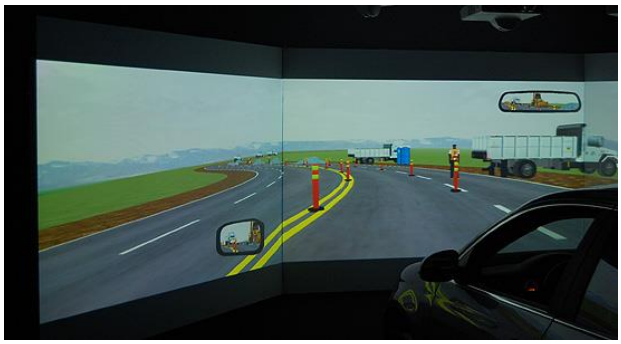

Express Lane Marker Color Human Factors Study on Concrete and Open-Graded Friction Course & Impact Testing for Express Lane Markers Installed on Open-Graded Friction Course

Contract Number: 800007664-01(BDV29-977-29)

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Submitted by

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Submitted to

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Research Center
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March 23, 2018

Disclaimer:

The contents of this report reflect the views of the authors who are solely responsible for the facts and accuracy of the data, and the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the State of Florida Department of Transportation, Florida International University, The Texas A&M University System, or Texas A&M Transportation Institute (TTI).

Metric Conversion Table

SI* (MODERN METRIC) CONVERSION FACTORS				
APPROXIMATE CONVERSIONS TO SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
in	inches	25.4	Millimeters	mm
ft	feet	0.305	Meters	m
yd	yards	0.914	Meters	m
mi	miles	1.61	Kilometers	Km
		AREA		
in^2	square inches	645.2	Square millimeters	mm^2
ft^2	square feet	0.093	Square meters	m^2
yd^2	square yard	0.836	Square meters	m^2
ac	acres	0.405	Hectares	ha
mi^2	square miles	2.59	Square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	Milliliters	mL
gal	gallons	3.785	Liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
	NOTE: volumes greater than 1000 L shall be shown in m^3			
		MASS		
oz	ounces	28.35	Grams	g
lb	pounds	0.454	Kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	Lux	lx
fl	foot-Lamberts	3.426	$candela/m^2$	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	Newtons	N
lbf/in^2	poundforce per square inch	6.89	Kilopascals	kPa
APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
mm	millimeters	0.039	Inches	in
m	meters	3.28	Feet	ft
m	meters	1.09	Yards	yd
km	kilometers	0.621	Miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	Hectares	2.47	Acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	Milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	Gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	Ounces	oz
kg	kilograms	2.202	Pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	$candela/m^2$	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	Poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380 (Revised March 2003)

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7. Author(s) Hesham Ali, Nathan D. Schulz, Mohamadtaqi Baqersad and Wanda L. Menges,		8. Performing Organization Report No. Test Report No. 607531-02-1-11
9. Performing Organization Name and Address Florida International University 10555 W. Flagler Street, Room EC3602, Miami, FL 33172		10. Work Unit No. (TRAIS) 11. Contract or Grant No. 800007664-01(BDV29)
12. Sponsoring Agency Name and Address State of Florida Department of Transportation 605 Suwannee Street, M.S. 75 Tallahassee, FL 32399-0450		13. Type of Report and Period Covered Draft Final Report 14. Sponsoring Agency Code

15. Supplementary Notes
Name of Contacting Representative: Karen Byram

16. Abstract

As the use of express lanes is expanding in Florida, FDOT is developing material specifications for Express Lane Markers (ELM). To complete the specifications, highway product safety and impact testing was conducted to ensure an optimum service life of ELMs and evaluate the performance of several products and installation methods. The Department's past installations of Express Lane Markers were on concrete pavements. Current and future installations will be on Open Graded Friction Course (OGFC) asphalt surfaces. A test strip with OGFC was constructed to allow product testing on this type of surface. Impact testing of various products, installation methods, surface types and weather conditions was performed. It is recommended that product tests on asphalt and concrete surface have a combined average that meets a minimum of 150 tire impacts and 50 bumper impacts resistance. In addition, the product's performance on asphalt or concrete should meet a minimum of 150 tire impacts and 45 bumper impacts resistance.

The Manual for Uniform Traffic Control Devices (MUTCD) currently allows the use of orange, white and yellow channelizing devices for emphasis of pavement marking patterns. The Department has used the color orange for existing installations on concrete surfaces to enhance visibility and provide a more aesthetic appearance after ELM receive black marks from impacting vehicles. The MUTCD was expected to be modified for the next version to only allow the use of the color orange in work zones. This report proposes a research plan to test the visibility of delineators with different color patterns and define the optimum color.

17. Key Word	18. Distribution Statement
Delineators, impact durability, impact endurance, roadside safety, human factors study, driver simulation, express lane markers.	Copyrighted. Not to be copied or reprinted without consent from State of Florida Department of Transportation.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	130	n/a

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EXECUTIVE SUMMARY

As the use of express lanes is expanding in Florida, FDOT is developing material specifications for Express Lane Markers (ELM). To complete the specifications, highway product safety and impact testing was conducted to ensure an optimum service life of ELMs and evaluate the performance of several products and installation methods. The Department's past installations of Express Lane Markers were on concrete pavements. Current and future installations will be on Open Graded Friction Course (OGFC) asphalt surfaces. A test strip with OGFC was constructed to allow product testing on this type of surface. Impact testing of various products, installation methods, surface types and weather conditions was performed.

The main failure mechanism observed was the delineator post-fracturing and failure to restore to specified list/lean values. In addition, a minimum performance level specification was recommend based on testing under this project and the previous project 605601(2). It is recommended that product tests on asphalt and concrete surface have a combined average that meets a minimum of 150 tire impacts and 50 bumper impacts resistance. In addition, the product's performance on asphalt or concrete should meet a minimum of 150 tire impacts and 45 bumper impacts resistance.

The Manual for Uniform Traffic Control Devices (MUTCD) currently allows the use of orange, white and yellow channelizing devices for emphasis of pavement marking patterns. The Department has used the color orange for existing installations on concrete surfaces to enhance visibility and provide a more aesthetic appearance after ELM receive black marks from impacting vehicles. However, there was a concern with the use of the color orange. The MUTCD was expected to be modified for the next version to only allow the use of the color orange in work zones. This report proposes a research plan to be conducted to test the visibility of delineators with different color patterns and define the optimum color.

1 Introduction

Task 1 of this project aims at developing a human factors study to determine the best color of Express Lane Markers (ELM). Two experiments are proposed; one uses a driving simulation and the other is a field study by means of driving express lanes in South Florida. The scope, schedule and cost of the two experiments are presented in this document.

To find the optimal color, participants will take part in a filed driving study as well as a simulated driving study. In this task, the participants during field driving will indicate where they detect the delineators as they approach them. This location which defines the distance from the delineators that a driver can see them, named "visibility distance", will be used to identify the optimal delineator color. To simulate various driving conditions, the field and driving simulation tests are needed, both are described below. If approved, this would be Task 5.

Task 2 of this project was to perform compliance testing on delineator products. FIU contracted with TTI to conduct the testing on manufacturer ELM samples. Testing was performed on concrete and asphalt OGFC surfaces and its results are in Appendix A of this report.

1.1 Driving Simulation

In the driving simulation test, a highway with an express lane will be simulated. The express lane will be separated from the general highway lanes by delineators. Participants will virtually drive a vehicle in the simulated environment, and the software will collect the data regarding the driver's speed and longitudinal distance from ELM when drivers detect the delineators.

Figure 1 Driving simulation lab

To perform the driving simulation and the field tests, obtaining Institution Review Board (IRB) is required. IRB is a committee established under the federal regulations for the protection of human subjects in research. This study needs to have participants to drive in driving simulation lab and field tests as a sample of people who drive in roads. Therefore, it is needed to obtain this committee approval for performing these tests.

The work is divided into the driving simulation and field testing tasks as presented in the following tasks:

1.2 Driving Simulation Tasks

Task 5.1**:** Identify the driving simulation lab experimental design. This testing plan contains the factors identified below.

Pavement surface: Pavement surface color may have an effect on the visibility of delineators color. Therefore, in simulating the driving environment, the pavement surface color will be changed. Asphalt pavements have a dark surface color and concrete pavements have a light surface color. Both pavement types will be simulated.

Ambient light condition: the visibility and reflectiveness of colors may differ in different ambient lights. Therefore, to consider the effect of ambient color, the tests will be conducted in day and night conditions.

Traffic Condition and drivers speed: In order to control the variability of simulation runs, FIU team will simulate tests with high traffic volume and low traffic volume conditions. The driver will be instructed to drive with an average speed of 60 mph in low volume traffic and 45mph in high volume traffic. Moreover, the lane that drivers will drive may have an effect on the distance that drivers can detect the delineators. To omit this effect, the drivers will drive in the lane next to the delineators. Delineators will separate the express lane from highway general lanes. Therefore, the driver will be instructed to drive in the lane which is next to the delineators and is located in the general lanes.

Weather condition: the weather condition may influence the visibility distance of delineator colors. It is possible to simulate normal and foggy weather in simulation lab test. Therefore, the tests will be conducted in these two weather condition.

Participant Size: FIU team propose to select 30 people for each test scenario. In choosing the participants for each scenario, their age and gender will be considered. The participants will get 50$ for their cooperation in this test. This arrangement worked in past similar studies.

The color of delineators: The Department proposes to evaluate the three colors of white, black, and purple with white reflective sheeting. The simulation lab software has the below default

delineators. Therefore, to change the default colors, the 3D Max software will be used, and delineators with any color will be designed. Element 2 in Figure 2 will be used to construct delineators.

Figure 2: Software delineators

Delineators' interval distance: The department recently decided to change the delineators' interval distance from 10 ft. to 5 ft. Thus, in this study, the interval distance of 5ft. between delineators will be considered.

Visibility distance: To measure the visibility distance, each driver during his driving simulation will push a button as soon as detected the delineators. The pushing of this button will save the location and speed of the car at the time that the driver detected the delineators and define the visibility distance.

Table 1 represents the different scenarios that will be considered in simulation lab test.

Task 5.2: Execute the driving simulation and compile the data. The effect of weather condition, pavement surface, delineators color, and traffic condition on visibility of delineators will be

considered. Moreover, a questionnaire will be prepared and filled out by the participants to reveal their ideas regarding the visibility and color preference of delineators.

Task 5.3: Analyze the results of the executed simulation. The outcomes of this analysis will define the optimum color for ELMs regarding their visibility. Statistical data analysis will be conducted, and the best visible color for the concrete and asphalt pavement surface will be identified. The optimum color will have the maximum visibility distance.

Due to the fact that driving simulation is not 100% realistic and colors shown in the simulator screen may not match actual colors 100%, field testing will be conducted. Field testing can be expensive and time consuming. Therefore, the results of the driving simulator will be used to eliminate one of the three colors and select the best two for field evaluation. Field tests will recommend the best color of the two selected in the driving simulation.

1.3 Field Testing

To measure the visibility distance in field tests, each vehicle will be equipped with a data acquisition system. This equipment contains a differential global positioning system (DGPS), a computer with a hard disc, and a button uses by the experimenter (a person seated in the vehicle with the driver) to mark the position where the driver detects the delineators. Also, the location of delineators is already defined by DGPS. Using these locations, it is possible to measure the visibility distance. Figure 3 shows a commercial DGPS model that can be used for the purpose of this experiment.

Figure 3: Global positioning system device

1.4 Experimental Test Tasks

ELMs field testing will be conducted using the standard 36-inch height and 5-foot center-to-center spacing installed on both concrete and asphalt OGFC surfaces. 4 sections will be selected from the six sections identified in Figures 4-9. The Department will install the ELMs and provide the Temporary Traffic Control (TTC) required for the installation and data collection. FIU will provide the equipment and personnel (i.e., students, volunteers, etc.) to perform data collection. FIU will comply with the Department's public notification requirements and roadway availability restrictions when planning and performing field testing.

Task 5.4: Identify the test sites for the purpose of developing an experimental testing plan. The project team will consult with District 6 staff to identify the 4 test locations. The experimental testing plan contains the mixed factors repeated-measures design. These factors are presented below:

Pavement surface: Pavement surface color may have an effect on the visibility of delineators color. Therefore, in selecting of test sites, the pavement surface color is considered. As asphalt pavements have a dark surface color and concrete pavements have a light surface color, test sites with asphalt and concrete pavement will be. Two sections of asphalt pavement and two sections of concrete pavement will be selected.

Ambient light condition: The visibility and reflectiveness of colors may differ in different ambient lights. Therefore, to consider the effect of ambient color, the tests will be conducted in daytime and nighttime.

Traffic Condition and drivers speed: In order to have the same condition in field testing, FIU team will perform the field testing in times that the traffic volume is high and low. The driver will be instructed to drive with the average speed of 60 mph in low volume traffic and 45mph in high volume traffic. Moreover, the lane that drivers will drive may effect on the visibility distance. To omit this effect, the drivers will drive in the lane next to the delineators. Delineators will separate the express lane from highway general lanes. Therefore, the driver will be instructed to drive in the general lane next to the delineators.

Weather condition: The weather condition in roads may have an effect on the visibility distance of delineator colors. However, having rainy or foggy weather during testing is random and will be difficult to schedule the test runs to cover such conditions. Therefore, all the experimental test will be conducted in normal weather condition.

Participant size: FIU team propose to select 30 people for each experimental scenario. In choosing the participants for each scenario, their age and gender will be considered. The participants will receive $100 for their participation. This arrangement worked in past similar studies.

The color of delineators: The team will evaluate the best two colors selected in the Driving simulation.

Test sections: It is proposed to install the delineators in 4 test sections. This is a result of 2 delineator colors and 2 pavement types. Two test sections will have concrete pavement, and the other two will have asphalt pavement surface. These delineators will be installed in I-95 highway in Miami. In each test section, the first 100 delineators will be installed at the entrance of express lane with five ft. interval distance. This will allow the driver to see the delineator from a distance as they will not be hidden behind other delineators. Figures 4-9 show six possible test sections to choose 4 sections from. These sections were identified by the project team with input from District 6 ITS staff. The 6 sections represent entry points where delineator visibility comes to play.

Visibility distance: To measure the visibility distance, each vehicle will be equipped with a data acquisition system. The equipment contains a differential global positioning system (DGPS), a computer with a hard disc, and a button uses by the experimenter to mark the position where the driver sees the delineators.

Questionnaire: A questionnaire will be prepared and filled out by the participants to share their input regarding the visibility and color preference of delineators.

Table 2 presents the different scenarios that will be considered in the field test design.

Table 1: Driving Simulation Experimental Plan

Scenario		Color of delineator			Pavement Surface		weather Condition		Light Condition		Traffic Volume		Participant
		White	Black	Purple	Concrete	Asphalt	Normal	Fog	Day	Night	Low	High	
1	1	*			*		*		*		*		30
	2		*		*		*		*		*		
	3			*	*		*		*		*		
	4	*				*	*		*		*		
	5		*			*	*		*		*		
	6			*		*	*		*		*		
2	1	*			*		*			*	*		30
	2		*		*		*			*	*		
	3			*	*		*			*	*		
	4	*				*	*			*	*		
	5		*			*	*			*	*		
	6			*		*	*			*	*		
3	1	*			*		*			*		*	30
	2		*		*		*			*		*	
	3			*	*		*			*		*	
	4	*				*	*			*		*	
	5		*			*	*			*		*	
	6			*		*	*			*		*	
4	1	*			*			*		*	*		30
	2		*		*			*		*	*		
	3			*	*			*		*	*		
	4	*				*		*		*	*		
	5		*			*		*		*	*		
	6			*		*		*		*	*		
												Total	120

Figure 4: Asphalt Site 1—I-95 Express Lanes Southbound ramp from I-95 Mainline/Ives Dairy Road (CCTV-014 ELP2)

Table 2: Field Test Experimental Plan

Scenario	Test Site	Color of delineator		Pavement Surface		weather Condition		Light Condition		Traffic Volume		Participants
		Color 1	Color 2	Concrete	Asphalt	Normal	Fog	Day	Night	Low	High	
1	1	*		*		*		*		*		30
	2		*	*		*		*		*		
	3	*			*	*		*		*		
	4		*		*	*		*		*		
2	1	*		*		*			*	*		30
	2		*	*		*			*	*		
	3	*			*	*			*	*		
	4		*		*	*			*	*		
3	1	*		*		*		*			*	30
	2		*	*		*		*			*	
	3	*			*	*		*			*	
	4		*		*	*		*			*	
											Total	90

Figure 5: Asphalt Site 3—I-95 Express Lanes Northbound ramp from I-95 Mainline/Hallandale Beach Blvd (CCTV 18.0 ELP2)

Figure 6: Asphalt Site 3—I-95 Express Lanes Southbound ramp from I-95 Mainline/Griffin Road (CCTV 22.3 ELP2)

Figure 7: Asphalt Site 4— I-95 Express Lanes Southbound ramp from I-95 Mainline/Ives Dairy Road (CCTV-014 ELP2)

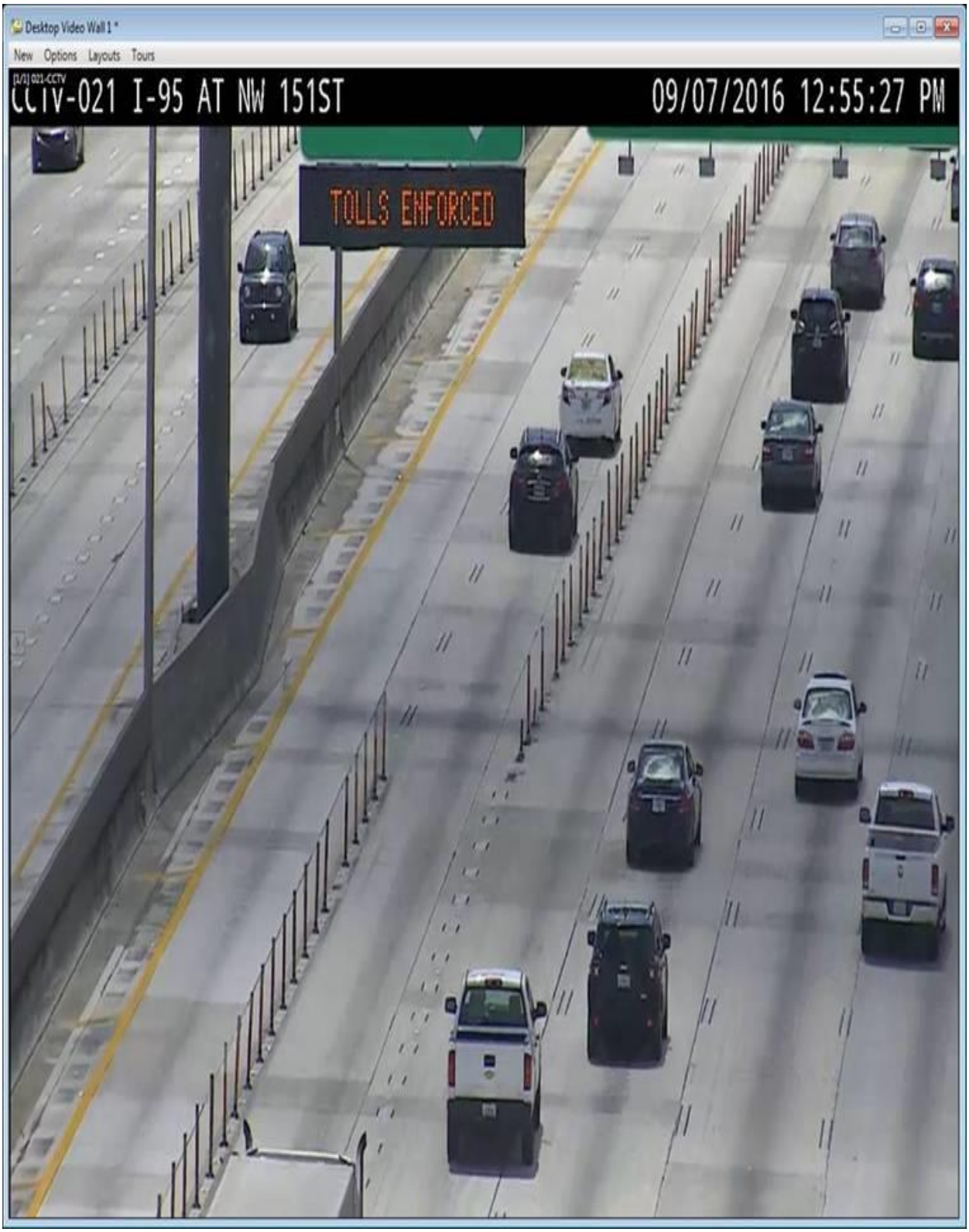

Figure 8: Concrete Site 1— 95 Express Lanes Southbound ramp from I-95 Mainline/Golden Glades Interchange (CCTV 021)

Figure 9: Concrete Section 2—I-95 Express Lanes Northbound ramp from I-95 Mainline - (CCTV 033)

Task 5.5: Execute the experimental testing plan and collect the data. FIU will carry out the plan identified above. In data collection, the visibility distance will be measured. To record the location where the driver detects the delineators, the experimenter, a person seated next to the driver, will record the position by GPS instrument upon notification by the driver.

Task 5.6: Analyze the results of the executed field testing plan. The outcomes of this analysis will define the optimum color for ELMs based on the visibility distance. Statistical data analysis will be conducted, and the best visible color for the concrete and asphalt pavement surface will be identified. The optimum color will have the maximum visibility distance for the majority of driving conditions. The effect of driver age and driver gender will also be defined in the results. Moreover, the simulation results and field results will be compared.

1.5 Preparing Final Report

A final report shall be submitted to the department. The report shall document the entire evaluation effort, summarize findings, draw conclusions, and present data analysis. This report will be incorporated in Tasks 3 and 4, Draft Final Report and Final Report.

1.6 Estimated Schedule

Figure 10 presents the project schedule. It is estimated that a total of 15 months will be necessary to complete the task, ending the project on March 31, 2018. While the project team will try to accelerate the project, several tasks involve coordination with a large number of participants, third party approvals and field work that is subject to department operations and weather conditions.

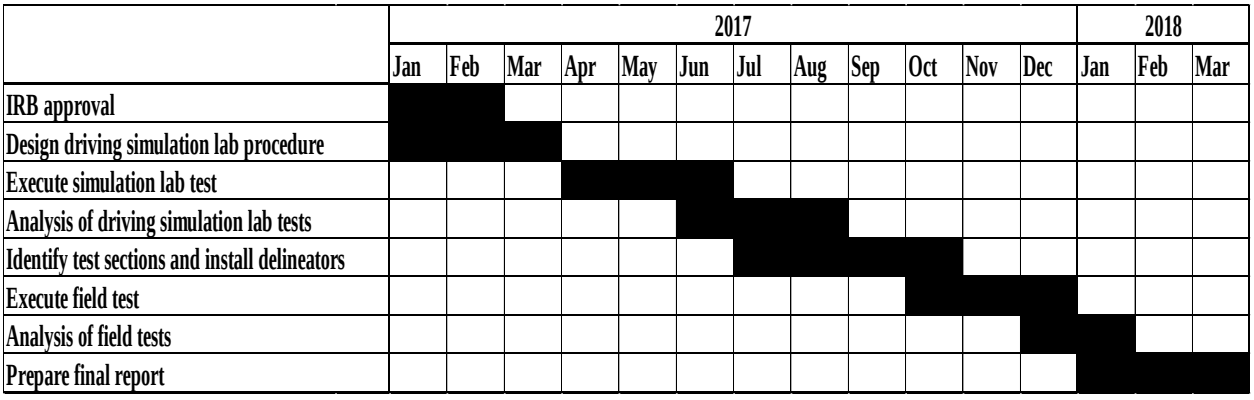

Figure 10: Task 5 Schedule

1.7 Estimated Cost

Table 3 shows expenses related to Task 5. Table 4 shows the total budget for Task 5, including salaries, stipend, fringe benefits, student tuition, expenses listed above, indirect expenses, etc. The total cost is $154,800.79. The addition of Task 5 will bring the total budget to $658,134.06.

Table 3: Task 5 Expenses

Item	**Number**	**unit price ($)**	**Total Price ($)**
Delineators and their installation. FDOT will pay for under existing contracts in D6 or otherwise. FDOT will provide the MOT and installation oversight.	400	80	Paid by FDOT
Gift card to the field test participants	90	100	$ 9,000.00
GPS devices	3	525	$ 1,575.00
Car Rental and Gasoline	60 (days)	45	$ 2,700.00
Gift card to the simulation lab participants	120	50	$ 6,000.00
3D MAX license for one month	1	185	$ 185.00
Experimenter for field tests and driving simulation lab tests (undergraduate student)	400 (hr)	20 per hr	$ 8,000.00
Total			**$27,460.00**
Above Expenses Expressed in Budget Categories			
OPS			$ 8,000.00
Participant Payments			$15,000.00
Materials and Supplies			$ 4,460.00
Totoal			**$27,460.00**

Table 4: Task 5 and Project Budget

FLORIDA INTERNATIONAL UNIVERSITY PROPOSAL BUDGET SHEET						
Principal Investigator/Project Director:	Hesham Ali					
Agency:	FDOT					
Level 4 Budgetary Account	**Tasks 1-4**	**Task 5**				**Total Task 1 - 5**
P77100 - Salaries & Wages	33,132.64	61,270.07	-	-	-	**$ 94,402.71**
P77150-OPS	16,586.46	25,084.05	-	-	-	**$ 41,670.51**
P77156 - Fringe	12,031.91	21,614.20	-	-	-	**$ 33,646.11**
P71121 - Domestic Travel	1,500.00	-	-	-	-	**$ 1,500.00**
P71123 - Foreign Travel	-	-	-	-	-	**$ -**
P71119 - Long Distance Telephone Calls	-	-	-	-	-	**$ -**
P77300 - Materials and Supplies	-	4,460.00	-	-	-	**$ 4,460.00**
P71190 - Other Operating Expenses	-	-	-	-	-	**$ -**
P71100 - Participant Payments	-	15,000.00	-	-	-	**$ 15,000.00**
P71150 - Patient Care Cost	-	-	-	-	-	**$ -**
P77200 - Professional Fees	-	-	-	-	-	**$ -**
P77210 - Professional Fees / Consultants	-	-	-	-	-	**$ -**
P71140 - Rent Expense Other Than Buildings	-	-	-	-	-	**$ -**
P76100 - Repairs and Maintenance	-	-	-	-	-	**$ -**
P76800 - Scholarships	-	-	-	-	-	**$ -**
P76830 - Stipends	-	-	-	-	-	**$ -**
P77295 - Subcontractors over $25K	342,591.00	-	-	-	-	**$ 342,591.00**
P7729U - Subcontractors under $25K	25,000.00	-	-	-	-	**$ 25,000.00**
P76840 - Tuition	6,839.10	7,181.06	-	-	-	**$ 14,020.16**
P77220 - Advertising Services	-	-	-	-	-	**$ -**
P72110 - Books & Film	-	-	-	-	-	**$ -**
P77320 - Building and Construction	-	-	-	-	-	**$ -**
P71117 - Cellular Phones	-	-	-	-	-	**$ -**
P77218 - Construction Services	-	-	-	-	-	**$ -**
P77382 - Data Processing Supplies	-	-	-	-	-	**$ -**
P77380 - Food Products	-	-	-	-	-	**$ -**
P71116 - Local Telephone Calls	-	-	-	-	-	**$ -**
P71145 - Memberships & Subscriptions	-	-	-	-	-	**$ -**
P71130 - Moving Expenses	-	-	-	-	-	**$ -**
P77330 - Office Supplies	-	-	-	-	-	**$ -**
P71101 - Postage	-	-	-	-	-	**$ -**
P71144 - Rent Expense Buildings	-	-	-	-	-	**$ -**
P71118-Telephone Equipment	-	-	-	-	-	**$ -**
P72100 - Other Capital Outlay	-	-	-	-	-	**$ -**
Total Direct Costs By Year	**437,681.10**	**134,609.38**	**-**	**-**	**-**	**572,290.49**
P75700 - Indirect Costs	65,652.17	20,191.41	-	-	-	**$ 85,843.57**
Total Direct & Indirect Costs By Year	**$ 503,333.27**	**$ 154,800.79**	**$ -**	**$ -**	**$ -**	**$ 658,134.06**

Appendix 1: Test Strip Installation and Impact Testing

(TTI Report)

Texas A&M Transportation Institute

Proving Ground

Test Report No. 607531-02-1-11
Test Report Date: March 2018

STANDARD DELINEATOR TESTING SPECIFIC TO MANAGED LANE USE FOR OPTIMIZATION OF SERVICE LIFE – PHASE 2

by

Nathan D. Schulz
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and

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Contract No.: 800007664-01 (BDV29)
Test Nos.: 607531-02 1 through 11

Sponsored by
State of Florida Department of Transportation

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Nathan D. Schulz
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16. Abstract

Delineators have become popular across the United States and are being used in several different applications with unique impact conditions and/or impact frequency. Recently, the Texas and Florida Departments of Transportation (TxDOT and FDOT) developed a categorical testing specification for evaluating the impact performance of delineators for given applications, including express lane markers (ELMs). The researchers focused on developing a reproducible test method and attempted to reproduce failure modes witnessed through field observations. The researchers also attempted to optimize the testing standard to minimize the cost and effort to evaluate the products.

