Review of Non-Standard Warm Asphalt Mix Projects

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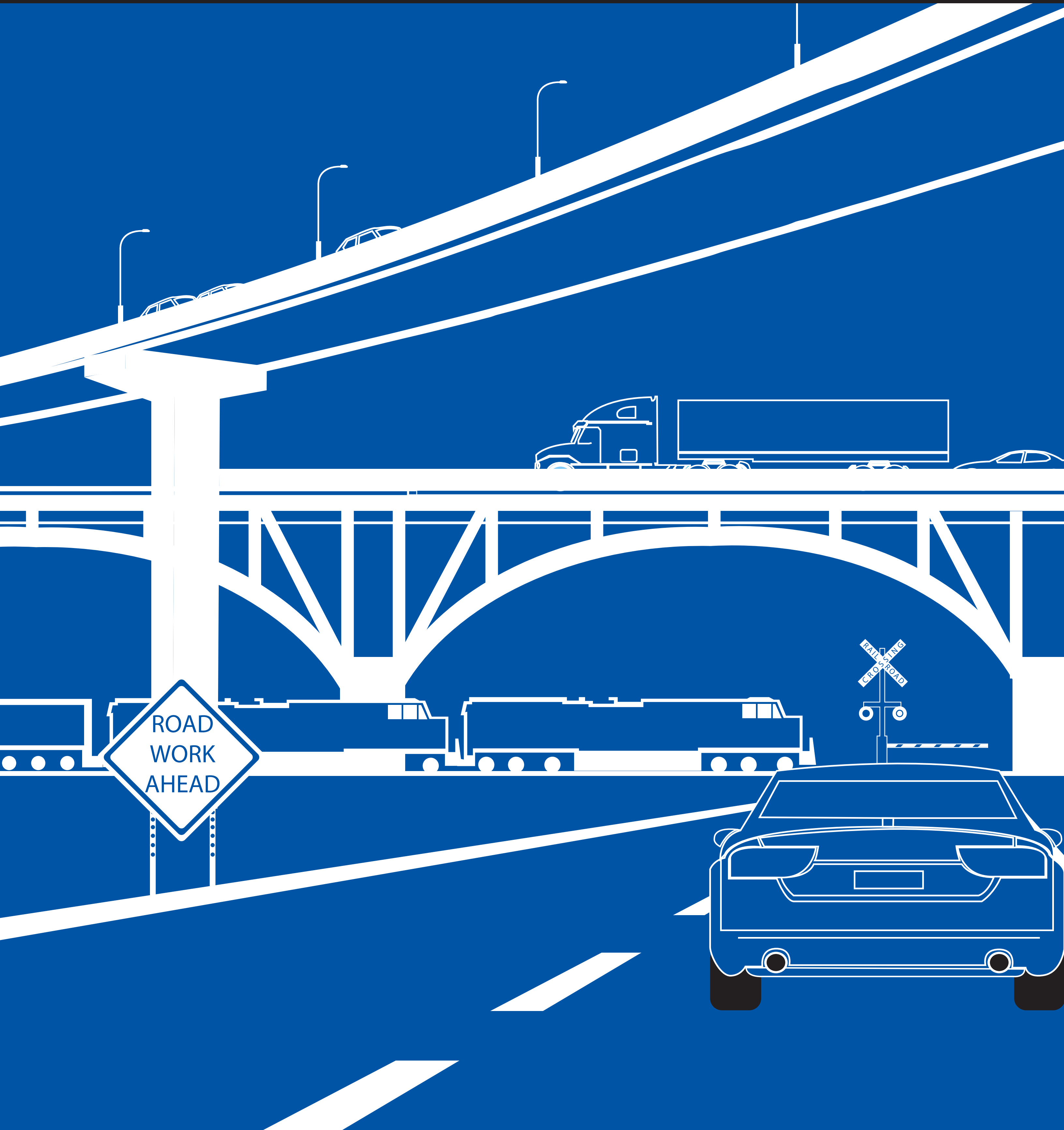

Kentucky Transportation Center
College of Engineering, University of Kentucky, Lexington, Kentucky

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Research Report
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Review of Non-Standard Warm Mix Asphalt Projects

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1. Introduction and Problem Statement

Periodically, when the Kentucky Transportation Cabinet's (KYTC) the Division of Construction receives requests to use non-standard warm mix asphalt technologies, it may be asked to waive the temperature specification or other product specifications/processes. The short-term and long-term impacts of this waiver are not completely understood. The Division of Construction approves these requests and notes their use, however, no follow-up studies have been done to evaluate the performance of non-standard warm mix asphalt. Similarly, no previous studies have compared data on quality assurance/quality control (QA/QC) and performance for these mixtures with those of standard warm mix asphalt mixtures. Thus, the performance of non-standard warm mix asphalt projects has not been thoroughly evaluated.

Before discussing the performance of different asphalt mixtures, it is beneficial to identify the mixtures currently used in Kentucky. Hot mix asphalt has been the most commonly used asphalt mixture since its inception. Several years ago, warm mix asphalt was introduced in an attempt to reduce fuel costs and realize environmental benefits. And now a modified version of warm mix has been implemented. This modified version of warm mix is called non-standard asphalt. Each product is described in the sections below.

