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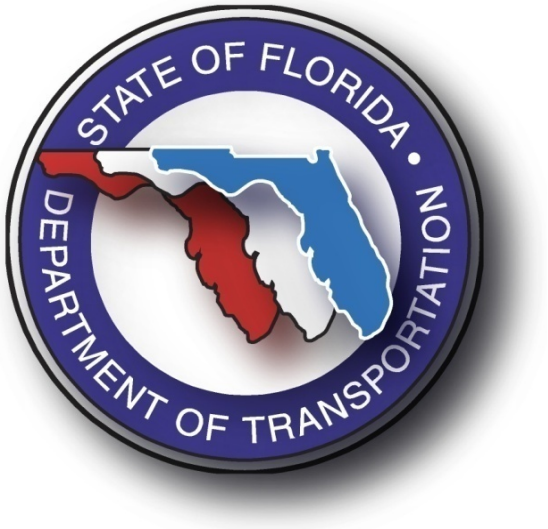

FDOT's Experience with Warm Mix Asphalt

Research Report
FL/DOT/SMO/09-527

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INTRODUCTION

Warm mix asphalt (WMA) is asphalt mix produced at a lower temperature than conventional hot mix asphalt (HMA). Temperature reductions are typically in the range of 40-75°F less than HMA. The ability to produce and place asphalt mix at a reduced temperature is accomplished through the addition of an additive (either water or a chemical) to the asphalt binder prior to mixing with the aggregate or into the asphalt drum during the mixing process.

The benefits of using WMA are: 1) reduced burner fuel consumption at the asphalt plant, 2) lower emissions (smoke and fumes) from the asphalt mix, 3) better workability of the mix resulting in better compactability and easier handwork, 4) ability to pave in cooler weather due to a slower mix cooling rate in the workable temperature range of the WMA, and 5) less aging of the asphalt binder during production.

Concerns with the use of WMA are: 1) incomplete drying of the aggregate (especially with absorptive limestones), 2) potential for increased moisture susceptibility when utilizing WMA processes that use water, 3) unknown effects of chemical additives on the long term performance of the asphalt binder, 4) concerns with the WMA's ability to provide enough radiant energy to heat the reclaimed asphalt component in mixtures containing reclaimed asphalt pavement (RAP), and 5) lack of overall long term performance information.

The Florida Department of Transportation, herein referred to as the Department, started using WMA on a trial basis in 2006, with a slow, gradual increase in usage to date. Table 1 shows the number of warm mix projects constructed by the Department per year.

Table 1 – Number of Warm Mix Projects Constructed per Year

Year	Number of Projects Constructed
2006	1
2007	2
2008	2
2009 (as of October 2009)	11

In March 2009, Materials Bulletin/Construction Memorandum 03-09 was issued by the Department providing specification language for the use of WMA for projects where the Contractor proposed its use, at no additional cost, provided the Engineer's approval was obtained. Subsequent to the bulletin, the Department's standard specifications were modified to allow the use of warm mix asphalt for all asphalt mixture types, at the Contractor's option, effective with the January 2010 letting.

This report will focus on the following areas: 1) a detailed analysis of the first three warm mix projects constructed by the Department, 2) an overview of all of the projects constructed to date, and 3) an analysis of the differences in construction variability between HMA and WMA.

DETAILED ANALYSIS OF THE FIRST THREE WMA PROJECTS

The first three WMA asphalt projects (one in 2006 and two in 2007) were constructed by different Contractors and utilized different warm mix technologies. This section will provide a detailed discussion of each project, including laboratory performance test data, construction test data and pavement condition survey information.

SR-417, Seminole County, FIN 413669-1-52-01, Turnpike District

This project consists of a 0.758 mile test section of FC-5 open graded friction course placed in the southbound passing lane of SR-417 (see Figure 1) utilizing the Aspha-min WMA process. Directly to the north of the WMA test section is a 1.024 mile control section, consisting of the same FC-5, without the Aspha-min additive. Both mixtures contain a polymer modified PG 76-22 asphalt binder and were constructed in February 2006.

