County of San Diego Department of Public Works

Fiber Reinforced Asphalt Concrete (FRAC) Pilot Project
Pilot Study Report Work Plan(18 Month Review 10/22)

Executive Summary

Asphalt Concrete (AC) is a widely employed material in flexible pavement construction worldwide and is commonly used as a surface course in road construction. Flexible pavements experience plastic deformation under high traffic volume and load. Repeated loading leads to tensile stresses and strain within the flexible pavement structural section. In time, these stresses lead to the deterioration of asphalt concrete including cracking on the surface course. Asphalt concrete deteriorates rapidly once cracking develops which triggers the need to perform maintenance on the road. Maintenance of road networks is costly and leads to delays and inconvenience to the motoring public. If the onset of cracking can be delayed by using asphalt concrete designed to resist cacking the costs and inconvenience associated with pavement maintenance can be minimized.

As traffic volumes continue to increase, the proper maintenance of roadways will require the use of high-quality paving materials, particularly characteristics that provide strength, durability and rideability. At the same time, engineers and material experts are continually researching and testing various means focused on improving the performance and life span of asphalt concrete pavement. One such method includes reinforcing asphalt mixtures by incorporating fibers.

Fiber Reinforced Asphalt Concrete (FRAC) is produced by adding a mixture of thin polypropylene and aramid fibers to conventional asphalt concrete. The fibers are evenly distributed within the asphalt concrete to create a 3-dimensional reinforcement matrix. The fibers incorporated into asphalt mixture enhance the asphalt concrete's strength, improve its resistance to rutting and help prevent reflective cracking.[1] This pilot study will focus on the incorporation of FRAC into the County of San Diego's (County) Pavement Management Program and evaluate the performance and costs compared to conventional asphalt concrete at 4 different locations representing typical conditions of the County's road network.

Introduction

Background

Fiber Reinforced Asphalt Concrete has been used for resurfacing roads since the mid 1950's when asbestos fibers were added to conventional AC[1] . Today the technology consists of blending thousands of polymer-based fibers with asphalt concrete during the batch mixing process to create a 3-dimensional reinforcement matrix within the asphalt concrete layer. Fiber is easily incorporated into standard AC mixes without modification of the mix design, there is no need to adjust the proportions of other materials. Multiple studies have shown that this process improves the mechanical performance of AC including strength in tension and resistance to rutting and fatigue[1]. Another study showed that the high ductility of fiber reinforced asphalt mixtures significantly decreased the effect of the long-term aging in comparison with the other mixtures resulting in increased service life[2]. Indeed, there seems to be a consensus that the addition of fiber positively impacts the long-term performance compared to conventional AC, however, there is limited information correlating performance to the increased cost of FRAC.

Problem Statement

The main objectives of the County's Road Maintenance Team are to properly evaluate the existing condition of a road, recommend spot repairs (digouts, surface distresses, etc.) and select a treatment that is effective within limited budgets. If the selected treatment is not adequate, then a road can fail at a quicker rate than expected. This leads to several issues including resident complaints, premature failures, and the need to perform expensive repairs. Conversely, if the selected treatment is too robust, funding that could be used to treat additional roads is needlessly wasted. Again, this could lead to resident complaints and inquires.

One issue of concern related to quality is early reflective cracking of newly placed asphalt concrete. Early reflective cracking can occur if there is insufficient structural section to support traffic loads or if existing cracks are not properly treated prior to resurfacing. These cracks can potentially lead to several issues including water induction to the subbase/subgrade leading to base failures, striping/raveling, and potholes/voids in the newly placed surface course. Depending on the extent and severity these issues can lead to costly repairs that increase the maintenance cost for the road.

Several methods are currently used to mitigate reflective cracking including milling the existing surface, performing digouts to repair distressed areas prior to paving, crack sealing to treat existing cracks and the use of pavement reinforcing fabrics. The County has used each of these treatments with varying levels of success but none have been effective in all cases.