1.1 Hot Mix Asphalt (HMA)

Hot Mix Asphalt (HMA) is a combination of 95% stone, sand, or gravel bound together by asphalt cement. The mixture is typically heated to a temperature between 300º and 350º F. Due to its flexibility and water resistance HMA has been used across Kentucky. Placement of HMA should only be done when the air temperature is at least 40 º F.

1.2 Warm Mix Asphalt (WMA)

Warm Mix Asphalt (WMA) is a generic term encompassing a number of technologies that let producers of HMA lower the temperatures at which the material is mixed and placed. Typically, WMA is heated to temperatures 30º to 120º F lower than HMA. Due to the lower temperatures, the use of WMA injects less hydrocarbon emissions and greenhouse gases into the atmosphere, making it a more environmentally friendly product.

The technology associated with WMA reduces the viscosity of the asphalt binder, allowing for the coating of aggregate to occur at lower temperatures. To achieve this goal additives (e.g., water-based, organic, chemical, or hybrid) are incorporated into the mix. This process enables the mixing of asphalt binders and aggregate at lower temperatures. Reducing the viscosity also makes the mixture easier to place and compact at lower temperature. In Kentucky water is the primary additive chosen to address viscosity concerns.

Some benefits of using WMA include:

> Reduced Paving Cost
>
> Each ton of WMA is typically $3 to $5 more expensive than a ton of HMA. However, the fuel requirements to produce WMA are much lower, which results in cost savings.

Improved Asphalt Compaction

As with any asphaltic pavement proper compaction is critical. Density is often checked to verify the proper compaction is achieved. Many states base their pay on the density of compacted asphalt.

Improved Working Conditions

WMA is a much safer option than HMA. Workers are exposed to less fumes, both at the production plant and at construction sites. Less exposure to fumes can reduce respiratory issues. The mixture temperature is also considerably lower, creating a more comfortable working environment.

Extended Paving Season

As the difference in temperature between the asphalt mixture and outside temperature increases the time required for a mixture to cool declines. At cooler outside temperatures there is a smaller difference between the temperature of WMA and the environment than between HMA and the ambient environment, therefore allowing the mat to cool slower. This feature lets contractors work later into the season.

1.3 Non-Standard Warm Mix Asphalt

This asphalt mixture is virtually the same as WMA except for higher mixing temperatures. Additives are still used but the asphalt is heated to HMA specifications. In rural parts of Kentucky there are often very long haul times required to transport WMA to job sites. Overheating the asphalt mixture ensures that it remains pliable after extremely long hauls in cold weather. Overheating of the asphalt mixture is the focus for this research.

1.4 Review Pavement Management System Data

KYTC's Division of Maintenance collects pavement performance data as part of its Pavement Management System (PMS). Collected data are used to evaluate pavement performance and establish a rehabilitation schedule.

For this project, to evaluate pavement performance KTC researchers used a Mandli Mark IV pavement profiler. The software collects an array of data that can later be filtered for specific data outputs. Our research focused on the International Roughness Index, wheel path rutting, and cracking (transverse and longitudinal).

1.5 International Roughness Index (IRI)

The IRI is a useful tool for determining overall pavement ride quality. To determine ride quality a continuous profile along the roadway is measured and analyzed to summarize pavement surface deviations that impact a vehicle's suspension movement. The output is reported in units of inches per mile. IRI is the total vertical movement a standard car's body experiences when driven over a one-mile segment of pavement at 50 mph. Higher IRI values indicate a rougher ride.

1.5 Wheel Path Rutting

A rut is a depression or groove worn into a roadway by vehicle tires. Rutting is caused by deformation in any of a pavement's layers. Rutting is usually attributed to consolidation or lateral movement of materials due to loading.

1.6 Transverse Cracking

Transverse cracking is one of the most common pavement distresses. Transverse cracks run perpendicular to a pavement's centerline. If related to thermal cracking, the crack originates at the surface and propagates downward. If associated with reflective cracking, the crack originates at the bottom and expands upward.

1.7 Longitudinal Cracking

Longitudinal cracks run parallel to a pavement's centerline. They can be caused by improperly constructed joints, upward reflection cracking from an underlying layer, or shrinkage of the asphalt layer.

1.8 Site Selection

KYTC provided route information to assist with selection of standard WMA and non-standard WMA sites for evaluation. We selected six sites with standard WMA and six sites with the non-standard WMA for evaluation. The following sections summarize the information we collected from PMS data and visual inspections.

Photographs (Figures 1-48) depict several examples of the type and severity of distress we observed. Because the study segments varied in length, normalizing data to one-mile segments assists in determining the total linear feet of cracking per segment.

2. Standard WMA Sites

2.1 KY 465 Gallatin County (MP 5.5 – 7.19)

Eaton Paving was the general contractor for this project. The firm used PG 64-22 binder with a nominal aggregate size of 3/8 inch. Except for transverse and longitudinal cracking, the pavement has performed fairly well since following application of an overlay five years ago. There are a few areas with base failure along the pavement's outside edge. When outside edges experience base failure pavement cracks appear sooner, therefore accelerating rehabilitation schedule.