Testing was performed on an Open Graded Friction Course (OGFC) and a concrete surface above the required 81°F ambient temperature to evaluate impact durability performance for products in warm weather. While testing at lower temperatures produced several notable failure of the attachment methods, this round of testing in warm temperatures produced few notable failure of the attachment methods. The main failure mechanism was the delineator posts fracturing and failure to restore to specified list/lean values. In addition, a minimum performance level specification was recommend based on testing under this project and a previous project 605601[(2)]. It is recommended that a product tested on an asphalt and concrete surface have a combined average that meets a minimum of 150 tire impacts and 50 bumper impacts resisted. In addition, the product's performance on asphalt or concrete should meet a minimum 150 tire impacts and 45 bumper impacts resisted.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSTIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
	NOTE: volumes greater than 1000L shall be shown in m^3			
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5(F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	$candela/m^2$	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSTIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	Square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	$candela/m^2$	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lb/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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CHAPTER 1. INTRODUCTION

(A) 1.1 BACKGROUND

Delineators have four main parts: the retroreflective sheeting (required for nighttime use), the post (can be various colors), the mechanism that connects the post and the base (typically a proprietary component). Figure 1.1 shows these parts that comprise one delineator.

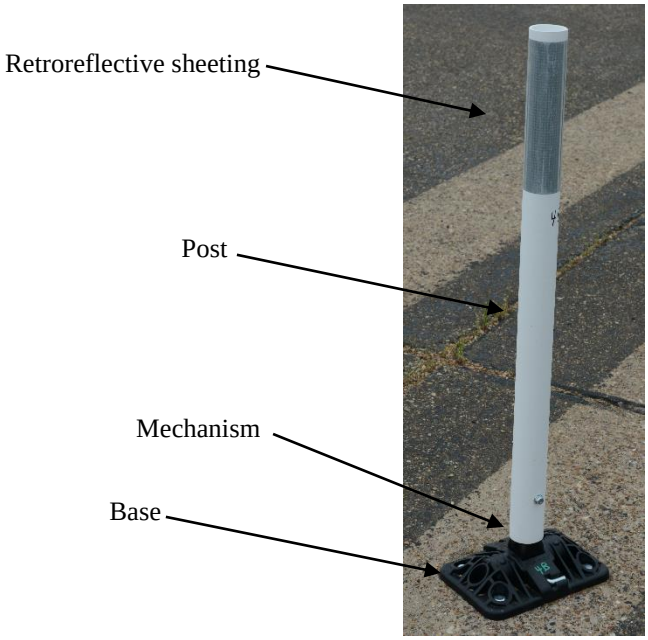


Figure 0.1 Delineator Parts

When installed, there are two additional considerations: the attachment method (connects the base to the pavement) and the pavement. Any of these components may fail when the delineator is struck. Based on past efforts, the researchers developed a list of failure modes, which are described below:

Sheeting failure: The retroreflective sheeting is damaged from abrasions or tearing and is not providing sufficient retroreflectivity at night.

Post failure to restore: The post is kinked or ruptured above the connection to the mechanism. This usually occurs around vehicle bumper height.

Post failure at connection: The post is fractured near the bottom where it connects to the mechanism. This includes failures where the post is completely missing from the mechanism.

Mechanism failure: The proprietary connection has failed and no longer keeps the post erect.

Base failure: The base (or mechanism housing) may potentially become fractured. While conceivable, this type of failure has not been seen in past research efforts.

Attachment failure: The attachment has become completely separated from either the base or the pavement.

Pavement failure: The entire delineator is missing and a portion of the pavement is also missing.

(B) 1.2 INITIAL TESTING OF DELINEATOR PRODUCTS

Delineators have become popular across the United States and are being used in several different applications with unique impact conditions and/or impact frequency. Recently, the Texas and Florida Departments of Transportation (TxDOT and FDOT) developed a categorical testing specification for evaluating the impact performance of delineators for given applications, including express lane markers (ELMs). The researchers focused on developing a reproducible test method and attempted to reproduce failure modes witnessed through field observations. The researchers also attempted to optimize the testing standard to minimize the cost and effort to evaluate the products.

(C) 1.3 SUMMARY OF STANDARD TESTING PROCEDURE (*1*, *2*)

Delineators under consideration must be installed on a concrete or asphalt pavement surface at a laboratory listed on FHWA's list of "Laboratories Accredited to Crash Test Roadside Safety Hardware." Each test deck should consist of eight samples installed in two parallel lines with four samples in each line. A maximum of 200 vehicle impacts per sample should be performed. A tire impact should be performed by the vehicle impacting the sample with the centerline of the sample aligned with the centerline of the vehicle tire. A bumper impact should be performed by the vehicle impacting the sample with the front bumper at the ⅓-point of the vehicle. To pass the evaluation criteria when mounted on a concrete surface, the delineators must meet and be able to withstand two minimum requirements: 1) 150 tire impacts, and 2) 45 bumper impacts. Additional testing must be performed to develop a minimum requirement for delineators tested on an asphalt surface.

(D) IMPACT TESTING PROCEDURE

TTI researchers developed the following testing procedure and product specification under TxDOT study 0-6772-1[(1)] and FDOT Project No. 605601[(2)]. The procedure utilized in the testing that is detailed in this summary report is summarized below:

(E) 2.1 PURPOSE

To define a standard method for evaluating a managed lane marker's impact performance with the intention of qualifying products that will minimize long-term maintenance costs.

(F) 2.2 SCOPE

Primary offices affected by this procedure include the State Materials Office (SMO), State Construction Office (SCO), District Construction Offices (DCO), District Materials Offices (DMO), and Resident Construction Offices (RCO).

(G) 2.3 BACKGROUND

This standard was developed to provide a fair, efficient, and repeatable method of evaluating the impact performance of a Managed Lane Marker.

(H) 2.4 MANAGED LANE MARKER SPECIFICATIONS

These specifications are necessary to unify critical design and aesthetic properties of the managed lane markers.

(i) 2.4.1 Dimension Requirements

The post shall have a minimum width of 2 inches perpendicular to traffic flow and generally provide a height of 36 inches above the pavement surface.

(j) 2.4.2 Color Requirements

The post shall be opaque white. The yellowness index shall not exceed 12 when tested in accordance with ASTM D1925 or ASTM E313. The daylight 45°, 0° luminous directional reflectance shall be a minimum of 70 when tested in accordance with ASTM E1347.

(k) 2.4.3 Retroreflective Sheeting Requirements

The retroreflective sheeting shall be Types IV or V and meet the requirements of Section 994 and shall be constructed of a reboundable material as defined in ASTM D4956 S2. The retroreflective sheeting shall have a minimum projected area of 18 square inches.

(l) 2.4.4 Attachment Method

Attachment methods are not restricted. Each attachment method and product will be individually considered, tested, and qualified.

(M) 2.5 IMPACT TESTING

All products shall be individually tested and qualified at an approved testing facility. All products must be tested using the same post, base, attachment method, hardware, and epoxy used in the field. Testing facilities will follow testing methodology described herein.

(n) 2.5.1 Approved Testing Facilities

Testing shall be performed by a laboratory listed on Federal Highway Administration's (FHWA's) list of "Laboratories Accredited to Crash Test Roadside Safety Hardware." A full list of approved labs can be found on FHWA's website at: http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/laboratories/.

(o) 2.5.2 Samples

A minimum number of 9 samples will be randomly selected and submitted to the selected lab for evaluation. One sample will be used for dimensional verification and material properties testing. Generic drawings and material specifications will be submitted along with samples.

(p) 2.5.3 Drawings

Generic drawings shall be provided. The generic drawings of the product shall include the following minimum dimensions: overall height, post wall thickness, post diameter, attachment method, base diameter, and base height.

(q) 2.5.4 Verification of Material and Dimensional Properties

One sample will be randomly selected for additional destructive lab testing to verify/document material and dimensional properties.

(r) 2.5.4.1 Dimensional Verification

One sample will be utilized to verify that the product is constructed according to drawings provided and to gather additional dimensional information that may not have been provided in generic drawings.

(s) 2.5.4.2 Material Property Testing

The same sample used for dimensional verification will be utilized for destructive testing to document material and physical properties of the post. Below is a list of laboratory tests to be performed:

Test Name	ASTM Number	Criteria
ASH Test	D5630	Documentation Only
Density and Specific Gravity	D792	Documentation Only
Tensile Strength and Elongation	D638-08	Documentation Only
Accelerated Weathering	G154-06	Documentation Only
Daylight Luminance	E1347	See Section 1.5.2

(t) *2.5.4.3 Attachment Methods*

All attachment methods/products shall be evaluated for impact performance. The evaluation is product specific and equivalencies are not permitted. A minimum of four samples of each product shall be tested.

(u) *2.5.4.4 Retroreflective Sheeting*

All retroreflective sheeting shall be evaluated for impact performance. The evaluation is product specific and equivalencies are not permitted. A minimum of four samples of each sheeting material shall be tested.

(v) 2.5.5 Installation

This section will describe how the test installation shall be constructed. Samples should be grouped together by product model, attachment method, and by sheeting type to simplify evaluation.

(w) *2.5.5.1 Vertical Installation Tolerance*

All samples shall be installed within 1 degree of vertical prior to the first impact.

(x) *2.5.5.2 Tire Impacts*

Half of the samples shall be installed such that the impact vehicle's front tire will traverse the base.

(y) *2.5.5.3 Bumper Impacts*

Half of the samples shall be installed such that the impacting vehicle's bumper will contact the post as the vehicle passes over without the base or post coming in contact with the tire.

(z) *2.5.5.4 Orientation of Samples*

Manufacturer has the option of defining the front face (0 degree) of the sample. If the manufacturer does not define the front face, then the lab will use reasonable judgement to determine the front face. Half of the bumper and half of the tire impact samples will be installed with the front face perpendicular to the path of the impacting vehicle (0 degree). The remaining samples will be rotated 25 degrees. The testing lab will determine which direction of rotation (clockwise or counterclockwise) is more

critical. Impact testing will be performed on the more critical direction of rotation. The lab will evaluate the effect of bumper interaction with the post and base. The samples will be installed such that the more critical orientation is tested. The more critical orientation is one that potentially induces more interaction with the vehicle and presents the higher risk of sample failure during testing.

(aa) *2.5.5.5 Multiple Configurations of Samples*

If multiple configurations of the same product are tested (i.e., different attachment methods or sheeting), an equal number of bumper and tire samples shall be installed for each configuration. Additionally, an equal number of 0 and 25 degree samples shall be installed for each configuration. The maximum number of samples that can be tested at one time is 12. If more than two attachment methods are proposed, the number of samples tested at one time can be increased at the testing facility's discretion with the addition 4 or more delineator samples to qualify each untested method. Should the number of attachment methods exceed the testing facility's ability to test, then testing can be performed on a separate set of samples at a later time.

(bb) *2.5.5.6 Spacing of Samples*

Samples will be installed in two parallel lines. One line will correspond to bumper impacts and the other will correspond to tire impacts. The spacing of these lines will be determined by the testing laboratory and shall ensure no interaction between any two samples on the test deck.

(cc) 2.5.6 Test Vehicle

The test vehicle should meet 1100C requirements set in current American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware* (*MASH*) with the following exceptions. The vehicle model year shall be within 10 model years of the date the test is performed. No vehicle instrumentation is required. Vehicle modifications described in TTI/TxDOT Report 0-6772-1 shall be followed (*2*). Additional modifications are allowed if it can be reasonably demonstrated that they will not adversely impact the results of the testing.

(dd) 2.5.7 Impact Conditions

For repeatability and unification of impact conditions across multiple products, all testing shall be performed under the following conditions.

(ee) *2.5.7.1 Temperature*

All impacts shall occur at an ambient temperature above 81°F.

(ff) *2.5.7.2 Impact Speed*

All impacts shall occur at a target impact speed of 70 mph ±5 mph. A test sequence that has 60 percent or more of impacts less than 70 mph should be considered invalid.

To verify the speed of the vehicle a digital speedometer is mounted on the windshield of the vehicle as seen in Figure 2.1. This digital speedometer was GPS verified to ensure the accuracy of the speed reading.

Figure 2.1. Edge Insight Monitor.

(gg) *2.5.7.3 Evaluation Criteria*

The lab will monitor and document list/lean, damage to post/base, damage to retroreflective sheeting, and failure to restore to an upright position.

(hh) *2.5.7.4 Sample Failure Criteria*

A sample shall be considered failed should it not restore within 15° of vertical in **any direction**. The sample should also be considered failed should the sample rupture (>50 percent of cross section) or if it should become detached from the test surface (partially or fully). The lab shall observe the performance of the samples during

testing and shall halt testing should a sample appear to not restore within 15° of vertical. Samples are allowed up to 5 minutes after the last impact to fully restore. Testing shall be postponed until all samples are deemed within 15° of vertical or the suspect sample is deemed failed.

(ii) *2.5.7.5 Sheeting*

While there is no specific requirement for sheeting performance, the performance and abrasion resistance shall be documented through photos as described in Section 1.6.9.

(jj) 2.5.8 Documentation

The following categories define the minimum amount of documentation required to be provided as part of the report or in addition to the report. Additional information can be provided should the manufacturer or testing laboratory desire to do so. Samples should be numbered so a reviewer can easily determine which product is being reviewed and whether the product is being impacted by the vehicle bumper or tire. All sample components should be labeled using this numbering method to aid in identifying samples after testing is completed (should further study be required).

(kk) *2.5.8.1 Material Classification*

Generic material properties provided by manufacturer shall be included in the report.

(ll) *2.5.8.2 Drawings*

Generic drawings as described in Section 2.6.3 shall be included in the report.

(mm) *2.5.8.3 Material Property Testing Results*

All material property testing reports shall be included in the report.

(nn) *2.5.8.4 Video Documentation*

Standard rate video shall be provided to document each impact performed. The impact number shall appear within view of the camera and shall not be added to the view after testing has been completed using video editing techniques. Failure to comply with this requirement will invalidate the testing results.

(oo) *2.5.8.5 Photo Documentation*

Extensive photo documentation shall be performed during testing. This includes documentation of the test installation, test vehicle, and test samples after the following impact numbers:

Prior to 1st impact
After 1st impact
After 5th impact
After 10th impact
After 50th impact

After 100th impact
After 150th impact
After 200th impact

Upon failure of any test sample, testing shall stop and the condition of the sample at the time of failure shall be documented. When documenting each sample, the following photos should be taken: photo of identifying label for test sample, frontal face of sample, any newly observed damaged to sample, and a close up image of the retroreflective sheeting to document sheeting loss or damage.

(pp) *2.5.8.6 Photo Table*

A table of photos shall be included in the report for each sample tested. Each table should include an image of the frontal face of the sample, any newly discovered damage to the sample, and a close up image of the retroreflective sheeting. This table shall have an entry for each of the impacts described in Section 2.6.8.5 of this standard.

(qq) *2.5.8.7 Written Documentation*

A written test log should be maintained documenting the progression of the testing and documenting any failures.

(rr) 2.5.8.7.1 List/Lean

A log of list and lean shall be maintained for inclusion in the test report. List/lean shall be measured as shown in Figure 2.2. List and lean shall be documented after the following impacts:

Prior to 1st impact
After 1st impact
After 10th impact
After 100th impact
After 200th impact

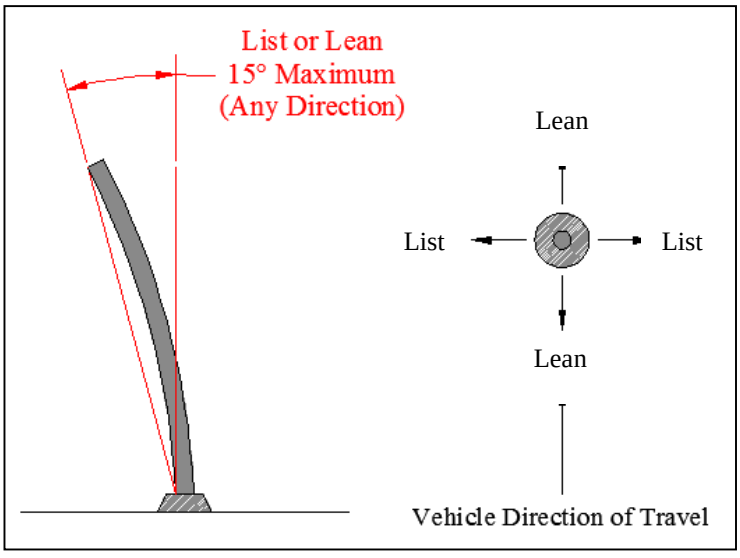


Figure 2.2. Measurement of List/Lean.

(ss) 2.5.8.7.2 Damage to Test Sample

A log of damage to samples should be maintained and shall include the impact number when the failure occurred and a description of the failure mode.

(tt) *2.5.8.8 Average Number of Impacts Resisted*

The testing lab shall calculate an average number of impacts resisted for: all samples, bumper impacts only, and tire impacts only. The resulting numbers shall be included in the final report.

(UU) 2.6 RE-EVALUATION

Should impact testing result in product performance the lab or manufacturer deems is not an accurate representation of the product's actual performance; the manufacturer has the option to resubmit the product for re-evaluation. The product can be reevaluated only one time without a significant change to the product to address failure modes witnessed in previous testing. When re-evaluating impact performance of a product, a minimum of nine samples of each attachment method and sheeting shall be evaluated.

(VV) 2.7 REQUALIFICATION

As impact durability of managed lane markers is directly tied to the profile and design of the impacting vehicle's bumper, it is recommended that products be requalified every 10 years.

CHAPTER 3. IMPACT DURABILITY TESTS

3.1. TEST FACILITY

From July 13, 2017 through October 26, 2017, TTI researchers performed nine impact durability tests at Texas A&M Transportation Institute (TTI) Proving Ground. Figure 3.1 shows the overhead view of the facility. The yellow line in Figure 3.1 represents the vehicle test path (approximately 0.8 mile loop). The blue, red, and green lines represent various locations used for sample testing. All test samples for this task were installed in the red and blue outlined areas (Asphalt and Concrete Surface Testing Area).

3.2. TEST INSTALLATION AND CONDITIONS

All tests for this task were installed on a Florida Standard Open Grade Friction Course (OGFC) or a Concrete surface. A detail of the TTI asphalt test deck can be found in Appendix A. Each test deck consisted of eight samples installed in two parallel lines with four samples in each line. One line of samples was positioned to receive bumper impacts. The second line of samples was positioned to receive tire impacts. A total of 200 vehicle impacts per sample were to be performed. A tire impact consisted of the vehicle impacting the sample with the centerline of the sample aligned with the centerline of the vehicle tire. During a tire impact, the vehicle tire traverses the sample. A bumper impact consisted of the vehicle impacting the sample with the front bumper at the ⅓-point of the vehicle. The bumper and tire impacts were performed simultaneously in a single pass of the vehicle. The vehicle was traveling at a nominal speed of 70 mph when impacting the samples, and at an ambient temperature greater than 81°F. Photographs and list/lean measurements were taken according to previously described testing procedures. These procedures are detailed in Chapter 2 of this report.

3.3. MATERIAL SAMPLING RESULTS

According to the procedures specified in Section 2.5.4, material and dimensional tests were conducted on a random sample for the nine different product submissions. Different labs were used to perform the required material testing. Documentation of the material testing for each random sample can be found in Appendix B. The documentation for the dimensional testing and verification for each product can be found in Table 3.1. For each product a random sample was selected and cut to measure the wall thickness at four locations (A, B, C, and D) around the circumference of the post.

Figure 3.1. TTI Test Facility.

Table 3.1. Wall Thickness Measurements for Product Samples.

	Wall Thickness (in)			
	A	B	C	D
Pexco City Post Glue Down Sample – White Post	0.134	0.145	0.150	0.143
Pexco City Post Surface Mount Mechanical Anchor Sample	0.156	0.143	0.150	0.143
Pexco City Post Surface Mount Anchor Cup Sample	0.139	0.127	0.142	0.140
Pexco City Post Glue Down Sample – Orange Post	0.151	0.142	0.137	0.145
Safe-Hit Dura-Post Surface Mount Epoxy Sample	0.157	0.152	0.152	0.159
Flexstake 780 Series 9-inch Round Base Surface Mount Sample	0.118	0.147	0.140	0.128
Flexstake 780 Series 10-inch x 24-inch Base Surface Mount Sample	0.144	0.130	0.122	0.132
Safe-Hit Dura-Post Surface Mount Mechanical Anchor Sample	0.140	0.184	0.180	0.146
eNdoto Evelux Post Sample - Epoxy	0.167	0.157	0.173	0.181
eNdoto Evelux Post Sample – Mechanical Anchor	0.163	0.155	0.161	0.157

3.4. IMPACT DURABILITY TEST NO. 607531-02-1

(ww) 3.4.1 Pexco City Post 8GD36ORG101 Glue Down Sample – Epoxy

Test No. 607531-02-1, performed on July 17, 2017, was an impact durability test on 36-inch Pexco – Davidson Traffic Control Products' City Post 8GD36ORG101 Glue Down Samples secured with FIRMmarker™ #18M900C20 2-part epoxy adhesive on asphalt. Detailed diagrams of the test samples and test layout can be found in Figures 3.2 and 3.3. Figure 3.4 shows images of the test sample setup and impact vehicle at the beginning of testing. Figure 3.5 shows the test setup and impact vehicle after testing was completed. No particular orientation was specified for the samples due to the symmetry of the delineator post.

(xx) 3.4.2 Impact Performance

Test No. 607531-02-1 yielded the results shown in Table 3.2. For the Pexco City Post 8GD36ORG101 Glue Down Sample, seven samples failed to resist 200 impacts. A failure to restore to within 15 degrees of vertical was observed for delineator #4B on run 3, delineator #3B on run 10, delineator #1B on run 54, delineator #2B on run 60, delineator #2T on run 168, and delineator #3T on run 189. Delineator #1T had a tear of more than 50% of the cross on run 189. Delineator #4T completed all 200 runs. Ambient temperature was greater than or equal to 82°F throughout the conducted test.

The primary mode of failure was fracturing of the samples near the base and exceeding the maximum allowable degree of list/lean.

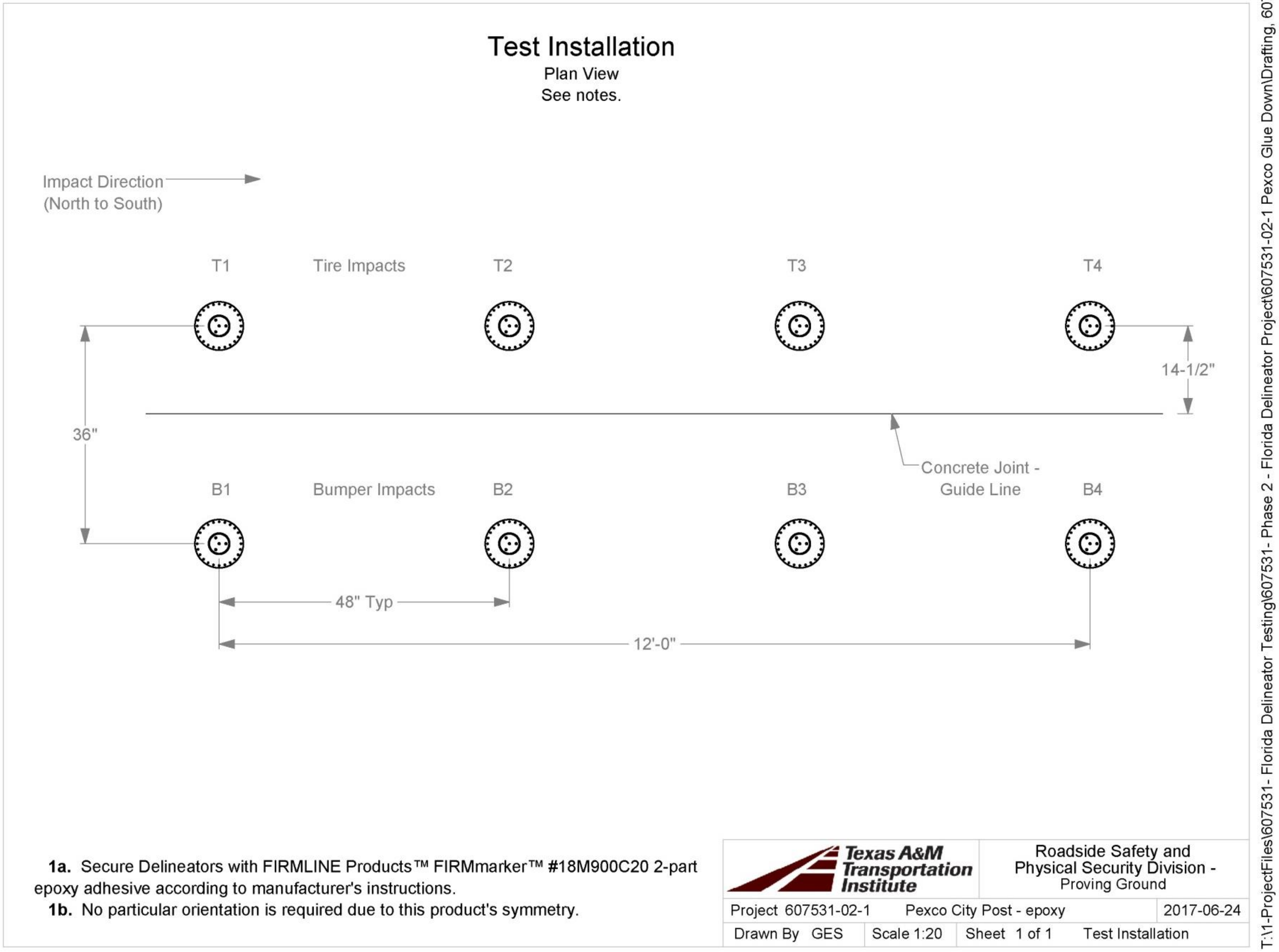


Figure 3.2. Test Setup.

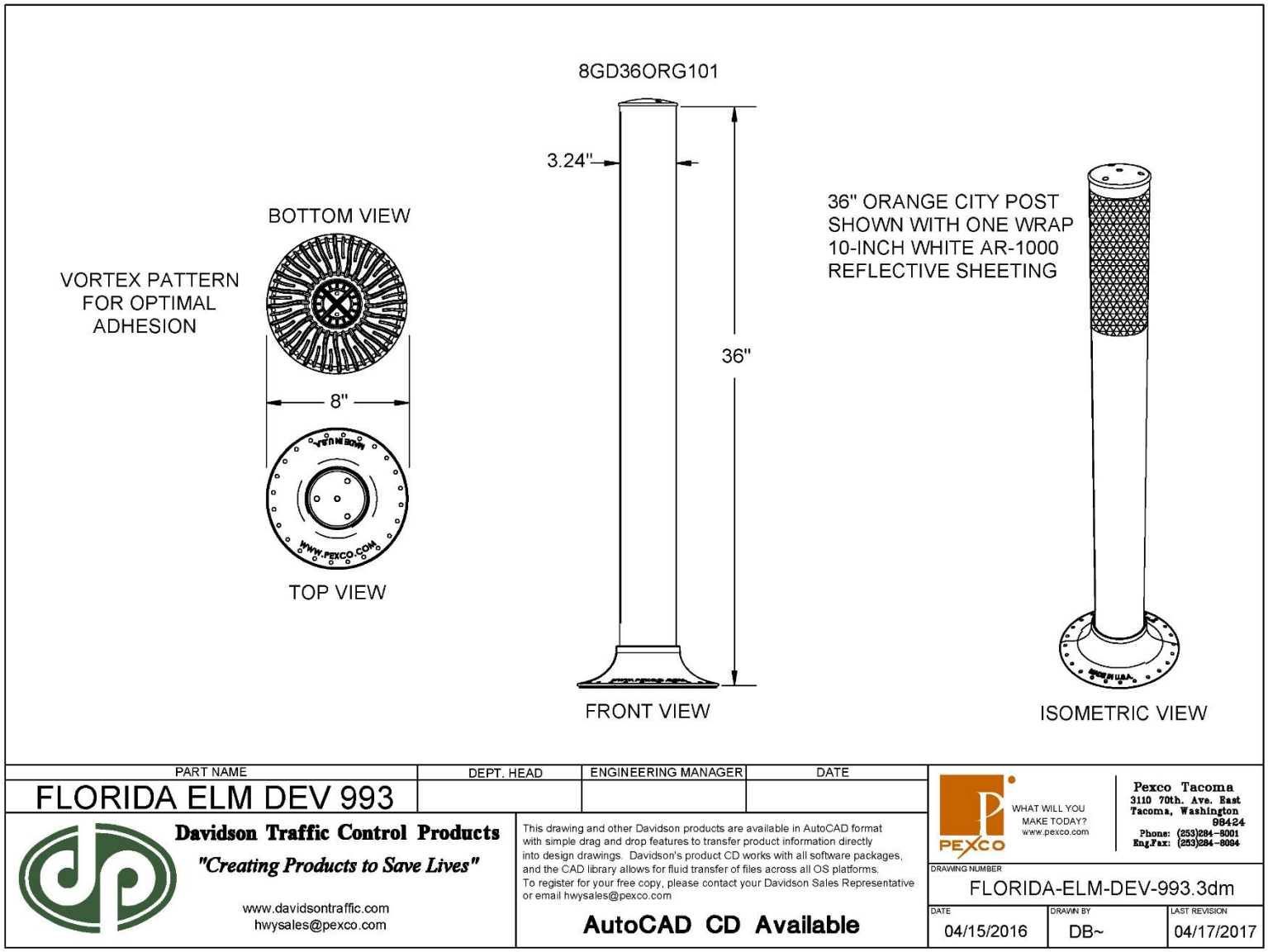


Figure 3.3. 607531-02-1 Sample Details.