Milling the road prior to resurfacing removes surface level cracks but if the cracks are deeper than the mill depth, small cracks still remain and could reflect. Removing existing pavement distresses and replacing them with new pavement has been effective in preventing reflective cracking in spot areas, but these repairs are costly.

Crack sealing is a treatment practice designed to fill and seal existing cracks in asphalt concrete pavements. If the crack sealing is done properly on non-working cracks, this can be an effective measure against reflective cracking. However, if not done using the proper technique, crack sealing can make underlying issues worse for newly placed pavement.

The use of pavement reinforcing fabric is an effective treatment for the mitigation of non-load related reflective cracking by improving the tensile strength at the bottom of the new mat, but its not effective at mitigating top down cracking. Additionally, the road must be properly prepared, including performing digouts and crack sealing prior to the placement of fabric. This treatment must be applied per the manufactures recommendations to ensure there is no excessive overlapping or bunching of material. Pavement reinforcing fabric is not appropriate for all roads and in some cases presents future maintenance issues when it has to be removed and disposed of during construction.

Another issue of concern is premature rutting of newly placed asphalt concrete. Rutting can be caused by lack of compaction, insufficient pavement thickness, and weak asphalt mixtures. It has been shown that adding fiber can significantly improve the rutting resistance of the asphalt mixture. It has also been shown that fiber reinforced mixes experienced higher recoverable deformation and tensile strength against control mixes which contributes to a better resistance in permanent deformation and crack propagation[3].

Study Objective

The goal of this pilot study includes two objectives. First, FRAC will be compared to the control (conventional AC) to determine if there are material performance improvements under various typical conditions. Secondly, the study will look at the associated cost increase for FRAC to determine if/where its continued use will benefit the County most.

Construction Cost Summary

Because the scope of work at each location was generally the same when comparing control to the fiber sections evaluation of the construction costs is straight forward. The addition of fiber increased the material cost between 8-10%. Conventional asphalt concrete pricing was $83/Ton and polymer modified asphalt concrete pricing was $100/Ton. Fiber reinforcement was bid at $8.25/Ton. Once the evaluation phase is complete the project team will evaluate this cost increase compared to the performance to determine if adding fiber is a cost-effective practice.

Materials

Fiber Characteristics

Forta-FI® fibers, manufactured by FORTA (Grove City, PA) were used for this study. These fibers consist of a blend of synthetic polyolefin and aramid fibers designed for use in Hot Mix Asphalt (HMA) applications. Fiber was added at the manufactures recommended dosing of 1lb of fibers/ ton of asphalt concrete produced. Figure 1 shows typical fibers contained in the aramid and polypropylene. Table 1 shows the main physical properties of both fibers.

Figure 1 - Close up of Reinforced Fibers: Polypropylene and Aramid

Table 1 - Physical Characteristics of Used Fibers

Materials	**Polyolefin**	**Aramid**
Form	Serrated	Monoflilament[2]
Specific Gravity	0.91	1.44
Tensile Strength (MPa)	NA[1]	2758
Length (mm)	19.05	19.05
Color	yellow	yellow

Acid/Alkali Resistance	inert	inert
Operating Temperature (°C)	NA[1]	up to 427

1. Fibers melt or deform plasticly during mix production
2. Strands become fibrillated during mix production

Asphalt Concrete

Asphalt concrete used in this study was produced using the County's standard HMA specification (Attachment 1) which is based on the Caltrans standard specification. The key difference is that the County specification requires the asphalt concrete to be produced based on the Hveem design method whereas the current Caltrans specification produces asphalt concrete using the Superpave design method. All other construction related requirements match the current Caltrans standard. The fiber and control asphalt concrete used at each location where identical in composition with the exception of added fiber in the FRAC mixes. Both conventional and polymer modified asphalt concrete were used as the control material for this study. The approved mix designs are included in Attachment 2. All material used was subject to the standard QA/QC testing and acceptance criteria show in the specification. Test results are included in Attachment 3. A summary of the mix designs used are as follows:

Mix ID	Mix #	Mix Type	Gradation	Producer
1	21212305F	AC	1/2"	CCA (Lakeside)
1F	21212305	FRAC	1/2"	CCA (Lakeside)
2	21212415	PMAC	1/2"	CCA(Lakeside)
2F	21212415F	FRPMAC	1/2"	CCA(Lakeside)

Scope

Overview

This study will compare FRAC to conventional AC at 4 different locations representing typical conditions of the County's road network.

Location 1: FRPMAC - Neighborhood Collector with Wheel Path Rutting (4.5-5.5" Existing AC Section on Native)					
Section	**Road**	**To**	**From**	**Length (MI)**	**Treatment**
1	Corral Canyon Rd	Central Ave	Jockey Way	0.37	3" Mill Inlay w/ PMAC
2	Corral Canyon Rd	Jockey Way	Leadrope Way	0.42	3" Mill Inlay w/ FRPMAC
3	Corral Canyon Rd	Leadrope Way	Chula Vista CL	0.37	3" Mill Inlay w/ PMAC

Location 1: Corral Canyon Road

Location 2: FRPMAC - Rural Arterial (5.25-6" Existing AC Section with 2" of AC and the remainder ROM sitting on native)					
Section	**Road**	**To**	**From**	**Length (MI)**	**Treatment**
1	Skyline Truck Trail	MP 1.0	MP 1.5	0.50	2.5" Mill/ Inlay w/ FRPMAC
2	Skyline Truck Trail	MP 1.5	MP 2.0	0.50	2.5" Mill/ Inlay with PMAC
3	Skyline Truck Trail	MP 2.0	MP 2.5	0.50	2.5" Mill/ Inlay with FRPMAC
4	Skyline Truck Trail	MP 2.5	MP 3.0	0.50	2.5" Mill/ Inlay with PMAC

Location 2: Skyline Truck Trail

Location 3: FRAC - Residential streets with minimal AC thickness					
Section	**Road**	**To**	**From**	**Length (MI)**	**Treatment**
1	St George St	Sweetwater Rd	St George Pl	0.25	2" mill/inlay with TYPE A FRAC
2	Bruckner Ave	Orville St	Cul-De-Sac	0.34	2" mill/inlay with TYPE A AC
3	Safford Ave	St George St	Orville St	0.22	2" mill/inlay with TYPE A FRAC
4	Kelso St	Safford Ave	Bruckner Ave	0.12	2" mill/inlay with TYPE A AC
5	Adriana St	Safford Ave	Bruckner Ave	0.10	2" mill/inlay with TYPE A FRAC
6	Hiel St	Safford Ave	Bruckner Ave	0.14	2" mill/inlay with TYPE A FRAC
7	Orville St	Sweetwater Rd	Thayer Dr	0.43	2" mill/inlay with TYPE A AC

Location 3: Spring Valley Neighborhood

Location 4: FRPMAC / PMAC / Conventional AC on high volume arterial with engineered base					
Section	**Road**	**To**	**From**	**Length (MI)**	**Treatment**
1	Camino Del Norte	4S Ranch Pkwy	Dove Canyon	0.28	3" M/I PMAC
2	Camino Del Norte	Rancho Bernardo Rd	4S Ranch Pkwy	0.26	3" M/I FRPMAC

Location 4: Camino Del Norte

Each location will be surveyed and photo documented before, during, and post construction. Post construction, the roads will be reviewed on the following schedule:

1. 6 months post construction- Complete
2. 12 months post construction- Complete
3. 18 months post construction
4. 24 months post construction
5. Annually for a period of 5-7 years post construction

The evaluation will be focused on measured visual observation of cracking, rutting and other distresses and their growth over time. Review forms are included in Attachment 4. Condition updates will be provided after each review cycle. As this study moves through the evaluation phase, the project team will continue to provide summary reports (appendix 1). At the completion of the evaluation phase a summary report will be developed and provided so the County can determine the benefit of continued use in its road maintenance program.