Figure 1. View of Roadway


Figure 2. Base Failure Outside Edge


Figure 3. Transverse Cracking


Figure 4. Water Pumping

Install Date	Test Date	Dir	AADT	IRI	Rutting (in.)	Longitudinal Cracking (ft.)	Transverse Cracking (ft.)	Total All Cracking (ft.)	Total Cracking per Mile (ft.)
4/23/14	9/3/15	E	477	137	.07	307.3	37.71	345.02	**202.95**
4/23/14	9/3/15	W	477	136	.06	405.23	83.87	489.10	**287.71**

2.2 KY 562 Gallatin County (MP 0.0 – 3.0)

Eaton Paving was also the general contractor for this project. The firm used PG 64-22 binder with a nominal aggregate size of 3/8 inch. At the time of our visual evaluation, the pavement was approximately five years old. Moderate cracking has occurred throughout this roadway segment, primarily transverse and longitudinal cracking. There are locations that have water-related issues due to the pumping of water to pavement surface.

Figure 5. View of Roadway

Figure 6. Moderate Cracking Across Lane

Figure 7. Moderate Cracking Middle of Lane

Figure 8. Transverse & Longitudinal Cracks

Install Date	Test Date	Dir	AADT	IRI	Rutting (in.)	Longitudinal Cracking (ft.)	Transverse Cracking (ft.)	Total All Cracking (ft.)	Total Cracking per Mile (ft.)
5/5/14	9/3/15	N	334	113	.05	134.11	34.93	169.04	**56.35**
5/5/14	9/3/15	S	334	120	.05	188.28	36.12	224.40	**74.80**

2.3 KY 1827 Hart County (MP 0.0 – 1.64)

Scotty's Paving was the general contractor for this project. The firm used PG 64-22 binder with a nominal aggregate size of 3/8 inch. This roadway segment has experienced transverse and longitudinal cracking, patching, shoving, and base failure. As with most rural routes, base failure is a concern and will often result in pavement failing prematurely. Base failure along outside edge of pavement typically promotes cracking and patching.

Figure 9. Overview of Roadway

Figure 10. Heavy Shoving

Figure 11. Severe Base Failure with Patching

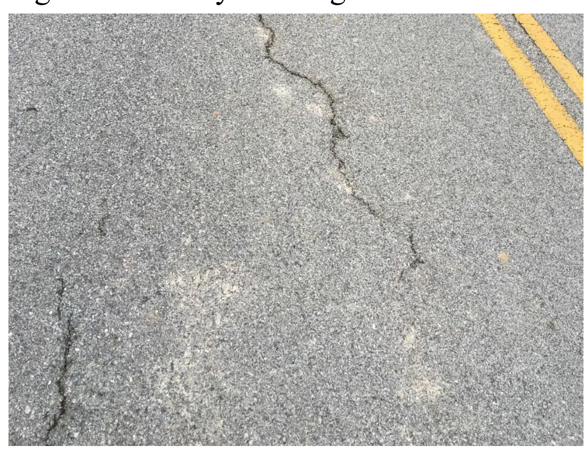

Figure 12. Longitudinal Cracking

Install Date	Test Date	Dir	AADT	IRI	Rutting (in.)	Longitudinal Cracking (ft.)	Transverse Cracking (ft.)	Total All Cracking (ft.)	Total All Cracking per Mile (ft.)
11/10/14	9/8/16	N	559	88	.05	105.24	5.2	110.44	**67.34**
11/10/14	9/8/16	S	559	83	.05	387.57	1.83	389.40	**237.44**

2.4 US 421 Trimble County (MP 13.8 – 14.6)

OVA Paving was the general contractor for this project. The firm used PG 64-22 binder with a nominal aggregate size of 3/8 inch. This site is performing well. There are several transverse cracks over the length of the segment. However, significantly more longitudinal cracking is present. The longitudinal cracking is located primarily between the wheel paths and extends throughout the segment.

Figure 13. Overview of Roadway

Figure 14. Transverse Cracking

Figure 15. Longitudinal Cracking

Figure 16. Another View of the Road

Install Date	Test Date	Dir	AADT	IRI	Rutting (in.)	Longitudinal Cracking (ft.)	Transverse Cracking (ft.)	Total All Cracking (ft.)	Total All Cracking per Mile (ft.)
11/4/14	2/26/18	N	4377	84	.06	109.82	127.14	236.96	**296.20**
11/4/14	2/26/18	S	4377	90	.07	92.26	68.47	160.73	**200.91**

2.5 US 421 Trimble County (MP 16.5 – 17.2)

OVA Paving was the general contractor for this project. The firm used PG 64-22 binder with a nominal aggregate size of 3/8 inch. Except for several minor transverse cracks throughout the entirety of segment, the pavement is performing well at this location. The only other noticeable distress is longitudinal cracking along centerline of pavement. Transverse cracking is more common than longitudinal cracking.