Figure 3.4. 607531-02-1 Delineators and Test Vehicle before Testing.

Figure 3.5. 607531-02-1 Delineators and Test Vehicle after Testing.

Table 3.2. Test No. 607531-02-1 List/Lean Values.

#	Before		Run #1		Run #10		Run #100		Run #200		Failure	
	List	Lean	List	Lean	List	Lean	List	Lean	List	Lean	Run #	Mode
1T	89	89	89	89	90	87	89	86	-	-	189	Tear of Post near the base (more than 50% of cross section)
1B	90	89	89	87	89	86	-	-	-	-	54	Failure to restore due to fracture near base
2T	89	89	89	89	89	87	88	86	-	-	168	Failure to restore
2B	89	89	89	87	89	86	-	-	-	-	60	Failure to restore due to fracture near base
3T	89	89	89	89	90	89	88	86	-	-	189*	Failure to restore
3B	89	89	89	87	-	-	-	-	-	-	10	Post completely torn from base
4T	89	89	89	88	90	87	88	85	88	85	-	No failure
4B	89	89	89	87	-	-	-	-	-	-	3	Failure to restore due to fracture near base
Other Notes:												
Run 24, 61, 79, 96, 102, 139, 159, 173 under 70 mph												
T3 run 24 failure to restore (restored to 88 list and lean)												
114°F surface temperature at 2:05 p.m.												
132°F surface temperature at 4:25 p.m.												

3.5. IMPACT DURABILITY TEST NO. 607531-02-2

(yy) 3.5.1 Pexco Surface Mount City Post SM36ORG101 Sample – Mechanical Anchor

Test No. 607531-02-2, performed on September 20, 2017 and September 22, 2017, was an impact durability test on 36-inch tall Pexco 8SM36ORG101 mechanical anchor samples secured with BOLTHOLD™ Asphalt Anchors Model SP-10. Detailed diagrams of the test samples and test layout can be found in Figures 3.6 and 3.7. Figure 3.8 shows images of the test sample setup and impact vehicle at the beginning of testing. Figure 3.9 shows the test setup and impact vehicle after testing was completed. Each sample was secured with four bolts, equally spaced. Samples #1T, #1B, #3T, and #3B were positioned with the centerline of the sample parallel to the impact vehicle path. Samples #2T, #2B, #4T, and #4B were positioned with the centerline of the sample turned 25 degrees clockwise from the line parallel to the impact vehicle path.

(zz) 3.5.2 Impact Performance

Table 3.3 documents the list/lean and failure modes witnessed under Test No. 607531-02-2. All eight of the samples failed to resist 200 impacts. A failure to restore to within 15 degrees of vertical was observed for delineator #2B on run 74, delineator #4B on run 87, delineator #3B on run 108, delineator #3T on run 110, delineator #4T on run 124, delineator #2T on run 140, and delineator #1T on run 190. Delineator #1B completely tore from the base on run 95. Ambient temperature was greater than or equal to 82°F throughout the conducted test.

The primary mode of failure was fracturing of the samples near the base and exceeding the maximum allowable degree of list/lean.

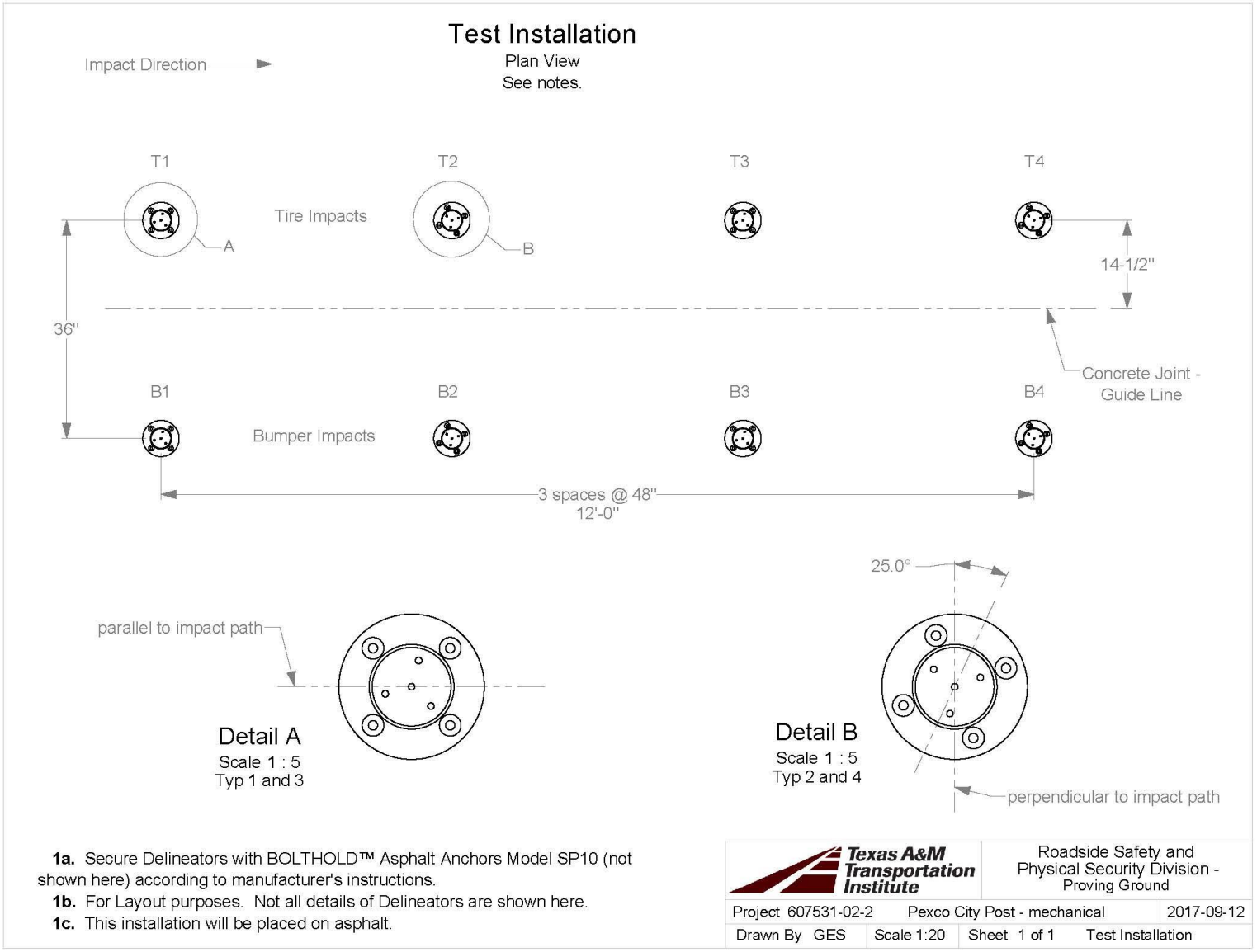


Figure 3.6. 607531-02-2 Test Setup and Sample Details.

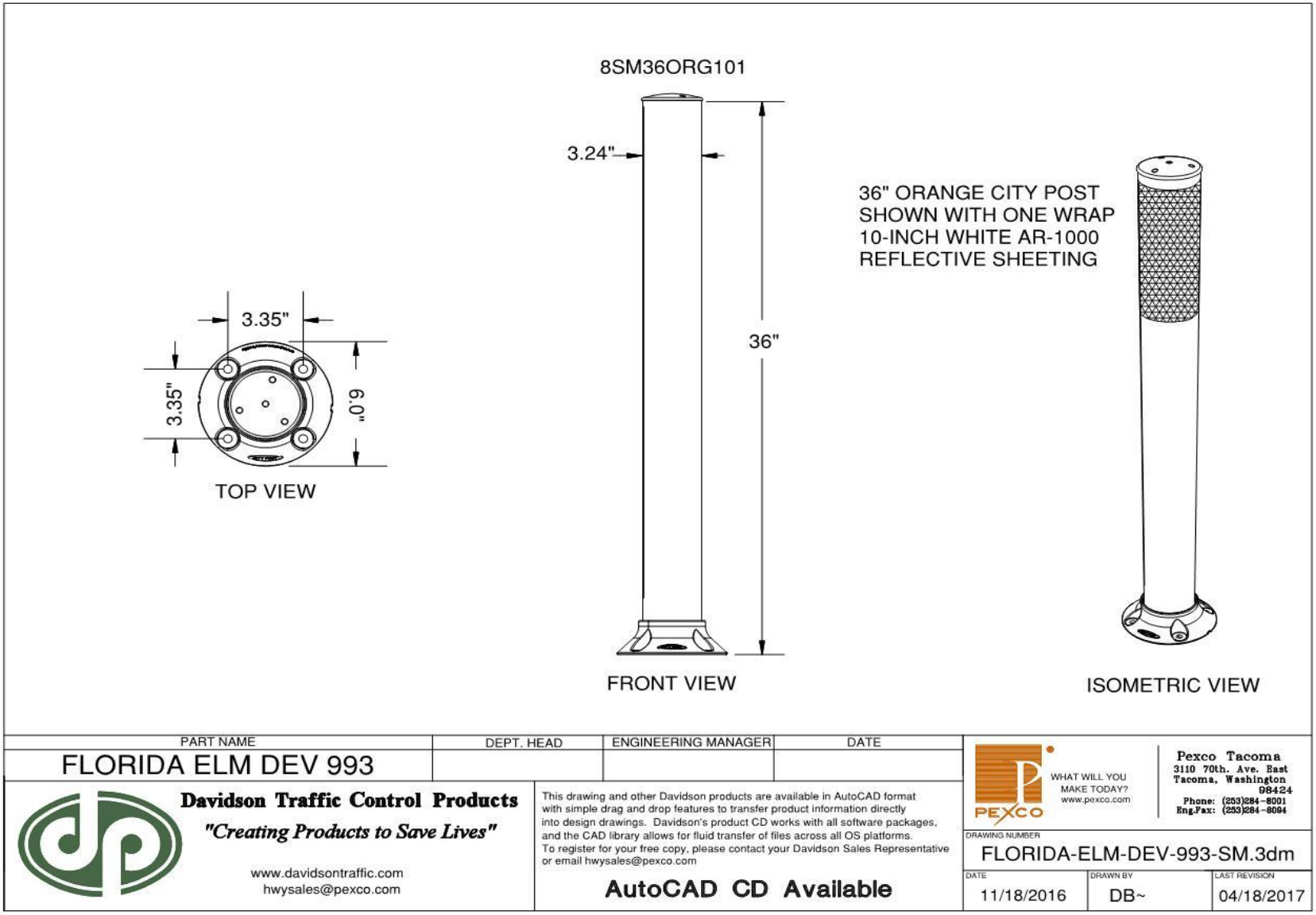


Figure 3.7. 607531-02-2 Sample Details.

Figure 3.8. 607531-2 Delineators and Test Vehicle before Testing.

Figure 3.9. 607531-2 Delineators and Test Vehicle after Testing.

Table 3.3. Test No. 607531-02-2 List/Lean Values.

#	Before		Run #1		Run #10		Run #100		Run #200		Failure	
	List	Lean	List	Lean	List	Lean	List	Lean	List	Lean	Run #	Mode
1T	90	90	90	90	89	90	88	87	-	-	190	Failure to restore due to post fracture
1B	89	90	89	90	90	85	-	-	-	-	95	Post completely torn from base
2T	90	90	90	90	89	89	88	86	-	-	140	Failure to restore
2B	89	89	90	90	90	87	-	-	-	-	74	Failure to restore / fracture near base
3T	89	89	89	90	90	89	89	87	-	-	110	Failure to restore due to post fracture
3B	89	90	89	88	88	86	88	83	-	-	108	Failure to restore
4T	89	90	89	90	90	89	89	87	-	-	124	Failure to restore
4B	90	89	90	88	90	86	-	-	-	-	87	Failure to restore / fracture near base
Other Notes:												
Runs 151-190 prformed on 2017-09-22												

3.6. IMPACT DURABILITY TEST NO. 607531-02-3

(aaa) 3.6.1 Pexco Surface Mount City Post Sample – Anchor Cup

Test No. 607531-02-3, performed on July 18, 2017, was an impact durability test on 36-inch Pexco City Post Samples secured with embedded anchor cups. Detailed diagrams of the test samples and test layout can be found in Figures 3.10 and 3.11. Figure 3.12 shows images of the test sample setup and impact vehicle at the beginning of testing. Figure 3.13 shows the test setup and impact vehicle after testing was completed.

(bbb) 3.6.2 Impact Performance

Table 3.4 documents the list/lean and failure modes witnessed under Test No. 607531-02-3. Seven of the samples failed to resist 200 impacts. A failure to restore to within 15 degrees of vertical was observed for delineator #1B on run 1, delineator #3T on run 3, delineator #2B on run 14, delineator #3B on run 19, delineator #4B on run 20, and delineator #4T on run 91. Delineator #2T completely tore from the base on run 3, and delineator #1T completed all 200 runs. Ambient temperature was greater than or equal to 82°F throughout the conducted test.

The primary mode of failure was exceeding the maximum allowable degree of list/lean and post fracture near the base.

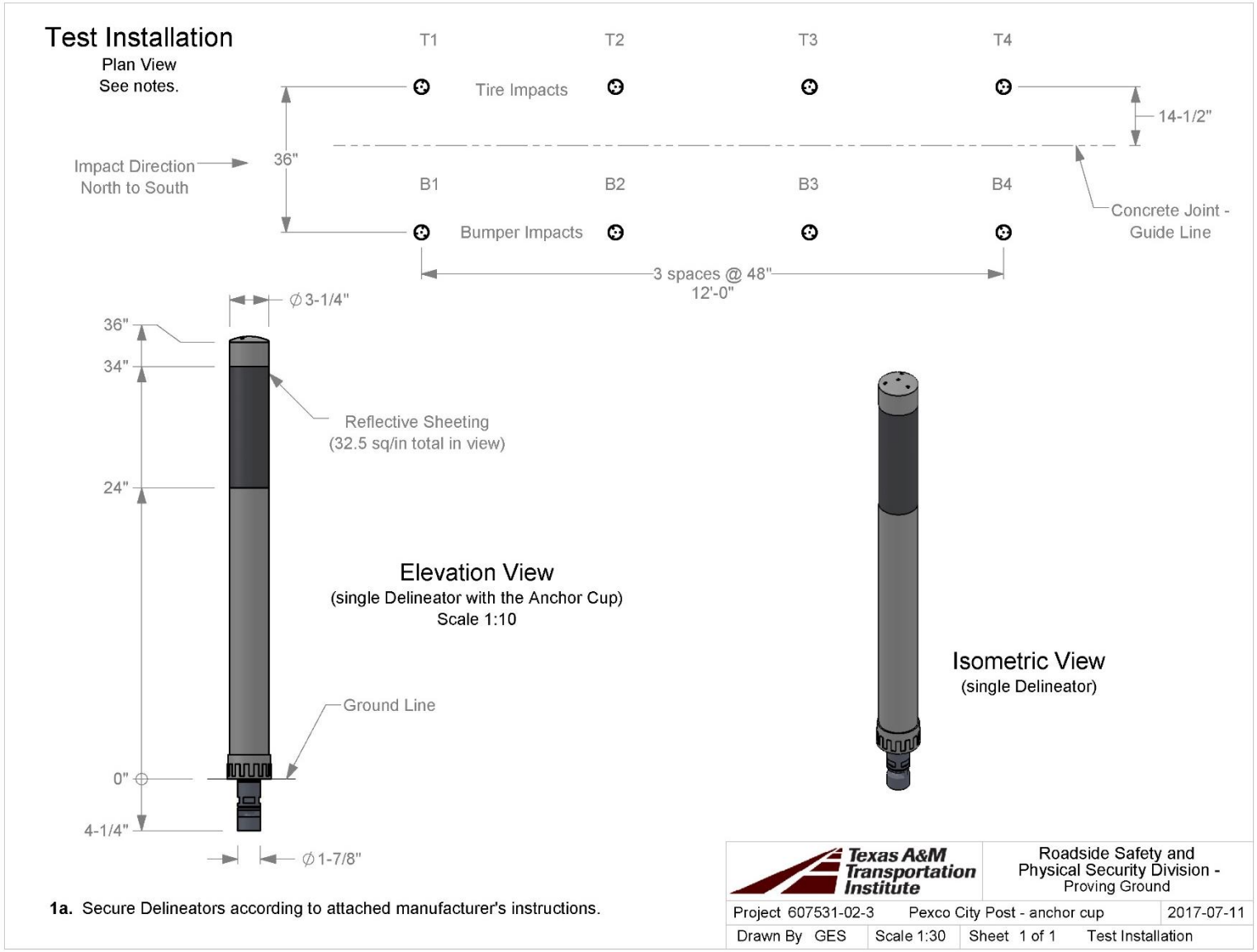


Figure 3.10. 607531-02-3 Test Setup.

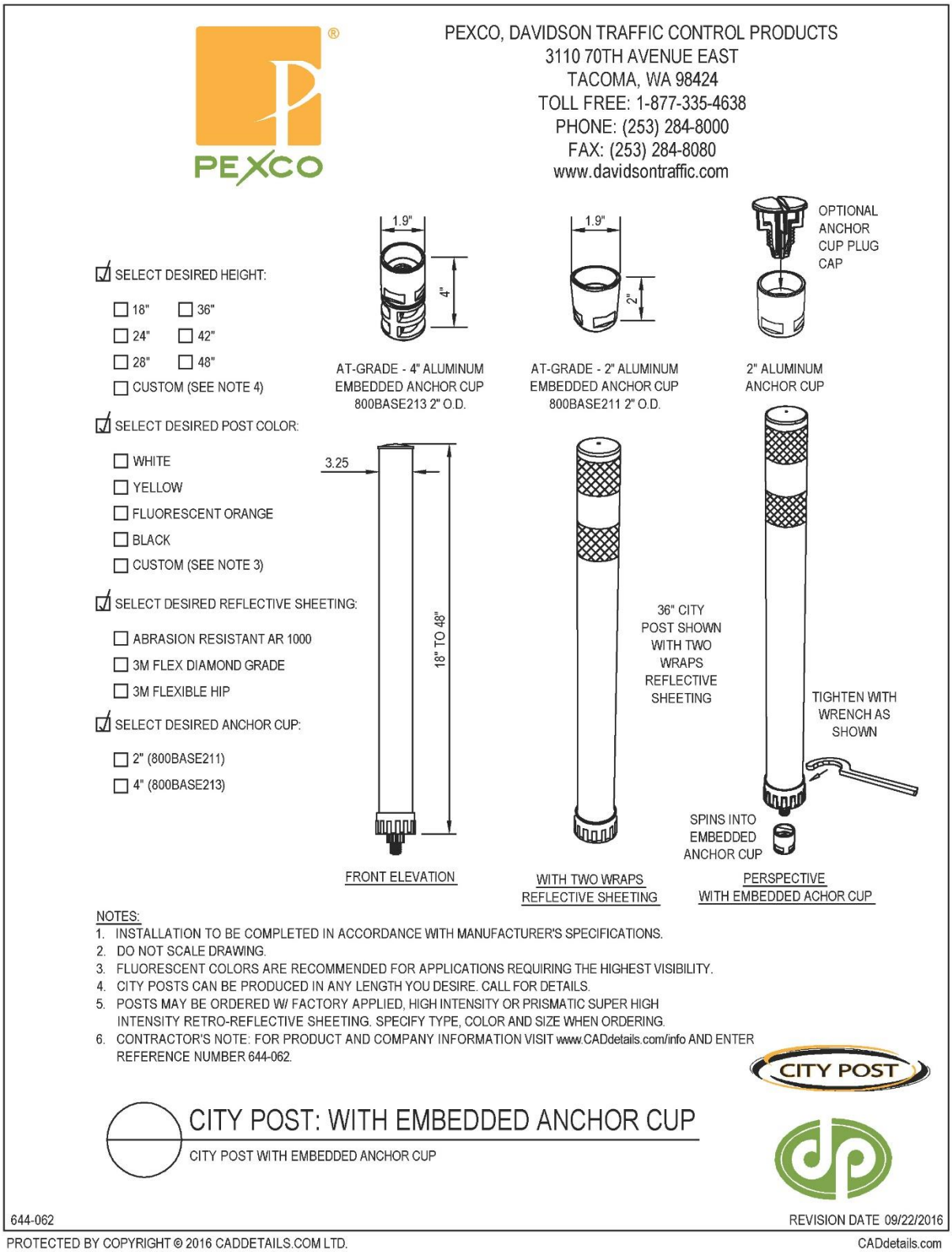


Figure 3.11. 607531-02-3 Test Sample Details.

Figure 3.12. 607531-02-3 Delineators and Test Vehicle before Testing.

Figure 3.13. 607531-02-3 Delineators and Test Vehicle after Testing.

Table 3.4. Test No. 607531-02-3 List/Lean Values.

#	Before		Run #1		Run #10		Run #100		Run #200		Failure	
	List	Lean	List	Lean	List	Lean	List	Lean	List	Lean	Run #	Mode
1T	88	89	88	89	89	87	88	86	87	85		
1B	90	89	-	-	-	-	-	-	-	-	1	Failure to restore
2T	89	89	88	86	-	-	-	-	-	-	3	Fractured at base
2B	89	89	89	87	90	84	-	-	-	-	14	Failure to restore
3T	89	89	90	88	-	-	-	-	-	-	3	Failure to restore
3B	89	87	88	85	-	-	-	-	-	-	19	Failure to restore
4T	90	88	89	89	88	90	-	-	-	-	91	Failure to restore
4B	90	90	89	88	89	85	-	-	-	-	20	Bolt pulled out of base/failed to restore
Other Notes:												
Runs 5, 26, 34, 57, 75, 107, 118, 136, 163 were lower than 70 mph												
1:50 p.m. 150°F surface temp												

3.7. IMPACT DURABILITY TEST NO. 607531-02-4

(ccc) 3.7.1 Pexco City Post 8GD36ORG101 Glue Down Sample

Test No. 607531-02-4, performed on September 19, 2017, was an impact durability test on Pexco City Post 8GD36ORG101 Glue Down Samples secured by E-BOND 1240/1241 2-part epoxy adhesive, 8 each on concrete and 8 each on asphalt. Detailed diagrams of the test samples and test layout can be found in Figures 3.14 through 3.16. Figures 3.17 and 3.18 show images of the test sample setup and impact vehicle at the beginning and after the testing on the concrete surface. Figures 3.19 and 3.20 show the test setup and impact vehicle at the beginning and after the testing on the asphalt surface.

(ddd) 3.7.2 Impact Performance

Table 3.5 documents the list/lean and failure modes witnessed under Test No. 607531-02-4. Seven of the Pexco City Post 8GD36ORG101 Glue Down samples failed to resist 200 impacts. Post fracture and/or failure to restore to within 15 degrees of vertical was observed for delineator #5B on run 10, delineator #7B on run 14, delineator #8B on run 76, delineator #4B on run 82, delineator #1B on run 84, delineator #3B on run 104, delineator #2B on run 154. Delineator #2T, #3T, #4T, #5T, and #7T had a tear of more than 50% of the cross section on runs 169, 98, 134, 198, and 98, respectively. The posts of delineators #6B, #8T, and #1T separated from the bases on runs 8, 15, and 22, respectively. Delineator #6T completed all 200 runs. Ambient temperature was greater than or equal to 82°F throughout the conducted test.

The primary mode of failure was tearing of the post approximately one foot above the base and fracture of the post at the base.

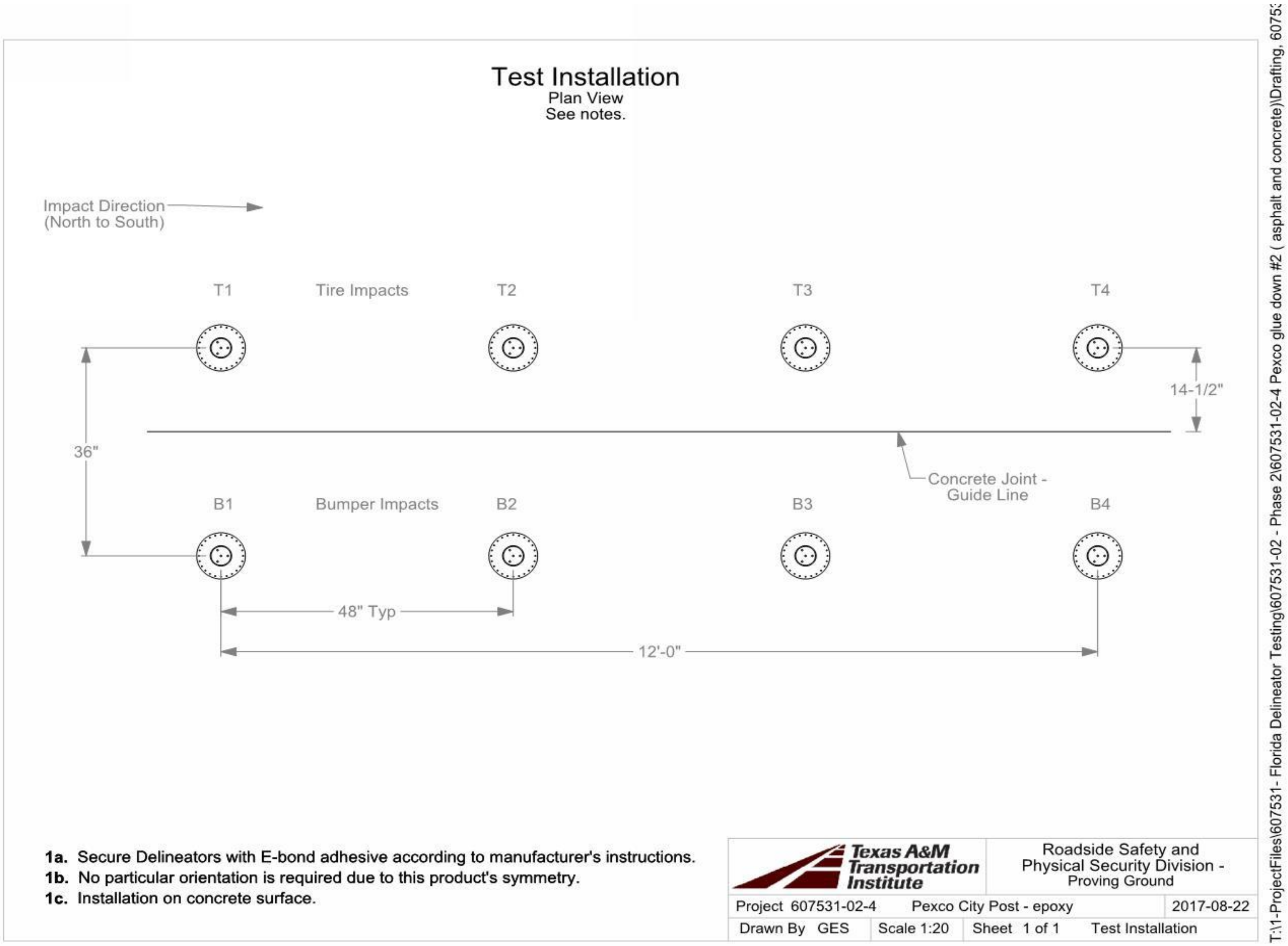


Figure 3.14. 607531-02-4 Test Setup Details on Concrete Surface.