References

1. Mateos, A & Harvey, J. (2019). Laboratory Evaluation of the Mechanical Properties of Asphalt Concrete Reinforced with Aramid Synthetic Fibers, UCPRC-RR-2019-01, University of California Pavement Research Center, Berkeley, CA.
2. Huang, H.& T. D. White. (1996) Dynamic Properties of Fiber-Modified Overlay Mixture. Transportation Research Record: Journal of the Transportation Research Board, Vol. 1545, pp. 98–104.
3. Shukla, M., Et Al(2014), Performance Characteristics of Fiber Modified Asphalt concrete Mixes, The International Journal of Pavement Engineering and Asphalt Technology (PEAT) ISSN 1464-8164. Volume: 15, Issue: 1, May 2014, pp.38-50

Appendix1: Summary Progress Reports

Location 1 Corral Canyon Road:

Location 1: FRPMAC - Neighborhood Collector with Wheel Path Rutting (4.5-5.5" Existing AC Section on Native)					
Section	**Road**	**To**	**From**	**Length (MI)**	**Treatment (Mix ID)**
1	Corral Canyon Rd	Central Ave	Jockey Way	0.37	3" Mill Inlay w/ PMAC (2)
2	Corral Canyon Rd	Jockey Way	Leadrope Way	0.42	3" Mill Inlay w/ FRPMAC (2F)
3	Corral Canyon Rd	Leadrope Way	Chula Vista CL	0.37	3" Mill Inlay w/ PMAC (2)

Pre Construction Summary: Corral Canyon Road was selected as a model for a Neighborhood Collector with heavy wheel path rutting. The majority of the distress at this location are age related. The depth of inlay was increased to 3-inches to ensure the top layer of asphalt distresses were removed.

Construction Summary: No major concerns were identified during construction. Both the FRPMAC and PMAC sections were placed according to specifications and passed all testing requirements.

6 Month Review Summary: No signs of cracking or other distresses at were present at any of the 3 locations. This was the expected result given the short duration since construction was completed. Representative photographs were taken to document the condition and compare visually to future reviews.

12 Month Summary: Still no signs of cracking or other distresses. The black color of the asphalt is beginning to fade, but no defects were noted. Representative photographs were taken to document the condition and compare visually to future reviews.

18 Month Summary: All segments are continuing to perform well. No signs of cracking or other distresses, but the surfacing is starting to fade. Representative photographs were taken to document the condition and compare visually to future reviews.

Location 1-1(PMAC)

Photo 1-1-1: 6 Months

Photo 1-1-2: 12 Months

Photo 1-1-3: 18 Months

Location 1-2(FRPMAC)

Photo 1-2-1: 6 Months

Photo 1-2-2: 12 Months

Photo 1-2-3: 18 Months

Location 1-3(PMAC)

Photo 1-3-1: 6 Months

Photo 1-3-2: 12 Months

Photo 1-3-3: 18 Months

Location 2: Skyline Truck Trail

Location 2: FRPMAC - Rural Arterial (5.25-6" Existing AC Section with 2" of AC and the remainder ROM sitting on native)					
Section	**Road**	**To**	**From**	**Length (MI)**	**Treatment (Mix ID)**
1	Skyline Truck Trail	MP 1.0	MP 1.5	0.50	2.5" Mill/ Inlay w/ FRPMAC (2F)
2	Skyline Truck Trail	MP 1.5	MP 2.0	0.50	2.5" Mill/ Inlay with PMAC (2)
3	Skyline Truck Trail	MP 2.0	MP 2.5	0.50	2.5" Mill/ Inlay with FRPMAC (2F)
4	Skyline Truck Trail	MP 2.5	MP 3.0	0.50	2.5" Mill/ Inlay with PMAC (2)

Pre Construction Summary: Skyline Truck Trail was selected as a model for a Rural Arterial with no engineered base section. Distresses are both base related and age related. The depth of inlay was increased to 2.5-inches to ensure the top layer of asphalt distresses were removed.