Figure 17. View of Roadway

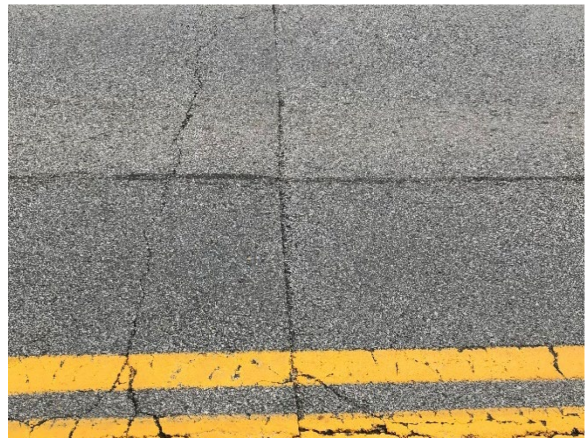
Figure 18. Transverse Cracking


Figure 19. More Transverse Cracking

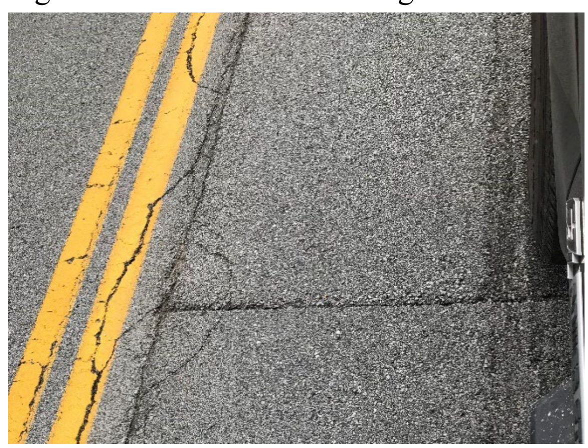
Figure 20. Longitudinal Cracking

Install Date	Test Date	Dir	AADT	IRI	Rutting (in.)	Longitudinal Cracking (ft.)	Transverse Cracking (ft.)	Total All Cracking (ft.)	Total All Cracking per Mile (ft.)
10/29/14	2/26/18	N	4377	101	.07	37.33	353.32	390.65	**558.07**
10/29/14	2/26/18	S	4377	115	.07	26.25	233.98	260.23	**371.76**

2.6 US 421 Trimble County (MP 17.2 – 18.3)

OVA Paving was the general contractor for this project. The firm used PG 64-22 binder with a nominal aggregate size of 3/8 inch. There is considerable longitudinal cracking throughout this roadway segment. Some of the longitudinal cracking is associated with base failure along outside pavement edges. Transverse cracking is present in many locations. Some of the transverse cracks have been sealed to slow the pavement's deterioration.

Figure 21. View of Roadway

Figure 22. Sealed Transverse Cracks

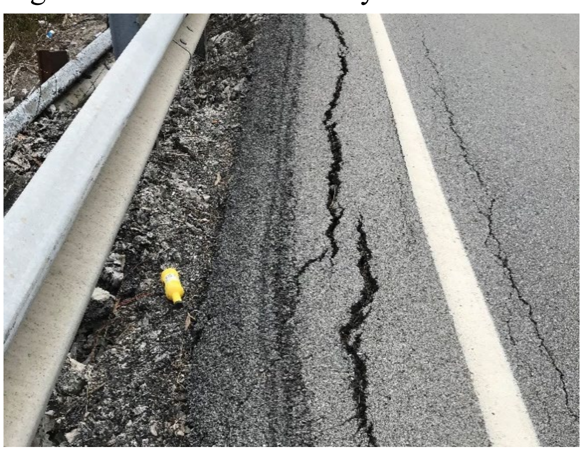

Figure 23. Moderate Base Failure

Figure 24. Longitudinal Cracking

Install Date	Test Date	Dir	AADT	IRI	Rutting (in.)	Longitudinal Cracking (ft.)	Transverse Cracking (ft.)	Total All Cracking (ft.)	Total All Cracking per Mile (ft.)
10/27/14	2/26/18	N	5429	90	.06	309.48	484.48	793.96	**721.78**
10/27/14	2/26/18	S	5429	100	.07	121.98	299.84	421.82	**383.47**

3. Non-Standard WMA Sites

3.1 KY 157 Henry County (MP 2.453 – 7.19)

OVA Paving was the general contractor for this project. The firm used PG 64-22 binder with a nominal aggregate size of 3/8 inch. This pavement has extensive cracking. There are a few areas with transverse cracking, however, most of the distress is from longitudinal cracking in the wheel paths. Several locations have already been patched due to heavy cracking.

