EVALUATION OF COOL PAVEMENT SURFACE TREATMENTS USING FRICTION, TEXTURE AND ADHSESION PROPERTIES

PREPARED FOR:
City of San Antonio

UTSA ROADRUNNERS

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University of Texas at San Antonio and TRANSTEC GROUP

1 OVERVIEW

The Transtec Group provided pavement surface friction and texture testing for cool pavement surface treatments as part of an evaluation of these treatments by the City of San Antonio (COSA) through The University of Texas, San Antonio. Each of the city's ten Council Districts had at least one treated test section. A list of the cool pavement project roads which were tested is found in Table 1. At each location, pavement surface texture and friction testing were performed on the treated section of pavement as well as a control surface which had not received the treatment for evaluation of the impact of the treatment on texture and friction properties. The map presented in Figure 1 shows the approximate locations of the treated sections measured in each council District.

Table 1. Cool pavement treatment locations and installation information.

Council District	Project Street	From Street	To Street	Product	Installer	Installation Date	Testing Date	Condition / Traffic
1	Grant Ave.	Craig	Cincinnati Ave.	Pave Tech	Pavement Restoration	April 24	June 21	Good condition, Low traffic
2	Carol Crest St.	Argonne Dr.	Kay Ann Dr.	GAF Streetbond	Creative Paving	May 17	June 21	Fair condition, Low traffic
3	Lucinda St.	Ashley Dr.	Sams Dr.	GuardTop Iron (dark)	Gallo Paving	July 13	Sept. 21	Good condition, Low traffic
4	Mountain Star	Stephens Ranch	Wolf Point	Seal Master	Gallo Paving	May 2	June 22 Sept. 21	Fair condition, Low traffic
4	Rebeccas Trail	Stephens Ranch	Wolf Point	Seal Master	Gallo Paving	May 2	June 22	Fair condition, Low traffic
5	SW 21st St.	Saltillo Rd.	S. Laredo St.	Seal Master	Gallo Paving	May 1	Sept. 21	Good condition, Med traffic
6	Spiral Creek	Ribbon Creek	Creek Ridge	GAF Streetbond	Creative Paving	May 18	June 21	Good condition, Low traffic

7	Piper Dr.	Loy	Freeman Dr.	GuardTop Iron (dark)	Gallo Paving	July 13	Sept. 20	Good condition, Low traffic
8	Frontier Hill	Buffalo Hills	Singing Forest	GuardTop Iron (light)	Gallo Paving	July 14	Sept. 20	Good condition, Low traffic
9	Encino Ridge St.	Encino Loop	Cul-de-sac	Pave Tech	Pavement Restoration	April 25	June 20	Fair condition, Med traffic
9	Park Farm	Park Bluff St.	Park Hollow	Pave Tech	Pavement Restoration	April 25	June 20	Fair condition, Med traffic
10	Villa Mercedes	Villa Camino	Escort Dr.	GuardTop Iron (light)	Gallo Paving	July 14	Sept. 20	Good condition, Low traffic

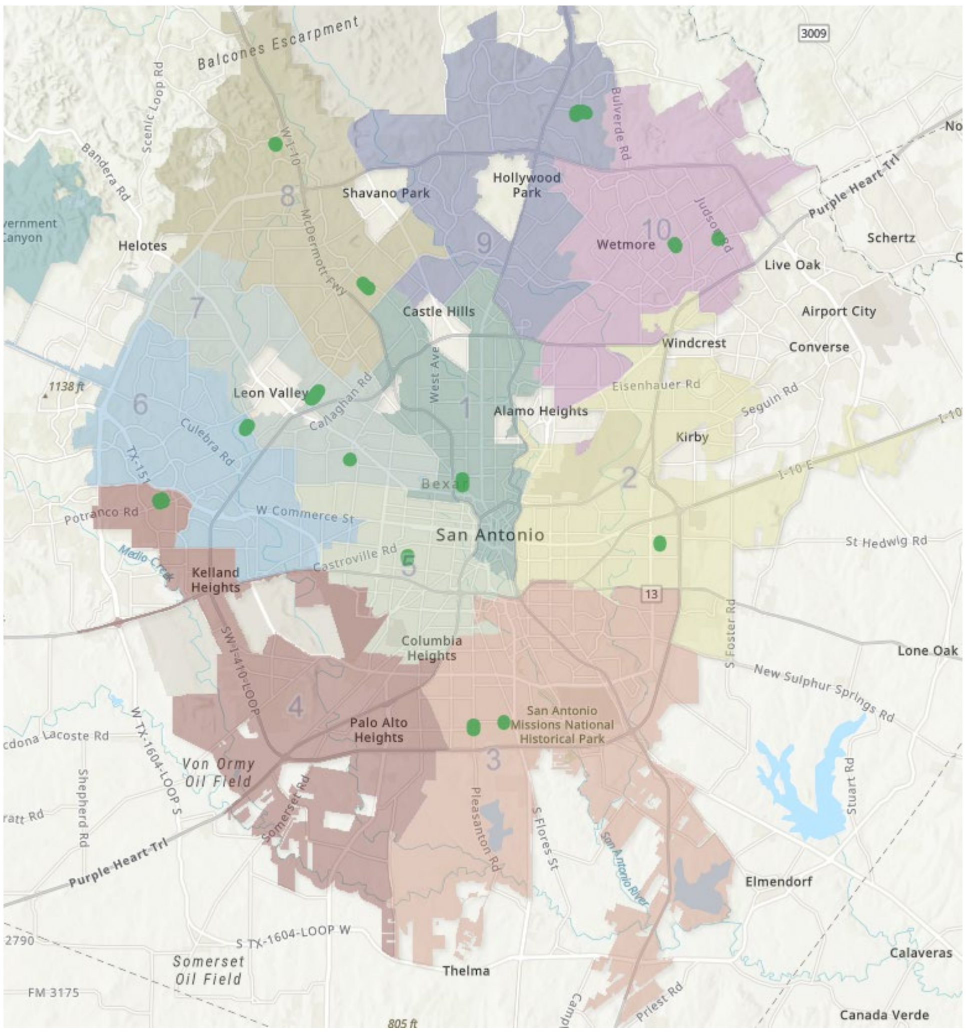


Figure 1. Approximate cool pavement project locations by Council District.

2 COOL PAVEMENT PRODUCTS AND SITES SELECTION

2.1 Cool Pavement Products

Four cool pavement products were evaluated in the study. Description of each product is as follow:

Seal Master (SolarPave®) is a polymer emulsion coating manufactured with UV resistant, reflective light-colored mineral pigments to provide minimum solar reflectance of 0.33. It is blended with ant-slip aggregate to increase surface texture.

GAF Streetbond (DuraShield®) Solar Gray is a two-component waterborne epoxy-modified acrylic coating blended with silica aggregates. The coating is formulated using ultraviolet reflective technology to provide an initial solar reflectance of 0.33. According to the manufacturer, GAF Streetbond has no odor during and after installation, and it resists UV damage. It is fully recyclable with asphalt.

GuardTop (CoalSeal®) is a water-based asphalt emulsion sealcoat. It has fine aggregate and asphalt content of at least 32% and 10% by weight, respectively. It has a Solar Reflectance of 0.33 and a final cured grey color.

Pave Tech (PlusTi®) is a TiO2-based asphalt rejuvenating/sealing agent. It is composed of a petroleum resin oil base uniformly emulsified with water. With its Photo Catalytic Technology, it enables removal of nitrogen oxides (NOx), volatile organic compounds (VOC), and other airborne vehicular exhaust pollutants. Aside from the other three products, Pave Tech product penetrates deep into the pavement surface and does not change the surface color and characteristics. According to the supplier, A light application of dry sand or rock dust shall be applied to all treated pavement after absorption and prior to reopening to traffic. The sand or rock dust should be removed within 24 hours.

Except Pave Tech, all cool pavement products are applied in one coat with application rate varied among products and depending on existing pavement conditions and age, traffic volume, and expected outcome from the treatment. The final treated surfaces are covered with light color seal coating. With regard to Pave Tech, the surface physical appearance remained unchanged after installation. All products have been previously pilot tested in other cities including LA Angeles, Phoenix, Austin, Charlotte, and Orlando. More information on product physical properties is shown in Appendix A.

2.2 Sites Selection

The selection of the cool pavement sites was based on an analytical approach utilizing a series of data sets between January and February of 2023. The data sets consist of; urban heat index, equity score, energy burden, urban tree canopy, pavement condition, and population. The COSA used heat and equity data to identify candidate census tracts with high scores of temperatures, poverty, and percentage of people of color. Within the candidate census tracts, COSA selected roads that were in adequate pavement condition and had minimal tree canopy. Finally, each City Council District Office decided on two locations from the candidate list as shown in Table 1. The COSA installed the plots of different cool pavement treatments across its ten city council districts beginning in April and ending in July of 2023.

3 MEASUREMENT EQUIPMENT

3.1 Background

Skid resistance is defined as the traction force generated between pavement surface and tires as they slide or roll on pavement surface. The presence of water or other contaminants on pavement surface reduces skid resistance as water acts as lubricant reducing the friction significantly. Water not only reduces the skid resistance, but it also affects the change of skid resistance with speed.

There are several factors that affect the skid level of pavements. These factors include pavement texture, traffic level, temperature, presence of water and speed. Several studies were conducted to investigate these factors.

Texture

The properties of pavement texture are directly related to its frictional properties. Pavement texture is expressed as surface deviations from a true planar surface. Pavement friction is affected mainly by the microtexture and macrotexture. Microtexture refers to the roughness of individual particles forming the pavement, and it is dependent upon the characteristics of the aggregates or stones in the mixture. Pavement microtexture decreases over time due to polishing and abrasion caused by traffic. The rate of change in pavement microtexture depends on resistance of aggregates to abrasion and polishing. Macrotexture is the overall irregularities in the pavement surface due to size, spacing or voids between aggregate particles. Macrotexture of the pavement surface is dependent on the aggregate gradation. Skid resistance at lower speed and dry conditions is affected mostly by the microtexture whereas the macrotexture is the governing factor at higher speed and wet conditions.

Traffic

Skid resistance is greatly affected by traffic volume over time as it decreases considerably with the increase in average daily traffic (ADT). Asphalt mixtures prepared with aggregates that have rough texture and higher resistance to abrasion and polishing (e.g., sandstone) have better skid resistance compared to aggregates with smooth texture and less resistance to abrasion and polishing (e.g., limestone)

Temperature

Rubber is a viscoelastic material, and its properties are affected by temperature. Previous studies demonstrated that tire pavement friction reduces with the increase in temperature which explains the seasonal fluctuations of the skid resistance. The skid resistance values were higher in fall and winter compared to summer and spring where temperature is higher. Luo (2003) investigated the effect of pavement temperature on frictional properties. pavement temperature had a considerable effect on the frictional properties of pavements, and it is influenced by the test speed. There was a slight decrease in friction with the increase in temperature at low speeds compared to the reduction in friction at higher speeds.

Presence of Water

Water acts as a lubricant between tires and pavement surface leading to reduction in skid resistance. There may be little to no contact between tires and pavement surface based on water film thickness. In addition, water fills up the asperities present on pavement surface which prevents the molecular bonding to form between pavement surface and tires leading to reduced adhesion friction. Harwood found that a water film thickness of 0.002 inches on pavement surface reduced pavement friction by 20 to 30 percent of dry friction. Further increase in water film thickness at high speed can lead to hydroplaning. Hydroplaning occurs when there is no contact between tires and pavement surface leading to a complete traction loss.

Speed

Speed is one of the most important factors affecting the friction between two surfaces. If an object is moving with a higher speed over another surface, there will be an increase in its momentum in the normal direction resulting in upward force on the upper surface. This upward force creates a separation between the two surfaces which decreases the true area of contact between them. Further, when the speed is higher, the time duration over which the two surfaces remain in contact decreases. Reduced area and duration of contact decreases the molecular bonding between the asperities and rubber tires leading to reduced adhesion and consequently lower friction. Therefore, skid resistance found to be satisfactory at one speed may not be adequate at a higher speed.

Characterization of Surface Frictional Characteristics

There are several devices available to characterize the frictional properties of pavement surface in terms of friction and texture. The Circular Track Meter is used to measure texture where the measurements are more related to Pavement macrotexture. The Dynamic Friction Tester is used to measure friction where the measurements are more related to the pavement microtexture. More details on each device are explained in the next section.

3.2 Circular Track Meter (CT Meter)

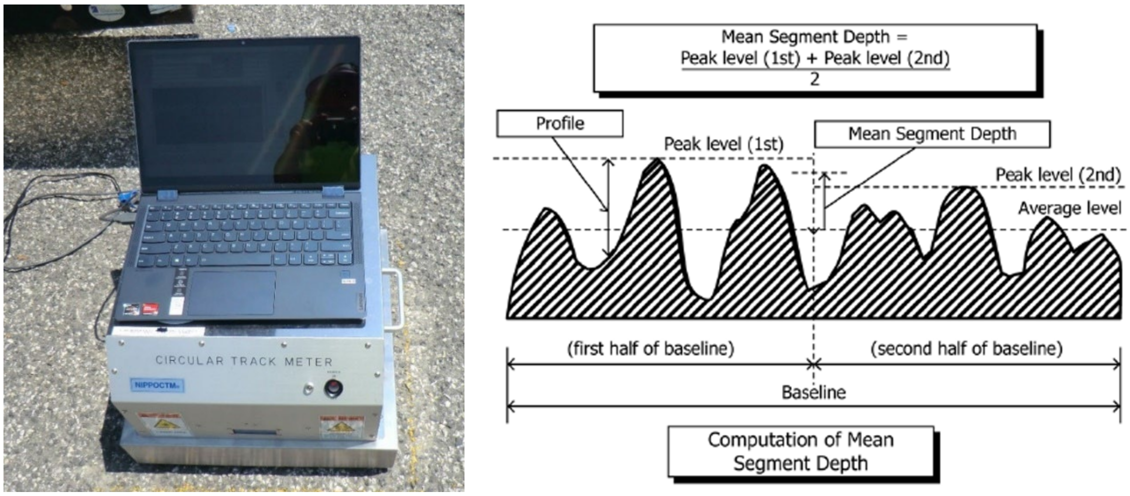
Pavement surface texture was measured with the Nippo Sangyo CT Meter (Figure 2a). The CT Meter is a laser-based device that reports surface texture and reports it as mean profile depth (MPD) in accordance with ASTM E 1845, *Standard Practice for Calculating Pavement Macrotexture Mean Profile Depth*. Transtec operates the CT Meter in accordance with ASTM E2157-15, *Standard Test Method for Measuring Pavement Macrotexture Properties Using the Circular Track Meter*.

The CT Meter uses a laser displacement sensor that is mounted on an arm that rotates clockwise at a fixed elevation from the measured surface. The device is controlled by a notebook computer that saves the processed data and reports the MPD, and the Root Mean Square (RMS), presented in Equation 2.2. The device measures a profile of a circle 284 mm in diameter and 892 mm in circumference (as shown in Figure 2). The profile is divided into eight segments of 111.5 mm. The MPD is determined for each of the segments of the circle and the MPD reported is the average of the eight segments (ASTM 2157, 2015). The CTM is a reliable and robust equipment for field operations. However, it measures texture along a circumference, so it has its limitations for measuring longitudinal or traverse texture separately.

$$RMS = \sqrt{\frac{1}{N}\sum_{i=1}^{N} h_i^2}$$

Where, N = number of coordinates and h_i = height value for coordinate i (mm)

The information collected from the CT Meter can be used to compute various profile statistics such as the Mean Profile Depth (MPD). The MPD is estimated by diving the texture profile into segments of 100 mm in length. After that, a slope suppression is applied to each segment by subtracting a linear regression; this provides a zero-mean profile segment. The segment is then divided into two halves, and the height of the highest peak within each half is determined. The average of these two peaks is referred to as the mean segment depth, as shown in Figure 2b. The average value of the mean segment depth of the measured profiles is the MPD (ASTM E 1845, 2009).



a) *b)*

Figure 2. a) Circular Track Meter (CT Meter) and b) Mean profile depth (MPD) procedure (ASTM E 1845, 2009)

3.3 Dynamic Friction Tester (DF Tester)

Pavement surface friction was measured with the Nippo Sangyo DF Tester (Figure 3). The DF Tester measures friction using three rubber sliders mounted to a disk that spins parallel to the test surface. The disk has a radius of 142 mm, corresponding to the path of the CT Meter texture measurements. A gravity-fed water system wets the pavement surface and when the disk reaches the desired upper limit rotational speed (typically 80 km/h), the DF Tester lowers the disk to the pavement surface. Friction is measured based on torque as the disk rotational velocity decreases to zero due to friction between the rubber slides and the pavement surface. Transtec operates the DF Tester in general accordance with ASTM E1911, *Standard Test Method for Measuring Paved Surface Frictional Properties Using the Dynamic Friction Tester*.