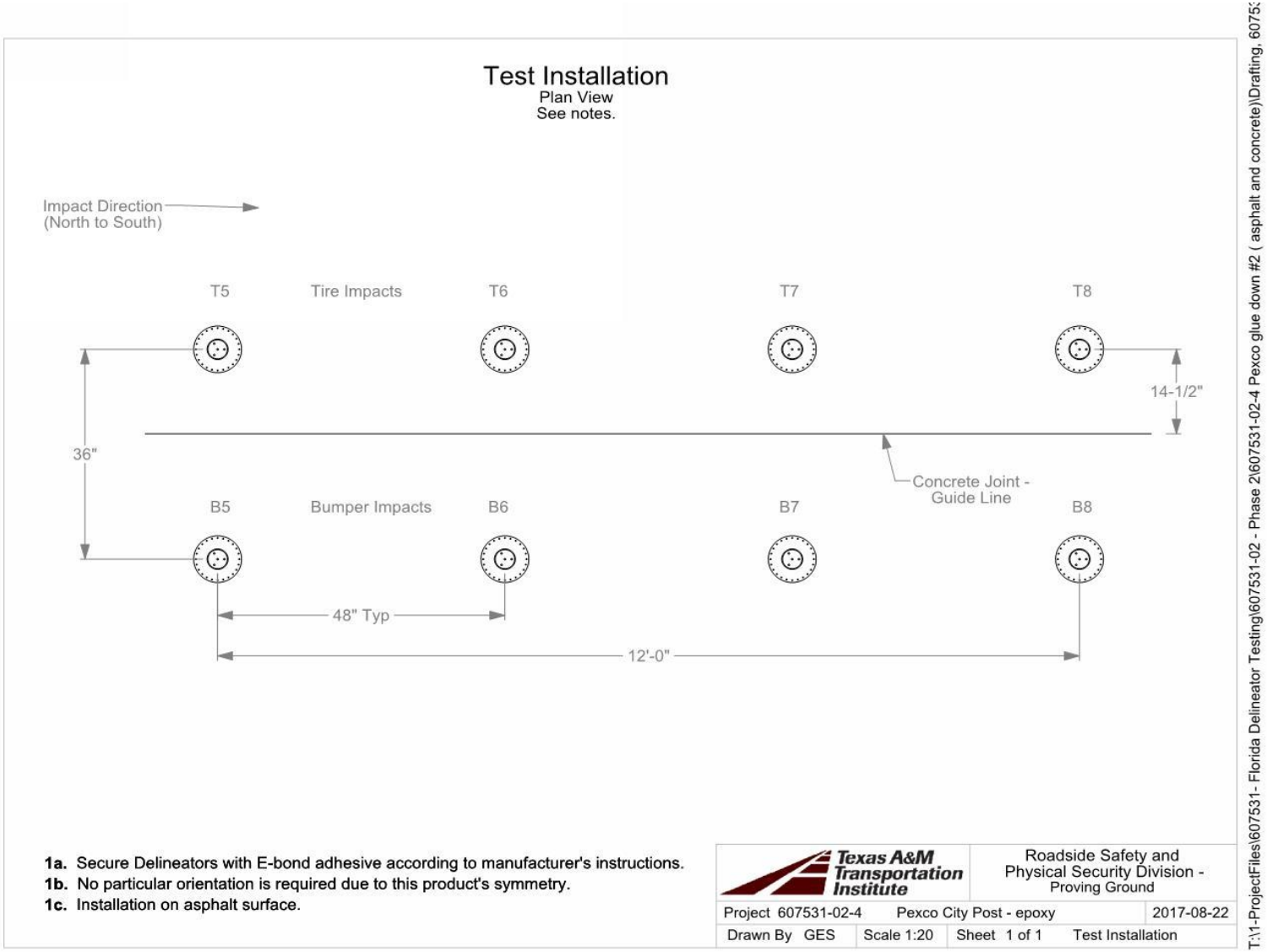


Figure 3.15. 607531-02-4 Test Setup Details on Asphalt Surface.

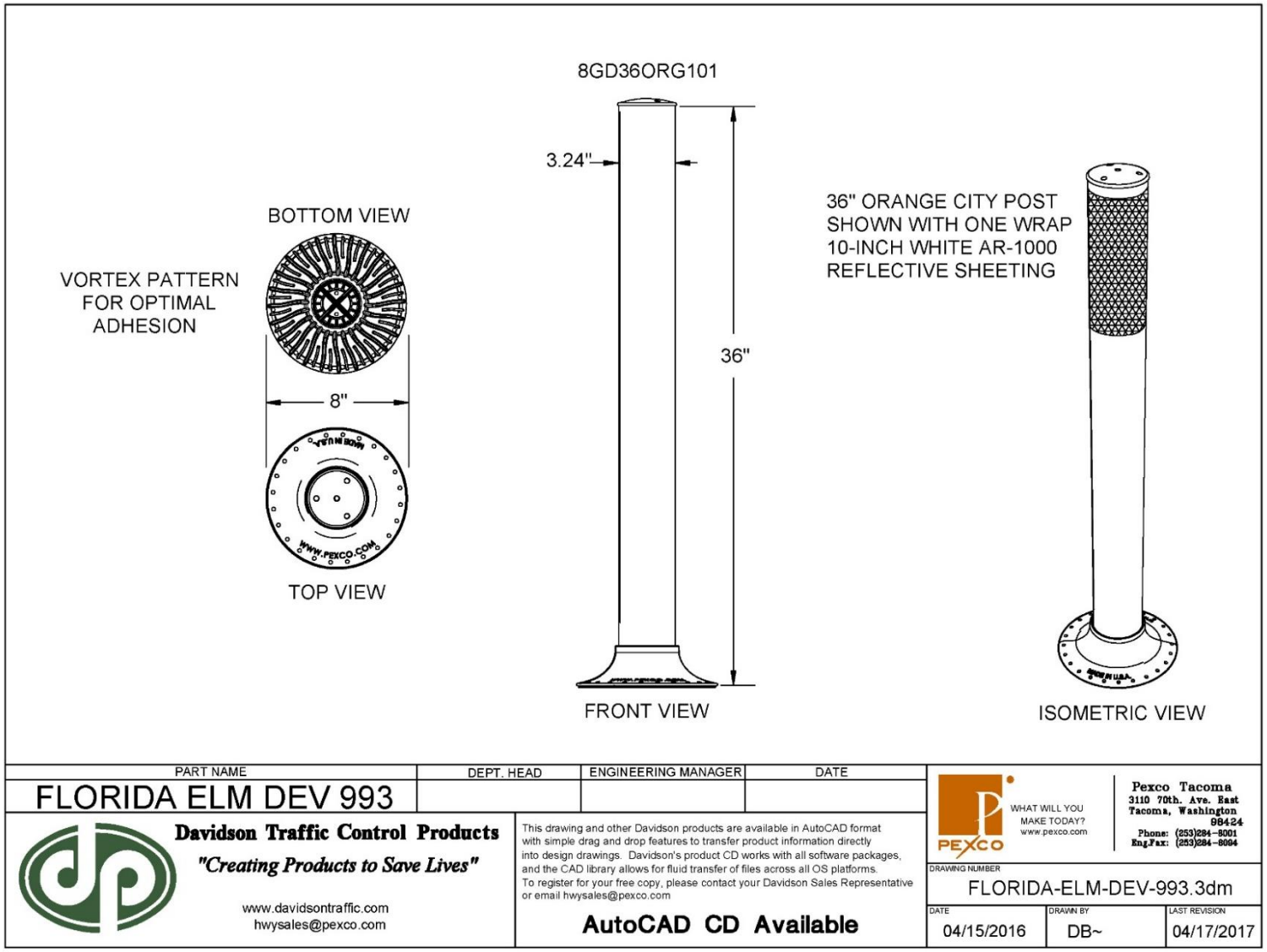


Figure 3.16. 607531-02-4 Test Sample Details.


Figure 3.17. 607531-02-4 Delineators and Test Vehicle before Testing (Concrete Surface).


Figure 3.18. 607531-02-4 Delineators and Test Vehicle after Testing (Concrete Surface).


Figure 3.19. 607531-02-4 Delineators and Test Vehicle before Testing (Asphalt Surface).


Figure 3.20. 607531-02-4 Delineators and Test Vehicle after Testing (Asphalt Surface).

Table 3.5. Test No. 607531-02-4 List/Lean Values.

#	Before		Run #1		Run #10		Run #100		Run #200		Failure	
	List	Lean	List	Lean	List	Lean	List	Lean	List	Lean	Run #	Mode
1T	89	89	90	89	89	88	-	-	-	-	15	Post fractured
1B	90	89	90	88	90	88	-	-	-	-	84	Post fractured at base
2T	90	89	90	89	88	88	88	87	-	-	169	Post tore ¾ through
2B	90	89	89	89	90	88	89	85	-	-	154	Post fractured at base
3T	89	90	90	90	89	89	-	-	-	-	98	Post tore ⅔ through
3B	89	89	89	89	89	88	89	85	-	-	104	Post fractured at base
4T	89	90	89	90	89	90	89	88	-	-	134	Post tore ¾ through
4B	89	89	89	88	89	87	-	-	-	-	82	Post fractured at base
5T	89	90	89	89	89	89	88	87	-	-	198	Post tore ¾ through
5B	89	87	89	86	-	-	-	-	-	-	10	Post fractured
6T	89	89	89	89	89	88	88	86	87	86	-	Completed 200 runs
6B	89	89	89	87	-	-	-	-	-	-	8	Post fractured
7T	90	90	89	89	89	89	-	-	-	-	98	Post tore ⅔ through
7B	89	89	89	88	89	87	-	-	-	-	14	Post fractured
8T	90	89	89	89	89	88	-	-	-	-	22	Post separated from base
8B	90	90	90	88	90	87	-	-	-	-	76	Post fractured at base
Other Notes:												
Runs 19, 48, 49, and 187 under 70 mph												

3.8. IMPACT DURABILITY TEST NO. 607531-02-5

(eee) 3.8.1 Safe-Hit Dura-Post™ Sample – Surface Mount Epoxy

Test No. 607531-02-5, performed on July 13, 2017, was an impact durability test on 36-inch Safe-Hit Dura-Post™ Samples. The base was secured to the asphalt surface using SHEPX-13-K1 epoxy for the first four posts (#1-2) and FIRMmarker™ #18M900C20 2-part epoxy adhesive for the second four posts (#3-4) according to manufacturer's instructions. Detailed diagrams of the test samples and test layout can be found in Figures 3.21 and 3.22.

Figure 3.23 shows images of the test sample setup and impact vehicle at the beginning of testing. Figure 3.24 shows the test setup and impact vehicle after testing was completed.

(fff) 3.8.2 Impact Performance

Table 3.6 documents the list/lean and failure modes witnessed under Test No. 607531-02-5. Four samples failed to resist 200 impacts. Delineators #2B, #3B, and #4B separated from the bases on run 22. A failure to restore to within 15 degrees of vertical was observed for delineator #1B on run 25. Delineators #1T, #2T, #3T, and #4T completed all 200 runs. Ambient temperature was greater than or equal to 82°F throughout the conducted test.

The primary mode of failure was post separation at the base. This was mainly caused by the pin tearing through the bottom of the post.

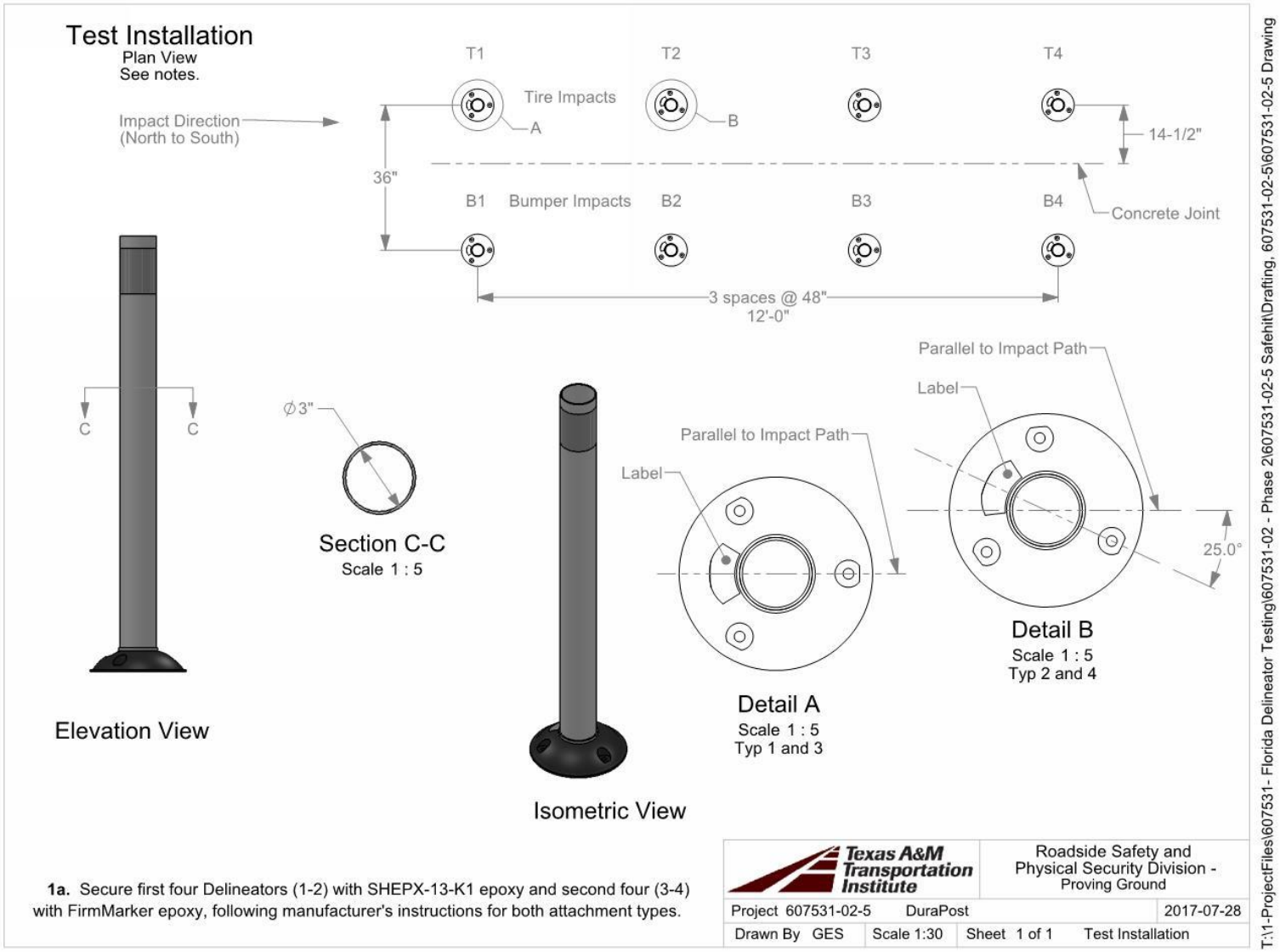


Figure 3.21. 607531-02-5 Test Setup.

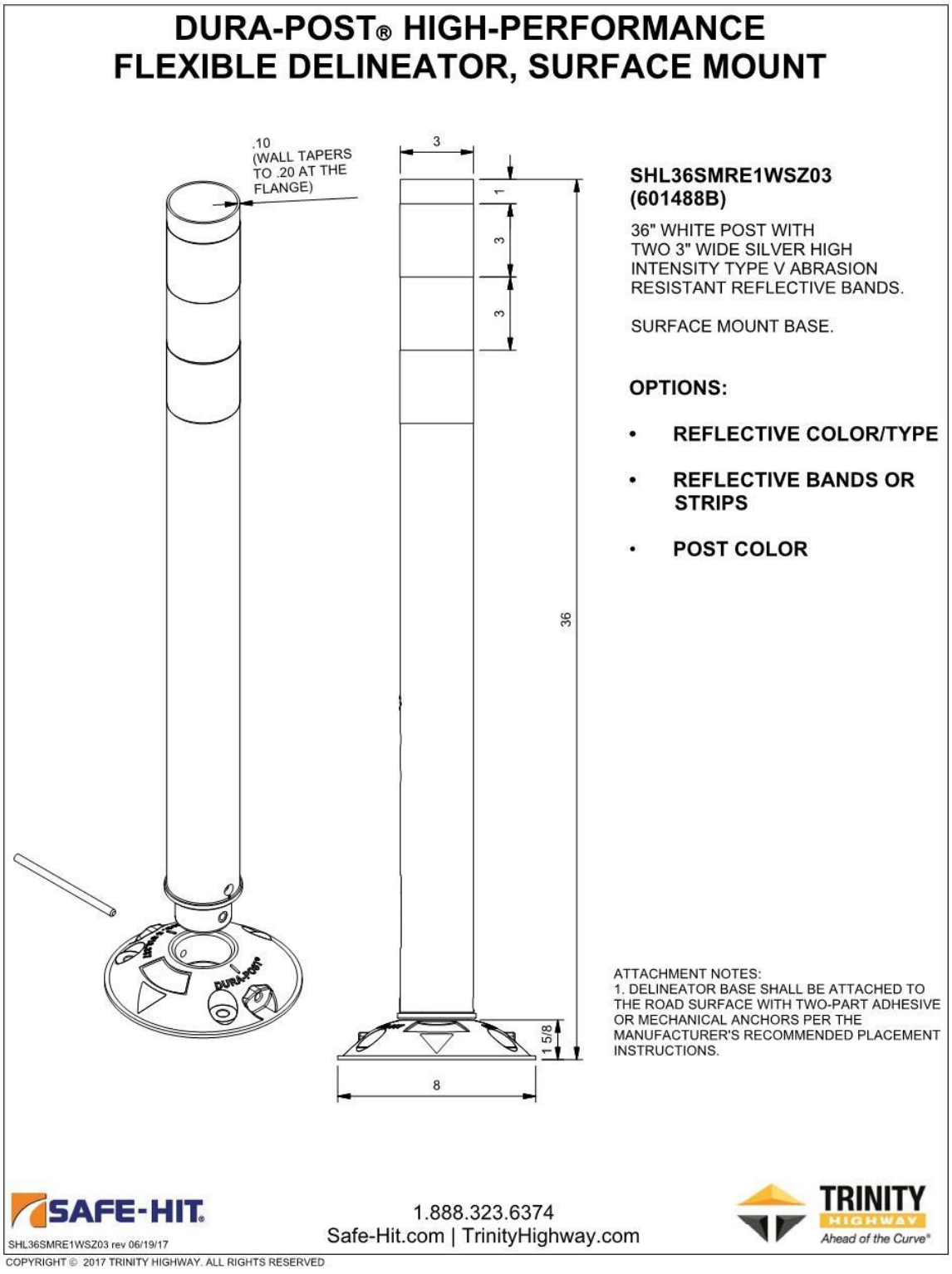


Figure 3.22. 607531-02-5 Test Sample Details.

Figure 3.23. 607531-02-5 Delineators and Test Vehicle before Testing.

Figure 3.24. 607531-02-5 Delineators and Test Vehicle after Testing.

Table 3.6. Test No. 607531-02-5 List/Lean Values.

#	Before		Run #1		Run #10		Run #100		Run #200		Failure	
	List	Lean	List	Lean	List	Lean	List	Lean	List	Lean	Run #	Mode
T1	89	90	90	87	89	87	87	87	85	84		No failure
B1	90	89	90	89	89	89	-	-	-	-	25	Failure to restore - 52°
T2	90	89	89	88	88	85	86	80	85	79		No failure
B2	90	89	89	87	86	82	-	-	-	-	22	Post separated from base
T3	90	89	88	87	88	86	86	83	84	82		No failure
B3	90	89	90	87	87	83	-	-	-	-	22	Post separated from base
T4	90	89	89	90	89	89	87	84	85	81		No failure
B4	90	90	89	87	90	86	-	-	-	-	22	Post separated from base
Other Notes:												
Run 2 and 114 under 70 mph												

3.9. IMPACT DURABILITY TEST NO. 607531-02-7

(ggg) 3.9.1 Flexstake 780 Series 9-inch Base Tubular Surface Mount Sample

Test No. 607531-02-7, performed on September 4 and September 18, 2017, was an impact durability test on Flexstake 780 Series 9-inch Base Tubular Surface Mount Samples secured to the concrete and asphalt surfaces using E-BOND 1240/1241 2-part epoxy adhesive, 8 each on concrete and 8 each on asphalt. Detailed diagrams of the test samples and test layout can be found in Figures 3.25 through 3.27. Figures 3.28 and 3.29 show images of the test sample setup and impact vehicle at the beginning and after testing on the concrete surface. Figures 3.30 and 3.31 show the test setup and impact vehicle at the beginning and after testing on the asphalt surface.

(hhh) 3.9.2 Impact Performance

Table 3.7 documents the list/lean and failure modes witnessed under Test No. 607531-02-7. Testing was discontinued after Run 127, per Sponsor's request. Thirteen of the Flexstake 780 Series 9-inch Base Tubular Surface Mount samples failed to resist 127 impacts. Delineators #2T, #4T, and #7T completed all 127 runs. All remaining delineators either tore or partially pulled off the base. Ambient temperature was greater than or equal to 82°F throughout the conducted test.

The primary mode of failure was tearing of the posts near the bolt connections.

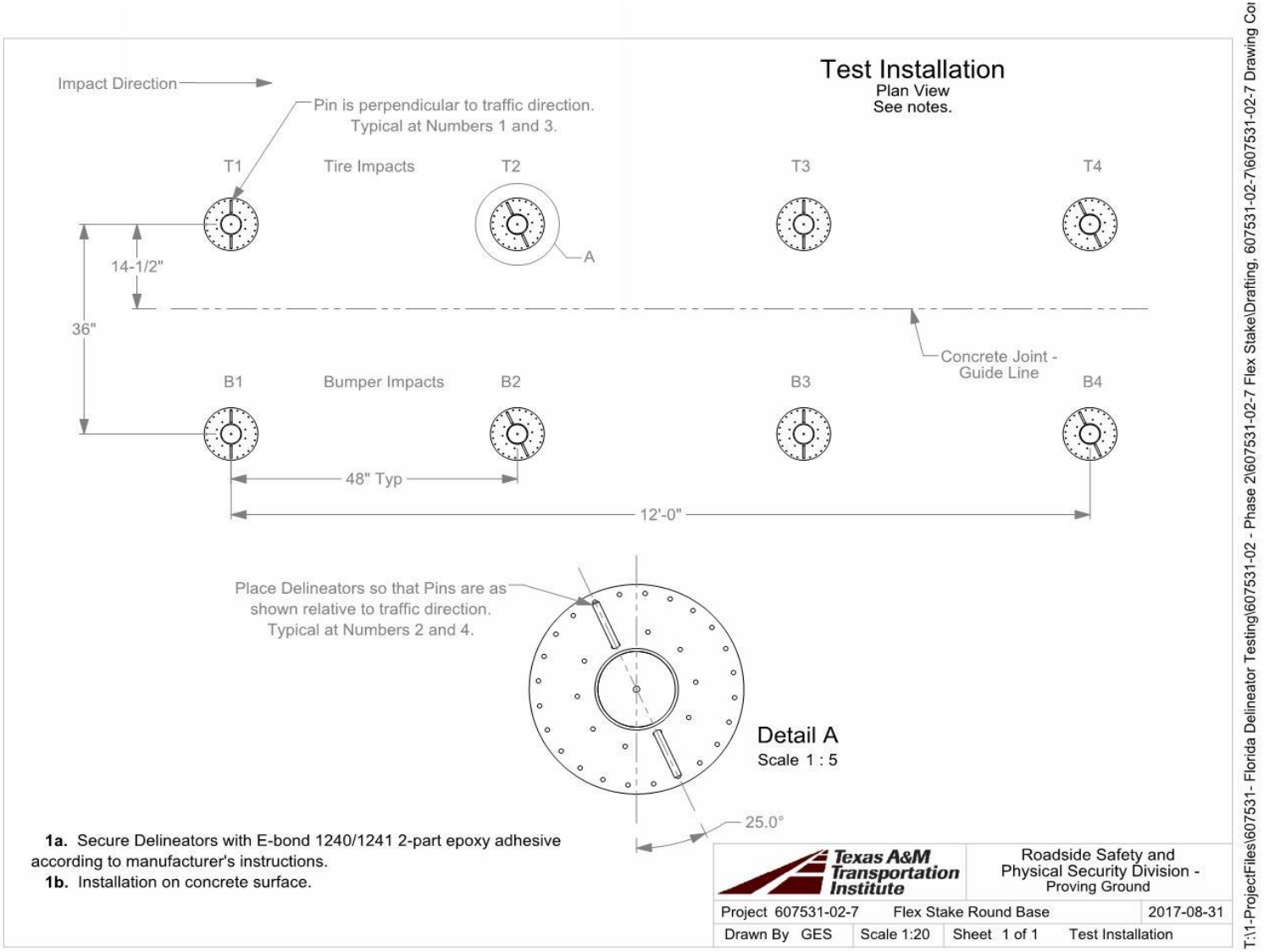


Figure 3.25. 607531-02-7 Test Setup on Concrete Surface.

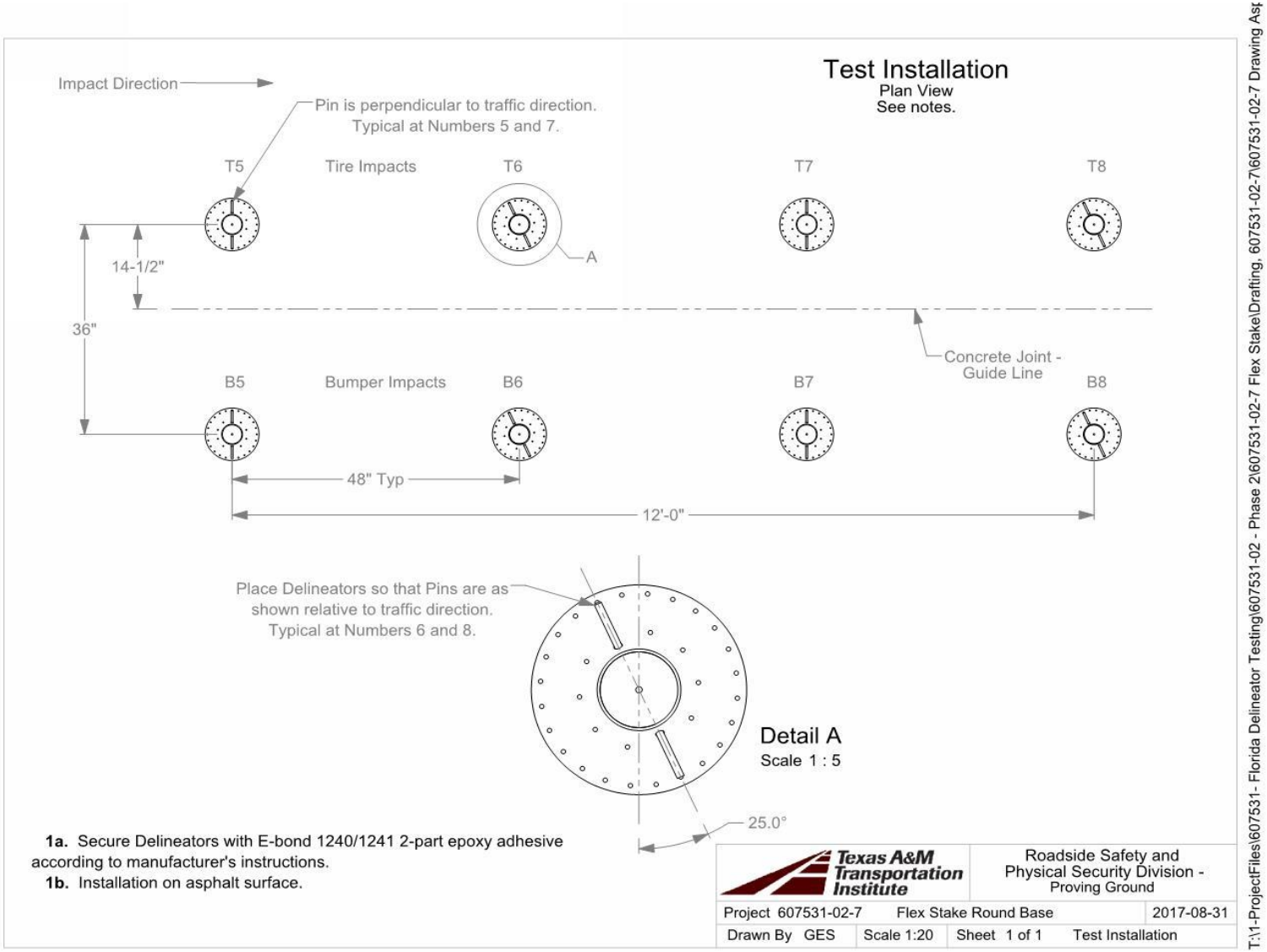


Figure 3.26. 607531-02-7 Test Setup on Asphalt Surface.