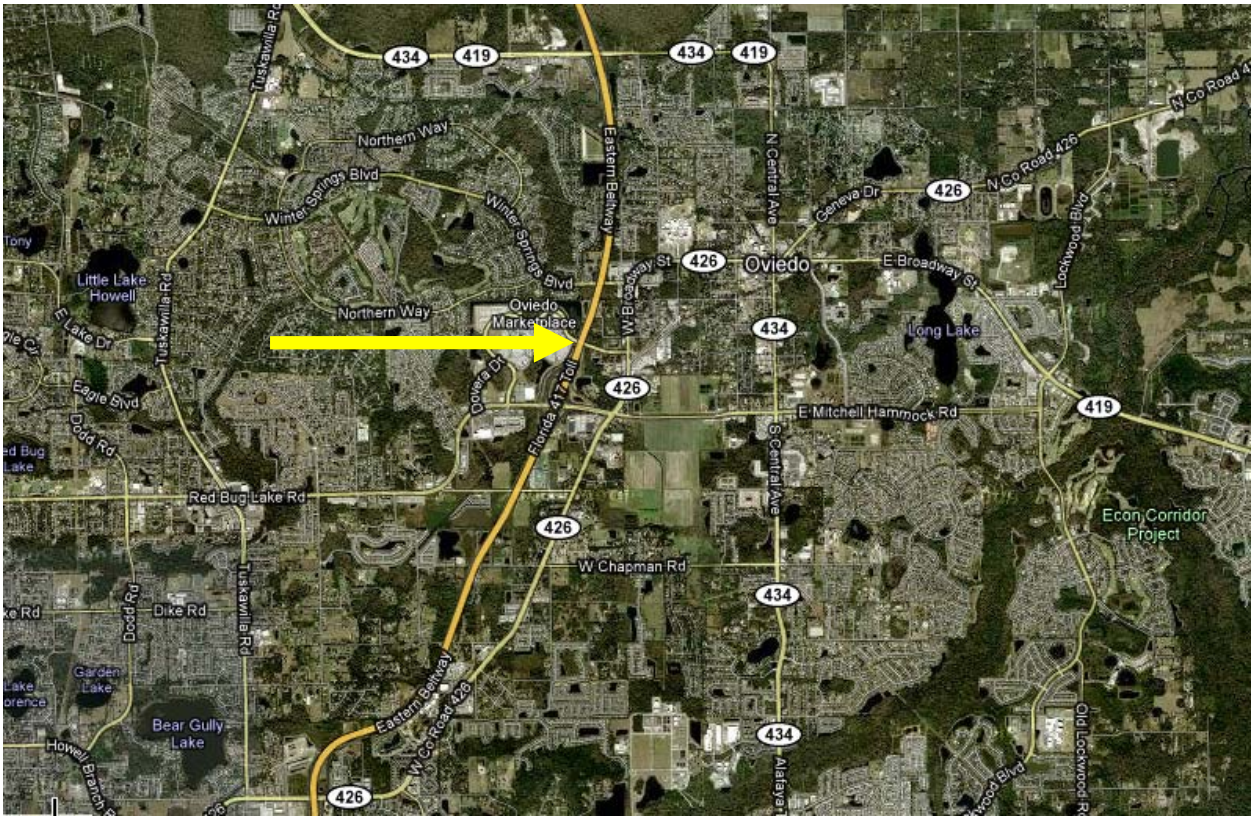

Figure 1 - SR-417 Project Location

Aspha-min is a white powder (Zeolite) that is injected into the asphalt drum at a rate of 6 lb. per ton of asphalt mixture (see Figure 2). This is equivalent to 0.3% by weight of asphalt mixture.

Figure 2 - Aspha-min Warm Mix Process

The mixing temperature for the HMA control mixture was 320°F and the mixing temperature for the WMA mixture was 270°F. During construction, the temperatures of the asphalt mat measured directly behind the paver were in the range of 280-290°F for the HMA mixture and 250-260°F for the WMA. State Material Office staff observed no issues with the placement of either mixture.