DF Tester serial number 01-1103A and CT Meter serial number 09-5044C were used to collect the data reported herein. Both devices were calibrated on June 13, 2023, prior to the first round of testing, and the DF Tester was recalibrated on September 11, 2023 after repair and prior to the second round of data collection.

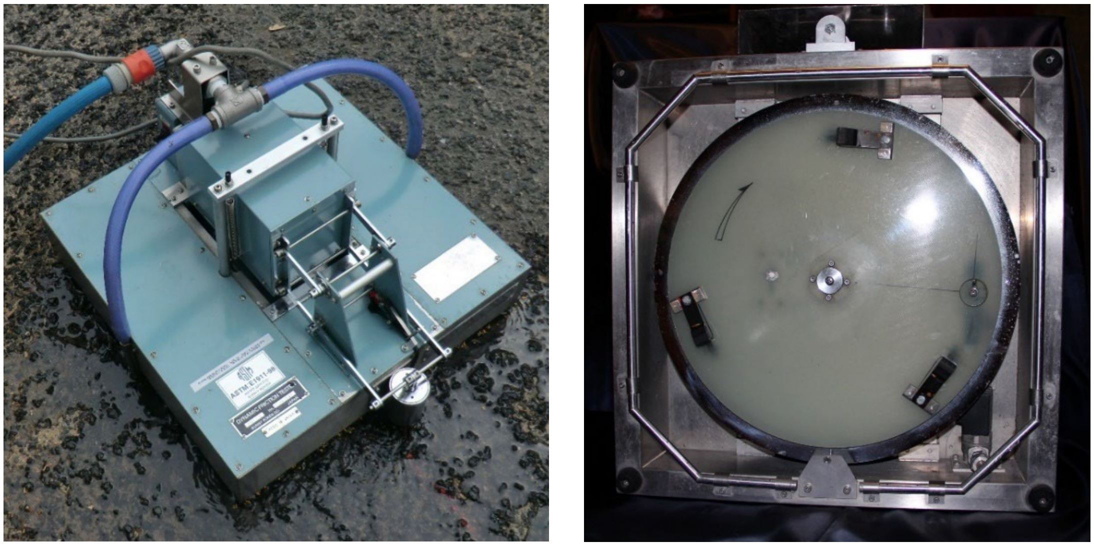


Figure 3. Dynamic Friction Tester (DF Tester).

4 MEASUREMENT PLAN

At each treatment location, friction and texture measurements were conducted on both the treated section of the roadway and on a control section of the same or similar pavement surface. Five measurements were made in the wheelpath, and two measurements were made outside of the wheelpath, to capture any potential variations in texture and friction due to traffic wear. Due to lane closure limitations at each site, measurement longitudinal locations were at different intervals to cover as much of the treated section as was closed. On some of the roads, the entire treated section was available and on others it was a portion of the treated section.

A visual determination of the wheelpath placement was made at each test section (refer to Figure 4a). Most roads were driven in a single path between parked cars on each side of the street, resulting in a wheelpath on each side of the center of the road. SW 21st St. had three visible wheelpath, one to the east of the center of the road and two on the west side of the center of the road due to cars parking only on the east side of the road. The eastmost wheelpath was measured on SW 21st St. On Lucinda St., there were four visible wheelpath. The outside wheelpath on the east side was measured. Additional details about measurement placement are found in the results section. Example of the testing layout at Rebacca Trail with a diagram of the testing locations in Figure 4b.

At each test site CT Meter measurements were collected first since DF Tester measurements require wetting the pavement surface which would affect CT Meter measurements. Before moving the CT Meter, a manufacturer-supplied guide was used to mark the exact position for the DF Tester such that measurements would be completed in the same location (Figure 5). New DF Tester rubber sliders were installed for each set of control/treated roadway measurements.

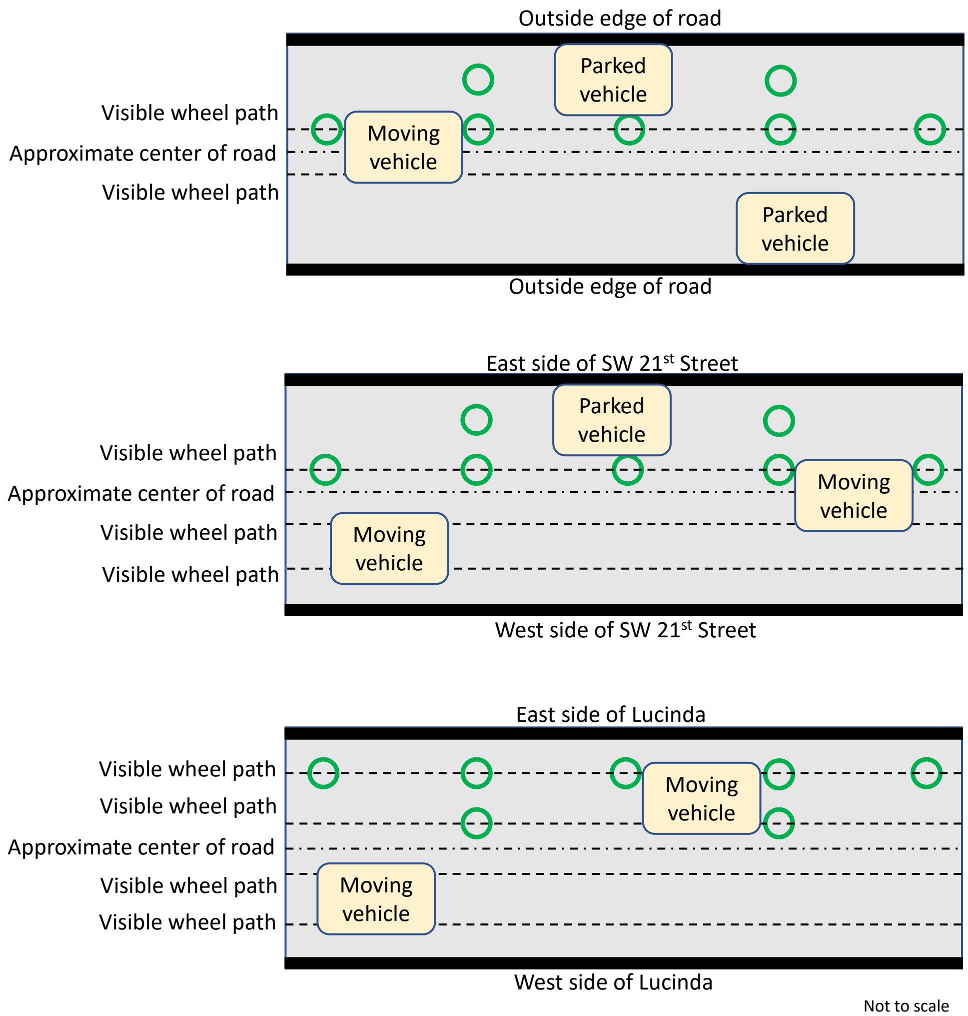


Figure 4a. Typical measurement locations relative to traffic.

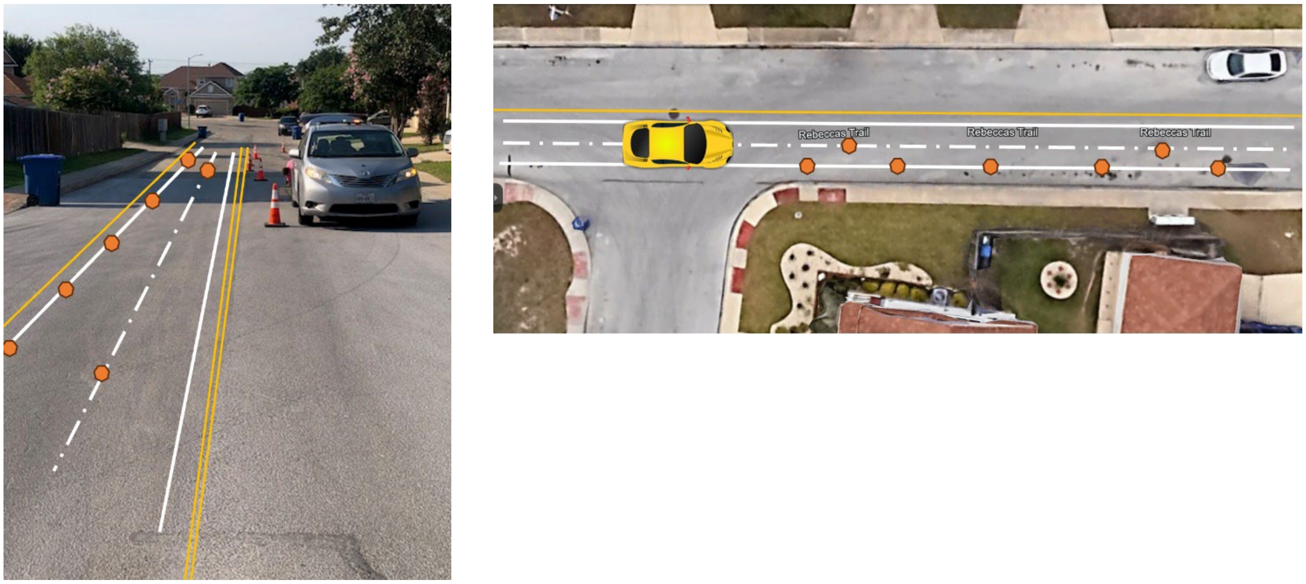


Figure 5b. Example layout of the testing locations along Rebeccas Trail.

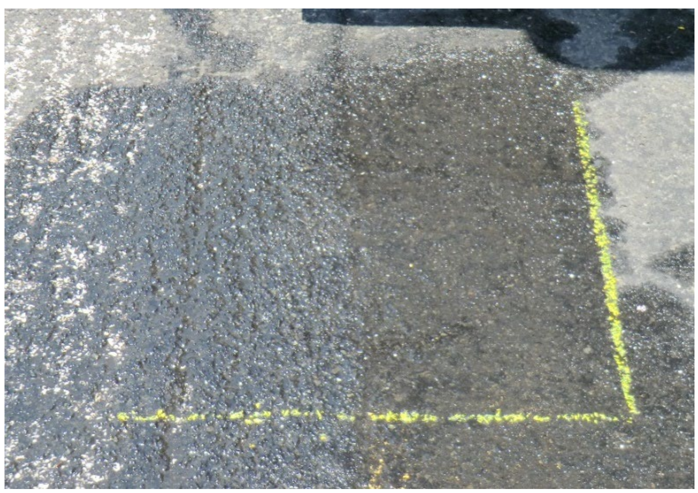


Figure 6. Marking from the CT Meter to align DF Tester in the same location.

5 MEASUREMENT RESULTS

A total of twelve treatment sites were included in the measurement series (Table 1). Details of the exact measurement locations and resulting data for each site are presented below. As noted above, CT Meter texture measurements are reported as MPD in mm. DF Tester friction coefficients (μ) are reported for 20, 40, and 60 kph test speeds.

5.1 Grant Ave. (Product: Pave Tech)

The treated surface on Grant Ave. where measurements were made is between W. Russell Place and W. Craig Place. The control section of Grant Ave. was between W. Craig Place and W.

Woodlawn Avenue. Longitudinal spacing between measurements was approximately 50 ft on both the treated and control sections. The wheelpath location was 10 ft from the east curb. The outside of the wheelpath measurements were taken at 5 ft from the east curb. The map in Figure 6 shows the approximate measurement area of the treated section in yellow and the control section in green.

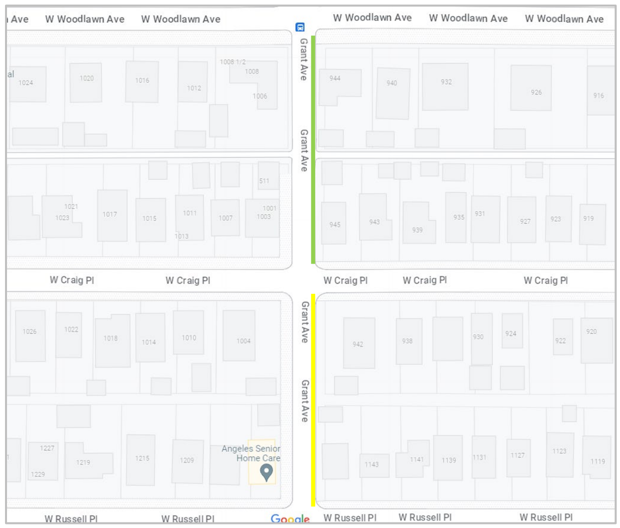


Figure 7. Location of measurements on Grant Ave.

Figure 8. Photos of Grant Ave. treatment with Pave Tech.

5.1.1 Texture Results

Texture values (MPD) for the treated and control sites are shown in Table 2 for the test locations at wheelpath and in Table 3 for the test locations outside of wheelpath.

Table 2. MPD for test locations at wheelpath.

Test Number	Grant Ave. (Product: Pave Tech)	
	Control	Treated
	MPD (mm)	MPD (mm)
1	0.62	0.42
2	0.60	0.59
3	0.60	0.40
4	0.56	0.36
5	0.55	0.48
Average	0.59	0.45

Table 3. MPD for test locations outside of wheelpath.

Test Number	Grant Ave. (Product: Pave Tech)	
	Control	Treated
	MPD (mm)	MPD (mm)
1	0.48	0.47
2	0.66	0.41
Average	0.57	0.44

5.1.2 Friction Results

DF Tester friction values from the wheelpath test locations for the treated and control sites are shown in Table 4, and values for the test locations outside of wheelpath are shown in Table 5.

Table 4. DF Tester friction coefficients (μ) for test locations at wheelpath.

Test Number	Grant Ave. (Product: Pave Tech)					
	Control			Treated		
	20 km/h	40 km/h	60 km/h	20 km/h	40 km/h	60 km/h
1	0.41	0.40	0.40	0.47	0.42	0.40
2	0.42	0.41	0.39	0.45	0.41	0.40
3	0.41	0.40	0.38	0.48	0.45	0.43
4	0.47	0.45	0.43	0.52	0.47	0.46
5	0.38	0.36	0.32	0.48	0.43	0.43
Average	0.42	0.40	0.38	0.48	0.44	0.42

Table 5. DF Tester friction coefficients (μ) for test locations outside of wheelpath.

Test Number	Grant Ave. (Product: Pave Tech)					
	Control			Treated		
	20 km/h	40 km/h	60 km/h	20 km/h	40 km/h	60 km/h
1	0.61	0.58	0.58	0.52	0.48	0.47
2	0.61	0.57	0.57	0.61	0.58	0.56
Average	0.61	0.58	0.58	0.57	0.53	0.52

5.2 Carol Crest St. (Product: GAF Streetbond)

For this location, the surface treatment began near the end of Argonne Dr., continued along Carol Crest St., and ended after turning the corner onto Kay Ann Dr. The control section was a 200-ft section on Kay Ann Dr. prior to a pavement change and appeared to be the same pavement surface as the treated section. From the treatment start on Argonne Dr. the measurements were made at 50, 250, 400, 550, and 700 ft distances along Carol Crest St. The wheelpath was 10 ft from the west curb and the outside of wheelpath data was collected at 5 ft from the west curb.

The control section measurements were made at 6, 50, 100, 150, and 200 ft from the treatment end. The wheelpath and outside of the wheelpath distances were 10 and 5 ft, respectively, from the north curb. Figure 8 shows the treated section in yellow highlight and control section in green.

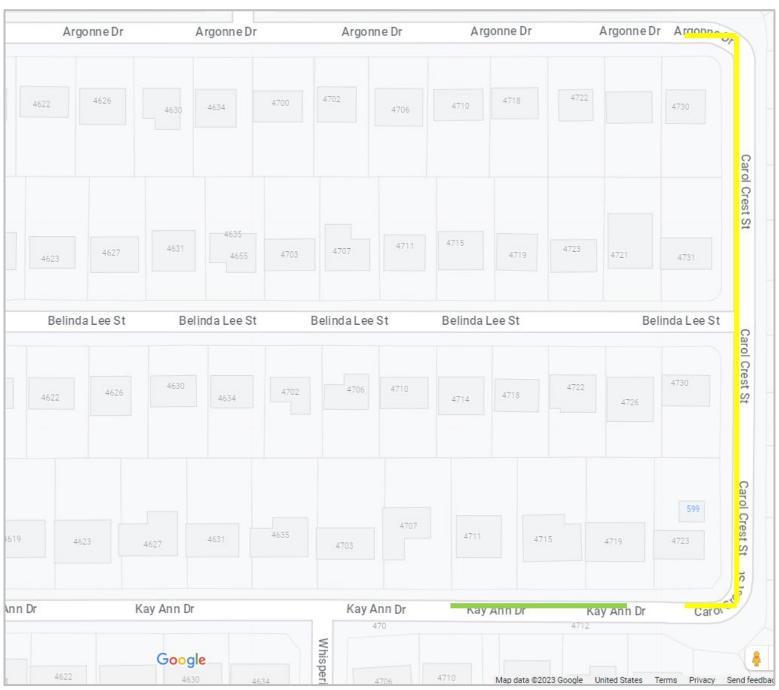


Figure 9. Measurement locations on Carol Crest St. and Kay Ann Dr.

