LONG-TERM PERFORMANCE OF A WARM-MIX ASPHALT OVERLAY ON AN AIRPORT MAJOR TAXIWAY: CASE STUDY

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ABSTRACT

Warm-Mix Asphalt (WMA) technology allows for lowering the production and placement temperature of the asphalt mix relative to conventional practices. WMA technology has been used in Europe since the 1990s and has gained acceptance in the US by State Highway Agencies since the early 2000's. Despite the environmental and cost benefits, very little work has been performed to implement WMA on airport infrastructure. This paper summarizes the construction and testing performed on test sections containing polymer-modified binders, Sasobit® wax additive and recycled asphalt pavement in the mix that were paved on Taxiway 'A', a high-volume taxiway at Logan International Airport in East Boston, Massachusetts. Levels of oxidative aging in asphalt mix samples collected from the surface were analyzed in-situ using a Diffused Reflectance Fourier-Transform Infrared spectroscopy technique. The oxidation levels were then related to volumetric parameters of the WMA mix and distresses accumulated over the eight years of service. Testing and the field survey show no significant differences between the various WMA test sections, suggesting minimal impacts of incorporating Sasobit as a WMA modifier to a top course of airfield pavement containing polymer modification and/or low levels of recycled asphalt pavement.

INTRODUCTION

In October of 2007, the first Warm-Mix Asphalt (WMA) surface course was placed as a surface course on airfield pavement, Taxiway 'A,' one of the busiest taxiways at Logan International Airport in East Boston, Massachusetts. The three overlay sections had the same structural thickness (6 inches) but were placed with two different construction methods (one- versus two-lift placement and compaction). The composition of the asphalt mixes varied between the sections in terms of binder performance grade (PG) and Recycled Asphalt Pavement (RAP) added to the mix. All sections contained Sasobit ® wax additive to reduce the production and placement temperatures. Initial testing conducted on cores included bulk specific gravity and air void content. Throughout the lifetime of the sections, periodic visual inspections were performed to identify any differences in distress performance. This paper summarizes the findings of the physical investigation of the asphalt surface aging and distress performance of the WMA sections after eight years of continuous high-volume traffic, serving nearly 800 aircraft per day.

BACKGROUND

WMA technologies have been used on roadways in Europe for over two decades (*1*). The United States began widely implementing WMA in the mid-2000's, primarily on roadways. By definition, WMA differs from conventional Hot-Mix Asphalt (HMA) by noticeably lower (30 to 100 °F) production and placement temperature (*2*). In order to preserve workability of asphalt mixture, the WMA technologies employ special treatments such as binder foaming or adding chemical plasticizers. Sasobit – an example of the latter - is a wax additive that reduces brittleness of asphalt mix at as low as 80 °C, which improves compactability and workability of WMA mixes (*2*, *3*). However, it has shown negative effect on rutting resistance of WMA mixes (*3*, *4*, *5*). Therefore, use of Sasobit may warrant use of greater high-temperature performance grade of binder to offset reduced viscosity of the resultant mix (*3*). In addition, use of Sasobit may need to be limited to low concentrations (<1%) and to the base courses (*3*, *4*).

When a WMA process is used for Recycled Asphalt Pavement (RAP) mix production, the main concern is that lowering the mixing temperature results in a reduced degree of blending between new binder and the RAP binder (*5*). In addition, the compatibility between new and RAP binder along with volumetric properties of the RAP mix influence extent of moisture damage and durability of the mix (*4*). Previous research has shown an elevated concentration of Sasobit in conjunction with very soft binder has allowed use of very high RAP content to achieve the same volumetric properties as in control HMA mix (6). One advantage of Sasobit over the other technologies such as water-injection/foaming is an improved moisture susceptibility of the mix when no RAP is present (7, 8). Most of the RAP-WMA studies report laboratory testing results with little or no information on the field performance of WMA mixes. Therefore, it is not surprising that the majority (11 out of 20) of the recent WMA-related research projects target field performance of RAP mixes (*9*). Notably, despite all the benefits of this past work, WMA trials on airfields are still justified due to larger tire loads, Marshall mix methods and more stringent failure criteria for airfield pavements.