Construction Summary: No major concerns were identified during construction. Both the FRPMAC and PMAC sections were placed according to specifications and passed all testing requirements.

6 Month Review Summary: No signs of cracking or other distresses at were present. This was the expected result given the short duration since construction was completed. Representative photographs were taken to document the condition and compare visually to future reviews.

12 Month Summary: Still no signs of cracking or other distresses. The black color of the asphalt is beginning to fade, but no defects were noted. Representative photographs were taken to document the condition and compare visually to future reviews.

18 Month Summary: Minor hairline cracks are starting to develop in all sections. This appears to be the start of reflective cracking. Cracks are hard to identify visually. Next review will focus on the progression and the percentage of road affected.. Representative photographs were taken to document the condition and compare visually to future reviews.

Location 2-1 (FRPMAC)

Photo 2-1-1: Skyline TT 6 Months

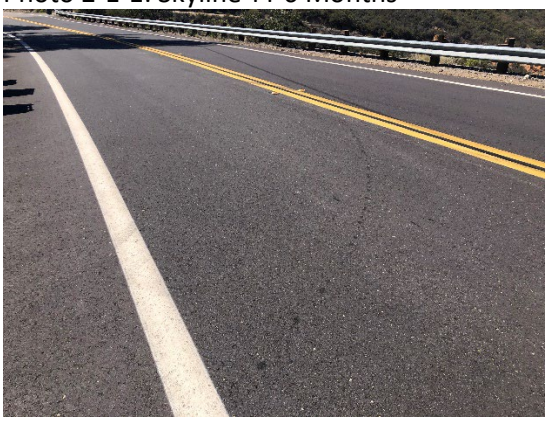

Photo 2-1-2: Skyline TT 12 Months

Photo 2-1-3: Skyline TT 18 Months

Photo 2-1-4; Skyline TT 18 Months- closeup of hairline cracking

Location 2-2 (PMAC)

Photo 2-2-1: Skyline TT 6 Months

Photo 2-2-2: Skyline TT 12 Months

Photo 2-2-3: Skyline TT 18 Months

Photo 2-2-4; Skyline TT 18 Months- closeup of hairline cracking

Location 2-3 (FRPMAC)

Photo 2-3-1: Skyline TT 6 Months

Photo 2-3-2: Skyline TT 12 Months

Photo 2-3-3: Skyline TT 18 Months

Photo 2-3-4: Skyline TT 18 Months. Representitive hairline cracking

Location 2-4 (PMAC)