Figure 10. Photos of Carol Crest St. treatment with GAF Streetbond.

5.2.1 Texture Results

Texture values (MPD) for the treated and control sites are shown in Table 6 for the test locations at wheelpath and in Table 7 for the test locations outside of wheelpath.

Table 6. MPD test locations at wheelpath.

	Carol Crest St. (Product: GAF Streetbond)	
Test Number	Control	Treated
	MPD (mm)	MPD (mm)
1	0.61	0.54
2	0.54	0.60
3	0.46	0.50
4	0.59	0.59
5	0.50	0.65
Average	0.54	0.58

Table 7. MPD for test locations outside of wheelpath.

	Carol Crest St. (Product: GAF Streetbond)	
Test Number	Control	Treated
	MPD (mm)	MPD (mm)
1	0.64	0.82
2	0.39	0.60
Average	0.52	0.71

5.2.2 Friction Results

DF Tester friction values from the wheelpath test locations for the treated and control sites are shown in Table 8, and values for the test locations outside of wheelpath are shown in Table 9.

Table 8. DF Tester friction coefficients (μ) for test locations at wheelpath.

	Carol Crest St. (Product: GAF Streetbond)					
Test Number	Control			Treated		
	20 km/h	40 km/h	60 km/h	20 km/h	40 km/h	60 km/h
1	0.30	0.30	0.31	0.67	0.65	0.65
2	0.36	0.35	0.38	0.59	0.58	0.60
3	0.36	0.35	0.39	0.48	0.47	0.48
4	0.36	0.36	0.39	0.60	0.59	0.62
5	0.39	0.39	0.41	0.55	0.53	0.54
Average	0.35	0.35	0.38	0.58	0.56	0.58

Table 9. DF Tester friction coefficients (μ) for test locations outside of wheelpath.

	Carol Crest St. (Product: GAF Streetbond)					
Test Number	Control			Treated		
	20 km/h	40 km/h	60 km/h	20 km/h	40 km/h	60 km/h
1	0.43	0.42	0.44	0.69	0.64	0.65
2	0.48	0.48	0.51	0.60	0.58	0.59
Average	0.46	0.45	0.48	0.65	0.61	0.62

5.3 Lucinda St. (Product: GuardTop Iron -Dark)

The treated surface of Lucinda St. where measurements were made is from Sams Dr. toward E. Ashley Rd. and the control section was on Lucinda St. from Sams Dr. toward Bernard Dr. Longitudinal spacing between measurements was approximately 50 ft on both the treated and control sections. The wheelpath location was 3.5 ft from the east curb. The outside of the wheelpath measurements were taken at 6 ft from the east curb. The map in Figure 10 shows the measurement area of the treated section in yellow and the control section in green.

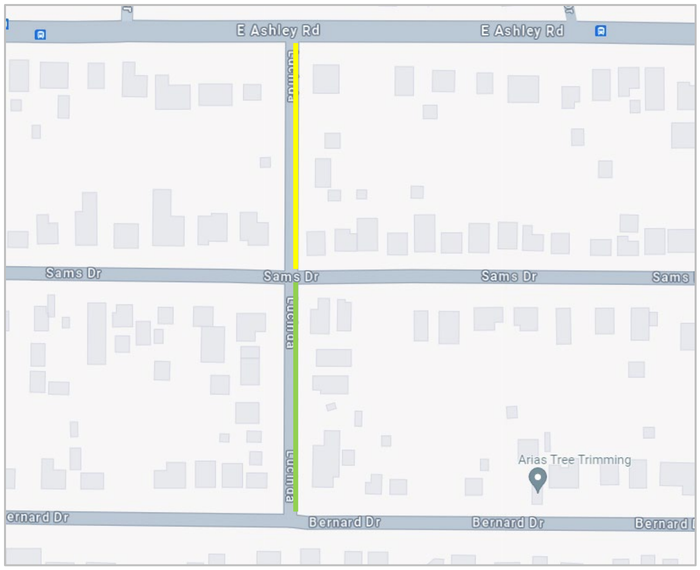


Figure 11. Approximate locations of measurements on Lucinda St.

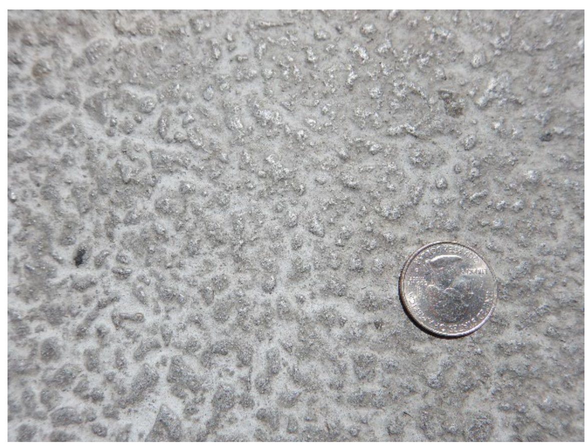


Figure 12. Photos of Lucinda St. treatment with GuardTop Iron -Dark.

5.3.1 Texture Results

Texture values (MPD) for the treated and control sites are shown in Table 10 for the test locations at wheelpath and in Table 11 for the test locations outside of wheelpath.

Table 10. MPD for test locations at wheelpath.

Test Number	Lucinda St. (Product: GuardTop Iron - Dark)	
	Control	Treated
	MPD (mm)	MPD (mm)
1	0.48	0.52
2	0.51	0.31
3	0.62	0.34
4	0.54	0.4
5	0.62	0.47
Average	0.55	0.41

Table 11. MPD for test locations outside of wheelpath.

Test Number	Lucinda St. (Product: GuardTop Iron -Dark)	
	Control	Treated
	MPD (mm)	MPD (mm)
1	0.48	0.35
2	0.52	0.43
Average	0.50	0.39

5.3.2 Friction Results

DF Tester friction values from the wheelpath test locations for the treated and control sites are shown in Table 12, and values for the test locations outside of wheelpath are shown in Table 13.

Table 12. DF Tester friction coefficients (μ) for test locations at wheelpath.

Test Number	Lucinda St. (Product: GuardTop Iron -Dark)					
	Control			Treated		
	20 km/h	40 km/h	60 km/h	20 km/h	40 km/h	60 km/h
1	0.46	0.41	0.39	0.25	0.22	0.18
2	0.57	0.53	0.51	0.27	0.21	0.18
3	0.53	0.49	0.48	0.28	0.22	0.19
4	0.53	0.5	0.45	0.27	0.22	0.19
5	0.48	0.45	0.44	0.28	0.22	0.21
Average	0.51	0.48	0.45	0.27	0.22	0.19

Table 13. DF Tester friction coefficients (μ) for test locations outside of wheelpath.

Test Number	Lucinda St. (Product: GuardTop Iron -Dark)					
	Control			Treated		
	20 km/h	40 km/h	60 km/h	20 km/h	40 km/h	60 km/h
1	0.50	0.47	0.44	0.29	0.22	0.22
2	0.51	0.47	0.45	0.28	0.22	0.21
Average	0.51	0.47	0.45	0.29	0.22	0.22

5.4 Mountain Star (Product: Seal Master)

The Mountain Star treatment site was tested in June and September due to a breakdown of the DF Tester during the June measurements, which required retesting in September to validate the June measurments.

The treated surface of Mountain Star where measurements were made is north of the alley between Summer Vail and Stephens Ranch, and the control section was south of the same alley. Longitudinal spacing between measurements was approximately 75 ft on the treated and 20 ft on the control section during the June measurements. The September measurements were performed at 50 ft intervals on the treated and 40 ft intervals on the control section. The wheelpath location was 12 ft from the west curb. The outside of the wheelpath measurements were taken at 6 ft from the west curb. The map in Figure 12 shows the approximate measurement area of the treated section in yellow and the control section in green.

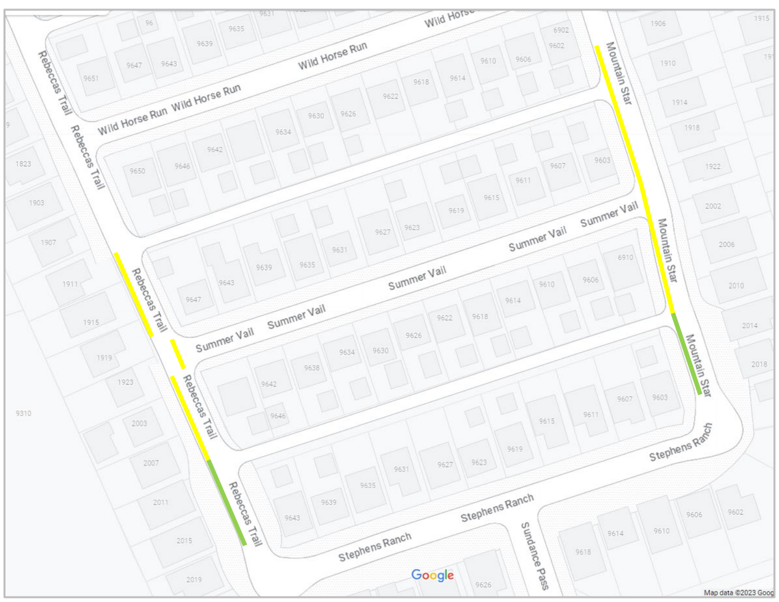


Figure 13. Measurement locations on Mountain Star and Rebeccas Trail.

Figure 14. Photos of Mountain Star treatment with Seal Master.

5.4.1 Texture Results

Texture values (MPD) for the treated and control sites are shown in Table 14 and Table 16 for the test locations at wheelpath from June and September, respectively, and in Table 15 and Table 17 for the test locations outside of wheelpath.

Table 14. MPD for test locations at wheelpath (June 2023).

	Mountain Star (Product: Seal Master)	
Test Number	**Control**	**Treated**
	MPD (mm)	**MPD (mm)**
1	0.86	0.92
2	0.86	0.72
3	0.81	0.73
4	0.94	0.96
5	0.83	0.94
Average	0.86	0.85

Table 15. MPD for test locations outside of wheelpath (June 2023).

	Mountain Star (Product: Seal Master)	
Test Number	Control	Treated
	MPD (mm)	MPD (mm)
1	0.77	0.62
2	0.84	0.90
Average	0.81	0.76

Table 16. MPD for test locations at wheelpath (September 2023).

	Mountain Star (Product: Seal Master)	
Test Number	Control	Treated
	MPD (mm)	MPD (mm)
1	0.84	0.9
2	0.80	0.65
3	0.73	0.60
4	0.84	0.70
5	0.99	0.95
Average	0.84	0.76

Table 17. MPD for test locations outside of wheelpath (September 2023).

	Mountain Star (Product: Seal Master)	
Test Number	Control	Treated
	MPD (mm)	MPD (mm)
1	0.87	0.64
2	0.83	0.87
Average	0.85	0.76

5.4.2 Friction Results

DF Tester friction values from the wheelpath test locations for the treated and control sites are shown in Table 18 and Table 20 for tests in June and September, respectively. Friction values for the test locations outside of wheelpath are shown in Table 19 and Table 21 for tests in June and September, respectively.

Table 18. DF Tester friction coefficients (μ) for test locations at wheelpath (June 2023).

	Mountain Star (Product: Seal Master)					
Test Number	**Control**			**Treated**		
	20 km/h	**40 km/h**	**60 km/h**	**20 km/h**	**40 km/h**	**60 km/h**
1	0.28	0.30	0.30	0.30	0.30	0.29
2	0.30	0.30	0.31	0.29	0.30	0.30
3	0.29	0.30	0.31	0.29	0.29	0.29
4	0.31	0.33	0.32	NA	NA	NA
5	0.34	0.36	0.36	NA	NA	NA
Average	0.30	0.32	0.32	0.29	0.30	0.29

Table 19. DF Tester friction coefficients (μ) for test locations outside of wheelpath (June 2023).

	Mountain Star (Product: Seal Master)					
Test Number	**Control**			**Treated**		
	20 km/h	**40 km/h**	**60 km/h**	**20 km/h**	**40 km/h**	**60 km/h**
1	0.48	0.47	0.46	0.30	0.30	0.30
2	0.55	0.53	0.53	NA	NA	NA
Average	0.52	0.50	0.50	0.30	0.30	0.30

Table 20. DF Tester friction coefficients (μ) for test locations at wheelpath (September 2023).

	Mountain Star (Product: Seal Master)					
Test Number	**Control**			**Treated**		
	20 km/h	**40 km/h**	**60 km/h**	**20 km/h**	**40 km/h**	**60 km/h**
1	0.27	0.29	0.29	0.29	0.29	0.29
2	0.26	0.29	0.29	0.3	0.25	0.25
3	0.3	0.3	0.3	0.29	0.25	0.24
4	0.37	0.37	0.36	0.29	0.24	0.24
5	0.3	0.3	0.32	0.28	0.28	0.28
Average	0.30	0.31	0.31	0.29	0.26	0.26

Table 21. DF Tester friction coefficients (μ) for test locations outside of wheelpath (September 2023).

	Mountain Star (Product: Seal Master)					
Test Number	**Control**			**Treated**		
	20 km/h	**40 km/h**	**60 km/h**	**20 km/h**	**40 km/h**	**60 km/h**
1	0.59	0.58	0.56	0.30	0.29	0.29
2	0.52	0.52	0.51	0.31	0.30	0.30
Average	0.56	0.55	0.54	0.31	0.30	0.30

5.5 Rebeccas Trail (Product: Seal Master)

The treated surface on Rebeccas Trail begins at the unnamed alley between Stephens Ranch and Summer Vail and continues northwest. The control section was on Rebeccas Trail southeast of the same alley. Longitudinal spacing between measurements on the treated section was was approximately 50 ft. Due to the short length of the control section a 20 ft spacing was used. The wheelpath location was 12 ft from the southwest curb for all measurements but one that was performed in the intersection with Summer Vail in the visually most traveled area. The outside of the wheelpath measurements were taken at 6 ft from the southwest curb. The map in Figure 12 shows the approximate measurement area of the treated section in yellow and the control section in green.

Figure 15. Photos of Rebeccas Trail treatment with Seal Master.

5.5.1 Texture Results

Texture values (MPD) for the treated and control sites are shown in Table 22 for the test locations at wheelpath and in Table 23 for the test locations outside of wheelpath.

Table 22. MPD for test locations at wheelpath.

	Rebeccas Trail (Product: Seal Master)	
Test Number	Control	Treated
	MPD (mm)	MPD (mm)
1	0.88	0.92
2	1.03	1.06
3	1.07	1.10
4	1.17	0.93
5	1.02	0.88
6	-	0.82
Average	1.03	0.96

Table 23. MPD for test locations outside of wheelpath.

	Rebeccas Trail (Product: Seal Master)	
Test Number	Control	Treated
	MPD (mm)	MPD (mm)
1	1.09	0.78
2	1.00	0.98
Average	1.05	0.88

5.5.2 Friction Results

DF Tester friction values from the wheelpath test locations for the treated and control sites are shown in Table 24, and values for the test locations outside of wheelpath are shown in Table 25.

Table 24. DF Tester friction coefficients (μ) for test locations at wheelpath.

Test Number	Rebeccas Trail (Product: Seal Master)					
	Control			Treated		
	20 km/h	40 km/h	60 km/h	20 km/h	40 km/h	60 km/h
1	0.31	0.35	0.37	0.25	0.24	0.24
2	0.39	0.40	0.43	0.23	0.24	0.25
3	0.36	0.40	0.41	0.25	0.24	0.25
4	0.31	0.38	0.42	0.25	0.25	0.25
5	0.31	0.34	0.33	0.26	0.25	0.25
Average	0.34	0.37	0.39	0.25	0.24	0.25

Table 25. DF Tester friction coefficients (μ) for test locations outside of wheelpath.

Test Number	Rebeccas Trail (Product: Seal Master)					
	Control			Treated		
	20 km/h	40 km/h	60 km/h	20 km/h	40 km/h	60 km/h
1	0.54	0.54	0.53	0.31	0.29	0.30
2	0.53	0.54	0.52	0.30	0.30	0.30
Average	0.54	0.54	0.53	0.31	0.30	0.30

5.6 SW 21st St. (Product: Seal Master)

The treated surface of SW 21st St. where the measurements was made is between S. Laredo and Persyn Streets and the control section was on SW 21st St. between S. Loredo and Potosi Streets. Longitudinal spacing between measurements was approximately 50 ft on both the treated and control sections. The wheelpath location was 8 ft from the east curb. The outside of the wheelpath measurements were taken at 4 ft from the east curb. The map in Figure 15 shows the measurement area of the treated section in yellow and the control section in green.