FLEXSTAKE
780 Series 9" Base

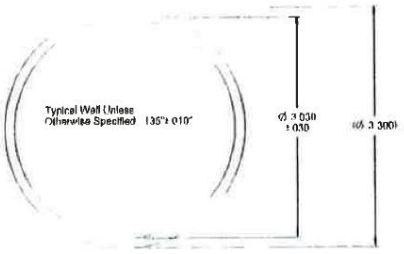
TUBULAR SURFACE
MOUNT DELINEATOR

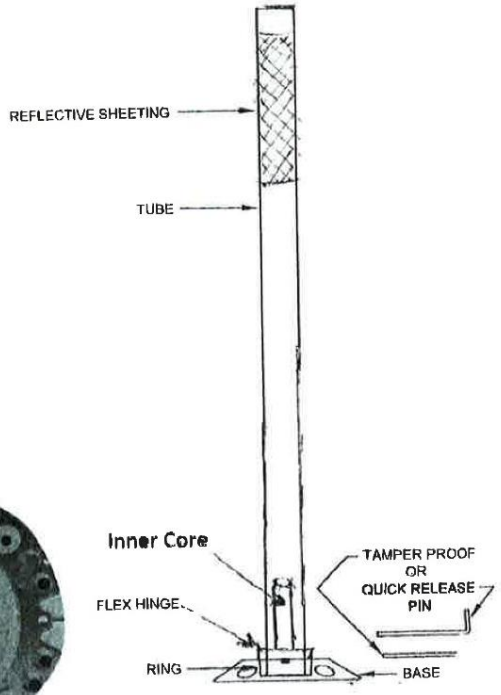
Reflective sheeting

Placement 2" from the top

Extending 10" vertical

Approximately 30 sq. inches in view





Base ABS

All other components are Urethane

Overall Height complete assembly 3'

Height of base 1.5" +/-

9" OD

BASE

(PLAN VIEW)

FLEXSTAKE, INC.
2150 Andrea Lane
Fort Myers, FL 33912

Patented

1-800- 348-9839 1-239- 481-3539 1-239-482-3539 (FAX)

Figure 3.27. 607531-02-7 Test Sample Details.

Figure 3.28. 607531-02-7 Delineators and Test Vehicle before Testing (Concrete Surface).

Figure 3.29. 607531-02-7 Delineators and Test Vehicle after Testing (Concrete Surface).

Figure 3.30. 607531-02-7 Delineators and Test Vehicle before Testing (Asphalt Surface).

Figure 3.31. 607531-02-7 Delineators and Test Vehicle after Testing (Asphalt Surface).

Table 3.7. Test No. 607531-02-7 List/Lean Values.

#	Before		Run #1		Run #10		Run #100		Run #127		Failure	
	List	Lean	List	Lean	List	Lean	List	Lean	List	Lean	Run #	Mode
1T	89	90	88	90	85	88	-	-	-	-	58	Post partially pulled off base/torn
1B	87	87	85	86	87	87	-	-	-	-	24	Post tear
2T	87	89	87	89	87	89	88	89	89	89	-	No failure
2B	88	90	90	88	89	87	-	-	-	-	21	Post tear
3T	89	88	90	89	88	87	87	88	-	-	127	Post separated from base/torn
3B	88	90	87	90	87	90	-	-	-	-	38	Post partially pulled off base/torn
4T	89	90	88	90	89	89	89	89	89	90	-	No failure
4B	90	88	90	88	88	86	-	-	-	-	22	Post tear
5T	88	90	88	89	89	89	-	-	-	-	95	Post partially pulled off base/torn
5B	88	90	88	88	88	88	-	-	-	-	33	Post tear
6T	90	90	90	89	89	89	-	-	-	-	93	Post tear
6B	90	90	90	89	89	88	-	-	-	-	30	Post partially pulled off base/torn
7T	89	90	90	89	88	89	87	89	89	86	-	No failure
7B	89	89	90	90	89	87	-	-	-	-	32	Post tear
8T	89	86	90	87	89	88	-	-	-	-	94	Post partially pulled off base/torn
8B	89	90	88	88	87	87	-	-	-	-	23	Post tear
Other Notes:												
Runs 2, 3, 4, 21, and 75 under 70 mph												
Run 103 on following day												
2017-09-18 resumed testing at Run 34												
Final run 127; discontinued at request of Sponsor												

3.10. IMPACT DURABILITY TEST NO. 607531-02-9

(iii) 3.10.1 Flexstake 780 Series 10-inch × 24 inch Tubular Surface Mount Sample

Test No. 607531-02-9, performed on September 5, 2017, was an impact durability test on Flexstake 780 Series 10-inch × 24 inch Tubular Surface Mount Samples secured to the concrete and asphalt surfaces using E-BOND 1240/1241 2-part epoxy adhesive, 8 each on concrete and 8 each on asphalt. Detailed diagrams of the test samples and test layout can be found in Figures 3.32 through 3.34. Figures 3.35 and 3.36 show images of the test sample setup and impact vehicle at the beginning and after testing on the concrete surface. Figures 3.37 and 3.38 show the test setup and impact vehicle at the beginning and after testing on the asphalt surface.

(jjj) 3.10.2 Impact Performance

Table 3.8 documents the list/lean and failure modes witnessed under Test No. 607531-02-9. Testing was discontinued after Run 168, due to observed failure for the bumper impacts. Eleven of the samples failed to resist 168 impacts. A failure to restore to within 15 degrees of vertical was observed for delineator #6B on run 4, delineator #1B on run 19, delineator #7B on run 34, delineator #1T on run 121, and delineator #7T on run 127. A complete post tear was observed for delineator #8B on run 12, delineator #2B on run 16, delineator #5B on run 27, delineator #3B on run 28, and delineator #4B on run 32. A tear of more than 50% of the cross section was observed for delineator #5T on run 62, and delineators #2T, #3T, #4T, #6T, and #8T completed 168 runs without failure. Ambient temperature was greater than or equal to 82°F throughout the conducted test.

The primary mode of failure was exceeding the maximum allowable degree of list/lean and post fracture near the bolt connections.

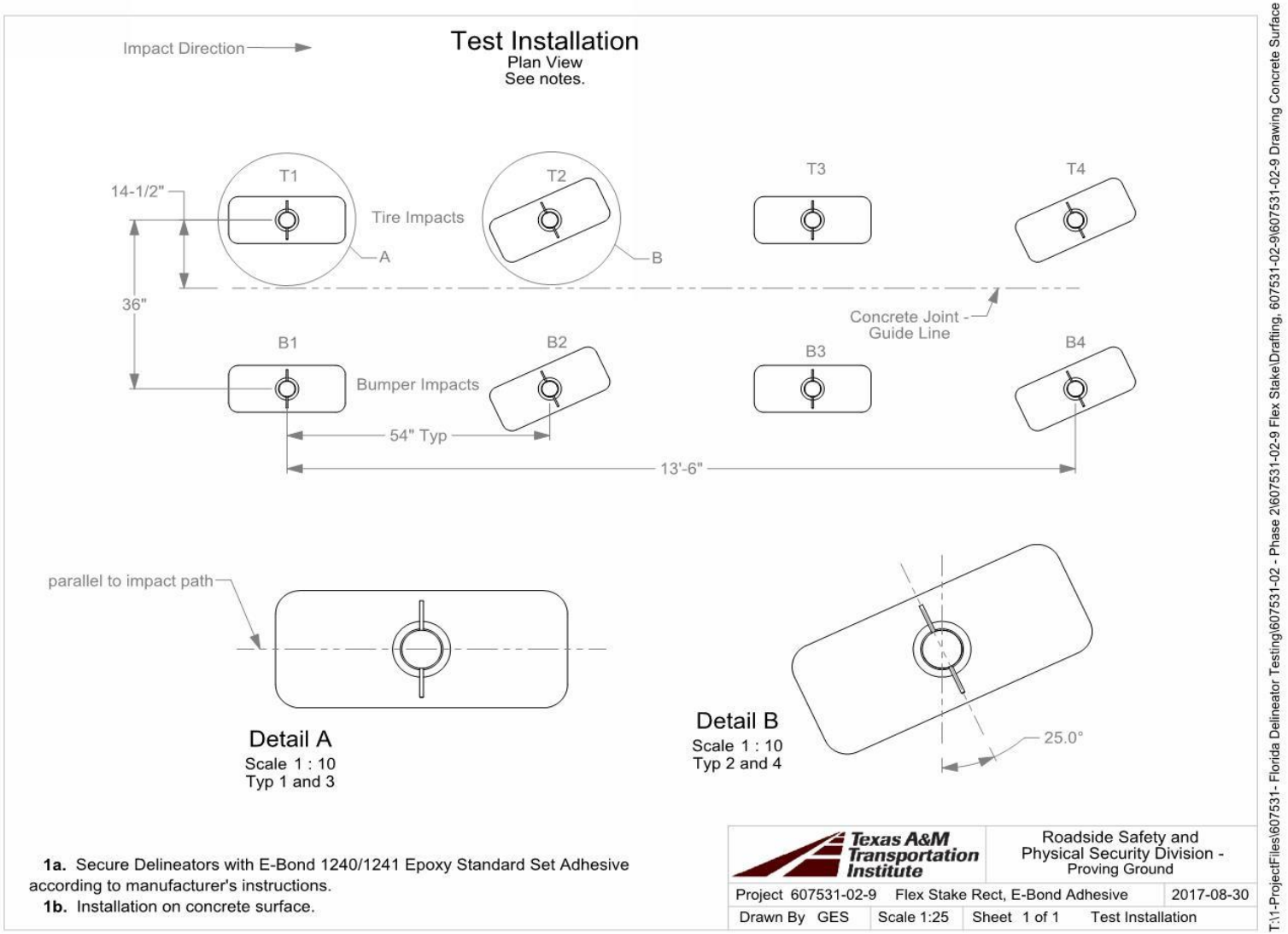


Figure 3.32. 607531-02-9 Test Setup on Concrete Surface.

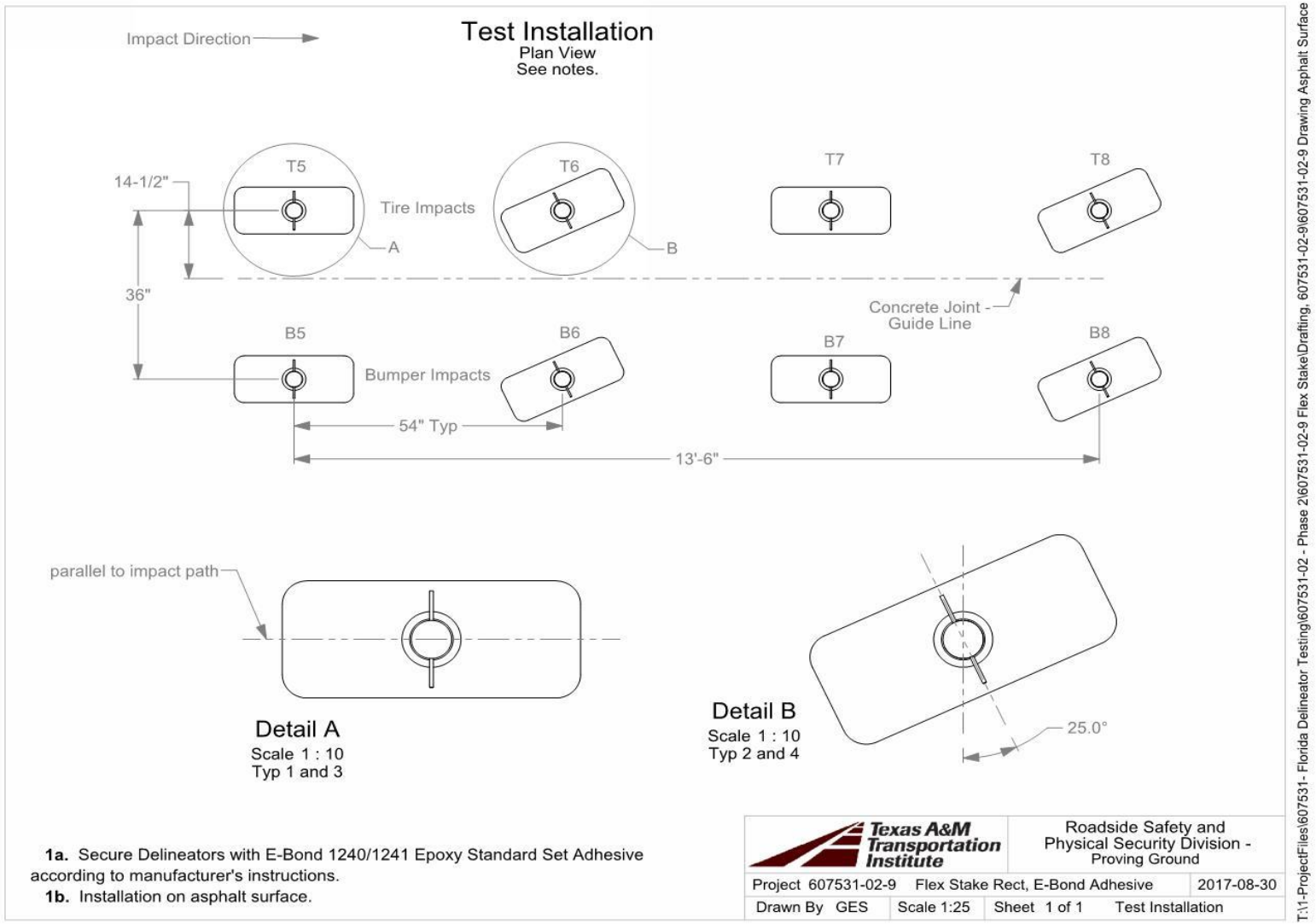


Figure 3.33. 607531-02-9 Test Setup on Asphalt Surface.

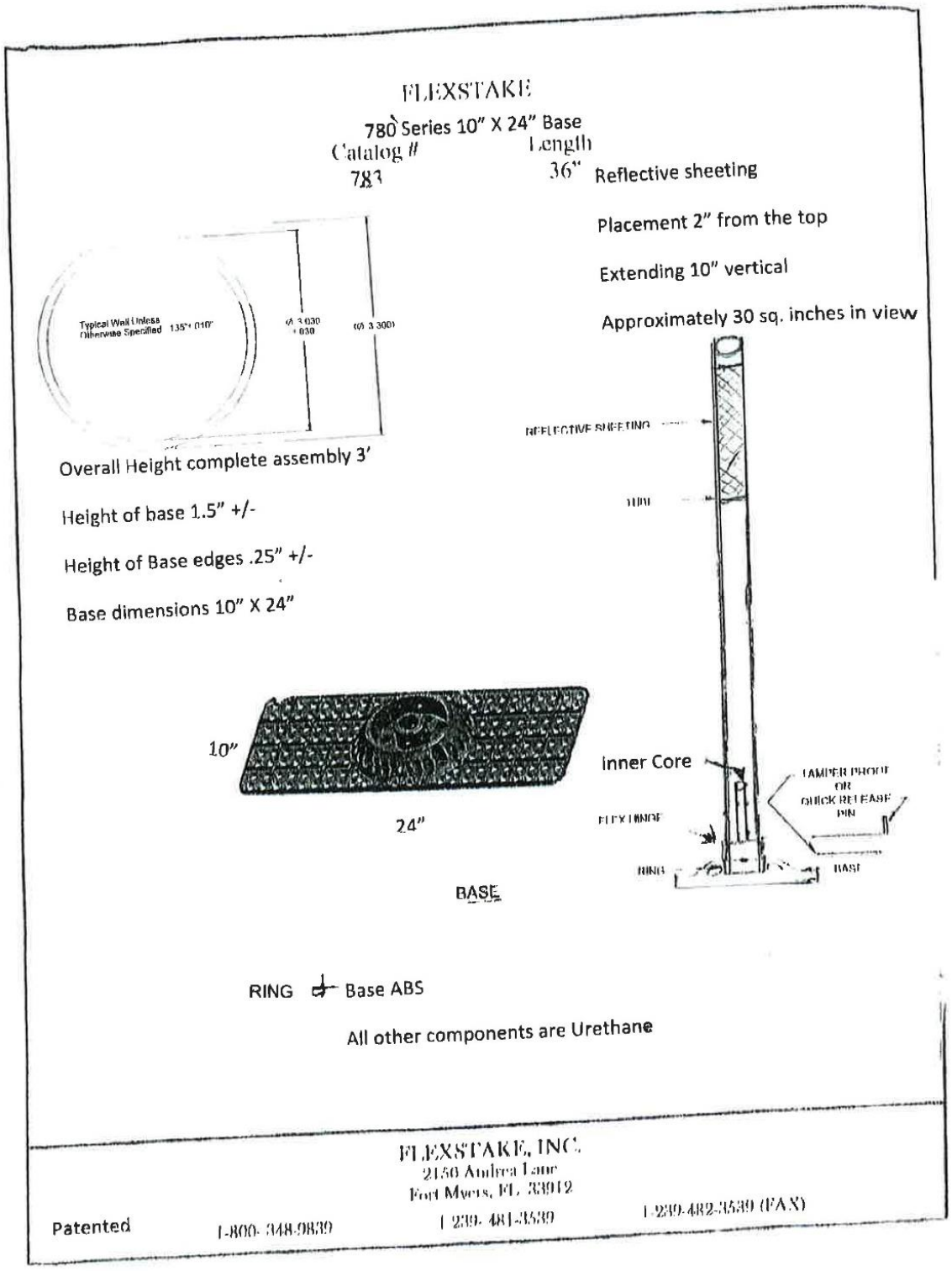


Figure 3.34. 607531-02-9 Test Sample Details.


Figure 3.35. 607531-02-9 Delineators and Test Vehicle before Testing (Concrete Surface).


Figure 3.36. 607531-02-9 Delineators and Test Vehicle after Testing (Concrete Surface).


Figure 3.37. 607531-02-9 Delineators and Test Vehicle before Testing (Asphalt Surface).


Figure 3.38. 607531-02-9 Delineators and Test Vehicle after Testing (Asphalt Surface).

Table 3.8. Test No. 607531-02-9 List/Lean Values.

#	Before		Run #1		Run #10		Run #100		Run #168		Failure	
	List	Lean	List	Lean	List	Lean	List	Lean	List	Lean	Run #	Mode
1T	88	90	87	88	85	89	84	87	-	-	121	Failure to restore due to post fracture near the base
1B	90	88	89	90	90	89	-	-	-	-	19	Failure to restore due to post fracture near the base
2T	88	88	89	88	89	88	88	89	89	89	168	No failure
2B	89	88	90	86	88	85	-	-	-	-	16	Post tore off near bolt connections
3T	89	90	88	89	86	90	86	89	86	90	168	No failure
3B	90	88	90	88	88	88	-	-	-	-	28	Post tore off near bolt connections
4T	87	89	88	90	89	89	89	89	89	88	168	No failure
4B	89	89	90	89	90	88	-	-	-	-	32	Post tore off near bolt connections
5T	89	88	89	89	88	89	-	-	-	-	62	More than 50% tear near base
5B	90	89	90	88	90	88	-	-	-	-	27	Post tore off near bolt connections
6T	90	88	89	89	90	89	87	89	88	88	168	No failure
6B	88	88	89	86	-	-	-	-	-	-	4	Failure to restore due to post fracture near the base
7T	89	90	90	89	89	90	87	90	-	-	127	Failure to restore due to post fracture near the base
7B	88	88	87	87	87	86	-	-	-	-	34	Failure to restore/post fracture near bolt connections
8T	89	89	88	89	86	89	84	88	84	88	168	No failure
8B	90	89	89	90	89	88	-	-	-	-	12	Failure to restore/post fracture near bolt connections
Other Notes:												
Runs 10, 12, 35, 73, 162 under 70 mph												
Testing halted after run 168 due to lighting and sponsor request												
Final run 127; discontinued at request of Sponsor												

3.11. IMPACT DURABILITY TEST NO. 607531-02-10

(kkk) 3.11.1 Safe-Hit® Dura-Post® Surface Mount Mechanical Anchor

Test No. 607531-02-10, performed on September 26, 2017, was an impact durability test on 36-inch Safe-Hit® Dura-Post® Surface Mount Mechanical Anchor Samples. The base was anchored to the asphalt surface using Powers Wedge-Bolt anchors for the first four delineators (#1-2) and Coupling Nut and Bolt anchors for the second four delineators (#3-4) according to manufacturer's instructions. Detailed diagrams of the test samples and test layout can be found in Figure 3.39. Figure 3.40 shows images of the test sample setup and impact vehicle at the beginning of testing. Figure 3.41 shows the test setup and impact vehicle after testing was completed.

(lll) 3.11.2 Impact Performance

Table 3.9 documents the list/lean and failure modes witnessed under Test No. 607531-02-10. Five samples failed to resist 200 impacts. A failure to restore to within 15 degrees of vertical was observed for delineator #2B on run 33, delineator #4B on run 39, delineator #3B on run 58, delineator #1B on run 62, and delineator #4T on run 108. Delineators #1T, #2T, and #3T completed 200 runs without failure. Ambient temperature was greater than or equal to 82°F throughout the conducted test.

The primary mode of failure was exceeding the maximum allowable degree of list/lean and tearing of the post.

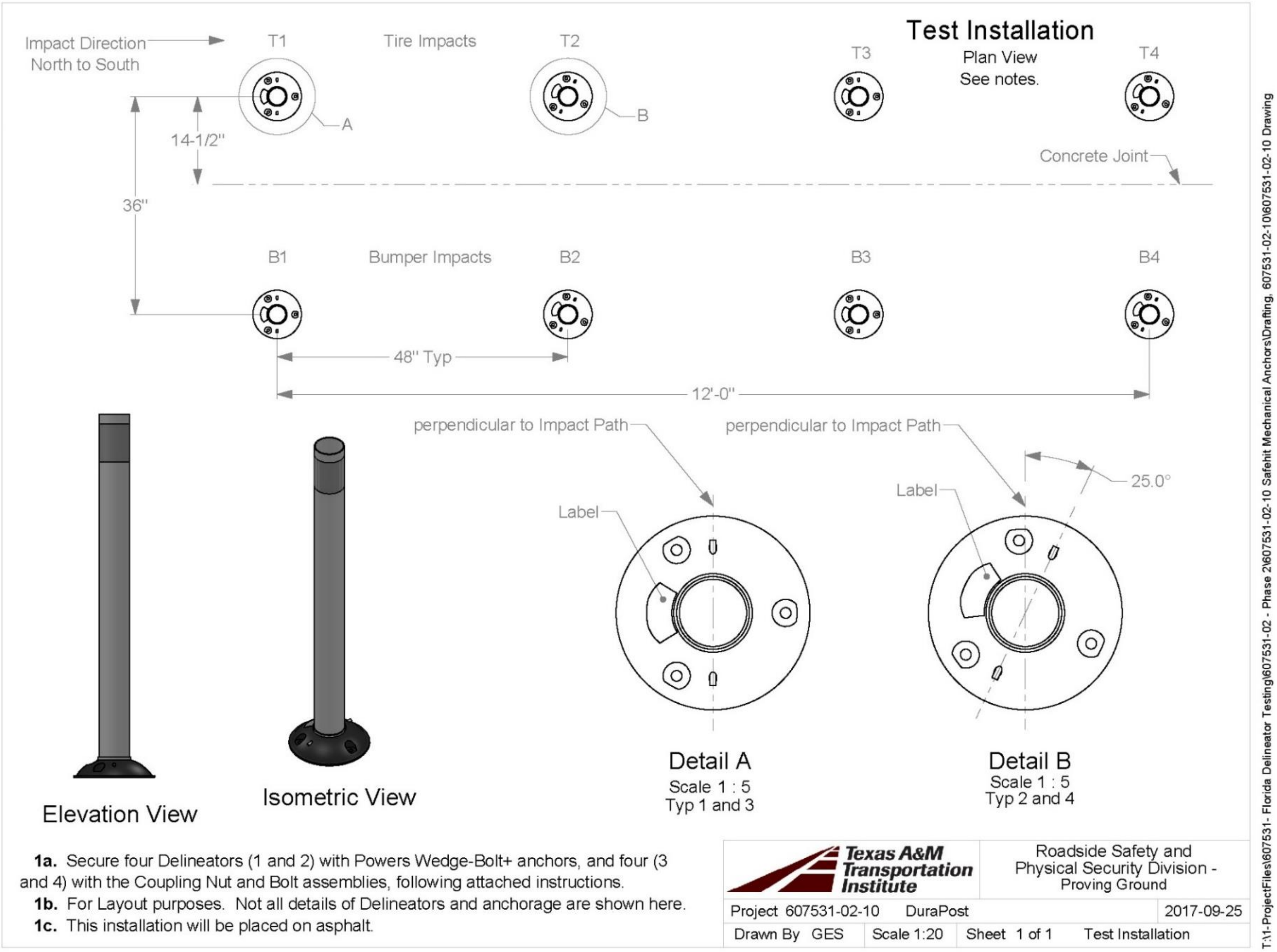


Figure 3.39. 607531-02-10 Test Setup and Sample Details.


Figure 3.40. 607531-02-10 Delineators and Test Vehicle before Testing.


Figure 3.41. 607531-02-10 Delineators and Test Vehicle after Testing.

Table 3.9. Test No. 607531-02-5 List/Lean Values.

#	Before		Run #1		Run #10		Run #100		Run #200		Failure	
	List	Lean	List	Lean	List	Lean	List	Lean	List	Lean	Run #	Mode
1T	89	89	88	88	87	87	86	86	84	87	200	No failure
1B	89	89	89	86	89	86	-	-	-	-	62	Failed to restore - 70°
2T	90	89	89	87	89	87	87	85	86	86	200	No failure
2B	90	88	89	86	90	86	-	-	-	-	33	Failure to restore due to tear of post
3T	90	89	89	88	88	87	86	87	85	86	200	No failure
3B	89	88	90	87	90	84	-	-	-	-	58	Failed to restore - 72°
4T	90	90	89	88	88	87	82	87	-	-	108	Failure to restore due to tear of post
4B	90	90	90	87	90	86	-	-	-	-	39	Failure to restore - 71°
Other Notes:					6							
Runs 115, 127, and 152 under 70 mph												
1B and 3B separated from base on run 63												

3.12. IMPACT DURABILITY TEST NO. 607531-02-11

(mmm) 3.12.1 eNdoto Evelux Flexible Rib-Post Sample

Test No. 607531-02-11, performed on October 26, 2017, was an impact durability test on eNdoto Evelux Flexible Rib-Post Samples secured, 8 each on concrete and 8 each on asphalt. The base of the eNdoto Evelux Flexible Rib-Post Delineator with 3 Point Anchor Base (Part #EV-12221-36) was then anchored to the concrete surface using a 3-point pin system. The base of the eNdoto Evelux Flexible Rib-Post Delineator and Base (Part #EV-12231-36) was anchored to the asphalt surface using FIRMmarker™ #18M900C20 2-part epoxy adhesive . Detailed diagrams of the test samples and test layout can be found in Figures 3.42 through 3.45. Figures 3.46 and 3.47 show images of the test sample setup and impact vehicle at the beginning and after testing on the concrete surface. Figures 3.48 and 3.49 show the test setup and impact vehicle at the beginning and after testing on the asphalt surface.

(nnn) 3.12.2 Impact Performance

Table 3.10 documents the list/lean and failure modes witnessed under Test No. 607531-02-11. Fourteen of the samples failed to resist 50 impacts. The attachment failed on all the delineators on the concrete surface, # 1T, #1B, #2T, #2B, #3T, #3B, #4T, and #4B, on run 1. A failure to restore to within 15 degrees of vertical was observed for delineator #5B on run 1, delineator #6B on run 2, delineator #7B on run 28, and delineator #5T on run 47. A complete post tear was observed for delineator #8B on run 6, and a tear of more than 50% of the cross section was observed for delineator #7T on run 25. Delineators #6T and #8T completed 50 runs without failure. Testing was discontinued after run 50, per Sponsor's request. Ambient temperature was greater than or equal to 60°F throughout the conducted test. This is below the required temperature.

The primary mode of failure was pull out of the mechanical anchors for the delineators on the concrete surface and exceeding the maximum allowable degree of list/lean for the delineators on the asphalt surface.