Samples of each mixture type were obtained and tested for their cracking properties utilizing the Energy Ratio concept developed at the University of Florida. A higher Energy Ratio indicates better resistance to cracking. The Energy Ratio results are presented in Table 2 and the results show that the WMA mixture had slightly better cracking properties than the HMA mixture.

Table 2 – Energy Ratio Test Results for SR-417 Project

Performance Measurement	Mixture Type	
	HMA FC-5	WMA FC-5
Energy Ratio	0.47	0.60

Pavement condition surveys (PCS) were performed in May 2006 and July 2009, evaluating the rutting, cracking, and ride rating performance of each section. Results of each survey are presented in Table 3 and show that there are no practical differences between the HMA and WMA sections.

Table 3 – PCS Test Results for SR-417 Project

Performance Measurement	PCS Test Date and Mixture Type			
	May 2006		July 2009	
	HMA FC-5	WMA FC-5	HMA FC-5	WMA FC-5
Rutting (inches)	0.00	0.00	0.00	0.00
Crack Rating (max = 10.0)	10.0	10.0	10.0	10.0
Ride Number (max = 5.0)	4.10	4.05	4.13	4.04

US-92 (SR-600), Polk County, FIN 197259-2-52-01, District 1

This project consists of a 1.164 mile test section of SP-12.5 structural mix placed in the eastbound travel and passing lanes of US-92 in Lakeland (see Figure 3) utilizing the Evotherm DAT WMA process. Directly to the west of the WMA test section is a 0.634 mile control section, consisting of the same SP-12.5 mixture, without the Evotherm additive. Both mixtures contain a polymer modified PG 76-22 asphalt binder and were constructed in October 2007. Subsequently, a conventional HMA FC-5 open graded friction course mixture was placed over the structural mix.

Figure 3 - US-92 Project Location

Evotherm DAT is a chemical additive that is injected into the asphalt binder supply line at a rate of 5% by weight of binder (see Figure 4).

Figure 4 - Evotherm DAT Warm Mix Process

The mixing temperature for the HMA control mixture was 325°F and the mixing temperature for the WMA mixture was 250°F. During construction, the temperature of the asphalt mat measured directly behind the paver was approximately 230°F for the WMA. There were no issues with placement of the WMA mixture.

Samples of each mixture type were tested for their cracking properties utilizing the Energy Ratio concept, their rutting performance utilizing the Asphalt Pavement Analyzer (APA), and their resistance to moisture damage utilizing the retained tensile strength approach per test method FM 1-T 283. The performance test results are presented in Table 4 and the results show that the WMA and HMA mixtures performed the same with the exception of moisture resistance, in which the HMA mixture had slightly better test results than the WMA mixture.

Table 4 – Laboratory Performance Test Results for US-92 Project

Performance Measurement		Mixture Type	
		HMA SP-12.5	WMA SP-12.5
Energy Ratio		1.66	1.64
APA Rut Depth (mm)		2.8	2.8
Moisture Damage Testing	Dry Strength (psi)	204.3	206.3
	Conditioned Strength (psi)	142.8	133.7
	Tensile Strength Ratio (%)	70	65

Pavement condition surveys were performed in November 2007 and December 2008, evaluating the rutting, cracking, and ride rating performance of each section. Results of each survey are presented in Table 5 and show that there are no practical differences between the HMA and WMA sections.

Table 5 – PCS Test Results for US-92 Project

Performance Measurement	PCS Test Date and Mixture Type (Results are from Traffic Lane)			
	November 2007		December 2008	
	HMA SP-12.5	WMA SP-12.5	HMA SP-12.5	WMA SP-12.5
Rutting (inches)	0.03	0.03	0.04	0.05
Crack Rating (max = 10.0)	10.0	10.0	10.0	10.0
Ride Number (max = 5.0)	4.06	4.02	4.07	4.11

SR-11, Flagler County, FIN 417141-1-52-01, District 5

This project consists of a 9.6 mile test section of SP-12.5 structural mix placed in the southbound and northbound lanes of SR-11, south of Bunnell (see Figure 5), utilizing the Astec Double Barrel Green WMA process. Directly to the north of the WMA test section, in the northbound lane, is a 4.9 mile control section, consisting of the same SP-12.5 mixture, without utilizing the Astec WMA process. Both mixtures contain a RA-800 asphalt binder and 45% fractionated RAP. The test sections were constructed in December 2007 and January 2008. Subsequently, a conventional HMA FC-12.5 dense graded friction course mixture was placed over the structural mixtures.