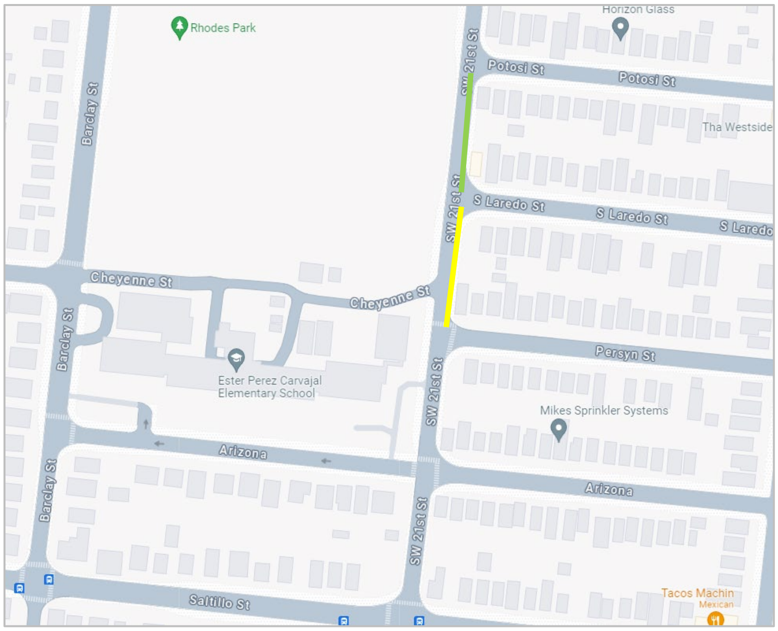


Figure 16. Approximate locations of measurements on SW 21st St.

Figure 17. Photos of SW 21st St. treatment with Seal Master.

5.6.1 Texture Results

Texture values (MPD) for the treated and control sites are shown in Table 26 for the test locations at wheelpath and in Table 27 for the test locations outside of wheelpath.

Table 26. MPD for test locations at wheelpath.

	SW 21st St. (Product: Seal Master)	
Test Number	**Control**	**Treated**
	MPD (mm)	**MPD (mm)**
1	0.55	0.45
2	0.58	0.45
3	0.54	0.5
4	0.46	0.45
5	0.52	0.46
Average	0.53	0.46

Table 27. MPD for test locations outside of wheelpath.

	SW 21st St. (Product: Seal Master)	
Test Number	**Control**	**Treated**
	MPD (mm)	**MPD (mm)**
1	0.48	0.47
2	0.39	0.43
Average	0.44	0.45

5.6.2 Friction Results

DF Tester friction values from the wheelpath test locations for the treated and control sites are shown in Table 28, and values for the test locations outside of wheelpath are shown in Table 29.

Table 28. DF Tester friction coefficients (μ) for test locations at wheelpath.

	SW 21st St. (Product: Seal Master)					
Test Number	**Control**			**Treated**		
	20 km/h	**40 km/h**	**60 km/h**	**20 km/h**	**40 km/h**	**60 km/h**
1	0.48	0.46	0.41	0.30	0.29	0.28
2	0.51	0.47	0.45	0.29	0.28	0.24
3	0.54	0.51	0.48	0.32	0.29	0.29
4	0.59	0.57	0.53	0.29	0.24	0.23
5	0.55	0.52	0.51	0.29	0.24	0.23
Average	0.53	0.51	0.48	0.30	0.27	0.25

Table 29. DF Tester friction coefficients (μ) for test locations outside of wheelpath.

	SW 21st St. (Product: Seal Master)					
Test Number	**Control**			**Treated**		
	20 km/h	**40 km/h**	**60 km/h**	**20 km/h**	**40 km/h**	**60 km/h**
1	0.65	0.60	0.58	0.32	0.29	0.29
2	0.66	0.63	0.62	0.34	0.29	0.29
Average	0.66	0.62	0.60	0.33	0.29	0.29

5.7 Spiral Creek (Product: GAF Streetbond)

The treated surface on Spiral Creek where measurements were made is northeast of the Ribbon Creek intersection, and the control section was southwest of the Ribbon Creek intersection. Longitudinal spacing between measurements was approximately 50 ft on both the treated and control sections. The wheelpath location was 10 ft from the northwest curb. The outside of the wheelpath measurements were taken at 5 ft from the northwest curb. The map in Figure 17 shows the approximate measurement area of the treated section in yellow and the control section in green.

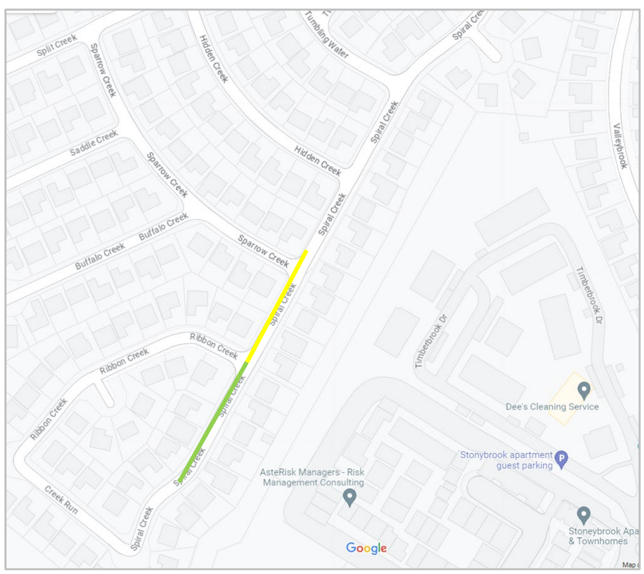


Figure 18. Location of measurements on Spiral Creek.


Figure 19. Photos of Spiral Creek treatment with GAF Streetbond.

5.7.1 Texture Results

Texture values (MPD) for the treated and control sites are shown in Table 30 for the test locations at wheelpath and in Table 31 for the test locations outside of wheelpath.

Table 30. MPD for test locations at wheelpath.

	Spiral Creek (Product: GAF Streetbond)	
Test Number	**Control**	**Treated**
	MPD (mm)	**MPD (mm)**
1	0.65	0.64
2	0.70	0.45
3	0.53	0.41
4	0.59	0.51
5	0.58	0.57
Average	0.61	0.52

Table 31. MPD for test locations outside of wheelpath.

	Spiral Creek (Product: GAF Streetbond)	
Test Number	**Control**	**Treated**
	MPD (mm)	**MPD (mm)**
1	0.58	0.62
2	0.64	0.47
Average	0.61	0.55

5.7.2 Friction Results

DF Tester friction values from the wheelpath test locations for the treated and control sites are shown in Table 32, and values for the test locations outside of wheelpath are shown in Table 33.

Table 32. DF Tester friction coefficients (μ) for test locations at wheelpath.

	Spiral Creek (Product: GAF Streetbond)					
Test Number	Control			Treated		
	20 km/h	40 km/h	60 km/h	20 km/h	40 km/h	60 km/h
1	0.52	0.51	0.51	0.52	0.48	0.48
2	0.41	0.40	0.38	0.47	0.41	0.41
3	0.53	0.51	0.48	0.47	0.42	0.42
4	0.48	0.47	0.46	0.49	0.42	0.42
5	0.44	0.42	0.42	0.52	0.47	0.47
Average	0.48	0.46	0.45	0.49	0.44	0.44

Table 33. DF Tester friction coefficients (μ) for test locations outside of wheelpath.

	Spiral Creek (Product: GAF Streetbond)					
Test Number	Control			Treated		
	20 km/h	40 km/h	60 km/h	20 km/h	40 km/h	60 km/h
1	0.56	0.52	0.49	0.51	0.46	0.45
2	0.55	0.47	0.47	0.42	0.36	0.36
Average	0.56	0.50	0.48	0.47	0.41	0.41

5.8 Piper Dr. (Product: GuardTop Iron - Dark)

The treated surface of Piper Dr. where the measurements were made is from Loy Dr. southwest and the control section was on Loy Dr. approximately centered on Piper Dr. to avoid visual changes in pavement on Loy Dr. east and west of Piper Dr. Longitudinal spacing between measurements was approximately 50 ft on both the treated and control sections. The wheelpath location was 11 ft from the east curb on Piper Dr. and the north curb on Loy. The outside of the wheelpath measurements were taken at 5 ft from the east curb on Piper Dr. and 5.5 ft on Loy Dr. The map in Figure 19 shows the approximate measurement area of the treated section in yellow and the control section in green.

It is not known whether the control surface on Loy Dr. is the same as the treated pavement surface on Piper Dr.

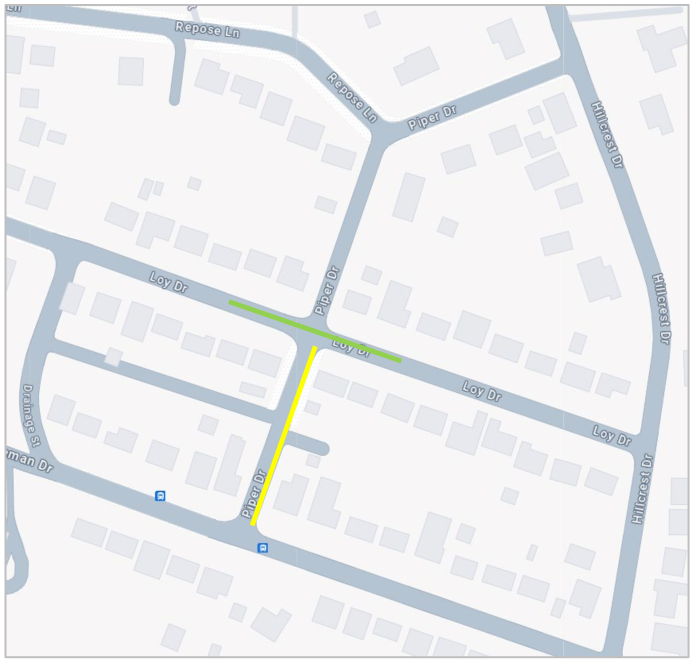


Figure 20. Measurement areas on Piper Dr. and Loy Dr.

Figure 21. Photos of Piper Dr. treatment with GuardTop Iron-Dark.

5.8.1 Texture Results

Texture values (MPD) for the treated and control sites are shown in Table 34 for the test locations at wheelpath and in Table 35 for the test locations outside of wheelpath.

Table 34. MPD for test locations at wheelpath.

	Piper Dr. (Product: GuardTop Iron - Dark)	
Test Number	**Control**	**Treated**
	MPD (mm)	**MPD (mm)**
1	0.39	0.33
2	0.75	0.33
3	0.42	0.30
4	0.41	0.43
5	0.48	0.37
Average	0.52	0.35

Table 35. MPD for test locations outside of wheelpath.

	Piper Dr. (Product: GuardTop Iron - Dark)	
Test Number	**Control**	**Treated**
	MPD (mm)	**MPD (mm)**
1	0.75	0.35
2	0.7	0.35
Average	0.73	0.35

5.8.2 Friction Results

DF Tester friction values from the wheelpath test locations for the treated and control sites are shown in Table 36, and values for the test locations outside of wheelpath are shown in Table 37.

Table 36. DF Tester friction coefficients (μ) for test locations at wheelpath.

	Piper Dr. (Product: GuardTop Iron - Dark)					
Test Number	**Control**			**Treated**		
	20 km/h	**40 km/h**	**60 km/h**	**20 km/h**	**40 km/h**	**60 km/h**
1	0.45	0.42	0.41	0.27	0.23	0.20
2	0.42	0.42	0.37	0.30	0.24	0.22
3	0.43	0.41	0.38	0.28	0.23	0.20
4	0.47	0.44	0.42	0.24	0.20	0.20
5	0.41	0.37	0.36	0.24	0.19	0.19
Average	0.44	0.41	0.39	0.27	0.22	0.20

Table 37. DF Tester friction coefficients (μ) for test locations outside of wheelpath.

	Piper Dr. (Product: GuardTop Iron - Dark)					
Test Number	**Control**			**Treated**		
	20 km/h	**40 km/h**	**60 km/h**	**20 km/h**	**40 km/h**	**60 km/h**
1	0.51	0.48	0.47	0.34	0.24	0.24
2	0.49	0.49	0.47	0.25	0.20	0.20
Average	0.50	0.49	0.47	0.30	0.22	0.22

5.9 Frontier Hill (Product: GuardTop Iron - Light)

The treated surface on Frontier Hill where measurements were made starts at the intersection with Singing Forest and proceeds toward Buffalo Hills and the control section was on Buffalo Hills from the stop sign at Frontier Hill eastward. Longitudinal spacing between measurements was approximately 50 ft on both the treated and control sections. The wheelpath location was 11 ft from the east curb on Frontier Hill and from the south curb on Buffalo Hills. The outside of the wheelpath measurements were taken at 5.5 ft from the respective curbs. The map in Figure 21 shows the approximate measurement area of the treated section in yellow and the control section in green. It is not known whether the control surface on Buffalo Hills is the same as the treated pavement surface on Frontier Hill.

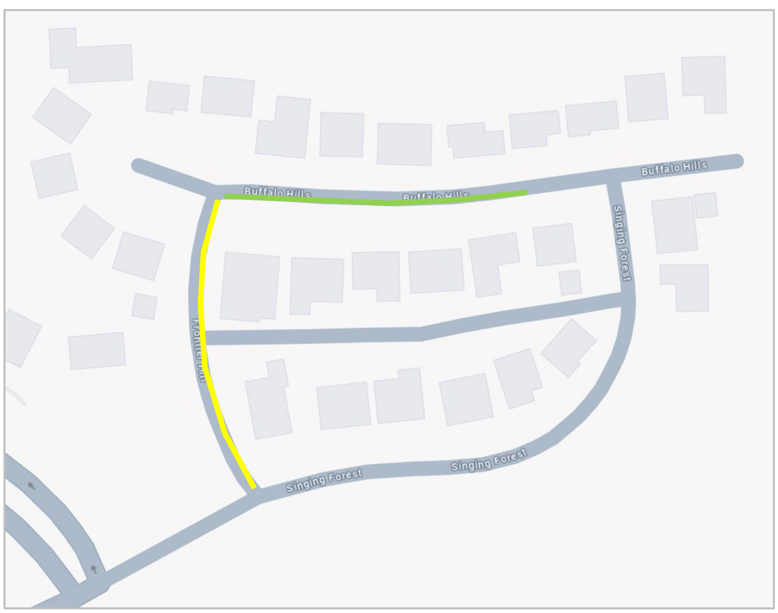


Figure 22. Approximate measurement areas on Frontier Hill and Buffalo Hills.

Figure 23. Photos of Frontier Hill treatment with GuardTop Iron – Light.

5.9.1 Texture Results

Texture values (MPD) for the treated and control sites are shown in Table 38 for the test locations at wheelpath and in Table 39 for the test locations outside of wheelpath.

Table 38. MPD for test locations at wheelpath.

	Frontier Hill (Product: GuardTop Iron - Light)	
Test Number	Control	Treated
	MPD (mm)	MPD (mm)
1	0.67	0.66
2	0.65	0.64
3	0.68	0.65
4	0.65	0.7
5	0.87	0.67
Average	0.70	0.66

Table 39. MPD for test locations outside of wheelpath.

	Frontier Hill (Product: GuardTop Iron - Light)	
Test Number	Control	Treated
	MPD (mm)	MPD (mm)
1	0.55	0.59
2	0.52	0.66
Average	0.54	0.63

5.9.2 Friction Results

DF Tester friction values from the wheelpath test locations for the treated and control sites are shown in Table 40, and values for the test locations outside of wheelpath are shown in Table 41.

Table 40. DF Tester friction coefficients (μ) for test locations at wheelpath.

	Frontier Hill (Product: GuardTop Iron - Light)					
Test Number	Control			Treated		
	20 km/h	40 km/h	60 km/h	20 km/h	40 km/h	60 km/h
1	0.45	0.44	0.43	0.25	0.23	0.21
2	0.47	0.47	0.47	0.25	0.23	0.20
3	0.41	0.41	0.42	0.29	0.24	0.22
4	0.36	0.38	0.37	0.24	0.20	0.20
5	0.40	0.39	0.42	0.23	0.19	0.20
Average	0.42	0.42	0.42	0.25	0.22	0.21

Table 41. DF Tester friction coefficients (μ) for test locations outside of wheelpath.

	Frontier Hill (Product: GuardTop Iron - Light)					
Test Number	Control			Treated		
	20 km/h	40 km/h	60 km/h	20 km/h	40 km/h	60 km/h
1	0.57	0.56	0.56	0.24	0.20	0.19
2	0.48	0.45	0.47	0.27	0.21	0.20
Average	0.53	0.51	0.52	0.26	0.21	0.20

5.10 Encino Ridge St. (Product: Pave Tech)

Encino Ridge St. measurement locations were distributed across three areas of the length of treatment as highlighted in yellow in Figure 23. The house numbers are referenced on the figure to help locate measurement locations. Measurements were spaced approximately 100 ft apart longitudinally. The wheelpath used was 13 ft from the curb and the non-wheelpath location used was 6.5 ft from the curb.