Figure 25. Heavy Longitudinal Cracking

Figure 26. Patched (Cracking Again)

Figure 27. Longitudinal Cracking at Edge

Figure 28. Transverse Cracking

Install Date	Test Date	Dir	AADT	IRI	Rutting (in.)	Longitudinal Cracking (ft.)	Transverse Cracking (ft.)	Total All Cracking (ft.)	Total All Cracking per Mile (ft.)
11/28/14	5/20/15	E	334	117	.04	578.02	44.76	622.78	**128.75**
10/27/14	5/20/15	W	334	120	.05	2979.46	14.77	2994.23	**619.03**

3.2 KY 465 Gallatin County (MP 1.821 – 3.337)

OVA Paving was the general contractor for this project. The firm used PG 64-22 binder with a nominal aggregate size of 3/8 inch. Except for several transverse and longitudinal cracks, the pavement looks pretty good. Several areas are exhibiting base failure along the roadway's outside. Base failure along the outside edges of pavement appears to be a common problem on rural routes throughout the state.

Figure 29. View of Roadway

Figure 30. Transverse Cracking

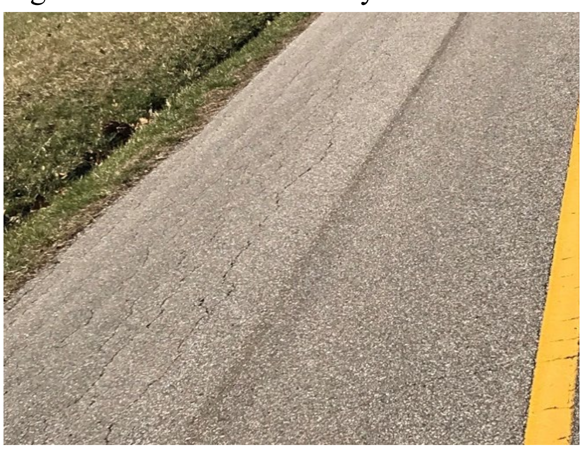

Figure 31. Base Failure Outside Edge

Figure 32. More Cracking

Install Date	Test Date	Dir	AADT	IRI	Rutting (in.)	Longitudinal Cracking (ft.)	Transverse Cracking (ft.)	Total All Cracking (ft.)	Total All Cracking per Mile (ft.)
11/14/13	9/3/15	E	209	138	.07	380.74	83.07	463.81	**305.94**
11/14/13	9/3/15	W	209	130	.06	651.62	73.32	724.94	**724.94**

3.3 KY 936 Hart County (MP 0.0 – 2.29)

Scotty's Paving was the general contractor for this project. The firm used PG 64-22 binder with a nominal aggregate size of 3/8 inch. The pavement looks good. The vast majority of cracking associated with this segment is longitudinal cracking. A few transverse cracks are present but longitudinal cracking is more prevalent. While considerable longitudinal cracking exists, it is not that severe, with most of the cracks being minor but visible nonetheless.

Figure 33. View of Roadway

Figure 34. Longitudinal Cracking

Figure 35. Moderate Longitudinal Crack

Figure 36. Transverse Cracking

Install Date	Test Date	Dir	AADT	IRI	Rutting (in.)	Longitudinal Cracking (ft.)	Transverse Cracking (ft.)	Total All Cracking (ft.)	Total All Cracking per Mile (ft.)
11/15/14	9/8/16	E	587	97	.05	1080.58	14.6	1095.18	**478.24**
11/15/14	9/8/16	W	587	110	.06	661.75	5.4	667.15	**291.33**

3.4 KY 1015 Hart County (MP 0.0 – 0.398)

Scotty's Paving was the general contractor for this project. The firm used PG 64-22 binder with a nominal aggregate size of 3/8 inch. This roadway segment is located in a rural area near Nolin River Lake. This segment is very short but has significant distress. There are areas with shoving, base failure, and transverse and longitudinal cracking.

Figure 37. View of Roadway

Figure 38. Shoving Pavement

Figure 39. Bases Failure Outside Edge

Figure 40. Moderate Longitudinal Cracking

Install Date	Test Date	Dir	AADT	IRI	Rutting (in.)	Longitudinal Cracking (ft.)	Transverse Cracking (ft.)	Total All Cracking (ft.)	Total All Cracking per Mile (ft.)
11/12/14	9/28/16	N	343	130	.06	445.19	2.1	447.29	**1123.84**
11/12/14	9/28/16	S	343	130	.10	632.53	2.3	634.83	**1595.05**

3.5 US 421 Henry County (MP 24.113 – 24.973)

OVA Paving was the general contractor for this project. The firm used PG 64-22 binder with a nominal aggregate size of 3/8 inch. This pavement has considerable distress throughout. There is a great deal of transverse cracking along this roadway segment. Like some of the other rural sites, this one has areas with base failure along the roadway's outside edges. Based on the level of transverse cracking, it is probable that concrete pavement lies beneath the asphalt.