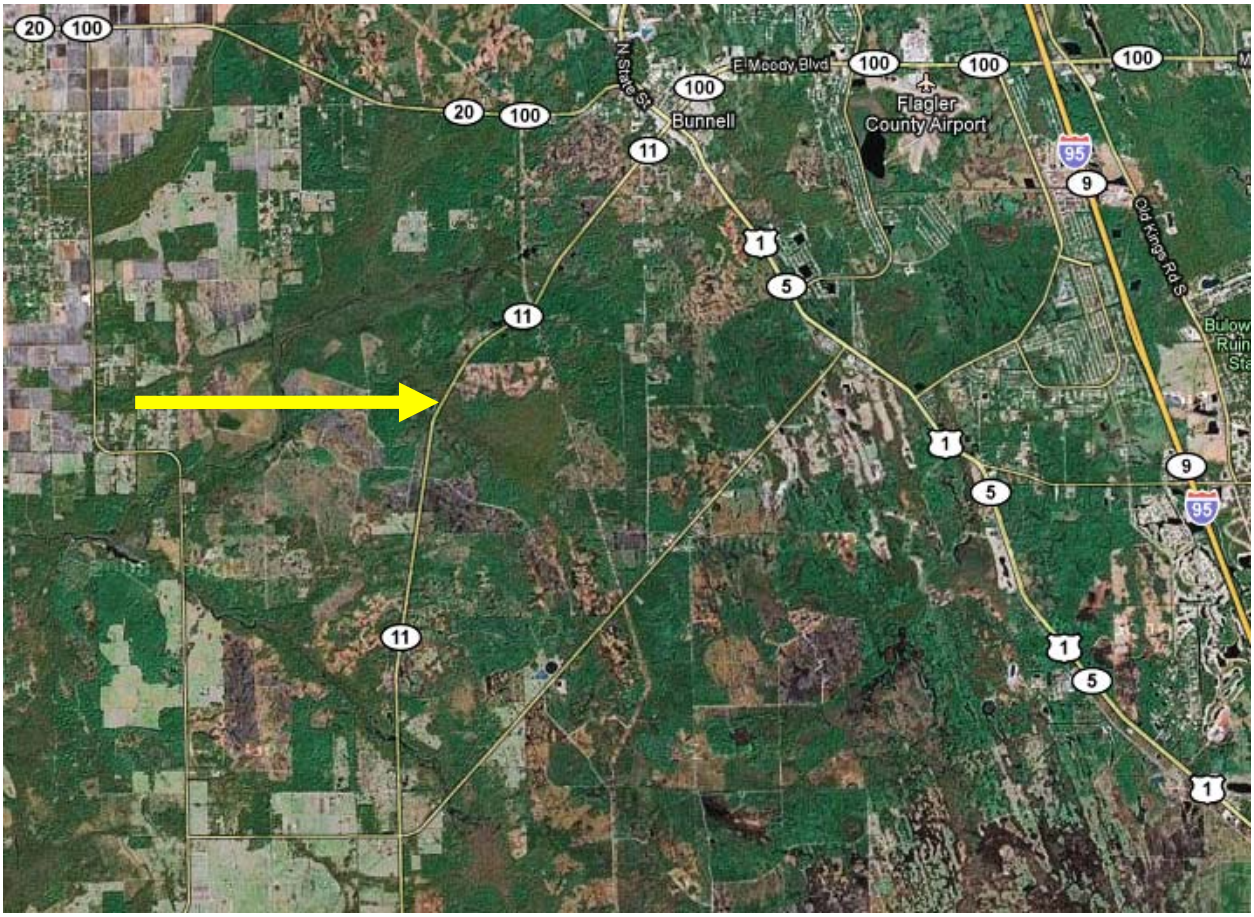

Figure 5 - SR-11 Project Location

The Astec Double Barrel Green WMA process is a foaming process that injects water into the asphalt binder supply line at a rate of 2% by weight of binder (see Figure 6). Astec claims that a large proportion of the water vaporizes instantly, leaving approximately 0.5% water by weight of binder to provide the enhanced mixture workability.