Encino Grove was the control surface for Encino Ridge St. and is highlighted in green. It is not known whether the pavement surface course of Encino Grove is the same as the treated surface on Encino Ridge St. Measurements were spaced approximately 50 ft apart longitudinally. The wheelpath locations used were between 10 and13 ft from the curb, while the non-wheelpath location used was 6.5 ft from the curb. It is not known whether the control surface on Encino Grove is the same as the pre-treated pavement surface on Encino Ridge St.

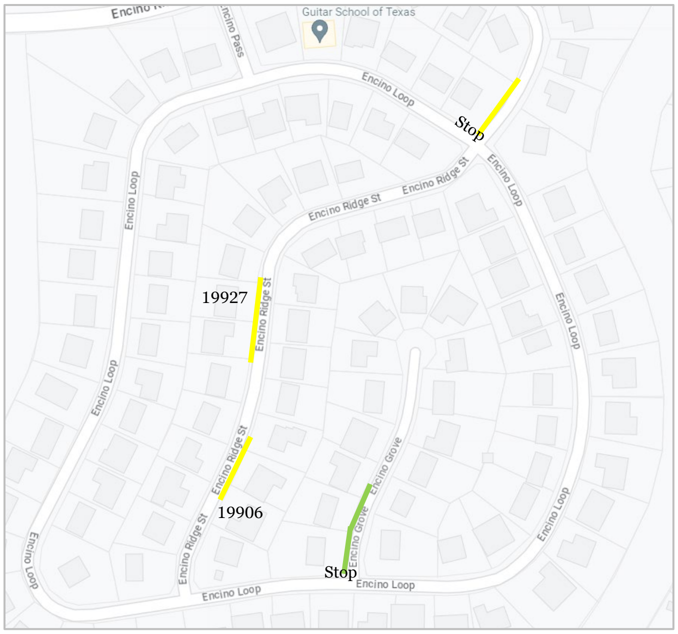


Figure 24. Locations measured on Encino Ridge St. and Encino Grove.

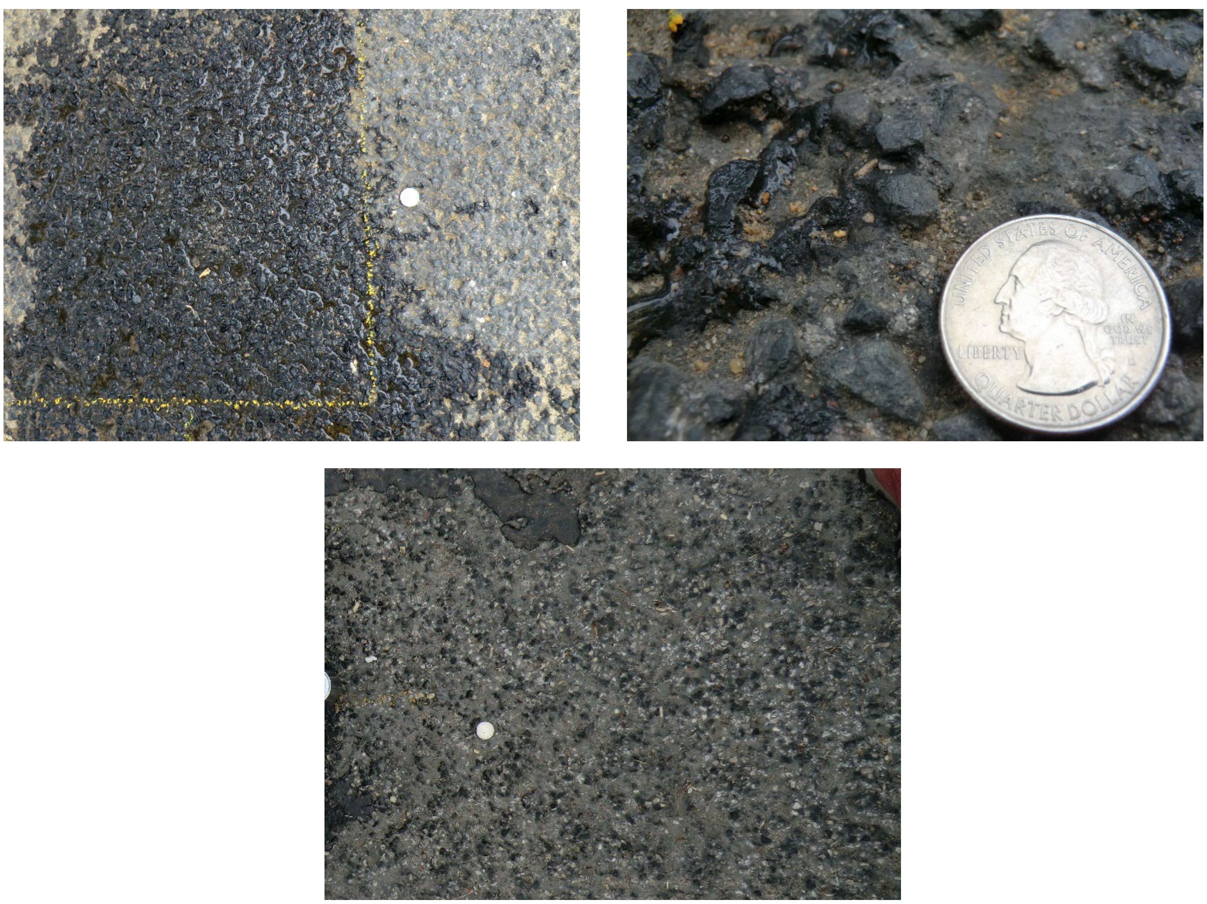


Figure 25. Photos of Encino Ridge St. treated section with Pave Tech (top) and Encino Grove control section (bottom).

5.10.1 Texture Results

Texture values (MPD) for the treated and control sites are shown in Table 42 for the test locations at wheelpath and in Table 43 for the test locations outside of wheelpath.

Table 42. MPD for test locations at wheelpath.

	Encino Ridge St. (Product: Pave Tech)	
Test Number	**Control**	**Treated**
	MPD (mm)	**MPD (mm)**
1	1.54	2.78
2	2.24	3.19
3	2.38	3.41
4	2.80	3.94
5	2.77	-
Average	2.35	3.33

Table 43. MPD for test locations at wheelpath.

	Encino Ridge St. (Product: Pave Tech)	
Test Number	**Control**	**Treated**
	MPD (mm)	**MPD (mm)**
1	2.66	2.59
2	3.67	3.81
3	-	3.85
Average	3.17	3.42

5.10.2 Friction Results

DF Tester friction values from the wheelpath test locations for the treated and control sites are shown in Table 44, and values for the test locations outside of wheelpath are shown in Table 45. It was noted by the test team that the treated surface was extremely rough and course-textured, which can sometimes affect DF Tester measurements.

Table 44. DF Tester friction coefficients (μ) for test locations at wheelpath.

	Encino Ridge St. (Product: Pave Tech)					
Test Number	**Control**			**Treated**		
	20 km/h	**40 km/h**	**60 km/h**	**20 km/h**	**40 km/h**	**60 km/h**
1	0.55	0.56	0.44	0.64	0.68	0.60
2	0.58	0.59	0.58	0.69	0.71	0.76
3	0.61	0.65	0.67	0.77	0.79	0.72
4	0.64	0.66	0.72	0.74	0.75	0.78
5	0.41	0.56	0.64	-	-	-
Average	0.56	0.60	0.61	0.71	0.73	0.72

Table 45. DF Tester friction coefficients (μ) for test locations outside of wheelpath.

	Encino Ridge St. (Product: Pave Tech)					
Test Number	**Control**			**Treated**		
	20 km/h	**40 km/h**	**60 km/h**	**20 km/h**	**40 km/h**	**60 km/h**
1	0.64	0.70	0.73	0.68	0.76	0.88
2	0.69	0.73	0.71	0.63	0.66	0.79
3	-	-	-	0.72	0.79	0.82
Average	0.67	0.72	0.72	0.68	0.74	0.83

5.11 Park Farm (Product: Pave Tech)

Untreated sections of Park Farm on the east and west ends of the street were used as the control section for Park Farm. The treated section was between the two control sections. The longitudinal spacing of the measurements was 50 ft. The wheelpath were located at 13 ft from the east curb except for the control section closest to Park Hollow and the first measurement on the treated section closest to Park Hollow where the wheelpath were 10 ft from the curb. The outside of the wheelpath measurements were made 6.5 ft from the east curb for all measurements. The map shown in Figure 25 highlights the treated section in yellow and the control sections in green.

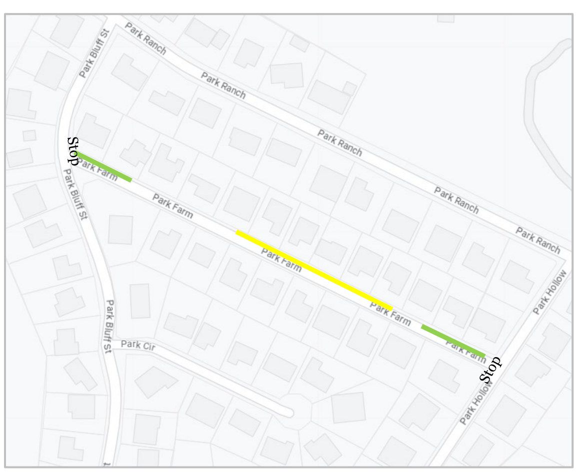


Figure 26. Measurement locations on Park Farm.

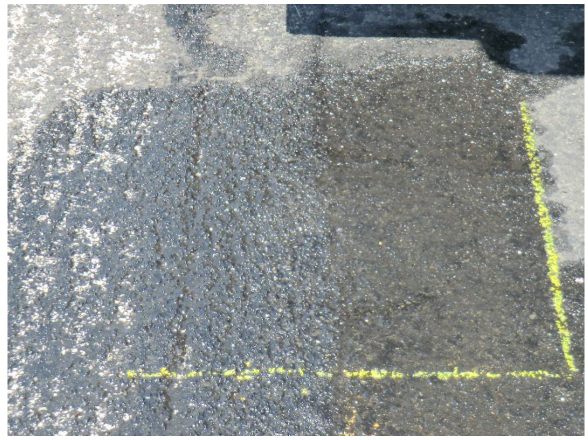


Figure 27. Photos of Park Farm treatment with Pave Tech.

5.11.1 Texture Results

Texture values (MPD) for the treated and control sites are shown in Table 46 for the test locations at wheelpath and in Table 47 for the test locations outside of wheelpath.

Table 46. MPD for test locations at wheelpath.

	Park Farm (Product: Pave Tech)	
Test Number	**Control**	**Treated**
	MPD (mm)	**MPD (mm)**
1	1.24	1.11
2	0.90	1.02
3	0.92	0.77
4	1.14	0.82
5	0.78	0.66
6	0.80	0.95
Average	0.96	0.89

Table 47. MPD for test locations outside of wheelpath.

	Park Farm (Product: Pave Tech)	
Test Number	**Control**	**Treated**
	MPD	**MPD**
1	0.91	1.2
2	-	1.19
Average	0.91	1.20

5.11.2 Friction Results

DF Tester friction values from the wheelpath test locations for the treated and control sites are shown in Table 48, and values for the test locations outside of wheelpath are shown in Table 49.

Table 48. DF Tester friction coefficients (μ) for test locations at wheelpath.

	Park Farm (Product: Pave Tech)					
Test Number	Control			Treated		
	20 km/h	40 km/h	60 km/h	20 km/h	40km/h	60 km/h
1	0.56	0.56	0.57	0.49	0.46	0.47
2	0.55	0.52	0.52	0.54	0.51	0.48
3	0.59	0.55	0.53	0.48	0.42	0.41
4	0.64	0.62	0.63	0.46	0.41	0.40
5	0.63	0.59	0.57	0.54	0.51	0.50
6	0.65	0.52	0.50	-	-	-
Average	0.60	0.56	0.55	0.50	0.46	0.45

Table 49. DF Tester friction coefficients (μ) for test locations outside of wheelpath.

	Park Farm (Product: Pave Tech)					
Test Number	Control			Treated		
	20 km/h	40 km/h	60 km/h	20 km/h	40 km/h	60 km/h
1	0.55	0.54	0.54	0.56	0.53	0.57
2	-	-	-	0.54	0.53	0.54
Average	0.55	0.54	0.54	0.55	0.53	0.56

5.12 Villa Mercedes (Product: GuardTop Iron - Light)

The treated surface on Villa Mercedes where measurements were made is between Villa Camino and Escort Dr., and the control section was on Champions Hill Dr. from Escort Dr. to Villa Camino. Longitudinal spacing between measurements on Villa Mercedes was approximately 50 ft and the spacing between measurements on Champions Hill Dr. was approximately 30 ft. The wheelpath location was 12 ft from the east curb. The outside of the wheelpath measurements were taken at 6 ft from the east curb. The map in Figure 27 shows the approximate measurement area of the treated section in yellow and the control section in green. It is not known whether the control surface on Champions Hill is the same as the treated pavement surface on Villa Mercedes.

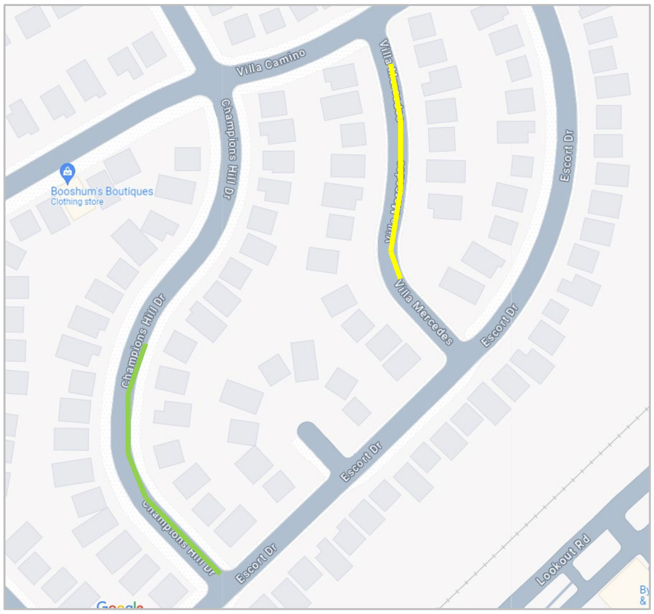


Figure 28. Measurement locations on Villa Mercedes and Champions Hill.

Figure 29. Photos of Villa Mercedes treatment with GuardTop Iron - Light.

5.12.1 Texture Results

Texture values (MPD) for the treated and control sites are shown in Table 50 for the test locations at wheelpath and in Table 51 for the test locations outside of wheelpath.

Table 50. MPD for test locations at wheelpath.

	Villa Mercedes (Product: GuardTop Iron - Light)	
Test Number	Control	Treated
	MPD (mm)	MPD (mm)
1	0.77	0.56
2	0.69	0.49
3	0.62	0.59
4	0.69	0.52
5	0.65	0.71
Average	0.68	0.57

Table 51. MPD for test locations outside of wheelpath.

	Villa Mercedes (Product: GuardTop Iron - Light)	
Test Number	Control	Treated
	MPD (mm)	MPD (mm)
1	0.90	0.65
2	0.58	0.50
Average	0.74	0.58

5.12.2 Friction Results

DF Tester friction values from the wheelpath test locations for the treated and control sites are shown in Table 52, and values for the test locations outside of wheelpath are shown in Table 53.

Table 52. DF Tester friction coefficients (μ) for test locations at wheelpath.

	Villa Mercedes (Product: GuardTop Iron - Light)					
Test Number	Control			Treated		
	20 km/h	40 km/h	60 km/h	20 km/h	40 km/h	60 km/h
1	0.33	0.32	0.31	0.29	0.24	0.21
2	0.40	0.39	0.36	0.26	0.22	0.20
3	0.45	0.43	0.42	0.30	0.24	0.23
4	0.41	0.39	0.37	0.28	0.23	0.20
5	0.43	0.42	0.41	0.26	0.23	0.20
Average	0.40	0.39	0.37	0.28	0.23	0.21

Table 53. DF Tester friction coefficients (μ) for test locations outside of wheelpath.

	Villa Mercedes (Product: GuardTop Iron - Light)					
Test Number	Control			Treated		
	20 km/h	40 km/h	60 km/h	20 km/h	40 km/h	60 km/h
1	0.58	0.56	0.53	0.31	0.25	0.25
2	0.52	0.48	0.47	0.27	0.20	0.20
Average	0.55	0.52	0.50	0.29	0.23	0.23

6 DISCUSSION OF RESULTS

6.1 Overall Summary

Table 54 summarizes the average texture and friction results from each of the test sites. For simplicity, only the DF Tester friction value at 20 km/h for each site as this is the friction value commonly reported for the device.