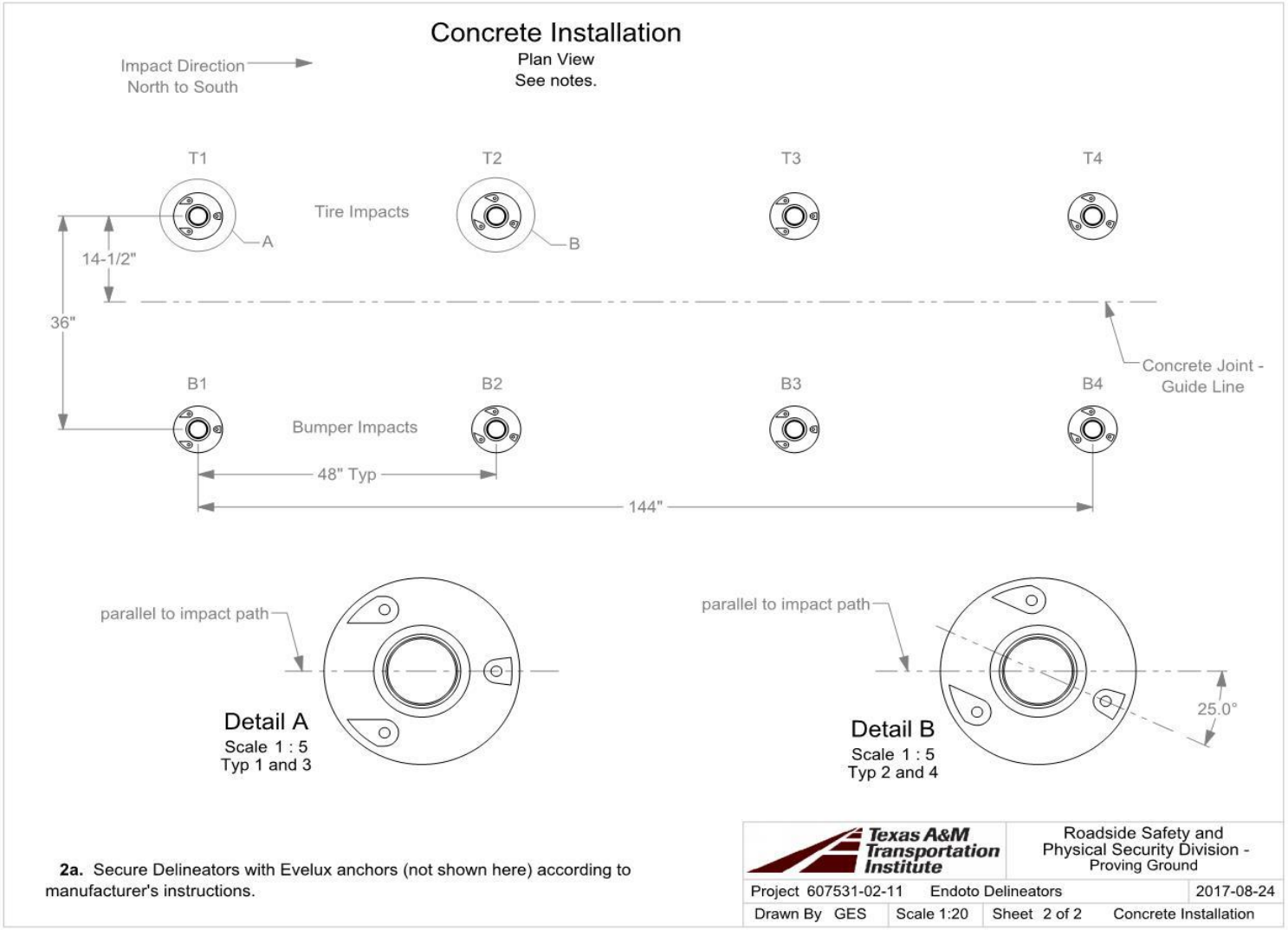


Figure 3.42. 607531-02-11 Test Setup Details on Concrete Surface (Mechanical Anchors).

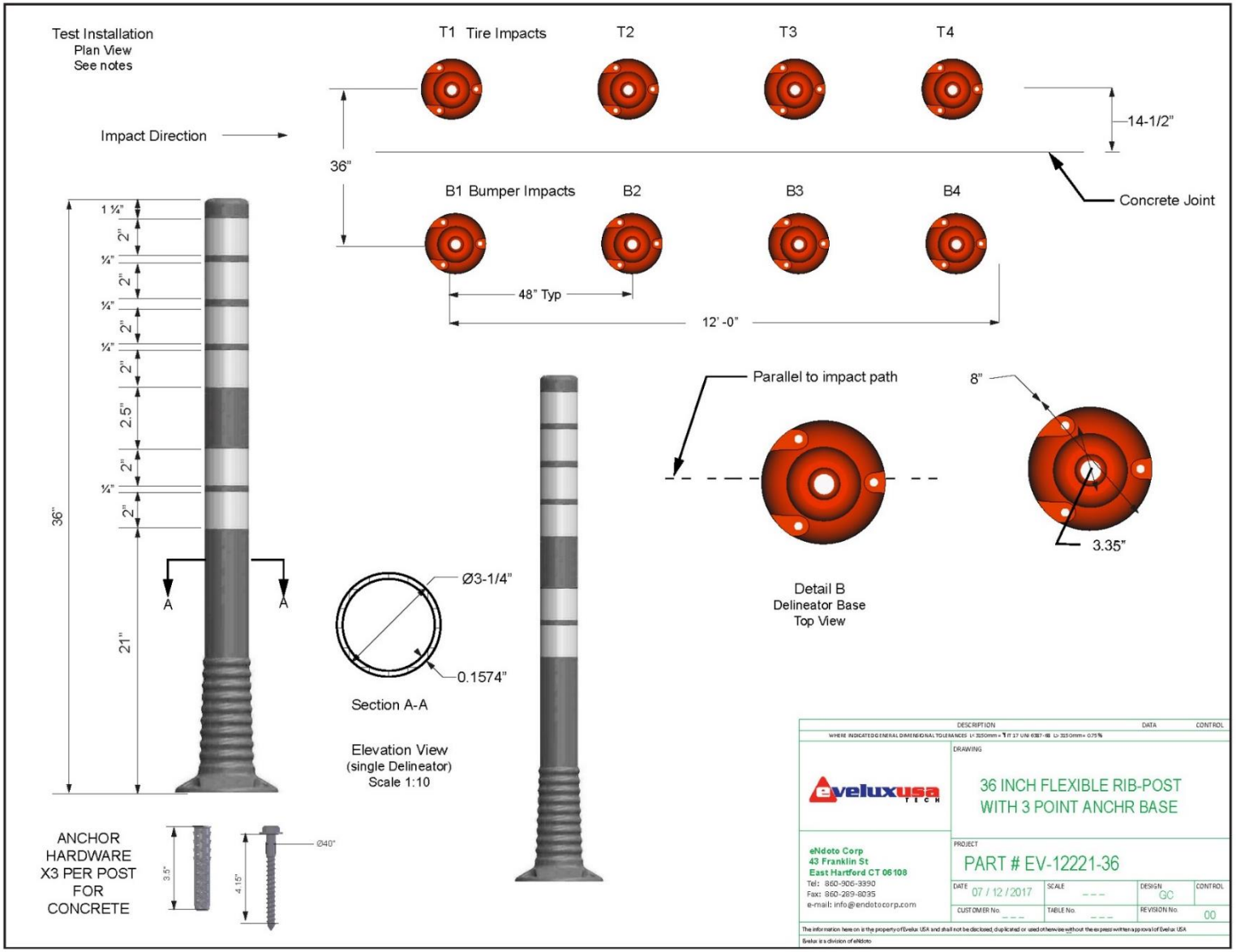


Figure 3.43. 607531-02-11 Test Sample Details on Concrete Surface (Mechanical Anchors).

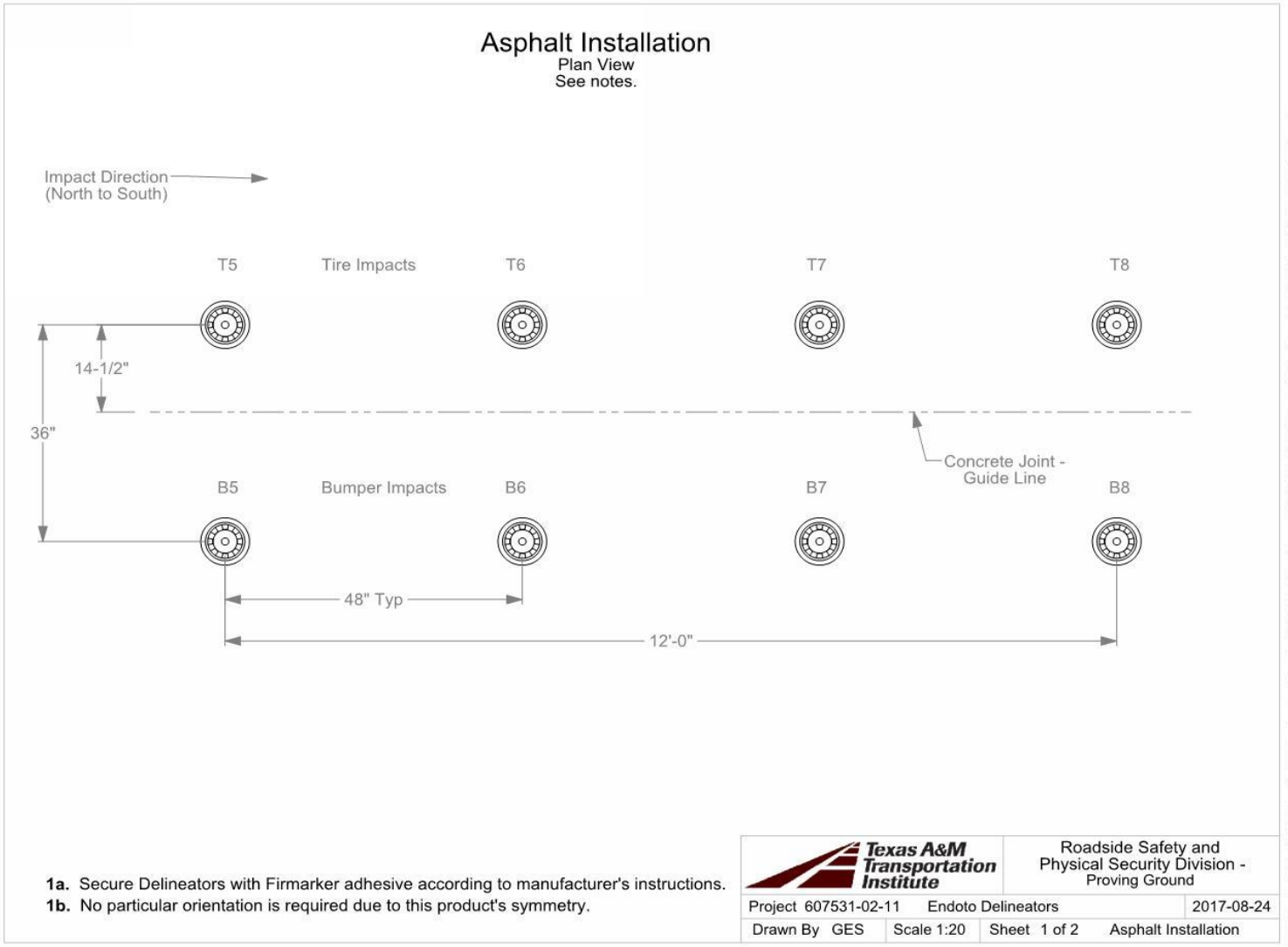


Figure 3.44. 607531-02-11 Test Setup Details on Asphalt Surface (Epoxy).

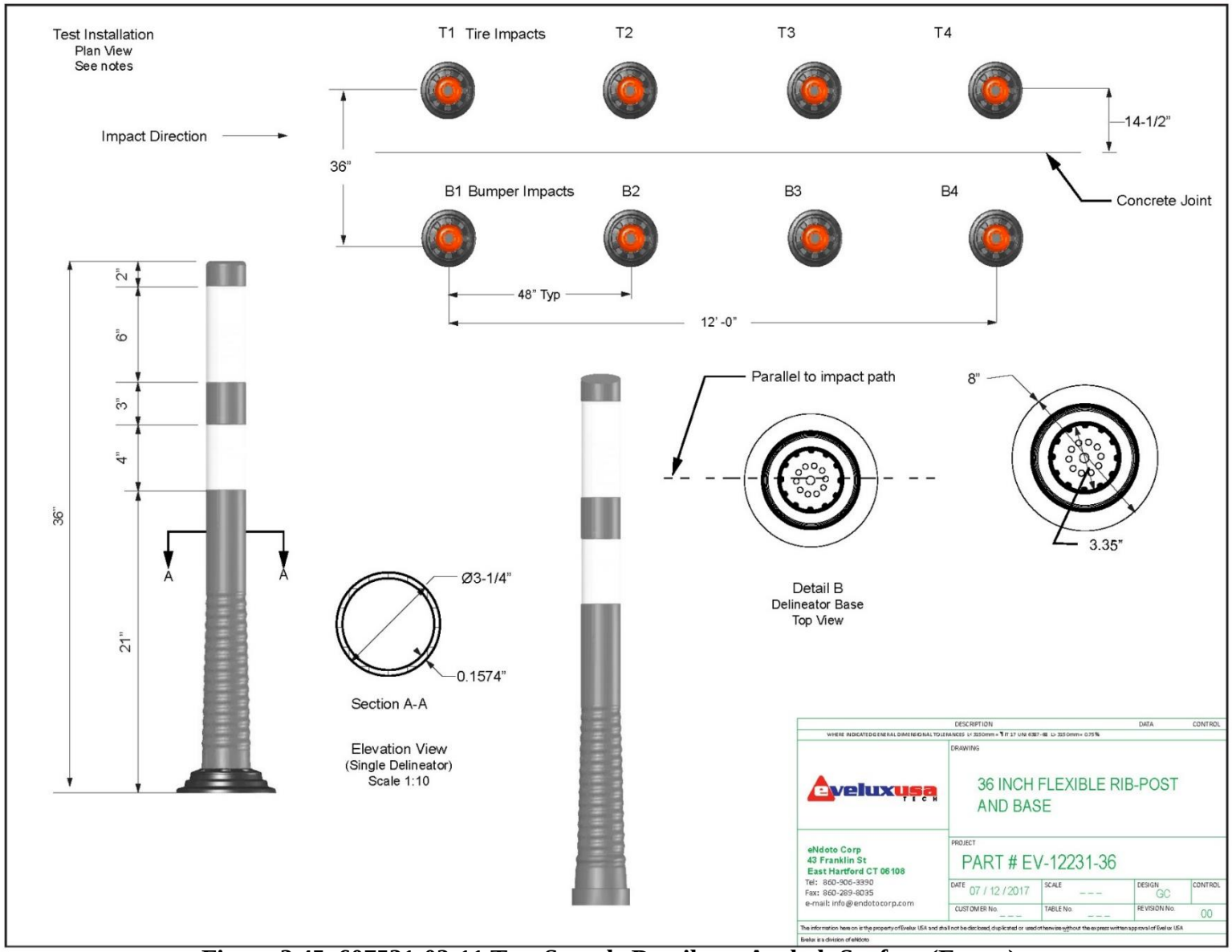


Figure 3.45. 607531-02-11 Test Sample Details on Asphalt Surface (Epoxy).


Figure 3.46. 607531-02-11 Delineators and Test Vehicle before Testing (Concrete Surface).


Figure 3.47. 607531-02-11 Delineators and Test Vehicle after Testing (Concrete Surface).


Figure 3.48. 607531-02-11 Delineators and Test Vehicle before Testing (Asphalt Surface).


Figure 3.49. 607531-02-11 Delineators and Test Vehicle after Testing (Asphalt Surface).

Table 3.10. Test No. 607531-02-11 List/Lean Values.

#	Before		Run #1		Run #10		Run #100		Run #200		Failure	
	List	Lean	List	Lean	List	Lean	List	Lean	List	Lean	Run #	Mode
1T	89	88	-	-	-	-	-	-	-	-	1	Attachment failed
1B	90	88	-	-	-	-	-	-	-	-	1	Attachment failed
2T	88	89	-	-	-	-	-	-	-	-	1	Attachment failed/Failure to restore
2B	89	89	-	-	-	-	-	-	-	-	1	Attachment failed
3T	89	87	-	-	-	-	-	-	-	-	1	Attachment failed
3B	89	90	-	-	-	-	-	-	-	-	1	Attachment failed
4T	88	90	-	-	-	-	-	-	-	-	1	Attachment failed/Failure to restore
4B	89	90	-	-	-	-	-	-	-	-	1	Attachment failed
5T	89	90	89	90	88	89	-	-	-	-	47	Failure to restore - 72°
5B	90	90	-	-	-	-	-	-	-	-	1	Failure to restore - 57°
6T	90	89	90	89	90	88	-	-	-	-	50	No failure
6B	90	90	90	86	-	-	-	-	-	-	2	Failure to restore - 56°
7T	90	89	90	90	84	80	-	-	-	-	25	Post tore/Failure to restore - 72°
7B	89	90	88	88	89	86	-	-	-	-	28	Failure to restore
8T	90	90	89	89	89	90	-	-	-	-	50	No failure
8B	89	89	90	89	-	-	-	-	-	-	6	Post tore and separated at the base
Other Notes:												
Testing stopped at run 50												

3.13. IMPACT DURABILITY SUMMARY

(ooo) 3.13.1 Impact Durability Test No. 607531-02-1

Test No. 607531-02-1, performed on July 17, 2017, was an impact durability test on 36-inch Pexco – Davidson Traffic Control Products' City Post 8GD36ORG101 Glue Down Samples secured with FIRMmarker™ #18M900C20 2-part epoxy adhesive on asphalt as shown in Figure 3.50. The product resisted an average of 186 tire impacts, and an average of 32 bumper impacts. Table 3.11 shows a summary of the results. The primary mode of failure was fracturing of the samples near the base and exceeding the maximum allowable degree of list/lean.

Figure 3.50. 607531-02-1 Product Sample.

Table 3.11. 607531-02-1 Summary Table.

City Post Epoxy		
	Tire	Bumper
1	189	54
2	168	60
3	189	10
4	200	3
Average	**186**	**32**

(ppp) 3.13.2 Impact Durability Test No. 607531-02-2

Test No. 607531-02-2, performed on September 20 and 22, 2017, was an impact durability test on 36-inch tall Pexco City Post 8SM36ORG101 mechanical anchor samples secured with BOLTHOLD™ Asphalt Anchors Model SP-10 on asphalt, as shown in Figure 3.51. The product resisted an average of 141 tire impacts, and an average of 91 bumper impacts. Table 3.12 shows a summary of the results. The primary mode of failure was fracturing of the samples near the base and exceeding the maximum allowable degree of list/lean.

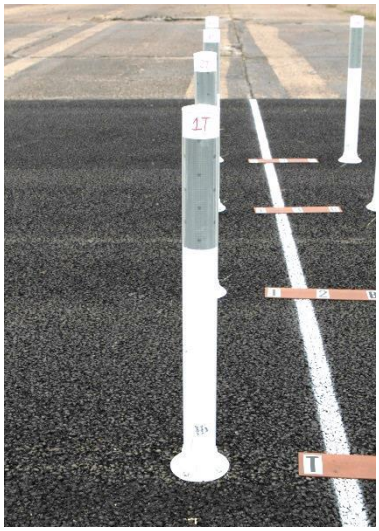


Figure 3.51. 607531-02-2 Sample.

Table 3.12. 607531-02-2 Summary Table.

City Post Mechanical Anchor		
	Tire	Bumper
1	190	95
2	140	74
3	110	108
4	124	87
Average	**141**	**91**

(qqq) 3.13.3 Impact Durability Test No. 607531-02-3

Test No. 607531-02-3, performed on July 19, 2017, was an impact durability test on 36-inch Pexco City Post Samples secured with embedded anchor cups as shown in Figure 3.52. The product resisted an average of 74 tire impacts, and an average of 14 bumper impacts.

Table 3.13 shows a summary of the results. The primary mode of failure was exceeding the maximum allowable degree of list/lean and post fracture near the base.

Figure 3.52. 607531-02-3 Sample.

Table 3.13. 607531-02-3 Summary Table.

City Post Anchor Cup		
	Tire	Bumper
1	200	1
2	3	14
3	3	19
4	91	20
Average	**74**	**14**

(rrr) 3.13.4 Impact Durability Test No. 607531-02-4

Test No. 607531-02-4, performed on September 19, 2017, was an impact durability test on Pexco City Post 8GD36ORG101 Glue Down samples secured by E-BOND 1240/1241 2-part epoxy adhesive, 8 each on concrete surface and 8 each on asphalt surface, as shown in Figures 3.53 and 3.54. The 36-inch delineators resisted an average of 102 tire and 106 bumper impacts on the concrete surface and 130 tire and 75 bumper impacts on the asphalt surface. Tables 3.14 and 3.15 show a summary of the results for each surface. The primary mode of failure was tearing of the post approximately one foot above the base and fracture of the post at the base.

Table 3.14. 607531-02-4 Summary Table (Concrete Surface).

City Post Epoxy		
	Tire	Bumper
1	15	84
2	169	154
3	98	104
4	134	82
Average	**104**	**106**

Figure 3.53. 607531-02-4 Sample (Concrete Surface).

Figure 3.54. 607531-02-4 Sample (Asphalt Surface).

Table 3.15. 607531-02-4 Summary Table (Asphalt Surface).

City Post Epoxy		
	Tire	Bumper
1	198	10
2	200	200
3	98	14
4	22	76
Average	**130**	**75**

(sss) 3.13.5 Impact Durability Test No. 607531-02-5

Test No. 607531-02-5, performed on July 13, 2017, was an impact durability test on Safe-Hit® Dura-Post™ Surface Mount samples, 4 each secured by SHEPX-13-K1 epoxy, and 4 each by FIRMmarker™ #18M900C20 2-part epoxy adhesive, as shown in Figures 3.55 and 3.56. With the SHEPX-13-K1 epoxy, the product resisted an average of 200 tire impacts, and an average of 24 bumper impacts. With the FIRMmarker™ epoxy, the product resisted an average of 200 tire impacts, and an average of 22 bumper impacts. Tables 3.16 and 3.17 show a summary of the results for each epoxy. The primary mode of failure was post separation at the base. This was mainly caused by the pin tearing through the bottom of the post.

Figure 3.55. 607531-02-5 Sample (SHEPX-13-K1).

Table 3.16. 607531-02-5 Summary Table (SHEPX-13-K1).

Dura-Post Epoxy (SHEPX-13-K1)		
	Tire	Bumper
1	200	25
2	200	22
Average	**200**	**24**

Figure 3.56. 607531-02-5 Sample (FIRMmarker).

Table 3.17. 607531-02-5 Summary Table (FIRMmarker).

Dura-Post Epoxy (FIRMmarker)		
	Tire	Bumper
1	200	22
2	200	22
Average	**200**	**22**

(ttt) 3.13.6 Impact Durability Test No. 607531-02-7

Test No. 607531-02-7, performed on September 4 and September 18, 2017, was an impact durability test on Flexstake 780 Series 9-inch Base Tubular Surface Mount samples secured to the concrete and asphalt surfaces using E-BOND 1240/1241 2-part epoxy adhesive, 8 each on concrete surface and 8 each on asphalt surface, as shown in Figures 3.57 and 3.58. The tested delineators resisted an average of 110 tire and 26 bumper impacts on the concrete surface and 102 tire and 30 bumper impacts on the asphalt surface. Tables 3.18 and 3.19 show a summary of the results for each surface. The primary mode of failure was tearing of the posts near the bolt connections.

Figure 3.57. 607531-02-7 Sample (Concrete Surface).

Table 3.18. 607531-02-7 Summary Table (Concrete Surface).

Flexstake Epoxy		
	Tire	Bumper
1	58	24
2	127	21
3	127	38
4	127	22
Average	**110**	**26**

Figure 3.58. 607531-02-7 Sample (Asphalt Surface).

Table 3.19. 607531-02-7 Summary Table (Asphalt Surface).

Flexstake Epoxy		
	Tire	Bumper
1	95	33
2	93	30
3	127	32
4	94	23
Average	**102**	**30**

(uuu) 3.13.7 Impact Durability Test No. 607531-02-9

Test No. 607531-02-9, performed on September 5, 2017, was an impact durability test on Flexstake 780 Series 10-inch × 24-inch Base Tubular Surface Mount samples secured to the concrete and asphalt surfaces using E-BOND 1240/1241 2-part epoxy adhesive, 8 each on concrete surface and 8 each on asphalt surface, as shown in Figures 3.59 and 3.60. The tested delineators resisted an average of 156 tire and 24 bumper impacts on the concrete surface and 131 tire and 19 bumper impacts on the asphalt surface. Tables 3.20 and 3.21 show a summary of the results for each surface. The primary mode of failure was exceeding the maximum allowable degree of list/lean and post fracture near the bolt connections.

Figure 3.59. 607531-02-9 Sample (Concrete Surface).

Table 3.20. 607531-02-9 Summary Table (Concrete Surface).

Flexstake Epoxy		
	Tire	Bumper
1	121	19
2	168	16
3	168	28
4	168	32
Average	**156**	**24**

Figure 3.60. 607531-02-9 Sample (Asphalt Surface).

Table 3.21. 607531-02-9 Summary Table (Asphalt Surface).

Flexstake Epoxy		
	Tire	Bumper
1	62	27
2	168	4
3	127	34
4	168	12
Average	**131**	**19**

(vvv) 3.13.8 Impact Durability Test No. 607531-02-10

Test No. 607531-02-10, performed on September 26, 2017, was an impact durability test on Safe-Hit® Dura-Post® Surface Mount Mechanical Anchor samples, 4 each secured by Powers Wedge-Bolt anchors, and 4 each by Coupling Nut and Bolt anchors, and shown in Figures 3.61 and 3.62. With the Powers Wedge-Bolt anchors, the product resisted an average of 200 tire impacts, and an average of 48 bumper impacts. With the Coupling Nut and Bolt anchors, the product resisted an average of 154 tire impacts, and an average of 49 bumper impacts. Tables 3.22 and 3.23 show a summary of the results for each mechanical anchor. The primary mode of failure was exceeding the maximum allowable degree of list/lean and tearing of the post.

Figure 3.61. 607531-02-10 Sample (Powers Wedge-Bolt).

Table 3.22. 607531-02-10 Summary Table (Powers Wedge-Bolt).

Dura-Post Mechanical		
	Tire	Bumper
1	200	62
2	200	33
Average	**200**	**48**

Figure 3.62. 607531-02-10 Sample (Coupling Nut and Bolt).

Table 3.23. 607531-02-10 Summary Table (Coupling Nut and Bolt).

Dura-Post Mechanical		
	Tire	Bumper
1	200	58
2	108	39
Average	**154**	**49**

(www) 3.13.9 Impact Durability Test No. 607531-02-11

Test No. 607531-02-11, performed on October 26, 2017, was an impact durability test on eNdoto Evelux Flexible Rib-Post Samples secured, 8 each on concrete and 8 each on asphalt. The base of the eNdoto Evelux Flexible Rib-Post Delineator with 3 Point Anchor Base (Part #EV-12221-36) was anchored to the concrete surface using a 3-point pin system. The base of the eNdoto Evelux Flexible Rib-Post Delineator and Base (Part #EV-12231-36) was anchored to the asphalt surface using FIRMmarker™ #18M900C20 2-part epoxy adhesive. Figures 3.63 and 3.64 show the two different product samples. The tested delineators resisted an average of 1 tire and 1 bumper impacts on the concrete surface and 43 tire and 9 bumper impacts on the asphalt surface. Tables 3.24 and 3.25 show a summary of the results for each surface. The primary

mode of failure was pull out of the mechanical anchors for the delineators on the concrete surface and exceeding the maximum allowable degree of list/lean for the delineators on the asphalt surface.

Figure 3.63. 607531-02-11 Sample (Concrete Surface).

Table 3.24. 607531-02-11 Summary Table (Concrete Surface).

eNdoto Mechanical		
	Tire	Bumper
1	1	1
2	1	1
3	1	1
4	1	1
Average	**1**	**1**

Figure 3.64. 607531-02-7 Sample (Asphalt Surface).

Table 3.25. 607531-02-11 Summary Table (Asphalt Surface).

eNdoto Epoxy		
	Tire	Bumper
1	47	1
2	50	2
3	25	28
4	50	6
Average	**43**	**9**

3.14. RESULTS

Table 3.26 shows the average number of impacts resisted by the tire, the average number of impacts resisted by the bumper, and the overall combined average number of tire and bumper impacts resisted for each sample, both on concrete and asphalt.

Table 3.26. Average Number of Impacts Resisted Summary Table.

			Concrete	Asphalt
Pexco City Post	E-Bond Epoxy	Tire	102	130
		Bumper	106	75
	FIRMmarker Epoxy	Tire	178*	186
		Bumper	145*	32
	Asphalt Anchors	Tire	-	141
		Bumper	-	91
	Hilti Anchors	Tire	180*	-
		Bumper	128*	-
	Embedded Anchor Cup	Tire	-	74
		Bumper	-	14
Flexstake	9-inch Round Base - Epoxy	Tire	110	102
		Bumper	26	30
	10-inch x 24-inch Base - Epoxy	Tire	156	131
		Bumper	24	19

*Concrete testing performed under Report No. 605601 *(2)* – evaluated at ambient temperatures at or above 65°F.

Table 3.26. Average Number of Impacts Resisted Summary Table (Continued).

			Concrete	Asphalt
eNdoto	Mechanical Anchor	Tire	1	-
		Bumper	1	-
	FIRMmarker Epoxy	Tire	-	43
		Bumper	-	9
Safe-Hit Dura-Post	SHEPX-13-K1 Epoxy	Tire	200*	200
		Bumper	85*	24
	FIRMmarker Epoxy	Tire	-	200
		Bumper	-	22
	Plastic Sleeve and Lag Screws	Tire	200*	-
		Bumper	77*	-
	Wedge Bolt Anchors	Tire	-	200
		Bumper	-	48
	Coupling Nut and Bolt Anchors	Tire	-	154
		Bumper	-	49

*Concrete testing performed under Report No. 605601 *(2)* – evaluated at ambient temperatures at or above 65°F.