Figure 41. Heavy Longitudinal Cracking


Figure 42. Heavy Cracking and Raveling


Figure 43. More Heavy Cracking


Figure 44. Transverse Cracking

Install Date	Test Date	Dir	AADT	IRI	Rutting (in.)	Longitudinal Cracking (ft.)	Transverse Cracking (ft.)	Total All Cracking (ft.)	Total All Cracking per Mile (ft.)
11/12/14	2/26/18	N	5807	96	.09	167.67	1106.55	1274.22	**522.22**
11/12/14	2/26/18	S	5807	88	.06	101.75	1528.21	1629.96	**668.02**

3.6 US 421 Trimble County (MP 6.67 – 9.11)

E & B Paving was the general contractor for this project. The firm used PG 64-22 binder with a nominal aggregate size of 3/8 inch. This route is located in a small community in a rural area. Pavement along this roadway segment has experienced heavy cracking in one area of town and has undergone patching. Like many of the other routes evaluated, this one has experienced transverse and longitudinal cracking. Rutting is comparable to other sites evaluated in this study.

Figure 45. View of Roadway

Figure 46. Patching Along Outside Edge

Figure 47. Moderate Transverse Cracking

Figure 48. More Transverse Cracking

Install Date	Test Date	Dir	AADT	IRI	Rutting (in.)	Longitudinal Cracking (ft.)	Transverse Cracking (ft.)	Total All Cracking (ft.)	Total All Cracking per Mile (ft.)
11/15/14	2/26/18	N	4078	113	.08	482.51	69.58	552.09	**641.97**
11/15/14	2/26/18	S	4078	124	.08	108.94	81.83	190.77	**221.83**

4. Conclusion

To understand the effects of overheating the warm mix asphalt we plotted all performance data for evaluation. Appendix A contains charts which plot the values of different metrics — rideability, rutting, transverse cracking, longitudinal cracking, and all cracking — against the age of overlays. For each study site, the age of the overlay is indicated on the x-axis while the value for individual metrics are plotted on the y-axis. The IRI is used to determine a pavement's rideability. Figure 49 shows the IRI values for each route we evaluated. The data suggest ride quality is not affected by using non-standard asphalt mixture. Figure 50 documents wheel path rutting, another aspect of our research. The graph shows non-standard asphalt can experience more pronounced rutting than standard asphalt. The non-standard asphalt mixtures rutting peaks at .10" whereas rutting for standard asphalt mixtures tops out at .07".

Pavements made from non-standard asphalt mixtures experience more transverse cracking than standard asphalt. The differences in cracking between the two mixtures is negligible until pavement reaches an age of 1,200 days. At that point the transverse cracking for non-standard asphalt outpaces the transverse cracking for standard asphalt. Longitudinal cracking is also affected by using non-standard asphalt. Longitudinal cracking worsens more rapidly than transverse cracking. At an age of approximately 650, longitudinal cracking for non-standard asphalt begins to outpace the standard asphalt. Figure 52 captures all longitudinal cracking for both mixtures.

Total cracking is a measure that combines transverse and longitudinal cracking. Once again cracking is prevalent in the early stages of a non-standard asphalt's life. As asphalt ages the difference in total cracking between non-standard asphalt and standard asphalt levels off. Thermal cracking in the earlier stages may be attributed to extreme temperature variability. Figure 53 plots total cracking.

As noted the Division of Maintenance collected all data we used to evaluate non-standard and standard asphalt mixtures. The data provided were the most current available at the time of reporting.