Table 54. Overall summary of average texture and friction results for all sites.

Treatment Location	Texture (MPD, mm)				Friction (DFT 20 km/h)			
	Wheelpath		Outside of Wheelpath		Wheelpath		Outside of Wheelpath	
	Control	*Treatment*	*Control*	*Treatment*	*Control*	*Treatment*	*Control*	*Treatment*
Grant Ave.	0.59	0.45	0.57	0.44	0.42	0.48	0.61	0.57
Carol Crest St.	0.54	0.58	0.52	0.71	0.35	0.58	0.46	0.65
Lucinda St.	0.55	0.41	0.50	0.39	0.51	0.27	0.51	0.29
Mountain Star (Sept)	0.84	0.76	0.85	0.76	0.30	0.29	0.56	0.31
Rebeccas Trail	1.03	0.95	1.05	0.88	0.34	0.25	0.54	0.31
SW 21st St.	0.53	0.46	0.44	0.45	0.53	0.30	0.66	0.33
Spiral Creek	0.61	0.52	0.61	0.55	0.48	0.49	0.56	0.47
Piper Dr.[1]	0.52	0.35	0.73	0.35	0.44	0.27	0.50	0.30
Frontier Hill[1]	0.70	0.66	0.54	0.63	0.42	0.25	0.53	0.26
Encino Ridge St. [1]	2.35	3.33	3.17	3.42	0.56	0.71	0.67	0.68
Park Farm	0.96	0.89	0.91	1.20	0.60	0.50	0.55	0.55
Villa Mercedes[1]	0.68	0.57	0.74	0.58	0.40	0.28	0.55	0.29
Minimum	0.52	0.35	0.44	0.35	0.3	0.25	0.46	0.26
Maximum	2.35	3.33	3.17	3.42	0.6	0.71	0.67	0.68

1. Locations where control site was on a different street than treated site.

From the summary of the texture and friction data, the minimum and maximum records of all sites are aligned with other studies conducted on 71 asphalt pavement highways in Texas (e.g., Martino and Weissmann 2008). In these studies, the MPD ranges from 0.39 to 3.80 mm and the DFT20 ranges from 0.20 to 0.90. This suggests that the treated and untreated pavement conditions are equivalent to state highways providing adequate surface characteristics.

6.2 Pavement Conditioning Index (PCI)

Comparing the pavement sites on the basis of their surface performance in terms of texture and friction characteristics is dependent on the existing structural conditions. Pavement with poor structural conditions would reflect lower surface performance in which applied treatment will have minimal impact to improve. Therefore, the structural conditions assessed through the Pavement Conditioning Index (PCI) are utilized in the purpose of comparing the sites performance among each other. Every three years Public Works performs a pavement condition assessment of the City's Street network through determining the PCI scores. The PCI is a numerical rating of the pavement condition of the street, ranges from 0 to 100 with 100 representing the best possible condition and zero representing fully deteriorated conditions. The PCI is measured for each roadway in segments. The average PCI value for all segments is combined and averaged to determine the overall roadway condition. In this study, PCI was obtained to be used as a base for comparing conditions among the sites and to navigate existing conditions to the treatment applications. Table 55 presents the PCI for the tested sites prior to the treatment applications and Table 56 presents the thresholds of the pavement condition and the PCI scores. PCI of all sites ranging from 88.27-96.62 suggest that pavements are in excellent conditions prior to the treatment application. Therefore, data suggests that the existing pavement conditions have minimal or no impact on the surface treatment performance.

Table 55. PCI records of the treated sites prior to the treatment application.

Project Street/Product	**From Street**	**To Street**	**PCI**
Grant Ave	**Craig**	**Cincinnati Ave**	
Pave Tech	CINCINNATI AVE	W ASHBY PLACE	93.62
	W ASHBY PLACE	W FRENCH PLACE	93.62
	W FRENCH PLACE	W RUSSELL PLACE	93.62
	W RUSSELL PLACE	W CRAIG PLACE	93.62
	Project PCI		**93.62**
Project Street	**From Street**	**To Street**	**PCI**
Carol Crest St.	**Argonne Dr**	**Kay Ann Dr.**	
GAF Streetbond	Argonne Dr	BELINDA LEE	93.46
	BELINDA LEE	KAY ANN DR	93.46
	Project PCI		**93.46**
Project Street	**From Street**	**To Street**	**PCI**
Lucinda St.	**Ashley Dr**	**Sams Dr**	
GuardTop Iron (dark)	**Ashley Dr**	**Sams Dr**	93.51
	Project PCI		**93.51**
Project Street	**From Street**	**To Street**	**PCI**
Mountain Star	**Stephens Ranch**	**Wolf Point**	
Seal Master	Stephens Ranch	SUMMER VAIL	93.45

	SUMMER VAIL	WILD HORSE RUN	76.96
	WILD HORSE RUN	WOLF PT	93.45
Project PCI			**88.27**
Project Street	**From Street**	**To Street**	**PCI**
Rebeccas Trail	**Stephens Ranch**	**Wolf Point**	
Seal Master	Stephens Ranch	SUMMER VAIL	85.27
	SUMMER VAIL	WILD HORSE RUN	88.99
	WILD HORSE RUN	WOLF PT	92.25
Project PCI			**88.85**
Project Street	**From Street**	**To Street**	**PCI**
SW 21st St	**Saltillo Rd**	**S. Laredo St**	
Seal Master	S LAREDO ST	PERSYN ST	98.32
	PERSYN ST	ARIZONA	98.32
	ARIZONA	SALTILLO ST	98.32
Project PCI			**98.32**
Project Street	**From Street**	**To Street**	**PCI**
Spiral Creek	**Ribbon Creek**	**Creek Ridge**	
GAF Streetbond	CREEK RDG	TUMBLING WATER	92.79
	TUMBLING WATER	HIDDEN CRK	93.81
	HIDDEN CRK	SPARROW CRK	93.81
	SPARROW CRK	RIBBON CRK	93.81
Project PCI			**93.58**
Project Street	**From Street**	**To Street**	**PCI**
Piper Dr.	**Loy**	**Freeman Dr.**	
GuardTop Iron (dark)	LOY	FREEMAN DR	96.62
Project PCI			**96.62**
Project Street	**From Street**	**To Street**	**PCI**
Frontier Hill	**Buffalo Hills**	**Singing Forest**	
GuardTop Iron (light)	Buffalo Hills	Singing Forest	93.87
Project PCI			**93.87**
Project Street	**From Street**	**To Street**	**PCI**
Encino Ridge St.	**Encino Loop**	**Cul-de-sac**	
Pave Tech	ENCINO LOOP	ENCINO LOOP	92.82
	ENCINO LOOP	CUL-DE-SAC	92.82
Project PCI			**92.82**
Project Street	**From Street**	**To Street**	**PCI**
Park Farm	**Park Bluff St.**	**Park Hollow**	
Pave Tech	Park Bluff St.	Park Hollow	89.77
Project PCI			**89.77**
Project Street	**From Street**	**To Street**	**PCI**
Villa Mercedes	**Villa Camino**	**Escort Dr.**	
GuardTop Iron (light)	Villa Camino	Escort Dr.	96.35

Project PCI	96.35

Table 56. Pavement conditions with respect to PCI scores

Condition	PCI Score
Excellent	86 - 100
Good	71 - 85
Fair	61 - 70
Poor	41 - 60
Failed	0 - 40

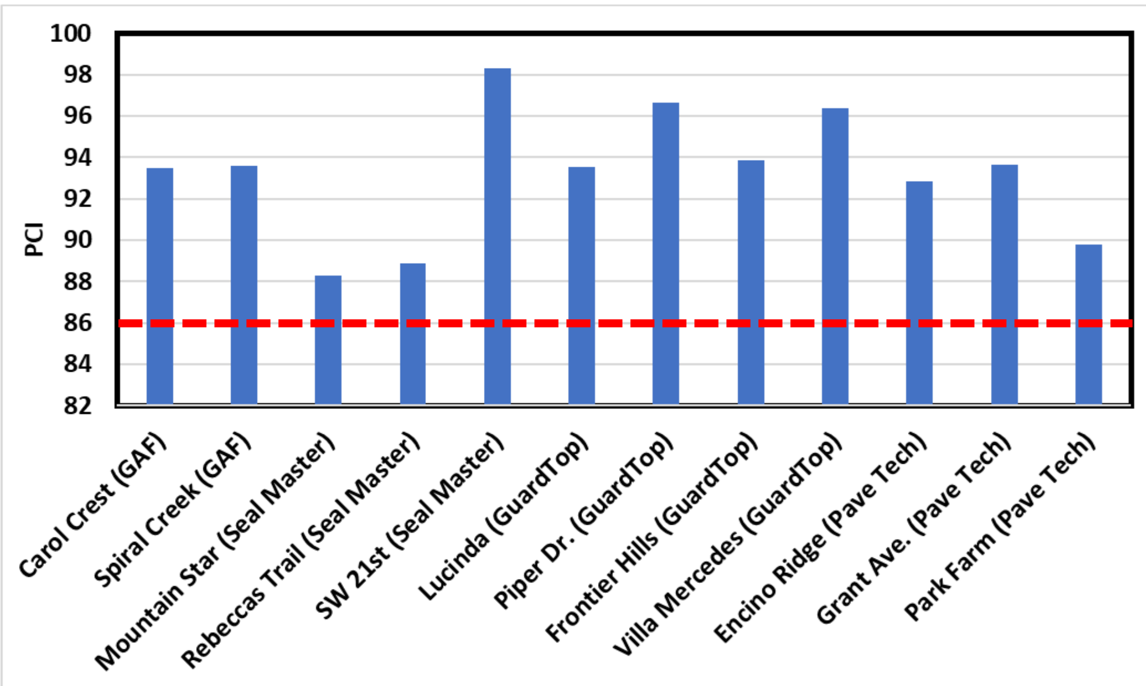


Figure 30. Summary of the projects PCI

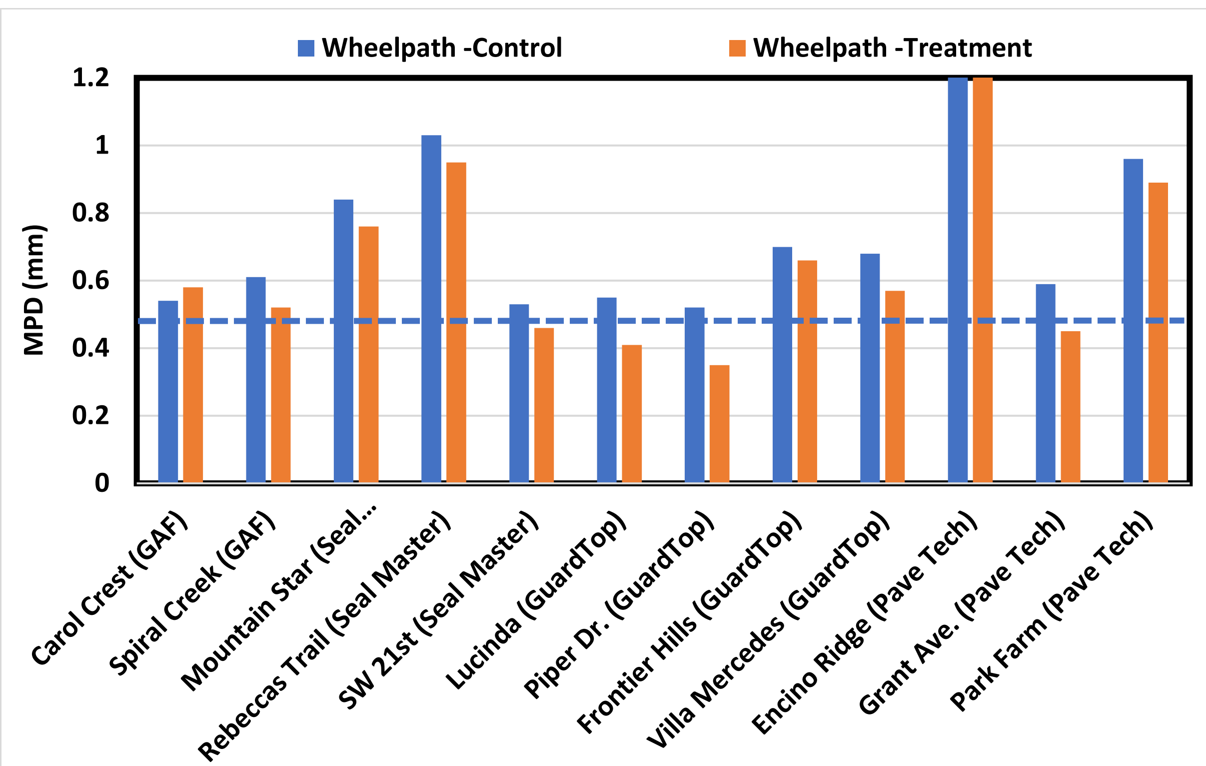
Another factor that affects surface performance on treated sites is traffic volume. As traffic volume increases it expedites the deterioration of pavement structural conditions and ultimately surface performance. From Table 1, the pavement sites have traffic levels ranging from low to medium average daily traffic (ADT) suggesting similar exposure to traffic during the performance period of the applied treatment. Other factors that have minimal effect on the treatment are weather and rain fall. Since all sites are geographically located within city limits and as far as 15 miles away from each other, weather conditions are considered irrelevant when comparing sites performance.

6.3 Summary of Texture Measurements

Figure 30 presents the MPD for control and treated sites at wheelpath and outside wheelpath. Table 57 provides the change in surface texture at and outside wheelpath due to applied treatment. Data suggests that the applications of cool pavement treatment reduced on average the surface texture for the Seal Master and GuardTop sites at and outside wheelpath to 10 and 20%, respectively. The drop in texture is consistent with other studies which depict the change to the application of surface emulsion layer that reduces the MPD with the treated surface. It is also noticed that the reduction in texture is more pronounced in these two treatments than in GAF and Pave Tech. Generally, there are limited studies that provide a minimum threshold of MPD that is directly related to skid resistance and reduction in traffic crashes. However, few studies suggested a minimum threshold of 0.50 as an appropriate measure of acceptable textured surface. Utilizing this measure, the majority of cool pavement treatments have exceeded the minimum threshold with the exception of one GuardTop site and two Seal Master sites. It is well documented in literature that the initial reduction in texture is temporary, and original texture will be recovered over time as the applied treatment worn out under traffic volume.

On the contrary, Pave Tech had an increase surface texture of 5% on average with less sensitivity to traffic impact at and outside wheelpath. This treatment is a penetrating technology in which it does not create a shield surface treatment separating between tires and pavement compared to the other three products. There is light application of sand on the treated sites which is recommended after installation. The sand layers may have contributed to the slight increase in texture. This is in agreement with other pilot studies conducted by the suppliers at Punta Gorda and Largo, Florida which showed a 3-20% increase in friction after 24 hours. While others show a reduction of 13-15% in 41 days after installation.

On another observation, GAF treatment has shown a reversal texture reduction from one site to another. However, it is suggested that after about 46 days of application, the texture in the wheel path reduced by about 12% due to traffic as compared to outside wheelpath. This reduction in texture may suggest a sensitivity of the product to traffic over time.