Figure 6 - Astec Double Barrel Green Warm Mix Process

The mixing temperature for the HMA control mixture was 310°F and the mixing temperature for the WMA mixture was 270°F. During construction, the temperature readings of the warm mix measured in the haul trucks varied substantially (from 250 to 290°F) due to the Contractor producing several mixture types for several projects within the same day. However, no issues with placement of the WMA mixture were noted.

Samples of each mixture type were tested for their cracking properties utilizing the Energy Ratio concept, their rutting performance utilizing the Asphalt Pavement Analyzer (APA), and their resistance to moisture damage utilizing the retained tensile strength approach per test method FM 1-T 283. The performance test results are presented in Table 6 and the results show that the WMA mixture performed slightly better than the HMA mixture with respect to cracking and rutting and nearly as well with respect to moisture damage resistance.

Table 6 – Laboratory Performance Test Results for SR-11 Project

Performance Measurement		Mixture Type	
		HMA SP-12.5	WMA SP-12.5
Energy Ratio		1.70	1.85
APA Rut Depth (mm)		4.1	2.7
Moisture Damage Testing	Dry Strength (psi)	211.5	198.2
	Conditioned Strength (psi)	129.0	115.1
	Tensile Strength Ratio (%)	61	58

Pavement condition surveys were performed in June 2008 and July 2009, evaluating the rutting, cracking, and ride rating performance of each section. Results of each survey are presented in Table 7 and show that there are no practical differences between the HMA and WMA sections.

Table 7 – PCS Test Results for SR-11 Project

Performance Measurement	PCS Test Date and Mixture Type (Results are from Traffic Lane)			
	June 2008		July 2009	
	HMA SP-12.5	WMA SP-12.5	HMA SP-12.5	WMA SP-12.5
Rutting (inches)	0.03	0.05	0.04	0.06
Crack Rating (max = 10.0)	10.0	10.0	10.0	10.0
Ride Number (max = 5.0)	4.32	4.36	4.29	4.34

SUMMARY OF ALL WARM MIX PROJECTS CONSTRUCTED TO DATE

The previous section of this report presented detailed laboratory performance test data and pavement condition survey data for the first three WMA projects constructed, which utilized three different WMA technologies, encompassing the major types of WMA processes used in Florida to date. Table 8 provides a summary of every WMA project constructed by the

Department, as of October 2009. To date, nearly 226,000 tons of WMA have been placed in six of the eight Districts in the state, utilizing five different WMA technologies. Note that three of the five WMA technologies (Astec Double Barrel Green, Meeker, and Terex) are all foaming processes that inject water into the asphalt binder supply stream. There have been no construction or performance problems noted on any of the WMA projects.