Appendix A HFST Sites Evaluated in 2018

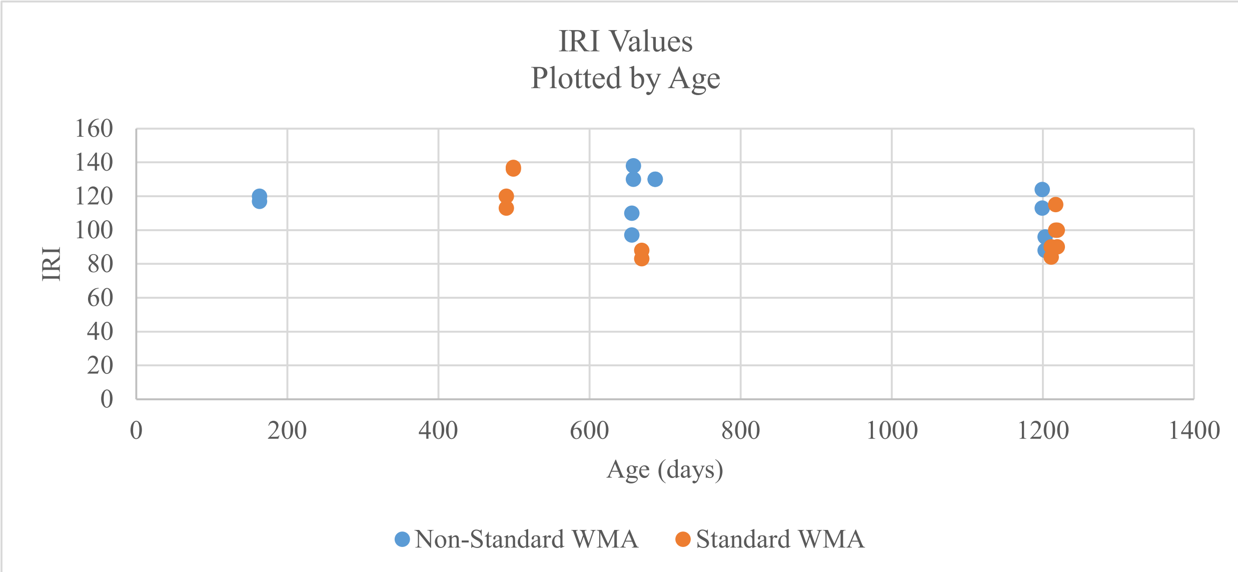

Figure 49. IRI Values Plotted by Age

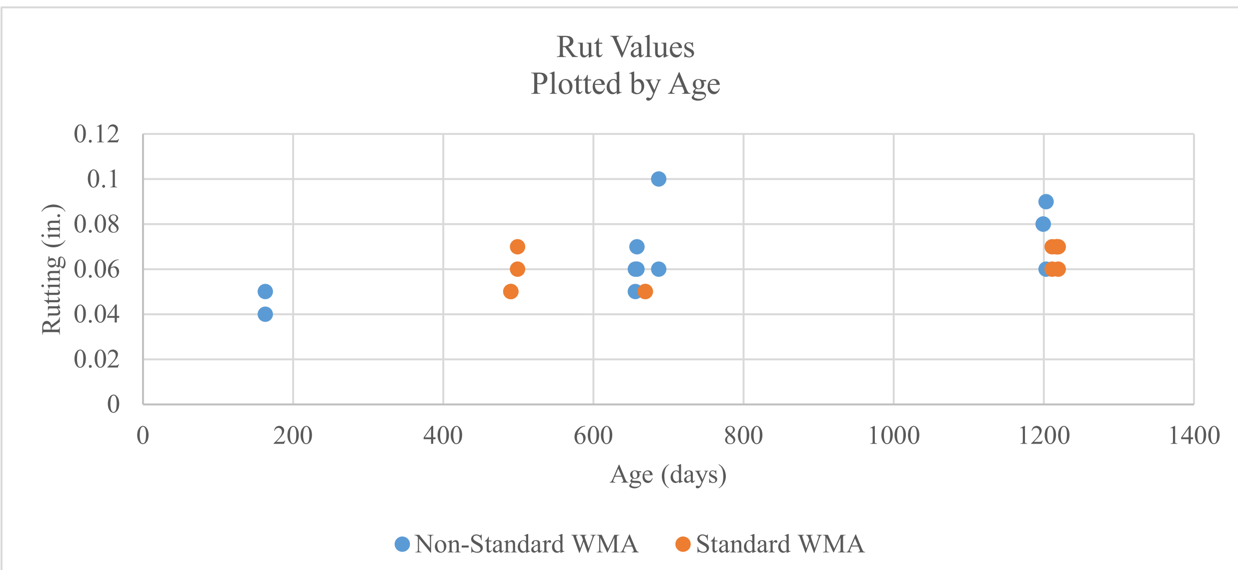

Figure 50. Rutting Values Plotted by Age

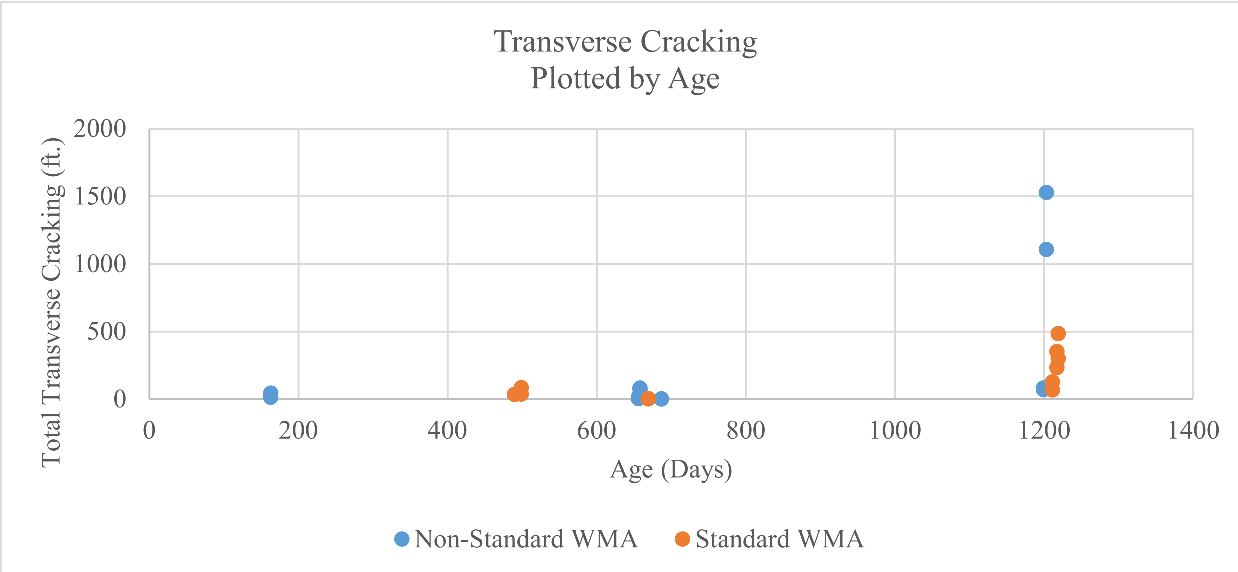

