233	217	191	183	147

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

The plant production rate was used to measure the efficiency of the WMA. The mix temperature is the temperature that the asphalt is produced at the plant. To change the mix 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 production rate. Table 4 has the mix temperature along with the plant production rate for the two days of paving with the WMA. This table displays when the mix temperature decreases the production rate increases improving the efficiency of the plant.

Warm Mix Asphalt - H-MDF-2-011(025)035		
Date	**Target Temperature**	**Average Production Rate Tons per Hour(TPH)**
7/21/2010	250	520
7/21/2010	240	545
7/22/2010	250	517
7/22/2010	235	560
7/22/2010	240	535

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

Field Evaluation - 2012

The field evaluation includes transverse crack counts, rut measurements, and an evaluation of pavement distresses caused by loading and traffic. The experimental and control section will be evaluated annually to observe if there is any differences in the distresses reflecting through the pavement overlay for the experimental and control section.

The final evaluation took place in October of 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. In Reference Point 56 there was a large area of alligator cracking that received full depth repairs. This area is next to a body of water as seen in Photo 2. The roadway this close to the water most likely has saturated subgrade and/or base and is the cause of the distress. This is portrayed in Table 5 with the low number of cracks in the first evaluation.

Photo 1 – Severe distresses on roadway near RP 56

<table>
<tr><th colspan="3">HMA - Control Section</th><th colspan="3">WMA Research Section</th></tr>
<tr><th rowspan="2">Reference Point</th><th colspan="2">Transverse Cracks</th><th rowspan="2">Reference Point</th><th colspan="2">Transverse Cracks</th></tr>
<tr><th>1st Evaluation 2011</th><th>2nd Evaluation 2012</th><th>1st Evaluation 2011</th><th>2nd Evaluation 2012</th></tr>
<tr><td>51</td><td>242</td><td>261</td><td>56</td><td>66</td><td>227</td></tr>
<tr><td>52</td><td>229</td><td>259</td><td>57</td><td>177</td><td>198</td></tr>
<tr><td>53</td><td rowspan="2">367*</td><td>267</td><td>58</td><td>172</td><td>235</td></tr>
<tr><td>54</td><td>215</td><td>59</td><td>168</td><td>249</td></tr>
<tr><td>55</td><td>156</td><td>185</td><td>60</td><td>162</td><td>219</td></tr>
</table>

Table 5 – Transverse cracking for both the research section and control section.

*Mile Marker was missing so the cracks were combined for these two miles

Summary

The density, 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 the difference in temperature.

The density and rolling efforts remained the same for both of these projects. The average compaction for the WMA was 93.9% and the HMA was 94.0%, indicating they are very similar to each other. The contractor did not change the rolling pattern when they began paving the WMA according to the Valley City district.

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 and control section is very minimal. This is expected since there was very little existing rutting due to the low number of traffic ESAL's (31 daily EASL's).

Recommendation

The WMA research section and the HMA control section are both performing the same. The construction method of the WMA provides 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

H-MDF-2-011(025)035 - Compaction Control - HMA				
Date	**Station**	**Core Density**	**Maximum Theoretical Density**	**Compaction**
7/19/2010	63330	141.2	149.3	94.6%
	65330	140.0	149.3	93.8%
	67330	138.0	149.3	92.4%
	69330	140.0	149.3	93.8%
	71330	139.5	149.3	93.4%
	73330	139.9	149.3	93.7%
	75330	139.3	149.3	93.3%
	77330	139.5	149.3	93.4%
	79330	138.4	149.3	92.7%
	81330	142.8	149.3	95.6%
	83330	142.2	149.3	95.2%
	85330	138.1	149.3	92.5%
	87330	141.4	149.3	94.7%
	89330	141.3	149.3	94.6%
	91330	138.6	149.3	92.8%
	107	139.3	149.3	93.3%
	2107	139.5	149.3	93.4%
	4107	142.0	149.3	95.1%
	6107	140.8	149.3	94.3%
	8107	138.3	149.3	92.6%
	10107	141.4	149.3	94.7%
	120107	139.8	149.3	93.6%
7/20/2010	81100	142.4	148.9	95.6%
	83100	142.6	148.9	95.8%
	85100	139.2	148.9	93.5%
	87100	142.0	148.9	95.4%
	89100	140.0	148.9	94.0%
	91100	143.1	148.9	96.1%
	0	138.7	148.9	93.1%
	2000	138.6	148.9	93.1%
	4000	139.2	148.9	93.5%
	6000	139.9	148.9	94.0%
	8000	141.1	148.9	94.8%
	10000	139.0	148.9	93.4%
	12000	140.9	148.9	94.6%
	14000	142.0	148.9	95.4%
	16000	140.4	148.9	94.3%
	13950	137.9	148.9	92.6%
	15950	138.6	148.9	93.1%
Average		**140.2**	**149.1**	**94.0%**

H-MDF-2-011(025)035 - Compaction Control - WMA				
Date	**Station**	**Core Density**	**Maximum Theoretical Density**	**Compaction**
7/21/2010	17055	139.7	149.3	93.6%
	19055	138.7	149.3	92.9%
	21055	137.7	149.3	92.2%
	23055	138.6	149.3	92.8%
	27055	139.2	149.3	93.2%
	29055	138.6	149.3	92.8%
	31055	138.9	149.3	93.0%
7/22/2010	17828	138.7	148.7	93.3%
	19828	143.0	148.7	96.2%
	21828	137.4	148.7	92.4%
	23828	136.7	148.7	91.9%
	25828	140.7	148.7	94.6%
	27828	141.3	148.7	95.0%
	29828	140.4	148.7	94.4%
	31828	139.3	148.7	93.7%
	33828	142.3	148.7	95.7%
	35828	139.5	148.7	93.8%
	37828	134.9	148.7	90.7%
	39828	141.1	148.7	94.9%
	33217	140.7	148.7	94.6%
	35217	140.6	148.7	94.6%
	37217	142.6	148.7	95.9%
	39217	142.9	148.7	96.1%
	41217	142.2	148.7	95.6%
Average		**139.8**	**148.9**	**93.9%**