Table 8 – Summary of All WMA Projects Constructed as of October 2009

District	Project Number	Route / County	Mix Type	Quantity (tons)	Additive/ Technology	Construction Date	Contractor	Mixing Temperature	Compaction Temperature	Location
1	197259-2	US-92/Polk	SP-12.5	2383	Evotherm	10/2007	Lane Construction	250	230	Mainline
	197373-2	US-92/Polk	SP-9.5	4000	Evotherm	Current	Lane Construction	250	230	Mainline
			SP-9.5	2000				250	240	Mainline
			FC-9.5	2000				250	240	Mainline
	197707-1	U-27/Polk	FC-5	6579	Astec DBG	04/2009	Orlando Paving	260	260	Mainline
	197753-2	SR-780/Sarasota	SP-9.5	3020	Meeker	Current	Ajax	265	265	Mainline
			SP-12.5	4000	Terex			270	270	
			SP-9.5	8000				270	270	
			FC-12.5	1174				290	290	
	420238-1	US-301/Manatee	SP-12.5	8000	Meeker	Current	Ajax	290	290	Mainline
			FC-5	3744			Ajax	290	290	Mainline
	420655-1	I-75/Collier	SP-12.5	173	Meeker	Current	Ajax	275	275	Shoulders
			SP-12.5	4885				275	275	
			SP-12.5	26405				265	265	
			FC-5	7159				290	285	Mainline
2	209733-4	SR-202/Duval	SP-12.5	9775	Astec DBG	Current	Duval Asphalt	265	265	Shoulders
3	415257-1	I-10/Gadsen	SP-12.5	4000	Astec DBG	Current	CW Roberts	270	260	Shoulders
	415258-1	I-10/Jackson	SP-12.5	8907	Astec DBG	02/2008	Anderson-Columbia	260	250	Shoulders
			SP-12.5	1511		01/2008		260	250	
	416909-1	I-10/Walton	SP-12.5	1127	Astec DBG	08/2008	Anderson-Columbia	260	250	Shoulders
			SP-12.5	3650		08/2008		260	250	
5	417141-1	SR-11/Flagler	SP-12.5	2000	Astec DBG	12/2007	P & S Paving	270	260	Mainline
			SP-12.5	3973				270	260	Mainline
	421981-1	SR-25/Lake	FC-5	36259	Astec DBG	03/2009	Orlando Paving	250	250	Mainline
			SP-12.5	51898				265	265	Mainline
7	257070-1	US-19/Pinellas	SP-12.5	537	Astec DBG	Current	APAC Southeast	260	260	Mainline
			SP-12.5	8000				260	260	Mainline
	416839-1	US-98/Pasco	FC-12.5	8000	Astec DBG	Current	APAC Southeast	260	260	Mainline
8	413669-1	SR-417/Seminole	FC-5	2730	Aspha-min	02/2006	Orlando Paving	270	270	Mainline
Total Tonnage 225,889										

ANALYSIS OF CONSTRUCTION VARIABILITY

To ascertain the difference in construction variability between WMA and HMA, an analysis of construction test data was conducted between WMA mixtures and HMA mixtures that were placed on the same project. Similar mixtures, within the same layer, were analyzed. A total of 11 projects and 12 mixture types were examined (three FC-5 mixtures, eight SP-12.5 mixtures, and one FC-12.5 mixture). A summary of the projects and mixture types is provided in Table 9.

Table 9 – Summary of WMA and HMA Projects Used for Analysis of Construction Variability

Project Number	Mixture Type	Warm Mix Process
1	FC-5 Open Graded	Aspha-min
2	SP-12.5 Dense Graded	Evotherm DAT
3	SP-12.5, FC-12.5 Dense Graded	Astec DBG
4	SP-12.5 Dense Graded	Astec DBG
5	SP-12.5 Dense Graded	Astec DBG
6	SP-12.5 Dense Graded	Astec DBG
7	SP-12.5 Dense Graded	Astec DBG
8	SP-12.5 Dense Graded	Meeker
9	FC-5 Open Graded	Astec DBG
10	SP-12.5 Dense Graded	Astec DBG
11	FC-5 Open Graded	Astec DBG

The standard deviation of the test results for gradation and asphalt binder content are graphically presented for both WMA and HMA FC-5 open graded friction course mixtures in Figure 7. The standard deviation of the test results for gradation, asphalt binder content, air voids, and roadway density are graphically presented for both WMA and HMA dense graded mixtures in Figure 8. The horizontal bars in Figures 7 and 8 represent the average standard deviation for each type of production (WMA and HMA).