Figure 51. Transverse Cracking Plotted by Age

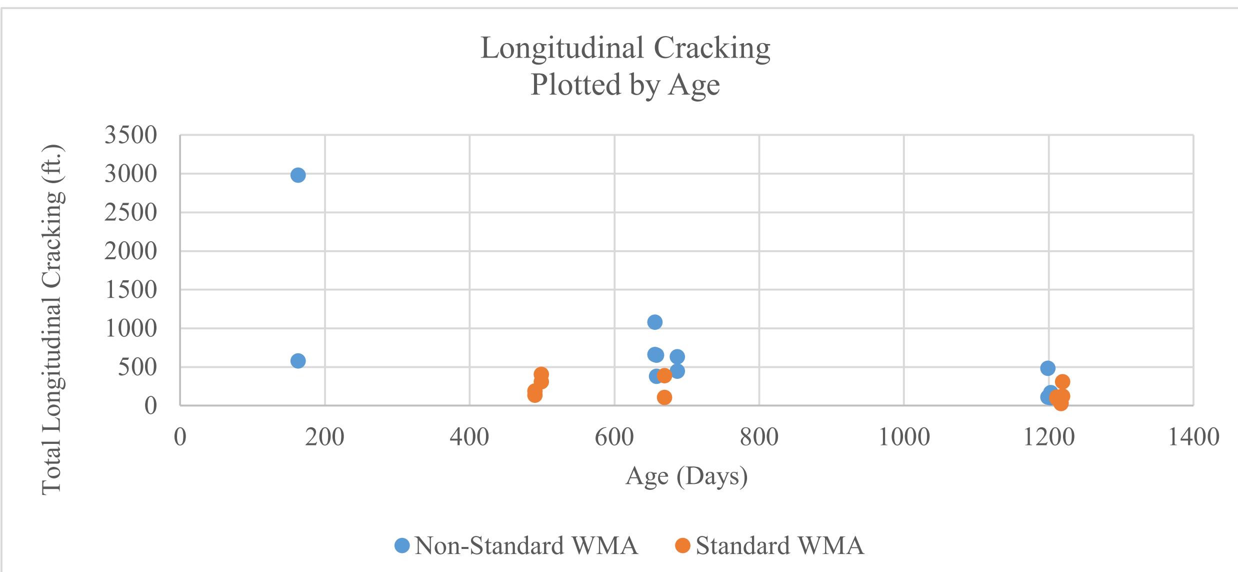

Figure 52. Longitudinal Cracking by Age

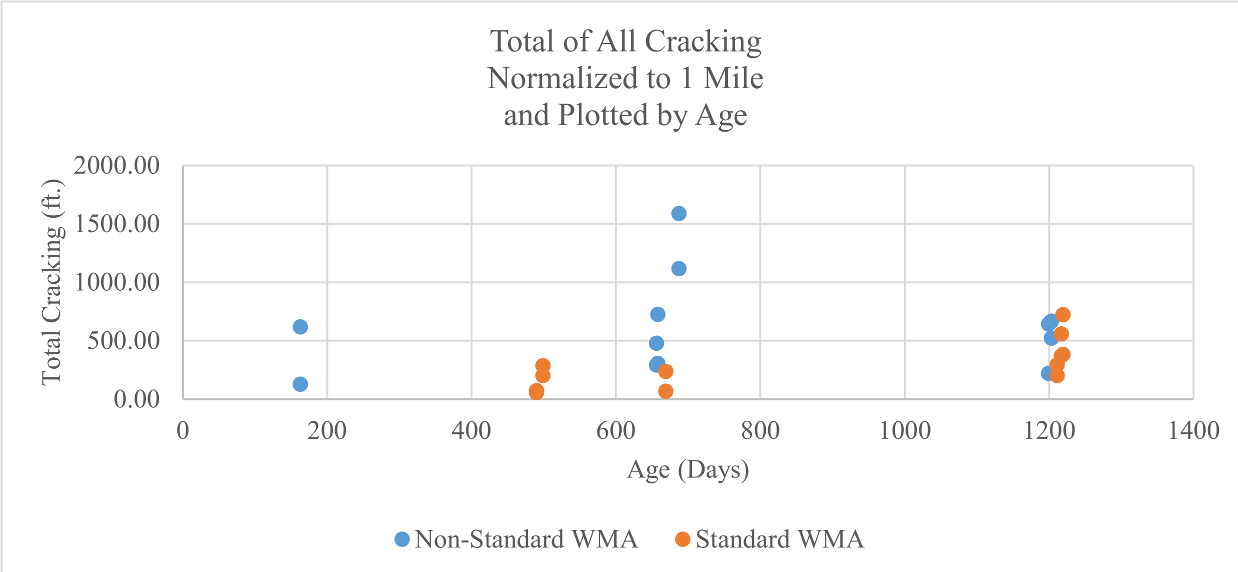

Figure 53. All Cracking Plotted by Age