Asphalt hardening and embrittlement are recognized as the principal outcome of oxidative aging of binders and a contributing cause of fatigue and moisture susceptibility in flexible pavements (*10, 11*). Hardening, i.e. increase in viscosity of aged binders, is associated with the increase in concentration of highly polar aromatics accompanied by formation of benzylic ketones within the binder (*10*). Fourier transform infrared (FT-IR) spectroscopy has been used to study long-term aging in asphalt binders for more than three decades (*10, 11, 12, 13*). Initially, FT-IR allowed identifying major products of asphalt oxidation (*10, 11*). Later studies confirmed that an increase in viscosity of aged binders is related to an increase in their carbonyl content as elucidated from the IR absorbance spectrum (*12, 13*).

A series of studies at the University of Connecticut identified Diffused Reflection Infrared Fourier Transform Spectroscopy (DRIFTS) as the most successful sampling method for FT-IR analysis of powderized asphalt samples recovered from the surface (*14, 15, 16*). In particular, the DRIFTS technique was successfully used to track differences in aging rate of HMA pavements constructed with binders of different performance grading (*14*). Furthermore, it was shown that an increase in RAP content was directly correlated with the increase in carbonyl content in the RAP-modified mixes (*15, 16*).

OBJECTIVES

The purpose of this study was to identify differences in performance and aging trends between the WMA pavement test sections placed on Taxiway Alpha at Logan International Airport. The methodology included the following steps:

- Identify differences (if any) in aging by DRIFTS technique
- Quantify distress level by visual inspection
- Analyze air voids data obtained from pavement cores (tested by others)
- Compare results to wheel-rutting data (obtained by others)
- Establish correlation between performance parameters by statistical analysis

EXPERIMENTAL PROTOCOL

Six test sections were placed at Boston-Logan International Airport on a portion of Taxiway ‘A’ between intersections with ‘A2’ and ‘E’ Table 1 summarizes material characteristics and construction methods for these sections, whereas Figure 1 depicts their configuration. All the mixes had the same aggregate gradation, however, the asphalt binder and additives varied. The six test sections had varied lengths, but all were greater than 100 ft and less than 250 ft. During placement, densities were monitored using a nuclear gauge and verified with core samples in the laboratory to ensure adequate compaction.

TABLE 1: Summary of Materials

Section ID	Binder PG	Additives	RAP content	Length (ft)	Construction Method
1-2L	64-28	Lime, 1.5% Sasobit, 4% SBR	18.5%	125	(2) 3” lifts
1-1L	64-28	Lime, 1.5% Sasobit, 4% SBR	18.5%	160	(1) 6” lift
2-1L	82-22	Lime, 1% Sasobit	0%	145	(1) 6” lift
2-2L	82-22	Lime, 1% Sasobit	0%	110	(2) 3” lifts
3-1L	82-22	Lime, 1% Sasobit	18.5%	230	(1) 6” lift
3-2L	82-22	Lime, 1% Sasobit	18.5%	230	(2) 3” lifts

*Styrene Butadiene Rubber (SBR)

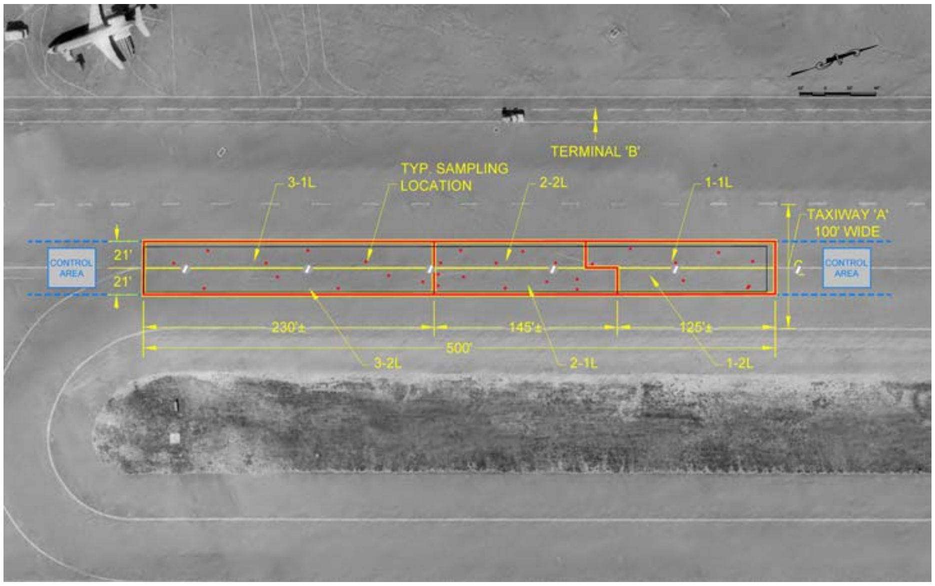

FIGURE 1: Configuration of the WMA test sections.