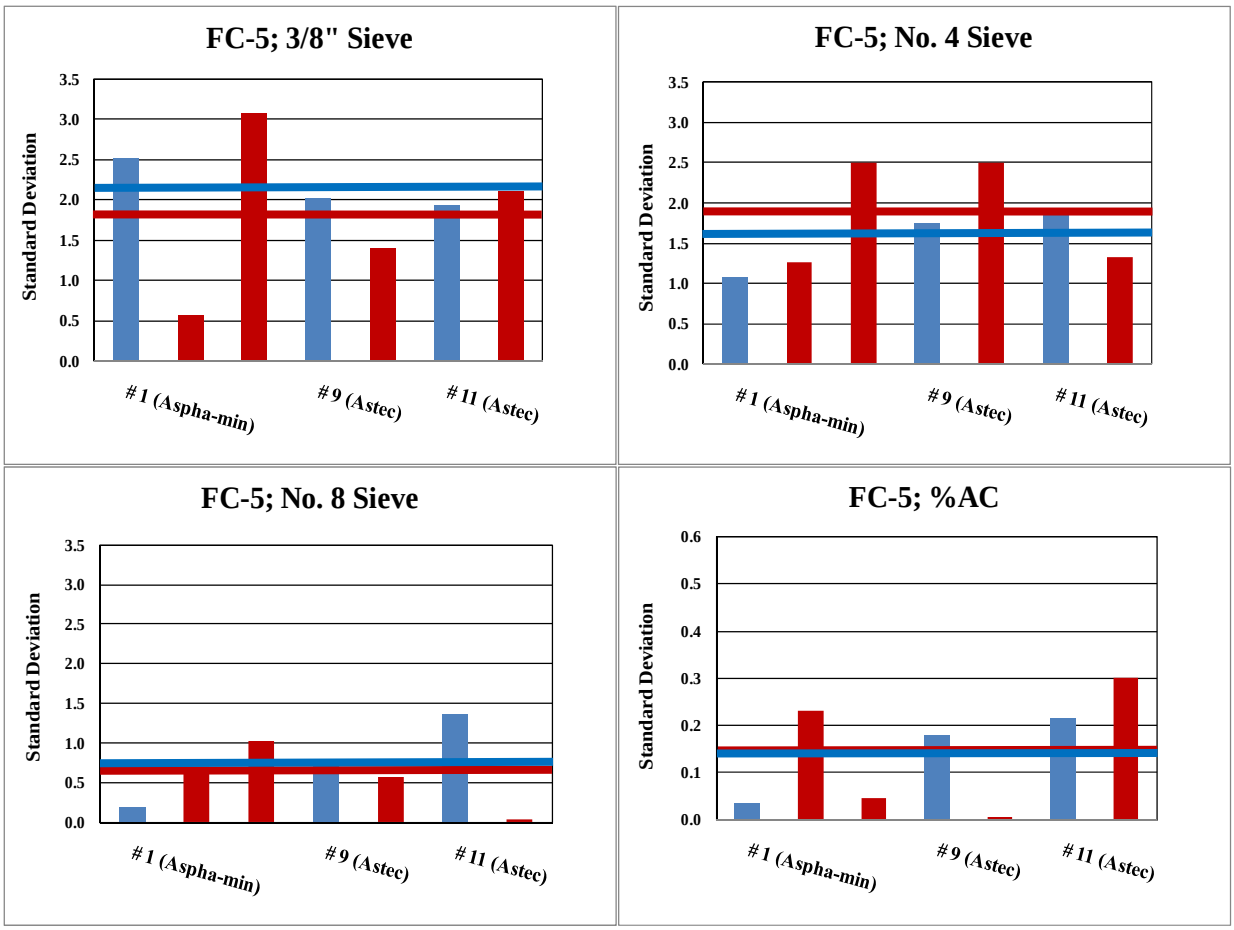

Figure 7 - Construction Variability for FC-5 Open Graded Friction Course Mixtures (Blue = Warm Mix Asphalt; Red = Hot Mix Asphalt)