Photo 2-4-1: Skyline TT 6 Months

Photo 2-4-2: Skyline TT 12 Months

Photo 2-4-3: Skyline TT 18 Months. Overall, the road is in good condition

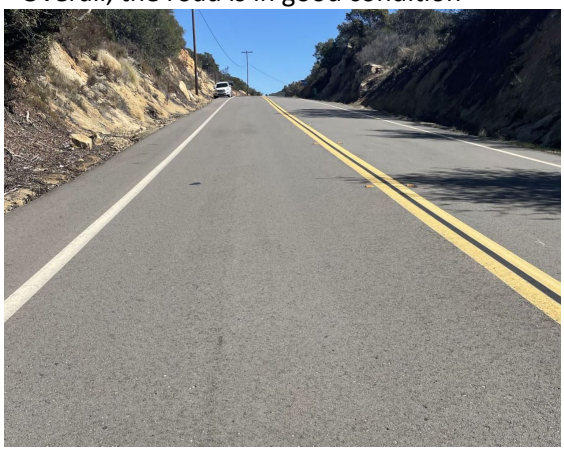

Photo 2-4-4: Skyline TT 18 Months Close up of Hairline cracking

Location 3: Spring Valley Residential Streets

Location 3: FRAC - Residential streets with minimal AC thickness					
Section	**Road**	**To**	**From**	**Length (MI)**	**Treatment (Mix ID)**
1	St George St	Sweetwater Rd	St George Pl	0.25	2" mill/inlay with TYPE A FRAC (1F)
2	Bruckner Ave	Orville St	Cul-De-Sac	0.34	2" mill/inlay with TYPE A AC (1)
3	Safford Ave	St George St	Orville St	0.22	2" mill/inlay with TYPE A FRAC (1F)
4	Kelso St	Safford Ave	Bruckner Ave	0.12	2" mill/inlay with TYPE A AC(1)
5	Adriana St	Safford Ave	Bruckner Ave	0.10	2" mill/inlay with TYPE A FRAC (1F)
6	Hiel St	Safford Ave	Bruckner Ave	0.14	2" mill/inlay with TYPE A FRAC (1F)
7	Orville St	Sweetwater Rd	Thayer Dr	0.43	2" mill/inlay with TYPE A AC (1)

Pre Construction Summary: These neighborhood roads in spring valley were selected as a model for a Residential Streets with moderate to heavy distress . The majority of the distress at this location are age related. The standard depth of a 2" was used for all inlays.

Construction Summary: Construction reports note unstable subgrade may have been paved over at Heil St, Adrianna St and Safford Ave. All of these locations received FRAC (1F). distress at these locations will need to be evaluated to determine if the unstable subgrade is the root cause. Depending on the severity these locations may need to be removed from further evaluation/ discussion related to this study. Both the FRAC and AC sections passed all testing requirements and were accepted by County staff.

6 Month Review Summary: No signs of cracking or other distresses at were present at any of the 3 locations. This was the expected result given the short duration since construction was completed. Representative photographs were taken to document the condition and compare visually to future reviews.

12 Month Summary: The majority of the roads we in a similar condition to the roads at 6 months. The black color is starting to fade but there were no signs of cracking with the exception of Orville St. Orville Street has 3 distinct areas that showed signs of fatigue related failures. Two of these locations are adjacent to commercial driveways. There is a large amount of delivery trucks using these driveways which likely contributed to the accelerated failure. Since these distresses presented shortly after construction and none of the other locations in the area have commercial driveways this study will disregard these spot areas and focus the comparison at locations similar in character to the other study roads.

18 Month Summary: Locations 2-6 continue to perform will with no signs of cracking or other distress. Pavement starting to age, but no concerns at this time. Two hairline cracks are starting to develop at location 1 (St George St, (FRAC) Orville Street had 3 distressed areas identified during the 12 month review. Those areas are continuing to fail at a faster rate than expected. Two of these locations are adjacent to commercial driveways. There is a large amount of delivery trucks using these driveways which likely contributed to the accelerated failure. Since these distresses presented shortly after

construction and none of the other locations in the area have commercial driveways this study will disregard these spot areas and focus the comparison at locations similar in character to the other study roads. Additionally there were several areas along Orville that started to develop hairline cracks.

Location 3-1 St. George St (FRAC)

Photo 3-1-1: 6 Months

Photo 3-1-2: 12 Months

Photo 3-1-3: 18 Months

Photo 3-1-4: 18 M Hairline Cracking

Photo 3-1-5: Close Up of Crack #1 (18 M)