During a site visit on December 19, 2012, samples from each section of pavement were drilled. The pulverized residue of asphalt mix was collected individually at the locations shown Figure 1. Figure 2 shows the dimensions and typical configuration of drilled holes at each location.

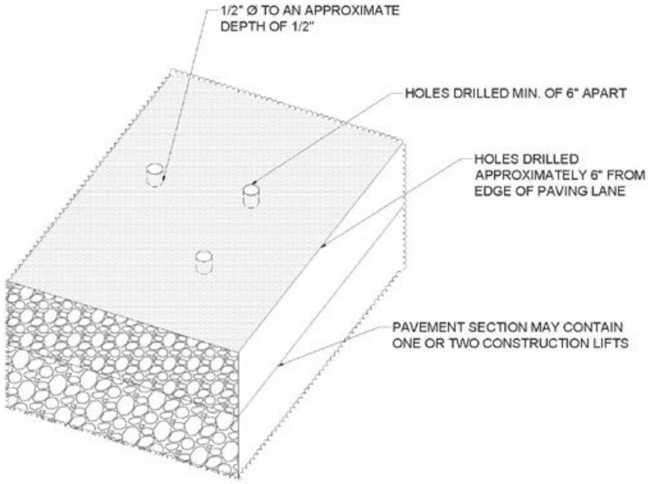

FIGURE 2: Typical sample collection detail and typical pavement cross-section.

The asphalt residue samples were tested in a compact DRIFTS spectrometer to obtain log (-Reflectance) spectra within the range between 4000 and 600 cm^{-1} wavenumbers. The IR spectrum for each sample was used for fingerprinting binder, aggregate, and additive components and for calculating carbonyl peak (P1700). Each powdered pavement sample was probed 3 times (0.2g per probe), each probe consisted of 24 scans of the sample which were averaged to produce its spectrum. Figure 3 shows a typical DRIFTS spectrum, or a “fingerprint,” for an asphalt mix sample collected at Logan Airport. The close-up view of the carbonyl peaks allow for distinction in oxidation level among three samples where the larger the magnitude of the peak at 1700 cm-1, the higher the level of oxidation.

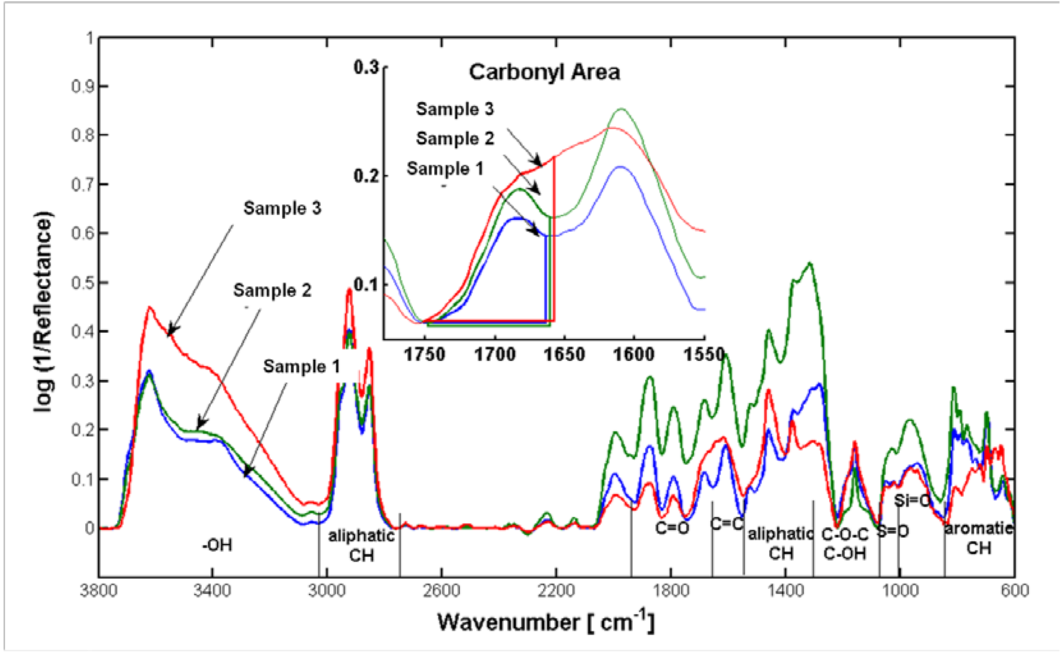

FIGURE 3 – Typical spectra from asphalt pavement mixes with close-up on carbonyl area.