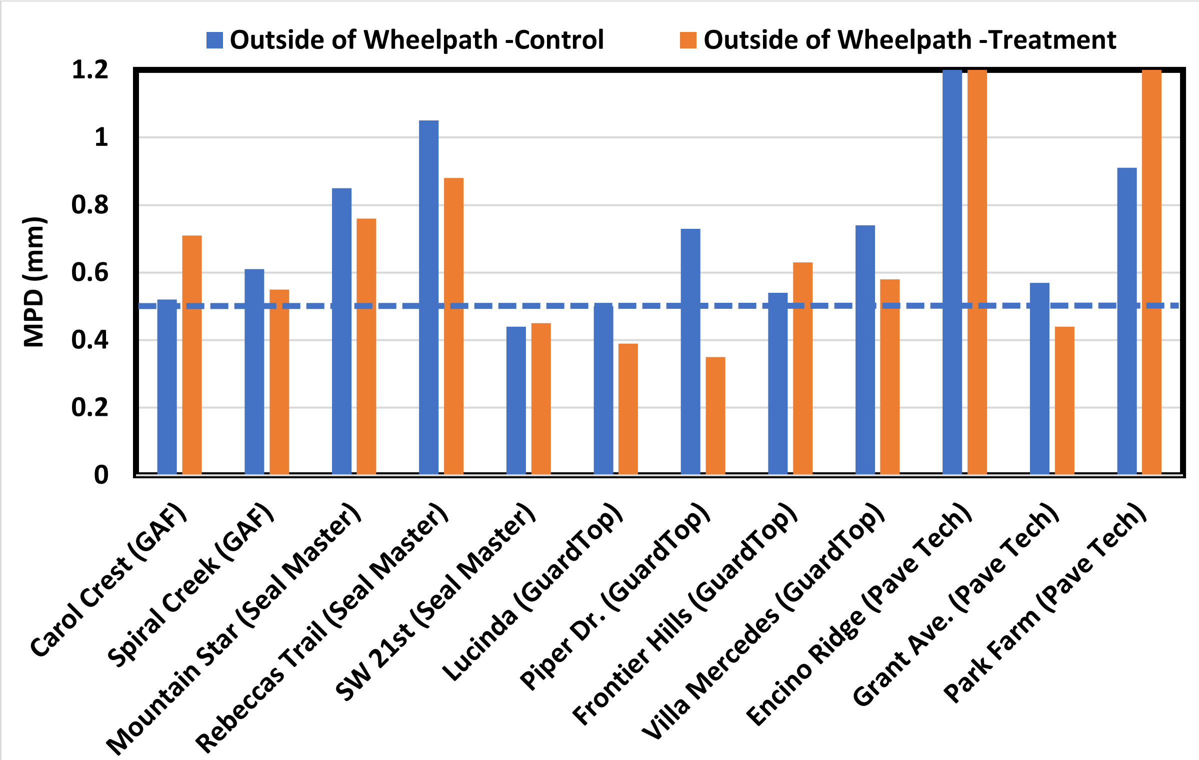


Figure 31. Summary of the texture measurements (MPD) for all projects.

Table 57. *Effect of applied treatment on surface texture changes*

Treatment	Reduction in Texture (%) at wheelpath	Reduction in Texture (%) outside wheelpath	Performance period (days)
GAF	4	-13*	46
Seal Master	10	8	88
GuardTop	20	20	75
Pave Tech	-4*	-6*	64

*-ve implies an increase in MPD, Performance period is the average difference in days from the installation and testing day for all treated sites.

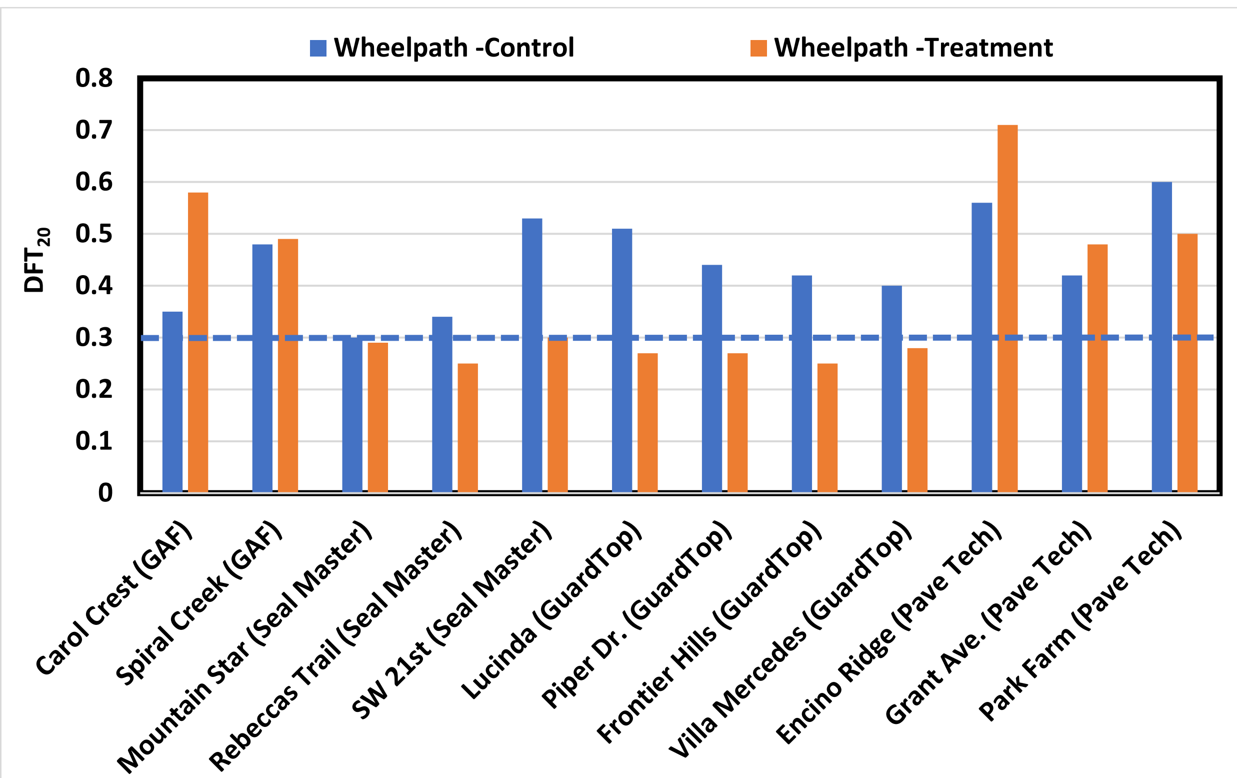
6.4 Summary of Friction Measurements

Figure 31 presents the Friction data (DFT_{20}) for control and treated sites at wheelpath and outside wheelpath. Table 58 provides the change in surface friction at and outside wheelpath due to applied treatment. Results from the site testing suggest that Seal Master and GuardTop have significantly reduced surface friction by 52 and 84% at wheelpath and outside wheelpath after less than 90 days of application, respectively. The friction reduction in the treated surface in the wheelpath is lesser degree than in outside wheelpath by 50 and 21% for Seal Master and GuardTop, respectively. The attribution to this reduction is due to the application of the polymer-based emulsion seal. This observation is not uncommon for recent sealed surfaces as suggested by literature. The surface friction will continue to increase and recover as the emulsified seal evaporates over time. It is expected that the induced anti-slip aggregate in the sealant to boost the surface friction over time. Further follow up testing is suggested to track the friction characteristics changes.

Pave Tech, the penetrable treatment, does not seem to provide a noticeable change outside the wheelpath. However, a noticeable increase in DFT20 is captured in two sites (Encino Ridge St. and Grant Ave.). With regard to GAF, no systematic pattern was noticed with one site showing substantial increase and the other showing slight decrease or no change.

Generally, the GAF and Pave Tech have maintained the recommended minimum thresholds of 0.30 suggested by literature, in all areas of treated surfaces (at wheelpath and outside wheelpath). On the contrary, GuardTop and Seal Master treatment have dropped the friction to the threshold level and slightly below.

As suggested by Obando et al. (2022), Friction fluctuates over time, but skid resistance on contrary is not linear and not depends only on the time. Friction increases or decreases depending on the level of interaction between tire and pavement which at its time depends on pavements surface condition. As treatment is applied and change in surface conditions may lead to change in friction and ultimately skid resistance. A more comprehensive skid resistance measure is suggested, and it is described in the next section.



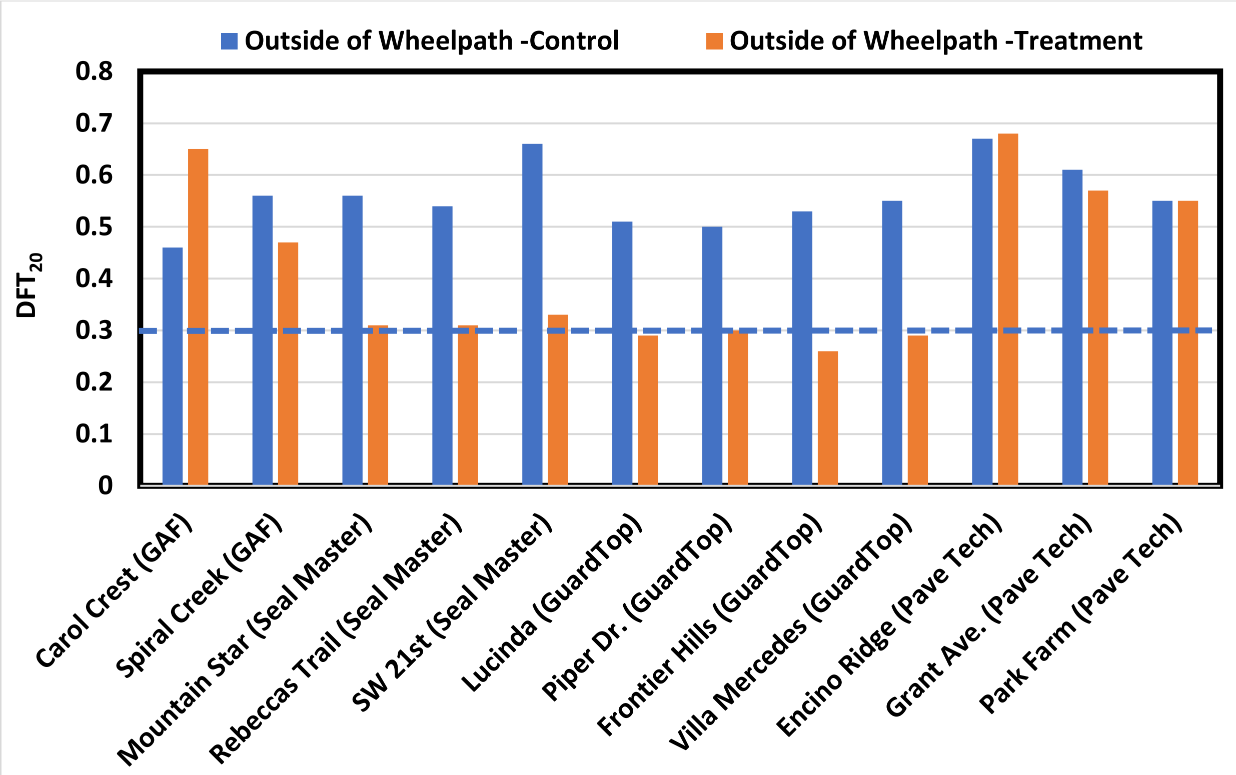


Figure 32. Summary of the friction measurements (DFT_{20}) for all projects.

Table 58. *Effect of applied treatment on surface friction changes*

Treatment	Reduction in Friction (%) at wheelpath	Reduction in Friction (%) outside wheelpath	Performance period (days)
GAF	-21*	-5*	46
Seal Master	39	85	88
GuardTop	66	84	75
Pave Tech	-5*	2	64

*-ve implies an increase in DFT_{20}, Performance period is the average difference in days from the installation and testing day for all treated sites.

6.5 International Friction Index (IFI)

Microtexture and macrotexture have a major impact on skid resistance of road pavements. The measured values with the DFT and CTM devices were used to calculate the International Friction Index (IFI), which takes into consideration these two surface characteristics. The IFI is being evaluated worldwide as a standard measure for skid resistance. It is used to quantify speed sensitivity of wet friction measurements on pavement surfaces. It consists of two parameters according to ASTM E1960: Sp a speed constant of wet pavement friction and *F60* that represents the wet friction of a pavement at 60 km/hr. Both parameters are calculated from the CT Meter and DFT data. The Sp may be estimated from the measurement of the pavement macrotexture, MPD (mm) using the following equation;

Sp = 14.2 + 89.7 *MPD*

F60 = 0.081 + 0.732 (DFT_{20}) *Exp*(-40/Sp)

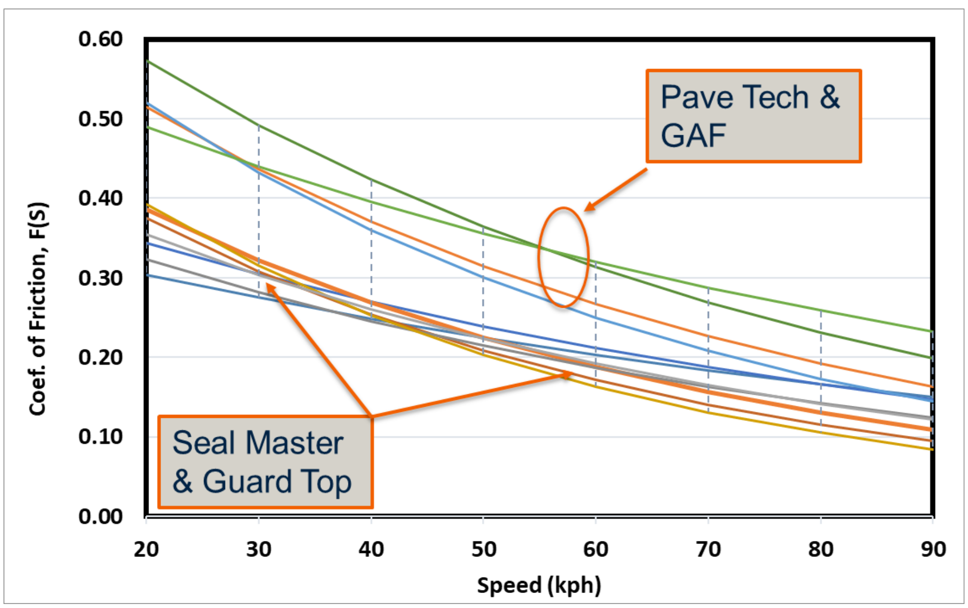
Using Sp and F60, the coefficient of friction F(*S*) at any speed *S* (km/hr) is calculated as follows

F(*S*) = *F60 Exp*[(60-S)/Sp]

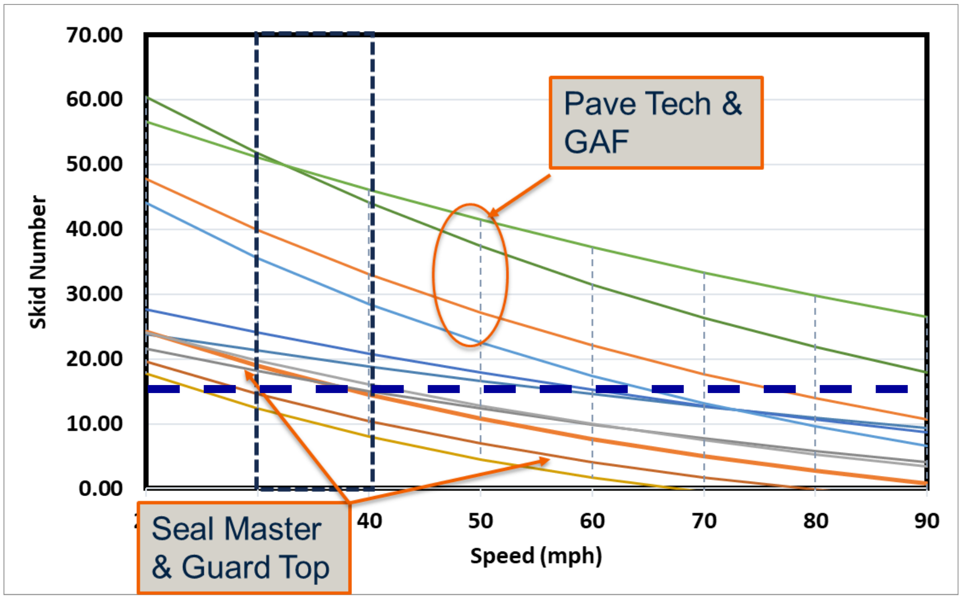
A study in Idaho used the microtexture (DFT_{20}) and macrotexture (MPD) and developed a statistical-based model to predict the skid number (SN) at various speeds (Kassem et al. 2019).

$$SN = 157.733\ DFT_{20}\ \mathrm{Exp}[-0.309(V/40)\ /\ MTD] - 9.631$$

where, V is the speed measured in mph. From Figure 32, It is found that in the wheelpath, sites treated with GAF and Pave Tech had higher coefficient of friction and skid number than Seal Master and GuardTop at low-speed range (e.g., 30-40 mph) which is applicable to COSA roadways. A skid number above 25 measured using a smooth tire is considered adequate while skid number below 15 indicates that the pavement requires surface treatment (Lebens and Troyer 2012). It is important to mention that testing with a smooth tire was not conducted as part of this study because the length of the treated sites was short to maintain a desirable driving speed for the data collection purposes. The determination of the coefficient of friction and skid number is used only for comparative analysis purposes and more field testing is strongly recommended with a long-span treated sites.



a)



b)

Figure 33. relationship of a) Coefficient of Friction F(S) and b) Skid Number in the wheelpath of treated sites as a function of speed.