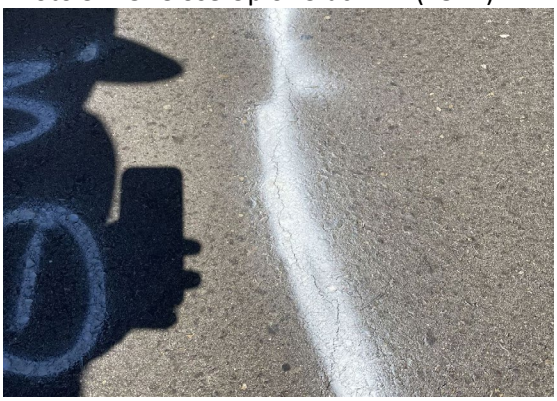

Photo 3-1-5: 18 M Hairline Crack #2

Location 3-2 Bruckner Ave (AC)

Photo 3-2-1: 6 Months

Photo 3-2-2: 12 Months

Photo 3-2-3: 18 Months

Location 3-3 Safford Ave (AC)

Photo 3-3-1: 6 Months

Photo 3-2-2: 12 Months

Photo 3-3-3: 18 Months

Location 3-4 Kelso St (AC)

Photo 3-4-1: 6 Months

Photo 3-4-2: 12 Months

Photo 3-4-3 18 Months

Location 3-5 Adriana St (FRAC)

Photo 3-5-1: 6 Months

Photo 3-5-2: 12 Months

Photo 3-5-3: 18 Months

Location 3-6 Heil St (FRAC)

Photo 3-6-1: 6 Months

Photo 3-6-2: 12 Months

Photo 3-6-3: 18 Months

Location 3-7 Orville St (AC)

Photo 3-7-1: 6 Months

Photo 3-7-2: 12 Months

Photo 3-7-3: 12M Distress Area 1 (6'x100')

Photo 3-7-4: 12M Closeup DA#1

Photo 3-7-5: 12M Distress Area 2 (6’x50’)

Photo 3-7-6: 12M Distress Area 3 (6’x75’)

Photo 3-7-5: 12M Close Up DA#3)

Photo3-7-6: 18 Months

Photo 3-7-7: 18 M DA #1

Photo 3-7-8: 18 M DA #2

Location 4: Camino Del Norte

Location 4: FRPMAC / PMAC / Conventional AC on high volume arterial with engineered base					
Section	**Road**	**To**	**From**	**Length (MI)**	**Treatment**
1	Camino Del Norte	4S Ranch Pkwy	Dove Canyon	0.28	3" M/I PMAC
2	Camino Del Norte	Rancho Bernardo Rd	4S Ranch Pkwy	0.26	3" M/I FRPMAC

Pre Construction Summary: Camino Del Norte was selected for this study as a model mutlilane residential arterial with an engineered base section. The majority of the distress at this location are age related The depth of inlay was increased to 3-inches to ensure the top layer of asphalt distresses were removed.

6 Month Review Summary: No signs of cracking or other distresses at were present at any of the 2 locations. This was the expected result given the short duration since construction was completed. Representative photographs were taken to document the condition and compare visually to future reviews.

12 Month Summary: Still no signs of cracking or other distresses. The black color of the asphalt is beginning to fade, but no defects were noted. Representative photographs were taken to document the condition and compare visually to future reviews.

18 Month Summary: All locations are still performing well. No signs of reflective cracking. The asphalt continues to age, but there is nothing to compare in terms of the pilot study at this point Representative photographs were taken to document the condition and compare visually to future reviews.

Location 4-1 (PMAC)

Photo 4-1-1: 6 Months (WB)

Photo 4-1-2: 6 Months (EB)

Photo 4-1-3: 12 Months (WB)

Photo 4-1-4: 12 Months (EB)

Photo 4-1-5: 18 Months (WB)

Photo 4-1-6: 18 Months (EB)

Location 4-2 (FRPMAC)

Photo 4-2-1: 6 Months (WB)

Photo 4-2-2: 6 Months (EB)

Photo 4-2-3: 12 Months (WB)

Photo 4-2-2: 12 Months (EB)

Photo 4-2-5: 18 Months (WB)

Photo 4-2-6: 18 Months (EB)