On June 10th, 2015 visual distress survey of the wearing surface was performed. The visual distress survey was conducted by walking the length of each test section and measuring the length or area of each distress and identifying the distress magnitude. The documented distresses were later converted to a Pavement Condition Index (PCI) according to ASTM D5340 (*17*)

RESULTS AND DISCUSSION

Original core density data taken from cores during construction was adapted from a report prepared by Dr. Mallick at Worcester Polytechnic Institute (*18*). Figure 4 presents air void data from the three different types of mix (1-3) with error bars indicating plus and minus one standard deviation for the corresponding sections. While there is no statistical difference between the field-compacted, core sample air voids, visually higher air voids can be seen in Section 2 and Sections 2 and 3 had higher variance. Sections 2 and 3 both had the same asphalt binder.

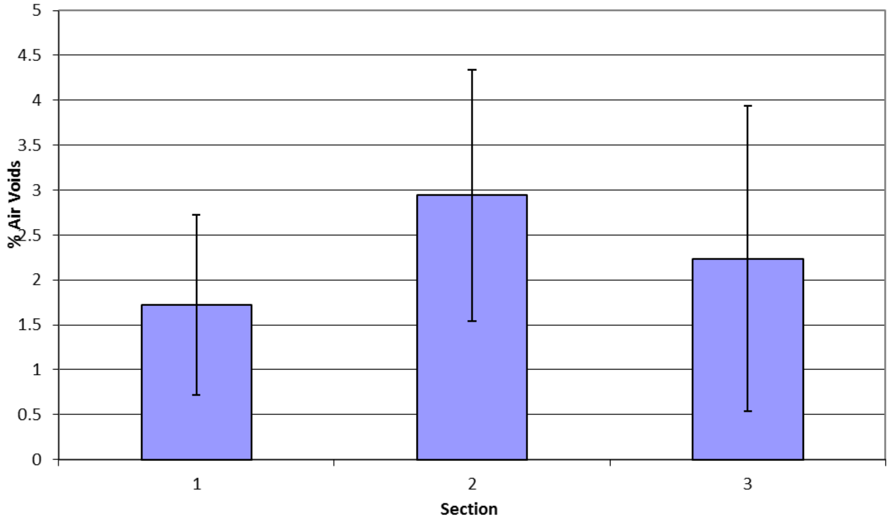

FIGURE 4: Air voids data from construction *(18)*

Laboratory rutting data was also reported by Dr. Mallick *(18)*, using a Model Mobile Load Simulator (MMLS). The MMLS applies a 2.7 kN load on tires with an internal pressure of 690 kPa. After 80,000 passes by the MMLS, rut depths are measured on the test specimens. The results from both a wet and *dry* test on multiple samples is adapted in Figure 5. The *dry* samples were tested at 25˚ C whereas the *wet* samples were tested at 50˚ C