CHAPTER4. RECOMMENDATIONS

Testing was performed on an Open Graded Friction Course (OGFC) and a concrete surface above the required 81°F ambient temperature to evaluate impact durability performance for products in warm weather. Previous testing at lower temperatures[3] produced several notable failure of the attachment methods, especially with the use of epoxy attachments. However, the testing performed in warm temperatures, produced no notable failures with the use of epoxy attachments. The main failure mechanism was the delineator posts fracturing and failure to restore to specified list/lean values. The performance of the epoxy attachment in warm temperatures can be considered non-critical as it did not produce any notable failures.

After extensive review of the testing data performed under this study and the previous report 605601[2], TTI researchers recommend two different minimum performance level specifications for the two different surface types. The performance levels were specified to allow for a minimum of two manufacturer's products to meet the specification, which allows FDOT to maintain competitive bids.

The first minimum performance level considers the average performance of a product attached to a concrete surface. In the previous 605601[2] study, a minimum performance level was specified based on the test data of 6 products installed on a concrete surface. Based on the evaluation of the data, a minimum average of 150 tire impacts and a minimum average of 45 bumpers impacts resisted was specified for FDOT. Previous testing with delineators attached to a concrete surface resulted in four products meeting the specification[2]. The Pexco City Post with Hilti anchors, Pexco City Post with FIRMMarker epoxy, Safe-Hit Dura-Post with SHEPX-13-K1 epoxy, and Safe-Hit Dura-Post with lag screw anchors all met the specification. None of the products installed on a concrete surface that were tested as specified in Chapter 3 met the previous specification. TTI researchers recommend the specification for delineators attached to a concrete surface remain the same minimum average of 150 tire impacts and minimum average of 45 bumpers impacts resisted.

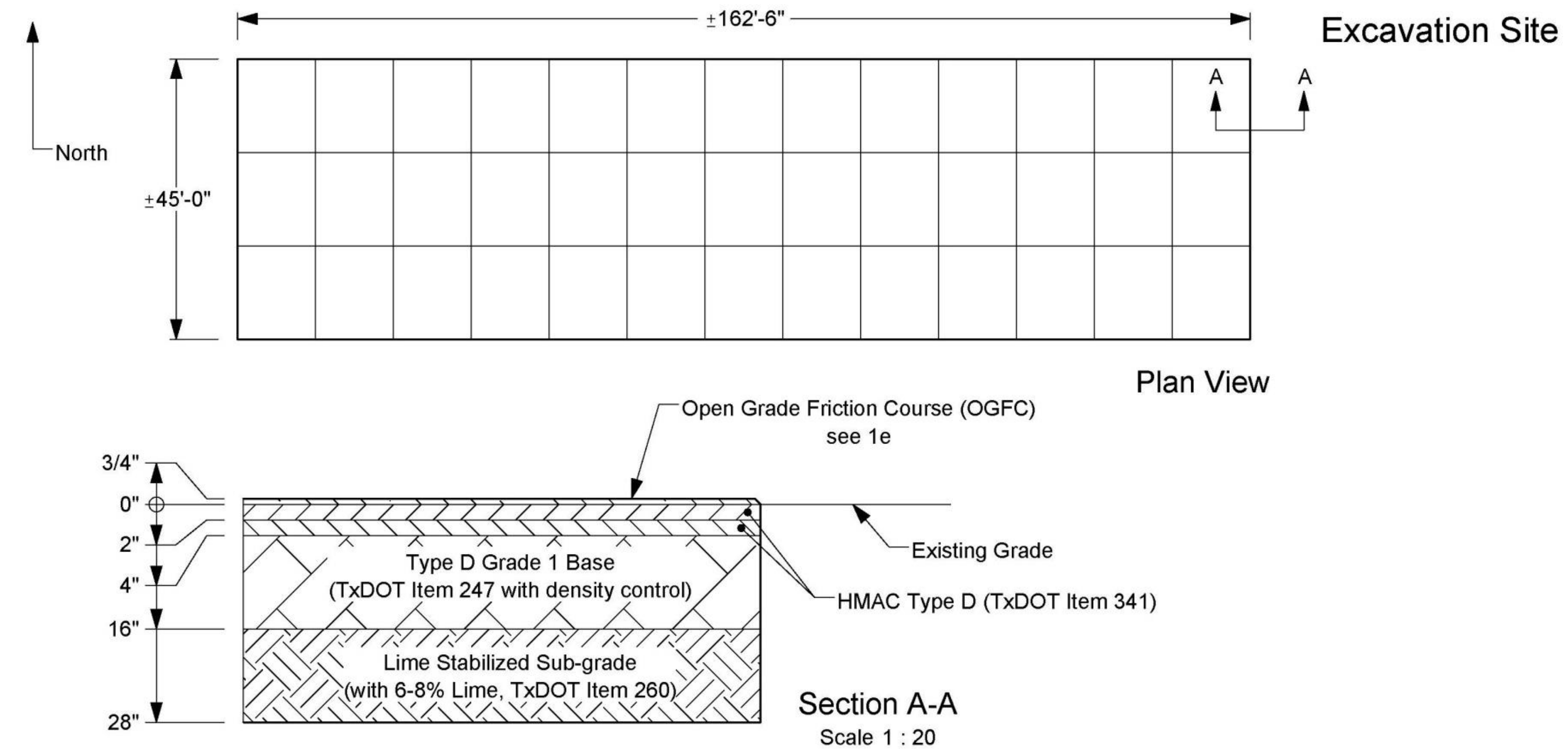
The second minimum performance level considers the average performance of a product attached to an asphalt surface. It is recommended that a product tested on an asphalt surface meet a minimum average of 125 tire impacts and 45 bumper impacts resisted. Four products meet this minimum recommendation for delineators attached to an asphalt surface. This includes the Safe-Hit Dura-Post with the Wedge Bolt Anchors, Safe-Hit Dura-Post with Coupling Nut and Bolt Anchors, Pexco City Post with Asphalt Anchors, and Pexco City Post with E-Bond epoxy.

At this point it is unknown the exact effects of temperature in relation to the performance of the delineator. Additional cold weather testing of products is needed to develop a relationship for the performance of the delineators versus temperature.

REFERENCES

1. D. R. Arrington, L. Theiss, R. A. Zimmer, and W. L. Menges. *Development of Delineator Testing Standard*. Report No. 0-6772-1, Texas A&M Transportation Institute, College Station, TX, February 2015.
2. D. R. Arrington and W. H. Garza. *Development of Delineator Testing Specific to Managed Lane Use for Optimization of Service Life*. Report No. 605601, Texas A&M Transportation Institute, College Station, TX, July 2016.
3. D. R. Arrington, W. L. Menges, and D. L. Kuhn. *Development of Delineator Testing Specific to Managed Lane Use for Optimization of Service Life*. Report No. 607531-1-4, Texas A&M Transportation Institute, College Station, TX, February 2018.

Appendix A. Details of the TTI Asphalt Test Deck



1a. TxDOT Items listed above correspond to TxDOT 2014 Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges.

1b. Contractor is responsible for demolition and removal of existing concrete and soil. Surrounding concrete and soil may be removed but must be replaced and returned to original condition or finished by extending the Asphalt and compacted base as shown in Section A-A.

1c. Contractor will provide testing to insure that specified in-place density has been obtained on all items.

1d. Contractor should use TxDOT Item 300 to select the asphalt binder for prime and tack coat of the base and HMAC layer.

1e. Follow TxDOT Item 342 for the OGFC layer with the following exceptions: Use gradation following FDOT SPM 13-11976A FC-5. Use a PG 76-22 asphalt binder. The minimum ambient temperature during placement and compaction should be 65° per Florida DOT specifications.

Texas A&M Transportation Institute
Roadside Safety and Physical Security Division
Proving Ground -

Project: Florida Delineator Excavation
Drawn By: GES | Scale 1:300 | Sheet 1 of 1 | Excavation Site
Approved: Dusty Arrington: | Date: 2015-10-09

T:\1-Pr

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION

ASPHALT MIX DESIGN

SUBMIT TO THE DIRECTOR, OFFICE OF MATERIALS, CENTRAL ASPHALT LABORATORY, 5007 NE 39TH AVE, GAINESVILLE, FL 32609

Contractor _____ Address _____

Phone No. _____ Fax No. _____ E-mail _____

Submitted By _____ Type Mix FC-5 Intended Use of Mix Friction Course

Product Description	Product Code	Producer Name	Product Name	Plant/Pit Number	Terminal
1. S1A Stone	C41	White Rock Quarries	S1A Stone	87339	
2. S1B Stone	C51	White Rock Quarries	S1B Stone	87339	
3. Screenings	F22	White Rock Quarries	Screenings	87339	
4.					
5.					
6.					
7. PG Binder	916-76PMA		PG 76-22 (PMA)		

PERCENTAGE BY WEIGHT TOTAL AGGREGATE PASSING SIEVES

	Blend	50%	45%	5%				JOB MIX	CONTROL	
	Number	1	2	3	4	5	6	FORMULA	POINTS	
SIEVE SIZE	3/4" 19.0mm	100	100	100				100	100	
	1/2" 12.5mm	80	100	100				90	85 - 100	
	3/8" 9.5mm	38	94	100				66	55 - 75	
	No. 4 4.75mm	6	35	100				24	15 - 25	
	No. 8 2.36mm	3	10	82				10	5 - 10	
	No. 16 1.18mm	3	4	57				8		
	No. 30 600µm	2	3	36				7		
	No. 50 300µm	2	2	20				6		
	No. 100 150µm	1	2	9				5		
	No. 200 75µm	1.0	1.0	2.0				3.5	2 - 4	
	G_{SB}	2.407	2.412	2.527				2.415		

The mix properties of the Job Mix Formula have been conditionally verified, pending successful final verification during production at the assigned plant, the mix design is approved subject to F.D.O.T. specifications.

JMF reflects aggregate changes expected during production

SPM 13-11976A (FC-5)

Director, Office of Materials: Timothy J. Ruelke, P.E.
Original document retained at the State Materials Office

Effective Date: 11 / 27 / 2013

Expiration Date: 11 / 27 / 2016

TR No. 607531-02

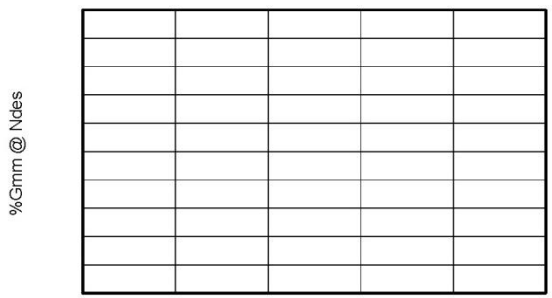
75

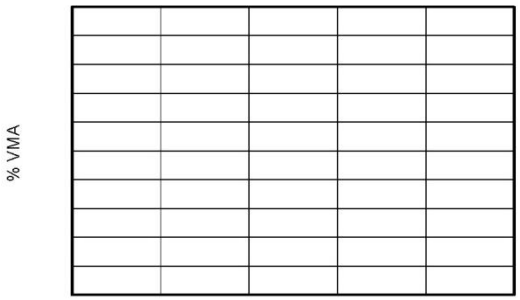
2018-03-28

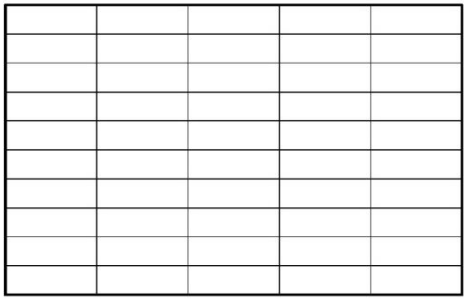
HOT MIX DESIGN DATA SHEET

SPM 13-11976A (FC-5)

P_b	G_{mb} @ N_{des}	G_{mm}	V_a	VMA	VFA	P_{be}	$P_{0.075}$ / P_{be}	%G_{mm} @ N_{ini}	%G_{mm} @ N_{max}







Total Binder Content 6.70 %

Spread Rate @ 1" 98 lbs/yd^2

VMA ____ %

FAA ____ %

%G_{mm} @ N_{des} ____

Ignition Oven Calibration Factor +0.29

(+To Be Added)/(-To Be Subtracted)

(Plant) Mixing Temperature 320 °F 160 °C

(Roadway) Compaction Temperature 320 °F 160 °C

Additives Antistrip 0.5 % Mineral Fiber 0.4 %

APPENDIX B. RANDOM SAMPLE MATERIAL TESTINGS RESULTS

FUTURE LABS, LLC
Highway Safety Product Testing

www.FutureLabsLLC.com
124 Lone Wolf Drive • Madison, MS 39110
601.855.7407

DATE: **November 28, 2017**

REPORT: The following report covers testing of the product received in accordance with **Research Study BVD29 TWO 977-29 (42417).**

PRODUCT: **Safehit Durapost – SG1 ALDOT White Delineator**

SAMPLE: **Product samples** were received on **June 6, 2017.**

PROCEDURE: Test samples were conditioned, prepared, and tested in accordance with the methods listed.

RESULTS:

Safehit Durapost - SG1 ALDOT [Research Study BVD29 TWO 977-29 (4/24/17)]		
Test Property	**Method**	**RESULTS**
Ash Content, % (Procedure B)	ASTM D5630	5.98% avg
Specific Gravity, g/cc	ASTM D792	1.234 g/cc avg
Color - CIE*Lab, Initial (C/2)*	ASTM E1347 / E1349	95.50L, -1.63a, 5.50b
Color - CIE*Yxy, Initial (C/2)*	ASTM E1347 / E1349	90.41Y, 0.3179x, 0.3274y
Yellowness Index, Initial (C/2)*	ASTM E1349 / E313	9.18
Tensile Strength, Initial, psi (Modified Type I; 20"/min)	ASTM D638	3292 psi avg
Tensile Elongation, Initial, % (Modified Type I; 20"/min)	ASTM D638	689% avg
Color - After QUV, CIE*Lab (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / G154 (Cycle 1)	83.97L, 3.66a, 31.70b
Color - After QUV, CIE*Yxy (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / G154 (Cycle 1)	66.26Y, 0.3799x, 0.3842y
Color - ΔE to Initial (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1347 / E1349 / G154 (Cycle 1)	ΔE CIE*Lab = 29.15
Yellowness Index, (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / E313 / G154	59.76
Tensile Strength, psi (Modified Type I; 20"/min) - (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM D638 / G154 (Cycle 1)	3215 psi avg
Tensile Elongation, % (Modified Type I; 20"/min) - (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	528% avg
*BYK Gardner Color-Guide 45°/0°		

Evaluated By:

James M. Swickard, Coatings Laboratory Manager
FIU Durapost SG1 ALDOT White-BYK (FL #1819) Research Study BVD29 TWO 977-29 (42417)

STATE OF MISSISSIPPI NOTARY PUBLIC ID # 113928 LORENA B. TOMPKINS Commission Expires Oct. 1, 2019 MADISON COUNTY

Date 11/28/17

Notary Public Lorena B. Tompkins

FUTURE LABS, LLC
Highway Safety Product Testing

www.FutureLabsLLC.com
124 Lone Wolf Drive • Madison, MS 39110
601.855.7407

DATE: **November 28, 2017**

REPORT: The following report covers testing of the product received in accordance with **Research Study BVD29 TWO 977-29 (42417).**

PRODUCT: **Safehit Durapost – SG1 ALDOT White Delineator**

SAMPLE: **Product samples** were received on **June 6, 2017.**

PROCEDURE: Test samples were conditioned, prepared, and tested in accordance with the methods listed.

RESULTS:

Safehit Durapost - SG1 ALDOT [Research Study BVD29 TWO 977-29 (4/24/17)]		
Test Property	**Method**	**RESULTS**
Ash Content, % (Procedure B)	ASTM D5630	5.98% avg
Specific Gravity, g/cc	ASTM D792	1.234 g/cc avg
Color - CIE*Lab, Initial (D65/10)*	ASTM E1347 / E1349	96.21L, -0.84a, 5.27b
Color - CIE*Yxy, Initial (D65/10)*	ASTM E1347 / E1349	90.52Y, 0.3219x, 0.3412y
Yellowness Index, Initial (D65/10)*	ASTM E1349 / E313	9.18
Tensile Strength, Initial, psi (Modified Type I; 20"/min)	ASTM D638	3292 psi avg
Tensile Elongation, Initial, % (Modified Type I; 20"/min)	ASTM D638	689% avg
Color - After QUV, CIE*Lab (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / G154 (Cycle 1)	84.68L, 5.31a, 32.14b
Color - After QUV, CIE*Yxy (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / G154 (Cycle 1)	65.38Y, 0.3836x, 0.3900y
Color - ΔE to Initial (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1347 / E1349 / G154 (Cycle 1)	ΔE CIE*Lab = 29.87
Yellowness Index, (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / E313 / G154	61.21
Tensile Strength, psi (Modified Type I; 20"/min) - (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	3215 psi avg
Tensile Elongation, % (Modified Type I; 20"/min) - (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	528% avg
*HunterLab MiniScan EZ 4500L		

Evaluated By:

James M. Swickard, Coatings Laboratory Manager
FIU Durapost SG1 ALDOT White-Hunter (FL #1819) Research Study BVD29 TWO 977-29 (42417)

STATE OF MISSISSIPPI NOTARY PUBLIC ID # 113928 LORENA B. TOMPKINS Commission Expires Oct. 1, 2019 MADISON COUNTY

Date 11/28/17

Notary Public Lorena B. Tompkins

FUTURE LABS, LLC
Highway Safety Product Testing

www.FutureLabsLLC.com
124 Lone Wolf Drive • Madison, MS 39110
601.855.7407

DATE: **November 28, 2017**

REPORT: The following report covers testing of the product received in accordance with **Research Study BVD29 TWO 977-29 (42417).**

PRODUCT: **City Post SM (Sample No. 8) – Surface Mount White Delineator**

SAMPLE: **Product samples** were received on **June 6, 2017.**

PROCEDURE: Test samples were conditioned, prepared, and tested in accordance with the methods listed.

RESULTS:

City Post SM (Sample No. 8) - Surface Mount [Research Study BVD29 TWO 977-29 (4/24/17)]		
Test Property	**Method**	**RESULTS**
Ash Content, % (Procedure B)	ASTM D5630	1.12% avg
Specific Gravity, g/cc	ASTM D792	1.127 g/cc avg
Color - CIE*Lab, Initial (C/2)	ASTM E1347 / E1349	92.96L, -0.92a, -1.27b
Color - CIE*Yxy, Initial (C/2)	ASTM E1347 / E1349	84.47Y, 0.3065x, 0.3143y
Yellowness Index, Initial (C/2)	ASTM E1349 / E313	3.28
Tensile Strength, Initial, psi (Modified Type I; 20"/min)	ASTM D638	3235 psi avg
Tensile Elongation, Initial, % (Modified Type I; 20"/min)	ASTM D638	423% avg
Color - After QUV, CIE*Lab (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM E1349 / G154 (Cycle 1)	84.14L, -0.90a, 32.72b
Color - After QUV, CIE*Yxy (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM E1349 / G154 (Cycle 1)	65.97Y, 0.3744x, 0.3840y
Color - ΔE to Initial (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM E1347 / E1349 / G154 (Cycle 1)	ΔE CIE*Lab = 35.13
Yellowness Index, (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM E1349 / E313 / G154	57.79
Tensile Strength, psi (Modified Type I; 20"/min) - (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	4162 psi avg
Tensile Elongation, % (Modified Type I; 20"/min) - (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	406% avg
*BYK Gardner Color-Guide 45°/0°		

Evaluated By:

James M. Swickard, Coatings Laboratory Manager
FIU CPSM No.8 White-BYK (FL #1820) Research Study BVD29 TWO 977-29 (42417)

STATE OF MISSISSIPPI NOTARY PUBLIC ID # 113928 LORENA B. TOMPKINS Commission Expires Oct. 1, 2019 MADISON COUNTY

Date 11/28/17

Notary Public Lorena B. Tompkins

FUTURE LABS, LLC
Highway Safety Product Testing

www.FutureLabsLLC.com
124 Lone Wolf Drive • Madison, MS 39110
601.855.7407

DATE: **November 28, 2017**

REPORT: The following report covers testing of the product received in accordance with **Research Study BVD29 TWO 977-29 (42417).**

PRODUCT: **City Post SM (Sample No. 8) – Surface Mount White Delineator**

SAMPLE: **Product samples** were received on **June 6, 2017.**

PROCEDURE: Test samples were conditioned, prepared, and tested in accordance with the methods listed.

RESULTS:

City Post SM (Sample No. 8) - Surface Mount [Research Study BVD29 TWO 977-29 (4/24/17)]		
Test Property	**Method**	**RESULTS**
Ash Content, % (Procedure B)	ASTM D5630	1.12% avg
Specific Gravity, g/cc	ASTM D792	1.127 g/cc avg
Color - CIE*Lab, Initial (D65/10)*	ASTM E1347 / E1349	94.21L, -1.17a, -5.13b
Color - CIE*Yxy, Initial (D65/10)*	ASTM E1347 / E1349	85.75Y, 0.3033x, 0.3223y
Yellowness Index, Initial (D65/10)*	ASTM E1349 / E313	-11.18
Tensile Strength, Initial, psi (Modified Type I; 20"/min)	ASTM D638	3235 psi avg
Tensile Elongation, Initial, % (Modified Type I; 20"/min)	ASTM D638	423% avg
Color - After QUV, CIE*Lab (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / G154 (Cycle 1)	84.80L, 2.34a, 35.30b
Color - After QUV, CIE*Yxy (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / G154 (Cycle 1)	65.65Y, 0.3845x, 0.3990y
Color - ΔE to Initial (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1347 / E1349 / G154 (Cycle 1)	ΔE CIE*Lab = 41.67
Yellowness Index, (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / E313 / G154	62.95
Tensile Strength, psi (Modified Type I; 20"/min) - (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	4162 psi avg
Tensile Elongation, % (Modified Type I; 20"/min) - (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	406% avg
*HunterLab MiniScan EZ 4500L		

Evaluated By:

James M. Swickard, Coatings Laboratory Manager
FIU CPSM No.8 White-Hunter (FL #1820) Research Study BVD29 TWO 977-29 (42417)

STATE OF MISSISSIPPI NOTARY PUBLIC ID # 113928 LORENA B. TOMPKINS Commission Expires Oct. 1, 2019 MADISON COUNTY

Date 11/28/17

Notary Public Lorena B. Tompkins

FUTURE LABS, LLC
Highway Safety Product Testing

www.FutureLabsLLC.com
124 Lone Wolf Drive • Madison, MS 39110
601.855.7407

DATE: **November 28, 2017**

REPORT: The following report covers testing of the product received in accordance with **Research Study BVD29 TWO 977-29 (42417).**

PRODUCT: **City Post EAC (Sample No. 8) – Embedded Anchor Cup White Delineator**

SAMPLE: **Product samples** were received on **June 6, 2017.**

PROCEDURE: Test samples were conditioned, prepared, and tested in accordance with the methods listed.

RESULTS:

City Post EAC (Sample No. 8) - Embedded Anchor Cup [Research Study BVD29 TWO 977-29 (4/24/17)]		
Test Property	**Method**	**RESULTS**
Ash Content, % (Procedure B)	ASTM D5630	1.08% avg
Specific Gravity, g/cc	ASTM D792	1.130 g/cc avg
Color - CIE*Lab, Initial (C/2)	ASTM E1347 / E1349	92.98L, -0.82a, -1.39b
Color - CIE*Yxy, Initial (C/2)	ASTM E1347 / E1349	84.53Y, 0.3064x, 0.3141y
Yellowness Index, Initial (C/2)	ASTM E1349 / E313	3.44
Tensile Strength, Initial, psi (Modified Type I; 20"/min)	ASTM D638	3556 psi avg
Tensile Elongation, Initial, % (Modified Type I; 20"/min)	ASTM D638	420% avg
Color - After QUV, CIE*Lab (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM E1349 / G154 (Cycle 1)	84.15L, -1.02a, 32.79b
Color - After QUV, CIE*Yxy (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM E1349 / G154 (Cycle 1)	65.99Y, 0.3743x, 0.3843y
Color - ΔE to Initial (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM E1347 / E1349 / G154 (Cycle 1)	ΔE CIE*Lab = 35.31
Yellowness Index, (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM E1349 / E313 / G154	57.78
Tensile Strength, psi (Modified Type I; 20"/min) - (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	3625 psi avg
Tensile Elongation, % (Modified Type I; 20"/min) - (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	332% avg
*BYK Gardner Color-Guide 45°/0°		

Evaluated By:

James M. Swickard, Coatings Laboratory Manager
FIU CPEAC No.8 White-BYK (FL #1821) Research Study BVD29 TWO 977-29 (42417)

STATE OF MISSISSIPPI NOTARY PUBLIC ID # 113928 LORENA B. TOMPKINS Commission Expires Oct. 1, 2019 MADISON COUNTY

Date 11/28/17

Notary Public Lorena B. Tompkins

FUTURE LABS, LLC
Highway Safety Product Testing

www.FutureLabsLLC.com
124 Lone Wolf Drive • Madison, MS 39110
601.855.7407

DATE: **November 28, 2017**

REPORT: The following report covers testing of the product received in accordance with **Research Study BVD29 TWO 977-29 (42417).**

PRODUCT: **City Post EAC (Sample No. 8) – Embedded Anchor Cup White Delineator**

SAMPLE: **Product samples** were received on **June 6, 2017.**

PROCEDURE: Test samples were conditioned, prepared, and tested in accordance with the methods listed.

RESULTS:

City Post EAC (Sample No. 8) - Embedded Anchor Cup [Research Study BVD29 TWO 977-29 (4/24/17)]		
Test Property	**Method**	**RESULTS**
Ash Content, % (Procedure B)	ASTM D5630	1.08% avg
Specific Gravity, g/cc	ASTM D792	1.130 g/cc avg
Color - CIE*Lab, Initial (D65/10)*	ASTM E1347 / E1349	94.24L, -1.07a, -5.35b
Color - CIE*Yxy, Initial (D65/10)*	ASTM E1347 / E1349	85.82Y, 0.3031x, 0.3219y
Yellowness Index, Initial (D65/10)*	ASTM E1349 / E313	-11.45
Tensile Strength, Initial, psi (Modified Type I; 20"/min)	ASTM D638	3556 psi avg
Tensile Elongation, Initial, % (Modified Type I; 20"/min)	ASTM D638	420% avg
Color - After QUV, CIE*Lab (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / G154 (Cycle 1)	84.76L, 2.31a, 35.38b
Color - After QUV, CIE*Yxy (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / G154 (Cycle 1)	65.55Y, 0.3846x, 0.3992y
Color - ΔE to Initial (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1347 / E1349 / G154 (Cycle 1)	ΔE CIE*Lab = 41.96
Yellowness Index, (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / E313 / G154	63.06
Tensile Strength, psi (Modified Type I; 20"/min) - (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	3625 psi avg
Tensile Elongation, % (Modified Type I; 20"/min) - (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	332% avg
*HunterLab MiniScan EZ 4500L		

Evaluated By:

James M. Swickard, Coatings Laboratory Manager
FIU CPEAC No.8 White-Hunter (FL #1821) Research Study BVD29 TWO 977-29 (42417)

STATE OF MISSISSIPPI NOTARY PUBLIC ID # 113928 LORENA B. TOMPKINS Commission Expires Oct. 1, 2019 MADISON COUNTY

Date 11/28/17

Notary Public Lorena B. Tompkins

FUTURE LABS, LLC
Highway Safety Product Testing

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601.855.7407

DATE: **November 28, 2017**

REPORT: The following report covers testing of the product received in accordance with **Research Study BVD29 TWO 977-29 (42417).**

PRODUCT: **City Post GD West (Sample No. 2) – Glue Down White Delineator**

SAMPLE: **Product samples** were received on **June 6, 2017.**

PROCEDURE: Test samples were conditioned, prepared, and tested in accordance with the methods listed.

RESULTS:

City Post GD West (Sample No. 2) - Glue Down [Research Study BVD29 TWO 977-29 (4/24/17)]		
Test Property	**Method**	**RESULTS**
Ash Content, % (Procedure B)	ASTM D5630	1.00% avg
Specific Gravity, g/cc	ASTM D792	1.132 g/cc avg
Color - CIE*Lab, Initial (C/2)	ASTM E1347 / E1349	93.15L, -0.88a, -1.28b
Color - CIE*Yxy, Initial (C/2)	ASTM E1347 / E1349	84.91Y, 0.3066x, 0.3143y
Yellowness Index, Initial (C/2)	ASTM E1349 / E313	3.26
Tensile Strength, Initial, psi (Modified Type I; 20"/min)	ASTM D638	3043 psi
Tensile Elongation, Initial, % (Modified Type I; 20"/min)	ASTM D638	408%
Color - After QUV, CIE*Lab (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM E1349 / G154 (Cycle 1)	85.06L, -1.47a, 31.92b
Color - After QUV, CIE*Yxy (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM E1349 / G154 (Cycle 1)	67.73Y, 0.3713x, 0.3824y
Color - ΔE to Initial (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM E1347 / E1349 / G154 (Cycle 1)	ΔE CIE*Lab = 34.18
Yellowness Index, (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM E1349 / E313 / G154	55.73
Tensile Strength, psi (Modified Type I; 20"/min) - (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	3862 psi avg
Tensile Elongation, % (Modified Type I; 20"/min) - (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	381% avg
*BYK Gardner Color-Guide 45°/0°		

Evaluated By:

James M. Swickard, Coatings Laboratory Manager
FIU CPGD West No.2 White-BYK (FL #1822) Research Study BVD29 TWO 977-29 (42417)

STATE OF MISSISSIPPI NOTARY PUBLIC ID # 113928 LORENA B. TOMPKINS Commission Expires Oct. 1, 2019 MADISON COUNTY

Date 11/28/17

Notary Public Lorena B. Tompkins

FUTURE LABS, LLC
Highway Safety Product Testing

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124 Lone Wolf Drive • Madison, MS 39110
601.855.7407

DATE: **November 28, 2017**

REPORT: The following report covers testing of the product received in accordance with **Research Study BVD29 TWO 977-29 (42417).**

PRODUCT: **City Post GD West (Sample No. 2) – Glue Down White Delineator**

SAMPLE: **Product samples** were received on **June 6, 2017.**

PROCEDURE: Test samples were conditioned, prepared, and tested in accordance with the methods listed.