6.6 Adhesion Strength

The purpose of this section is to measure the adhesive strength between the cool pavement treatment material and existing pavement. The Pull-off adhesion testing is the most widely used test method to assess bond strength (ASTM D 4541). In this assessment, the adhesion tester evaluates the pull-off strength of the treatment layer by determining the maximum tensile pull-off force of coating away from pavement using hydraulic pressure (Figure 33). The quality of adhesion strength of the treatment and pavement is quantified by the pull-off force. Coating adhesion is an indicator of how well the surface was prepared and how well the treatment has bonded to the pavement surface. Testing adhesion offers a quantifiable method of determining if the cool treatment system is fit-for-purpose and ready to meet the quality demands of what it intended for. In a standard ASTM D4541 pull-off adhesion test a pull stub is attached to a coated substrate and then removed through vertical loading (Figure 33). The force required to separate the coating from its substrate provides a measure of its adhesion strength. Pull-off adhesion tests provide a convenient, standardized, and rapid technique for evaluating the adhesion strength of a coating to an underlying substrate (Liddell et al. 2023).

Figure 34. Pull-off tester and diagram of the adhesion test procedure.

Testing methodology

The pull-off tester is applied in the wheel path and outside the wheelpath in the treated section only (see Figure 34). The maximum pull-off force is determined when the aluminum cylindrical disk is separated from the surface. The peak load time is also determined from the load -time curve provided by the instrument. Using the peak load and the duration time until the separation, the total adhesion energy is determined representing the area under the triangle in Figure 34. The summary of the pull-off forces and peak time are compiled in Table 59.

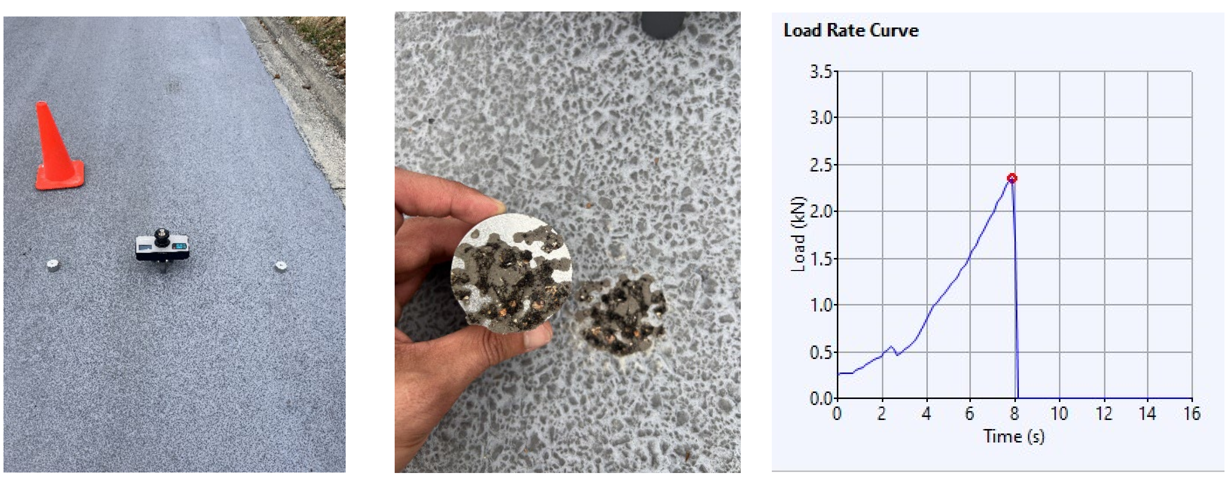


Figure 35. Demonstration of the Pull-off tester at the site with a sample diagram of the peak load over time.

Table 59: *Pull-off adhesion testing data on treated surfaces*

Treatment Location	Peak load (kN)			Peak Load Time (sec)		
	Wheelpath		outside Wheelpath	Wheelpath		Outside Wheelpath
	Left	*right*	*Treatment*	*Left*	*right*	*Treatment*
Carol Crest St. (GAF)	1.95	2.29	3.06	6.40	9.30	7.40
Spiral Creek (GAF)	1.01	0.91	1.34	4.10	3.90	4.40
Mountain Star (Seal Master)	1.41	1.60	1.18	4.20	5.80	4.20
Rebeccas Trail (Seal Master)	1.51	1.55	1.86	7.80	5.80	6.70
SW 21st St. (Seal Master)	0.69	0.72	1.15	8.90	8.10	7.10
Lucinda St. (GuardTop)		0.42	1.08		2.40	4.50
Piper Dr. (GuardTop)	2.31	1.24	1.74	7.1	6.10	6.50
Frontier Hill (GuardTop)	2.95	1.86	2.96	7.0	5.40	7.00
Villa Mercedes (GuardTop)						
Encino Ridge St. (Pave Tech)	1.49	3.06	2.36	8.20	80	7.80
Grant Ave. (Pave Tech)						
Park Farm (Pave Tech)	0.57	0.92	3.69	6.40	5.70	7.80

A summary of the adhesion energy in all sites is shown in Figure 35. It is suggested that traffic will deteriorate the adhesion strength of the treated layer over time. As shown in the figure, all sites experienced a reduction in the adhesion energy. The summary of the reduction in adhesion is shown in Table 60. The data suggests that Seal Master has the least reduction in adhesion energy while GuardTop has the highest reduction over the performance period. It was not determined to calculate the adhesion strength of Pave Tech due to the nature of the applied penetrating treatment where a substrate coating layer does not exist.

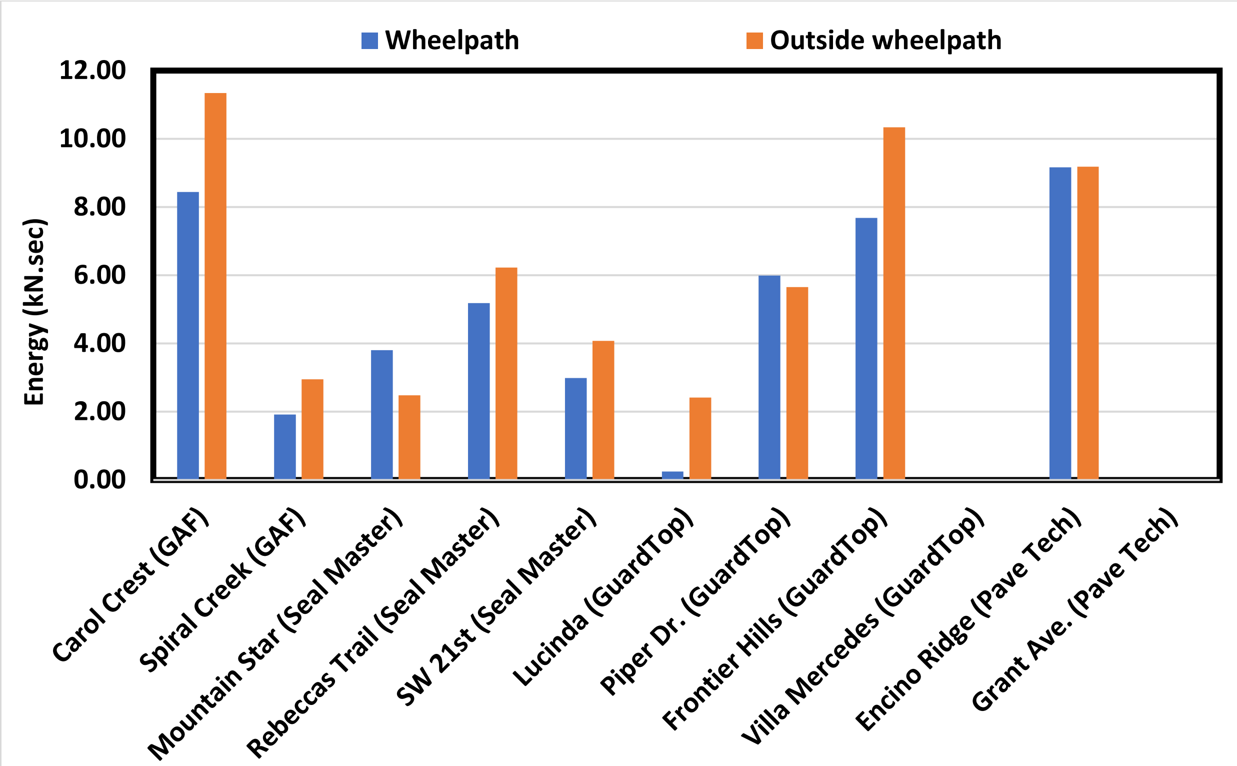


Figure 36. Summary of the Adhesion Energy for all projects

Table 60. *Summary of the effect of traffic on the adhesion of surface treatment to existing pavements*

Product	Reduction in adhesion due to traffic	Performance period (days)
GAF	30%	193
Seal Master	22%	173
GuardTop	36%	177
Pave Tech	zero	150

Performance period is the average difference in days from the installation and testing day for all treated sites

6.7 Summary of visual inspection

GAF, Seal Master and GuardTop provided a seal coat application that covers the pavement surface with its unique light color characteristics. They function similarly to any surface treatment applications that provide homogeneous appearance, fill all surface cracks, adhere firmly to the existing pavement surface, and build sufficient cohesion to resist abrasion due to traffic. During the visual inspection, the treated sites appeared to be distinct than their counterparts control sites from the surface color point of view. There were signs of tire marks along the wheel path (Figure 36). The extent of the tire marks is more pronounced in these products due to their light color as compared to conventional black surface treatment products.

Figure 37. Tire marks causing discoloration over treated site at Rebeccas Trail.

In a few areas, oil spills from parked vehicles along the curbs have negatively impacted the integrity of the sealcoat treatment due to separation and debonding with pavement surface. While the surface has been cleaned from dust and debris as part of the site preparation, oil spills seem to be a challenge to remove that ultimately affect the quality of the final surface appearance and bonding. Example of the oil spills is at Rebeccas Trail site (Figure 36).

Figure 38. Oil spill causing delamination at Rebeccas Trail.

It is also noted that the extent of discoloration of the applied treatment within the same site at different areas in the pavement (e.g., side curb, driving lane, turning lane) is noticeable. This is attributed primarily to the exposure to vehicle tires. The area near the curbs seems to be in much more light color appearance than the areas within the driving lanes. Since the driving lanes covered the majority of the pavement surface there may be a concern on whether treatment can withstand long enough to maintain higher reflectivity and solar reflectance.

In high traffic areas (e.g. SW 21st St.) recent visual inspection have shown signs of delamination and removal of the applied Seal Master treatment at various locations in the pavement surface. It appears that the delamination is primarily near the curbs with no traces of parked vehicles. This may be attributed to the presence of moisture from runoff or alike. That is not the case for other sites treated with Seal Master (e.g., Mountain Star) which suggests the impact of moisture on the treatment long-term bonding with existing pavement.

With regard to Pave Tech, due to the nature of the penetrating treatment there was no different appearance and no physical changes in the surface on the treated sites before and after installation. From the materials evaluation perspective, Pave Tech does not provide a coating that can function as a shield from temperature variation, a sealant to surface cracks and a rough texture surface to improve skid resistance. It however appears to work as a rejuvenator to mitigate oxidation to the top layer with its deep-treated feature which may suggest a longer impact to mitigate aging compared to other surface-treated products. Such verification to this impact requires testing mechanical properties (e.g., flexural, dynamic modulus) of core samples which was not conducted as part of this study. Notably, Pave Tech treatment may provide potential absorption of organic matter and NOXs into pavement surface. It is worth mentioning that the extent of Carbon and NOx removal was not tested as part of this study.

7 SUMMARY AND RECOMMENDATIONS

Four different cool pavement products were evaluated on the COSA roadways in residential areas namely; Seal Master, GAF Streetbond, GuardTop and Pave Tech. A pilot program was established to try each product on strategically data-driven sites distributed across the ten council districts. The products were installed by the suppliers or their licensed contractors whom they ensure proper site preparation and sufficient curing time before opening to traffic. The products were installed from April 24 to July 14, 2023, a generally hot summer period with no significant temperature changes. Each treated site was evaluated against a near proximity control sites that share similar pavement surface conditions and age and traffic volume. For comparative purposes, the pavement conditioning index, PCI, suggest that all sites have excellent structural and surface conditions prior to the treatment.

All sites have been evaluated based on their surface characteristics namely, friction and texture properties conducted by Transtec Group and adhesion strength conducted by UTSA. The friction and texture surface evaluation were conducted on treated and control section within 45-90 days after installation while adhesion strength was conducted on treated sections only within 150-190 days.

In terms of texture properties and with respect to control sections; GuardTop experienced the higher reduction (20%) in texture followed by Seal Master (10%). This represents the average reduction among the sites treated with this specific product. GAF showed a decrease in texture by 4% at wheelpath but an increase of 13% outside wheel path. In the case of Pave Tech, an average texture increases of 5% was measured across the surface.

In terms of friction properties and with respect to control sections: GAF experienced the higher reduction (66%) in friction followed by Seal Master (39%) in the wheel path, while Pave Tech and GAF experienced increase in friction of 5 and 21%, respectively.

In terms of the International Friction Index that reflects the combined effect of friction and texture on the skid resistance of pavement surface, the Pave Tech and GAF showed the higher coefficient of friction and skid number than in Seal Master and GuardTop at different driving speed.

In terms of adhesion strength with respect to exposure to traffic (wheelpath and outside wheelpath), Seal Master experienced the least reduction, followed by GAF and GuardTop after 5-6 months of installation. No difference in adhesion strength was noticed in the case of Pave Tech due to the lack of a coating layer.

From the pavement preservation prospective, treatment with GAF seems to provide the most desirable surface characteristics with improved skid resistance and friction over control sites. Seal Master and GuardTop have occasionally dropped the surface properties below recommended thresholds in the wheelpath areas. This is not a major concern as it is expected for these properties to recover over a period of time with oxidation of applied treatment.

Seal Master seems to provide the best adhesion strength across all products which reflects its longevity to adhere to pavement surface. However, testing was limited only to one location per site which may not suggest a comprehensive representation of the adhesion strength. That does not eliminate the effect of moisture that caused delamination along the curbs at one of the Seal Master sites.

Visual inspection on the treated sites provided more insight on the constructability, longevity and appearance of the tested products. For instance, presence of moisture along the curbs from runoff could wash off the product. Also, site contamination (e.g., oil spills) may prevent adhesion to surface and delamination of surrounded coating. Tire marks tracking appear to incrementally convert the wheelpath areas to same dark surface color as of control sites which may affect solar reflectance and the purpose of using these cool pavement products over time. More importantly, old pavements in near proximity to treated sites seem to have a lighter color due to the oxidation which naturally occur overtime for asphalt pavement surface. It is however of great importance to note that application of surface treatment coating is a major pavement preservation practice to maintain and preserve roadways performance and extend their service life and COSA is highly recommended to continue this practice.

Future evaluations of the aforementioned sites in Table 1 are highly recommended to provide a comprehensive assessment over extended period of time. With more exposure to traffic, temperature variation, rainfall, and other operational factors, the performance of the cool pavement products could alter with time. The assessment and findings presented here reflect the sites performance as of the publication of this report.

8 REFERENCES

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Appendix A. Summary of Cool Pavement products physical propertie

	Seal Master	GAF	Pave Tech Inc.	GuardTop - Dark Gray	GuardTop - Light Gray
Product Name	SolarPave (acrylic polymer emulsion pavement) sealcoat	Durashield Pavement Coating (water/acrylic based) *sealcoat*	PlusTi (oil based) *spray*	CoolSeal (asphalt based) *sealcoat*	CoolSeal (asphalt based) *sealcoat*
Costs	\$5/ yd^2 (material)	\$2.63-2.70/ yd^2 (material) \$13.50/yd^2 (installation)	\$3 to \$4/ yd^2 (installation costs)	\$5.50/ yd^2 (material only) \$6.40/sq. yd. (material& installation) \$22 per gallon	\$5.10/yd^2 (material only) \$6.10/yd^2 (material & installation) \$17 per gallon
Avg. Costs per Year			\$0.78/sq. yd per year of life	\$1.07/sq. yd per year of life, \$0.71/sq. yd per year of life	\$1.02/sq. yd per year of life, \$0.68/sq. yd per year of life
Color	Mocha Gray (Dark Gray)	Solar Gray	Light Gray	Dark Gray	Light Gray
Lifespan	unknown	5 - 7 yrs., max. 12 yrs.	4 - 5 yrs.	5 - 7 yrs., max. 9 yrs.	5 - 7 yrs., max. 9 yrs.
Solar Reflectance Index (SRI)	0.33	0.33	0.29 – 0.33	0.38	0.42
Application Rate	1 gallon = 8 sq. yds 2 coats are recommended	65 sq. ft. per gallon or 14 dry mils	0.04 to 0.10 gallons per sq. yd.	.25-.3 gallons per sq. ft.	.25-.3 gallons per sq. ft.
Density	10-12 lbs./gal	14.3 lbs./gal		9.5 to 12 lbs./gal	9.5 to 12 lbs./gal
Deployment Locations		Los Angeles, Phoenix, Scottsdale, Davis & Pacoima (CA)	Austin, Phoenix, Orlando, Orlando IA, Charlotte, Cincinnati	Los Angeles, Phoenix	Los Angeles, Phoenix