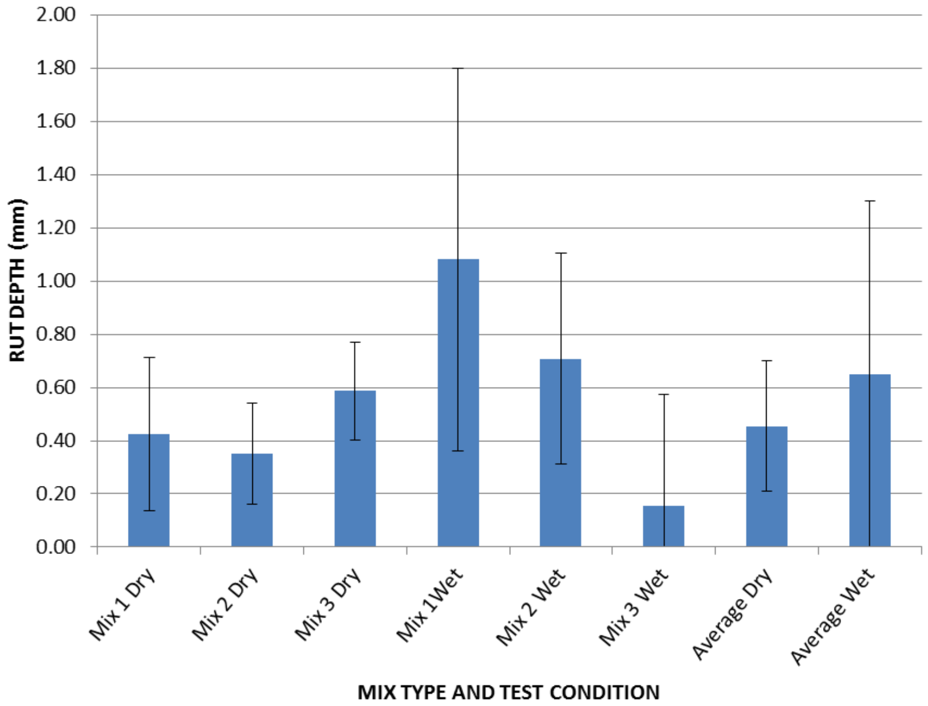

FIGURE 5: MMLS Wheel Rutting Data [Adapted] *(18)*

While the performance of the mixes can be described as statistically similar, as suggested by the overlap of the error bars. However, it is noteworthy that, graphically, mix 1 having SBR and Sasobit, had the largest rutting potential in the wet condition. In all, these mixes had minimal rutting when tested by the MMLS *(18)*.

Pavement distresses from each section were identified in accordance with ASTM D5340 (*17)*. Distresses identified on-site were a mix of medium- and low-severity longitudinal and transverse cracking, medium and low-severity alligator cracking, oil spillage, and medium and low-severity raveling/weathering. Due to the fact that this is a taxiway with relatively slow-moving aircraft, there is opportunity for oil spillage.

It can be seen in Figure 6 that mix 2 had the highest PCI rating and mix 3 had the lowest, with both the 3” and 6” lifts performing similarly. While the results in Figure 6 could be related to the performance of the mix, without comparison of the current surface to the condition of the milled surface beneath, an unknown amount of surface cracking could be reflective.

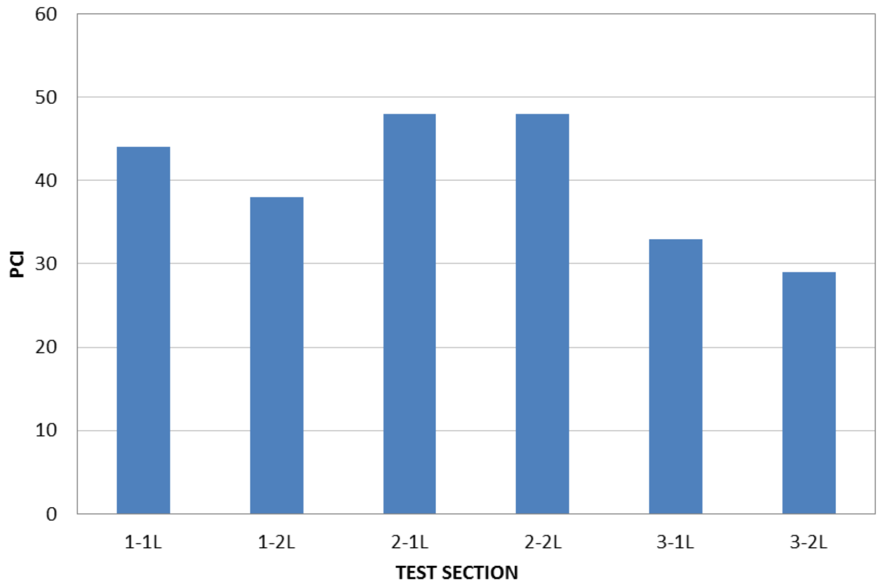

FIGURE 6: Pavement Condition Index

The results in Figure 7 show the oxidation indices computed as a normalized carbonyl peaks (P1700) from FT-IR analysis. On average, WMA Mix Section 1-2L has the strongest measurable oxidation and Section 1 overall varied more than any other section; this, however, can be attributed to a sample containing a concentration of RAP, whereas WMA Mixes 2 and 3 had visually comparable oxidation peaks. The error bars in Figure 7 show limits of confidence at level α=0.05. One can infer that due to a high overlap between the error bars, no statistically significant difference can be established among the sections at 95 percent reliability.