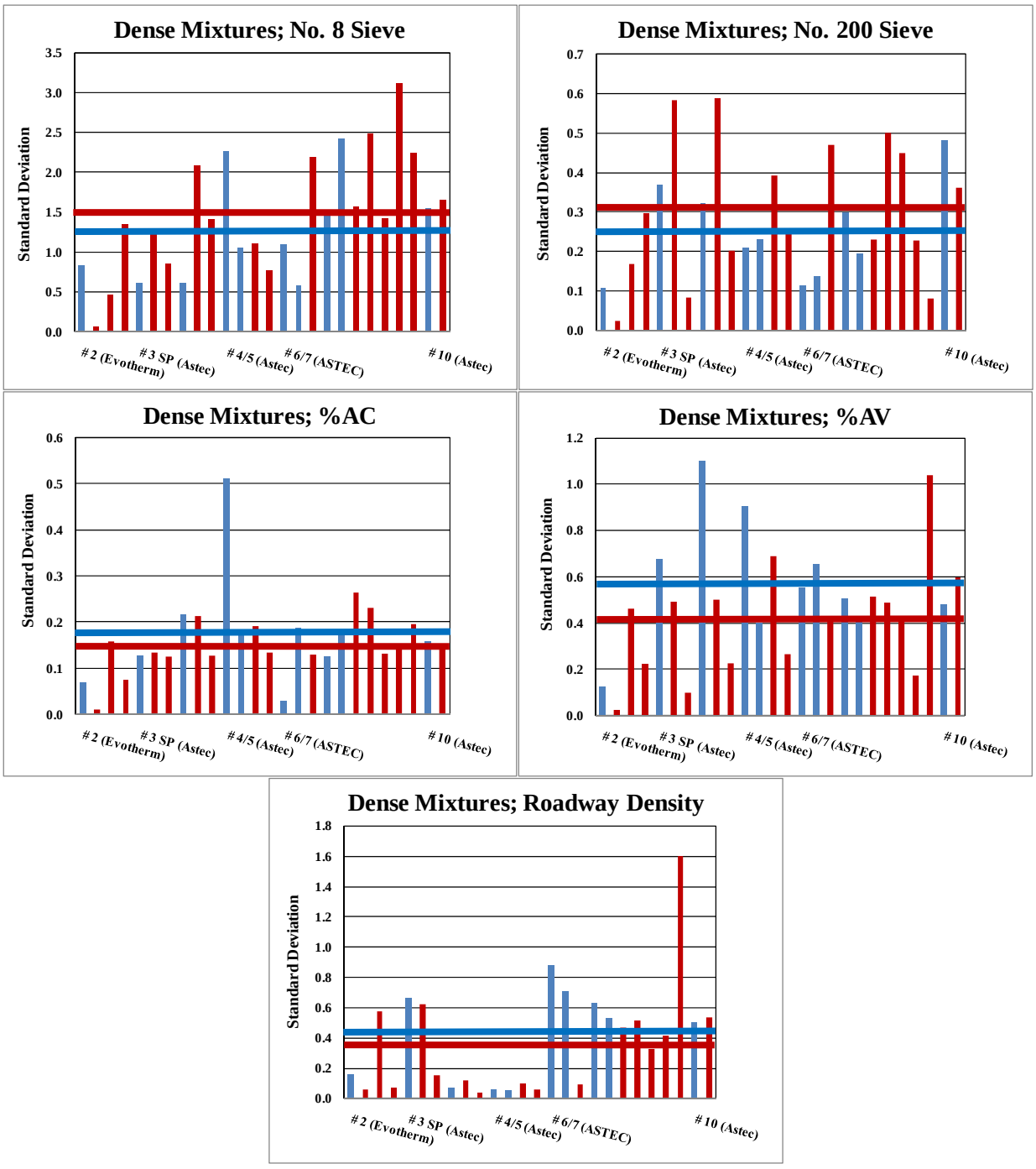

Figure 8 - Construction Variability for Dense Graded Friction Course Mixtures (Blue = Warm Mix Asphalt; Red = Hot Mix Asphalt)

As can be seen in Figures 7 and 8, the construction variability is similar between WMA and HMA, with some properties/projects having lower variability with WMA and some having higher variability.

CONCLUSIONS

This report has provided a summary of the Department's experience with WMA to date. A detailed analysis of the first three projects was provided indicating that there is no significant difference in laboratory performance or in measured pavement condition survey data (rutting, cracking and ride evaluation) between the WMA and HMA sections of the same mixture. Additionally, a listing of all of the WMA projects constructed to date was presented showing that nearly 226,000 tons of WMA has been placed in structural mixtures, dense graded friction course mixtures, and open graded friction course mixtures, utilizing five different WMA processes. To date, there have been no construction or performance problems noted on any of the projects. An analysis of construction variability indicated that there is no significant difference in the variability of measured quality control properties (binder content, air voids, gradation and roadway density) between companion WMA and HMA mixtures in the same project.