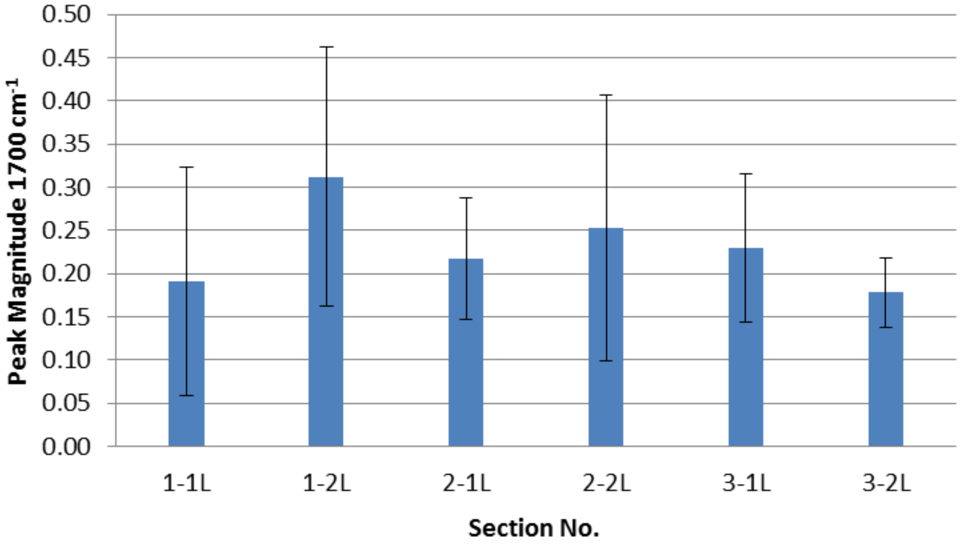

FIGURE 7: Average oxidation index versus treatment

Statistical analysis was conducted to compare variance between the parameters of the six treatments. The correlation test attempts to make a linear model given an independent and dependent set of data with each field (i.e. RAP vs. Oxidation Index). The accuracy of the model at predicting the results is then reported as *R*, on a scale of -1 to 1 where the value 0 has no relation and 1 and -1 are direct positive and negative relationships respectively. For parameters such as air voids, a sample size *n*=3 a statistically significant correlation between any two variables can be concluded at 95 percent reliability if *R* is greater than 0.95, and parameters including PCI and P1700, with a sample size of 6, the variables have significant correlation if *R* is greater than 0.75. Several such relationships are identified in Table 2. The *R*-values in Table 2 provide indication of relative pair-wise association.

TABLE 2: Correlation Coefficients

	Mix	*Base PG*	*RAP*	*P1700*	*PCI*	*Air Voids*
Mix	1.000					
Base PG	0.866	1.000				
RAP	0.000	-0.500	1.000			
P1700	-0.984	-0.762	-0.179	1.000		
PCI	-0.585	-0.101	-0.811	0.721	1.000	
Air Voids	-0.715	-0.270	-0.699	0.829	0.985	1.000

The take-away from the analysis summarized in Table 2 is that the three mix types evaluated, construction method and presence of RAP did not have significantly adverse effects on the lifetime performance of these pavements with the presence of Sasobit Wax as a WMA additive. While the data relating to PCI and air voids may indicate correlations, the level of data collected for this study would be too small to draw significant conclusions in that regard.

FINDINGS AND CONCLUSION

This paper attempted to quantify the differences, if any existed, between 3 test sections placed on Taxiway ‘Alpha’ at Logan International Airport. Each mix contained Sasobit Wax additive to improve the workability at lower temperatures. Visual inspection showed minor differences between the mixes, and Fourier Transform Infrared Spectroscopy determined oxidation levels in the pavement sections were also indiscriminant. After comparing the initial air voids from construction data and laboratory wheel-tracking test from a previous study (*18*) with the visual distress survey and oxidation levels from the FTIR testing measured after years of *in-situ* performance, the following conclusions can be made:

- There is no significant difference in oxidation levels across the mixes. This might be due to the low initial air voids of the Marshall Mix Design.

- No significant correlation can be drawn between the three mixes, construction method (lifts) or presence of RAP; suggesting the wax modifier had no adverse effects on the performance of the mix.
- Statistical analysis suggests a correlation may exist between the oxidation level and PCI. Statistical analysis suggests a correlation may exist between the oxidation level and the mix type.

In conclusion the data collected in this case study in conjunction with the work of previous researchers shows Warm-Mix Asphalt can perform adequately as a surface course for Airfield Pavements. After eight years of traffic and weather loading, it is evident that with high quality placement practices and consistent compaction, the three test mixes placed on this Taxiway deteriorate to a similar level despite the differences in binder modification or low-level RAP content.

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