RESULTS:

City Post GD West (Sample No. 2) - Glue Down [Research Study BVD29 TWO 977-29 (4/24/17)]		
Test Property	**Method**	**RESULTS**
Ash Content, % (Procedure B)	ASTM D5630	1.00% avg
Specific Gravity, g/cc	ASTM D792	1.132 g/cc avg
Color - CIE*Lab, Initial (D65/10)*	ASTM E1347 / E1349	94.44L, -1.13a, -5.01b
Color - CIE*Yxy, Initial (D65/10)*	ASTM E1347 / E1349	86.29Y, 0.3035x, 0.3224y
Yellowness Index, Initial (D65/10)*	ASTM E1349 / E313	-10.88
Tensile Strength, Initial, psi (Modified Type I; 20"/min)	ASTM D638	3043 psi
Tensile Elongation, Initial, % (Modified Type I; 20"/min)	ASTM D638	408%
Color - After QUV, CIE*Lab (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / G154 (Cycle 1)	85.79L, 1.80a, 34.63b
Color - After QUV, CIE*Yxy (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / G154 (Cycle 1)	67.57Y, 0.3817x, 0.3977y
Color - ΔE to Initial (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1347 / E1349 / G154 (Cycle 1)	ΔE CIE*Lab = 40.68
Yellowness Index, (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / E313 / G154	61.1
Tensile Strength, psi (Modified Type I; 20"/min) - (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	3862 psi avg
Tensile Elongation, % (Modified Type I; 20"/min) - (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	381% avg
*HunterLab MiniScan EZ 4500L		

Evaluated By:

James M. Swickard, Coatings Laboratory Manager
FIU CPGD West No.2 White-Hunter (FL #1822) Research Study BVD29 TWO 977-29 (42417)

STATE OF MISSISSIPPI
NOTARY PUBLIC
ID # 113928
LORENA B. TOMPKINS
Commission Expires
Oct. 1, 2019
MADISON COUNTY

Date 11/28/17

Notary Public Lorena B. Tompkins

FUTURE LABS, LLC
Highway Safety Product Testing

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124 Lone Wolf Drive • Madison, MS 39110
601.855.7407

DATE: **November 28, 2017**

REPORT: The following report covers testing of the product received in accordance with **Research Study BVD29 TWO 977-29 (42417).**

PRODUCT: **City Post GD West (Sample No. 4) – Glue Down White Delineator**

SAMPLE: **Product samples** were received on **June 6, 2017.**

PROCEDURE: Test samples were conditioned, prepared, and tested in accordance with the methods listed.

RESULTS:

City Post GD West (Sample No. 4) - Glue Down [Research Study BVD29 TWO 977-29 (4/24/17)]		
Test Property	**Method**	**RESULTS**
Ash Content, % (Procedure B)	ASTM D5630	0.94% avg
Specific Gravity, g/cc	ASTM D792	1.127 g/cc avg
Color - CIE*Lab, Initial (C/2)	ASTM E1347 / E1349	93.08L, -0.86a, -1.29b
Color - CIE*Yxy, Initial (C/2)	ASTM E1347 / E1349	84.76Y, 0.3065x, 0.3143y
Yellowness Index, Initial (C/2)	ASTM E1349 / E313	3.26
Tensile Strength, Initial, psi (Modified Type I; 20"/min)	ASTM D638	3366 psi avg
Tensile Elongation, Initial, % (Modified Type I; 20"/min)	ASTM D638	402% avg
Color - After QUV, CIE*Lab (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM E1349 / G154 (Cycle 1)	83.93L, -0.75a, 33.19b
Color - After QUV, CIE*Yxy (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM E1349 / G154 (Cycle 1)	68.04Y, 0.3756x, 0.3850y
Color - ΔE to Initial (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM E1347 / E1349 / G154 (Cycle 1)	ΔE CIE*Lab = 35.68
Yellowness Index, (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM E1349 / E313 / G154	58.70
Tensile Strength, psi (Modified Type I; 20"/min) - (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	3564 psi avg
Tensile Elongation, % (Modified Type I; 20"/min) - (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	331% avg
*BYK Gardner Color-Guide 45°/0°		

Evaluated By:

James M. Swickard, Coatings Laboratory Manager
FIU CPGD West No.4 White-BYK (FL #1823) Research Study BVD29 TWO 977-29 (42417)

STATE OF MISSISSIPPI NOTARY PUBLIC ID # 113928 LORENA B. TOMPKINS Commission Expires Oct. 1, 2019 MADISON COUNTY

Date 11/28/17

Notary Public Lorena B. Tompkins

FUTURE LABS, LLC
Highway Safety Product Testing

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601.855.7407

DATE: **November 28, 2017**

REPORT: The following report covers testing of the product received in accordance with **Research Study BVD29 TWO 977-29 (42417).**

PRODUCT: **City Post GD West (Sample No. 4) – Glue Down White Delineator**

SAMPLE: **Product samples** were received on **June 6, 2017.**

PROCEDURE: Test samples were conditioned, prepared, and tested in accordance with the methods listed.

RESULTS:

City Post GD West (Sample No. 4) - Glue Down [Research Study BVD29 TWO 977-29 (4/24/17)]		
Test Property	**Method**	**RESULTS**
Ash Content, % (Procedure B)	ASTM D5630	0.94% avg
Specific Gravity, g/cc	ASTM D792	1.127 g/cc avg
Color - CIE*Lab, Initial (D65/10)*	ASTM E1347 / E1349	94.38L, -1.17a, -4.93b
Color - CIE*Yxy, Initial (D65/10)*	ASTM E1347 / E1349	86.15Y, 0.3036x, 0.3226y
Yellowness Index, Initial (D65/10)*	ASTM E1349 / E313	-10.69
Tensile Strength, Initial, psi (Modified Type I; 20"/min)	ASTM D638	3366 psi avg
Tensile Elongation, Initial, % (Modified Type I; 20"/min)	ASTM D638	402% avg
Color - After QUV, CIE*Lab (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / G154 (Cycle 1)	84.67L, 2.55a, 35.86b
Color - After QUV, CIE*Yxy (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / G154 (Cycle 1)	65.36Y, 0.3859x, 0.3999y
Color - ΔE to Initial (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1347 / E1349 / G154 (Cycle 1)	ΔE CIE*Lab = 42.10
Yellowness Index, (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / E313 / G154	63.95
Tensile Strength, psi (Modified Type I; 20"/min) - (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	3564 psi avg
Tensile Elongation, % (Modified Type I; 20"/min) - (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	331% avg
*HunterLab MiniScan EZ 4500L		

Evaluated By:

James M. Swickard, Coatings Laboratory Manager
FIU CPGD West No.4 White-Hunter (FL #1823) Research Study BVD29 TWO 977-29 (42417)

STATE OF MISSISSIPPI NOTARY PUBLIC ID # 113928 LORENA B. TOMPKINS Commission Expires Oct. 1, 2019 MADISON COUNTY

Date 11/28/17

Notary Public Lorena B. Tompkins

FUTURE LABS, LLC
Highway Safety Product Testing

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601.855.7407

DATE: **November 28, 2017**

REPORT: The following report covers testing of the product received in accordance with **Research Study BVD29 TWO 977-29 (42417).**

PRODUCT: **SHUR-TITE White Delineator**

SAMPLE: **Product samples** were received on **June 6, 2017.**

PROCEDURE: Test samples were conditioned, prepared, and tested in accordance with the methods listed.

RESULTS:

SHUR-TITE [Research Study BVD29 TWO 977-29 (4/24/17)]		
Test Property	**Method**	**RESULTS**
Ash Content, % (Procedure B)	ASTM D5630	0.57% avg
Specific Gravity, g/cc	ASTM D792	1.144 g/cc avg
Color - CIE*Lab, Initial (C/2)	ASTM E1347 / E1349	93.21L, -2.90a, 7.57b
Color - CIE*Yxy, Initial (C/2)	ASTM E1347 / E1349	85.05Y, 0.3201x, 0.3325y
Yellowness Index, Initial (C/2)	ASTM E1349 / E313	12.20
Tensile Strength, Initial, psi (Modified Type I; 20"/min)	ASTM D638	3550 psi avg
Tensile Elongation, Initial, % (Modified Type I; 20"/min)	ASTM D638	366% avg
Color - After QUV, CIE*Lab (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM E1349 / G154 (Cycle 1)	82.34L, 0.66a, 34.89b
Color - After QUV, CIE*Yxy (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM E1349 / G154 (Cycle 1)	62.53Y, 0.3823x, 0.3880y
Color - ΔE to Initial (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM E1347 / E1349 / G154 (Cycle 1)	ΔE CIE*Lab = 29.62
Yellowness Index, (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM E1349 / E313 / G154	63.08
Tensile Strength, psi (Modified Type I; 20"/min) - (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	3575 psi avg
Tensile Elongation, % (Modified Type I; 20"/min) - (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	303% avg
*BYK Gardner Color-Guide 45°/0°		

Evaluated By:

James M. Swickard, Coatings Laboratory Manager
FIU SHUR-TITE White-BYK (FL #1824) Research Study BVD29 TWO 977-29 (42417)

STATE OF MISSISSIPPI NOTARY PUBLIC ID # 113928 LORENA B. TOMPKINS Commission Expires Oct. 1, 2019 MADISON COUNTY

Date 11/28/17

Notary Public Lorena B. Tompkins

FUTURE LABS, LLC
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601.855.7407

DATE: **November 28, 2017**

REPORT: The following report covers testing of the product received in accordance with **Research Study BVD29 TWO 977-29 (42417).**

PRODUCT: **SHUR-TITE White Delineator**

SAMPLE: **Product samples** were received on **June 6, 2017.**

PROCEDURE: Test samples were conditioned, prepared, and tested in accordance with the methods listed.

RESULTS:

SHUR-TITE [Research Study BVD29 TWO 977-29 (4/24/17)]		
Test Property	**Method**	**RESULTS**
Ash Content, % (Procedure B)	ASTM D5630	0.57% avg
Specific Gravity, g/cc	ASTM D792	1.144 g/cc avg
Color - CIE*Lab, Initial (D65/10)*	ASTM E1347 / E1349	93.94L, -1.72a, 8.49b
Color - CIE*Yxy, Initial (D65/10)*	ASTM E1347 / E1349	85.14Y, 0.3264x, 0.3481y
Yellowness Index, Initial (D65/10)*	ASTM E1349 / E313	14.93
Tensile Strength, Initial, psi (Modified Type I; 20"/min)	ASTM D638	3550 psi avg
Tensile Elongation, Initial, % (Modified Type I; 20"/min)	ASTM D638	366% avg
Color - After QUV, CIE*Lab (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / G154 (Cycle 1)	82.88L, 4.42a, 37.80b
Color - After QUV, CIE*Yxy (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / G154 (Cycle 1)	61.95Y, 0.3938x, 0.4026y
Color - ΔE to Initial (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1347 / E1349 / G154 (Cycle 1)	ΔE CIE*Lab = 31.93
Yellowness Index, (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / E313 / G154	69.10
Tensile Strength, psi (Modified Type I; 20"/min) - (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	3575 psi avg
Tensile Elongation, % (Modified Type I; 20"/min) - (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	303% avg
*HunterLab MiniScan EZ 4500L		

Evaluated By:

James M. Swickard, Coatings Laboratory Manager
FIU SHUR-TITE White-Hunter (FL #1824) Research Study BVD29 TWO 977-29 (42417)

STATE OF MISSISSIPPI NOTARY PUBLIC ID # 113928 LORENA B. TOMPKINS Commission Expires Oct. 1, 2019 MADISON COUNTY

Date 11/28/17

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601.855.7407

DATE: **November 28, 2017**

REPORT: The following report covers testing of the product received in accordance with **Research Study BVD29 TWO 977-29 (42417).**

PRODUCT: **Pexco City Post (with Anchor Cup) Orange Delineator**

SAMPLE: **Product samples** were received on **August 30, 2017.**

PROCEDURE: Test samples were conditioned, prepared, and tested in accordance with the methods listed.

RESULTS:

Orange Pexco City Post (with Anchor Cup) - [Research Study BVD29 TWO 977-29 (4/24/17)]		
Test Property	**Method**	**RESULTS**
Ash Content, % (Procedure B)	ASTM D5630	0.10% avg
Specific Gravity, g/cc	ASTM D792	1.113 g/cc avg
Color - CIE*Lab, Initial (C/2)*	ASTM E1347 / E1349	68.38L, 28.58a, 9.79b
Color - CIE*Yxy, Initial (C/2)*	ASTM E1347 / E1349	38.48Y, 0.3858x, 0.3135y
Yellowness Index, Initial (C/2)*	ASTM E1349 / E313	55.52
Tensile Strength, Initial, psi (Modified Type I; 20"/min)	ASTM D638	3775 psi avg
Tensile Elongation, Initial, % (Modified Type I; 20"/min)	ASTM D638	432% avg
Color - After QUV, CIE*Lab (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / G154 (Cycle 1)	60.29L, 29.68a, 35.77b
Color - After QUV, CIE*Yxy (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / G154 (Cycle 1)	28.46Y, 0.4661x, 0.3667y
Color - ΔE to Initial (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1347 / E1349 / G154 (Cycle 1)	ΔE CIE*Lab = 27.26
Yellowness Index, (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / E313 / G154	113.98
Tensile Strength, psi (Modified Type I; 20"/min) - (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM D638 / G154 (Cycle 1)	3854 psi avg
Tensile Elongation, % (Modified Type I; 20"/min) - (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	468% avg
*BYK Gardner Color-Guide 45°/0°		

Evaluated By:

James M. Swickard, Coatings Laboratory Manager
FIU CPAC Orange-BYK (FL #1880) Research Study BVD29 TWO 977-29 (42417)

STATE OF MISSISSIPPI NOTARY PUBLIC ID # 113928 LORENA B. TOMPKINS Commission Expires Oct. 1, 2019 MADISON COUNTY

Date 11/28/17

Notary Public Lorena B. Tompkins

FUTURE LABS, LLC
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601.855.7407

DATE: **November 28, 2017**

REPORT: The following report covers testing of the product received in accordance with **Research Study BVD29 TWO 977-29 (42417).**

PRODUCT: **Pexco City Post (with Anchor Cup) Orange Delineator**

SAMPLE: **Product samples** were received on **August 30, 2017.**

PROCEDURE: Test samples were conditioned, prepared, and tested in accordance with the methods listed.

RESULTS:

Orange Pexco City Post (with Anchor Cup) - [Research Study BVD29 TWO 977-29 (4/24/17)]		
Test Property	**Method**	**RESULTS**
Ash Content, % (Procedure B)	ASTM D5630	0.10% avg
Specific Gravity, g/cc	ASTM D792	1.113 g/cc avg
Color - CIE*Lab, Initial (D65/10)*	ASTM E1347 / E1349	60.08L, 69.12a, 63.82b
Color - CIE*Yxy, Initial (D65/10)*	ASTM E1347 / E1349	28.21Y, 0.5951x, 0.3536y
Yellowness Index, Initial (D65/10)*	ASTM E1349 / E313	202.30
Tensile Strength, Initial, psi (Modified Type I; 20"/min)	ASTM D638	3775 psi avg
Tensile Elongation, Initial, % (Modified Type I; 20"/min)	ASTM D638	432% avg
Color - After QUV, CIE*Lab (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / G154 (Cycle 1)	56.20L, 51.88a, 50.59b
Color - After QUV, CIE*Yxy (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / G154 (Cycle 1)	24.07Y, 0.5515x, 0.3663y
Color - ΔE to Initial (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1347 / E1349 / G154 (Cycle 1)	ΔE CIE*Lab = 22.08
Yellowness Index, (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / E313 / G154	170.10
Tensile Strength, psi (Modified Type I; 20"/min) - (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	3854 psi avg
Tensile Elongation, % (Modified Type I; 20"/min) - (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	468% avg
*HunterLab MiniScan EZ 4500L		

Evaluated By:

James M. Swickard, Coatings Laboratory Manager
FIU CPAC Orange-Hunter (FL #1880) Research Study BVD29 TWO 977-29 (42417)

STATE OF MISSISSIPPI NOTARY PUBLIC ID # 113928 LORENA B. TOMPKINS Commission Expires Oct. 1, 2019 MADISON COUNTY

Date 11/28/17

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DATE: **November 28, 2017**

REPORT: The following report covers testing of the product received in accordance with **Research Study BVD29 TWO 977-29 (42417).**

PRODUCT: **Safehit Durapost – SG1 ALDOT White Delineator**

SAMPLE: **Product samples** were received on **August 30, 2017.**

PROCEDURE: Test samples were conditioned, prepared, and tested in accordance with the methods listed.

RESULTS:

White Safehit Durapost - SG1 ALDOT - [Research Study BVD29 TWO 977-29 (4/24/17)]		
Test Property	**Method**	**RESULTS**
Ash Content, % (Procedure B)	ASTM D5630	5.43% avg
Specific Gravity, g/cc	ASTM D792	1.233 g/cc avg
Color - CIE*Lab, Initial (C/2)	ASTM E1347 / E1349	95.48L, -1.18a, 4.94b
Color - CIE*Yxy, Initial (C/2)	ASTM E1347 / E1349	90.36Y, 0.3175x, 0.3260y
Yellowness Index, Initial (C/2)	ASTM E1349 / E313	8.49
Tensile Strength, Initial, psi (Modified Type I; 20"/min)	ASTM D638	3888 psi avg
Tensile Elongation, Initial, % (Modified Type I; 20"/min)	ASTM D638	557% avg
Color - After QUV, CIE*Lab (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM E1349 / G154 (Cycle 1)	84.75L, 1.30a, 29.87b
Color - After QUV, CIE*Yxy (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM E1349 / G154 (Cycle 1)	67.15Y, 0.3719x, 0.3758y
Color - ΔE to Initial (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM E1347 / E1349 / G154 (Cycle 1)	ΔE CIE*Lab = 27.31
Yellowness Index, (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM E1349 / E313 / G154	55.27
Tensile Strength, psi (Modified Type I; 20"/min) - (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	3566 psi avg
Tensile Elongation, % (Modified Type I; 20"/min) - (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	629% avg
*BYK Gardner Color-Guide 45°/0°		

Evaluated By:

James M. Swickard, Coatings Laboratory Manager
FIU Durapost SG1 ALDOT White-BYK (FL #1881) Research Study BVD29 TWO 977-29 (42417)

STATE OF MISSISSIPPI NOTARY PUBLIC ID # 113928 LORENA B. TOMPKINS Commission Expires Oct. 1, 2019 MADISON COUNTY

Date 11/28/17

Notary Public Lorena B. Tompkins

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Highway Safety Product Testing

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601.855.7407

DATE: **November 28, 2017**

REPORT: The following report covers testing of the product received in accordance with **Research Study BVD29 TWO 977-29 (42417).**

PRODUCT: **Safehit Durapost – SG1 ALDOT White Delineator**

SAMPLE: **Product samples** were received on **August 30, 2017.**

PROCEDURE: Test samples were conditioned, prepared, and tested in accordance with the methods listed.

RESULTS:

White Safehit Durapost - SG1 ALDOT - [Research Study BVD29 TWO 977-29 (4/24/17)]		
Test Property	**Method**	**RESULTS**
Ash Content, % (Procedure B)	ASTM D5630	5.43% avg
Specific Gravity, g/cc	ASTM D792	1.233 g/cc avg
Color - CIE*Lab, Initial (D65/10)*	ASTM E1347 / E1349	95.87L, -0.58a, 5.18b
Color - CIE*Yxy, Initial (D65/10)*	ASTM E1347 / E1349	89.70Y, 0.3221x, 0.3409y
Yellowness Index, Initial (D65/10)*	ASTM E1349 / E313	9.24
Tensile Strength, Initial, psi (Modified Type I; 20"/min)	ASTM D638	3888 psi avg
Tensile Elongation, Initial, % (Modified Type I; 20"/min)	ASTM D638	557% avg
Color - After QUV, CIE*Lab (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / G154 (Cycle 1)	84.72L, 4.65a, 30.87b
Color - After QUV, CIE*Yxy (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / G154 (Cycle 1)	65.49Y, 0.3801x, 0.3883y
Color - ΔE to Initial (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1347 / E1349 / G154 (Cycle 1)	ΔE CIE*Lab = 28.55
Yellowness Index, (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / E313 / G154	58.80
Tensile Strength, psi (Modified Type I; 20"/min) - (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	3566 psi avg
Tensile Elongation, % (Modified Type I; 20"/min) - (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	629% avg
*HunterLab MiniScan EZ 4500L		

Evaluated By:

James M. Swickard, Coatings Laboratory Manager
FIU Durapost SG1 ALDOT White-Hunter (FL #1881) Research Study BVD29 TWO 977-29 (42417)

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Notary Public Lorena B. Tompkins

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601.855.7407

DATE: **November 28, 2017**

REPORT: The following report covers testing of the product received in accordance with **Research Study BVD29 TWO 977-29 (42417).**

PRODUCT: **Endoto Post (CTDOT) White Delineator**

SAMPLE: **Product samples** were received on **August 30, 2017.**

PROCEDURE: Test samples were conditioned, prepared, and tested in accordance with the methods listed.

RESULTS:

White Endoto Post (CTDOT) - [Research Study BVD29 TWO 977-29 (4/24/17)]		
Test Property	**Method**	**RESULTS**
Ash Content, % (Procedure B)	ASTM D5630	1.38% avg
Specific Gravity, g/cc	ASTM D792	1.214 g/cc avg
Color - CIE*Lab, Initial (C/2)	ASTM E1347 / E1349	96.20L, -1.37a, 5.65b
Color - CIE*Yxy, Initial (C/2)	ASTM E1347 / E1349	92.09Y, 0.3184x, 0.3274y
Yellowness Index, Initial (C/2)	ASTM E1349 / E313	9.60
Tensile Strength, Initial, psi (Modified Type I; 20"/min)	ASTM D638	2312 psi avg
Tensile Elongation, Initial, % (Modified Type I; 20"/min)	ASTM D638	652% avg
Color - After QUV, CIE*Lab (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM E1349 / G154 (Cycle 1)	94.86L, -1.73a, 9.98b
Color - After QUV, CIE*Yxy (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM E1349 / G154 (Cycle 1)	88.90Y, 0.3259x, 0.3359y
Color - ΔE to Initial (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM E1347 / E1349 / G154 (Cycle 1)	ΔE CIE*Lab = 4.54
Yellowness Index, (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM E1349 / E313 / G154	17.24
Tensile Strength, psi (Modified Type I; 20"/min) - (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	2187 psi avg
Tensile Elongation, % (Modified Type I; 20"/min) - (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	591% avg
*BYK Gardner Color-Guide 45°/0°		

Evaluated By:

James M. Swickard, Coatings Laboratory Manager
FIU Endoto CTDOT White-BYK (FL #1882) Research Study BVD29 TWO 977-29 (42417)

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601.855.7407

DATE: **November 28, 2017**

REPORT: The following report covers testing of the product received in accordance with **Research Study BVD29 TWO 977-29 (42417).**

PRODUCT: **Endoto Post (CTDOT) White Delineator**

SAMPLE: **Product samples** were received on **August 30, 2017.**

PROCEDURE: Test samples were conditioned, prepared, and tested in accordance with the methods listed.

RESULTS:

White Endoto Post (CTDOT) - [Research Study BVD29 TWO 977-29 (4/24/17)]		
Test Property	**Method**	**RESULTS**
Ash Content, % (Procedure B)	ASTM D5630	1.38% avg
Specific Gravity, g/cc	ASTM D792	1.214 g/cc avg
Color - CIE*Lab, Initial (D65/10)*	ASTM E1347 / E1349	97.02L, -0.65a, 4.82b
Color - CIE*Yxy, Initial (D65/10)*	ASTM E1347 / E1349	92.50Y, 0.3213x, 0.3402y
Yellowness Index, Initial (D65/10)*	ASTM E1349 / E313	8.44
Tensile Strength, Initial, psi (Modified Type I; 20"/min)	ASTM D638	2312 psi avg
Tensile Elongation, Initial, % (Modified Type I; 20"/min)	ASTM D638	652% avg
Color - After QUV, CIE*Lab (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / G154 (Cycle 1)	95.76L, -0.79a, 10.23b
Color - After QUV, CIE*Yxy (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / G154 (Cycle 1)	89.42Y, 0.3305x, 0.3504y
Color - ΔE to Initial (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1347 / E1349 / G154 (Cycle 1)	ΔE CIE*Lab = 5.57
Yellowness Index, (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / E313 / G154	18.02
Tensile Strength, psi (Modified Type I; 20"/min) - (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	2187 psi avg
Tensile Elongation, % (Modified Type I; 20"/min) - (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	591% avg
*HunterLab MiniScan EZ 4500L		

Evaluated By:

James M. Swickard, Coatings Laboratory Manager
FIU Endoto CTDOT White-Hunter (FL #1882) Research Study BVD29 TWO 977-29 (42417)

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601.855.7407

DATE: **November 28, 2017**

REPORT: The following report covers testing of the product received in accordance with **Research Study BVD29 TWO 977-29 (42417).**

PRODUCT: **FlexStake Orange Delineator**

SAMPLE: **Product samples** were received on **September 26, 2017.**

PROCEDURE: Test samples were conditioned, prepared, and tested in accordance with the methods listed.

RESULTS:

Orange FlexStake Delineator - [Research Study BVD29 TWO 977-29 (4/24/17)]		
Test Property	**Method**	**RESULTS**
Ash Content, % (Procedure B)	ASTM D5630	0.07% avg
Specific Gravity, g/cc	ASTM D792	1.151 g/cc avg
Color - CIE*Lab, Initial (C/2)	ASTM E1347 / E1349	45.14L, 53.29a, 46.60b
Color - CIE*Yxy, Initial (C/2)	ASTM E1347 / E1349	14.64Y, 0.5858x, 0.3437y
Yellowness Index, Initial (C/2)	ASTM E1349 / E313	195.86
Tensile Strength, Initial, psi (Modified Type I; 20"/min)	ASTM D638	4200 psi
Tensile Elongation, Initial, % (Modified Type I; 20"/min)	ASTM D638	426%
Color - After QUV, CIE*Lab (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM E1349 / G154 (Cycle 1)	41.78L, 48.27a, 43.85b
Color - After QUV, CIE*Yxy (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM E1349 / G154 (Cycle 1)	12.36Y, 0.5800x, 0.3476y
Color - ΔE to Initial (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM E1347 / E1349 / G154 (Cycle 1)	ΔE CIE*Lab = 6.84
Yellowness Index, (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM E1349 / E313 / G154	191.00
Tensile Strength, psi (Modified Type I; 20"/min) - (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	3935 psi avg
Tensile Elongation, % (Modified Type I; 20"/min) - (C/2; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	414% avg
*BYK Gardner Color-Guide 45°/0°		

Evaluated By:

James M. Swickard, Coatings Laboratory Manager
FIU FlexStake Orange-BYK (FL #1883) Research Study BVD29 TWO 977-29 (42417)

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601.855.7407

DATE: **November 28, 2017**

REPORT: The following report covers testing of the product received in accordance with **Research Study BVD29 TWO 977-29 (42417).**

PRODUCT: **FlexStake Orange Delineator**

SAMPLE: **Product samples** were received on **September 26, 2017.**

PROCEDURE: Test samples were conditioned, prepared, and tested in accordance with the methods listed.

RESULTS:

Orange FlexStake Delineator - [Research Study BVD29 TWO 977-29 (4/24/17)]		
Test Property	**Method**	**RESULTS**
Ash Content, % (Procedure B)	ASTM D5630	0.07% avg
Specific Gravity, g/cc	ASTM D792	1.151 g/cc avg
Color - CIE*Lab, Initial (D65/10)*	ASTM E1347 / E1349	44.39L, 54.86a, 45.44b
Color - CIE*Yxy, Initial (D65/10)*	ASTM E1347 / E1349	14.11Y, 0.5854x, 0.3479y
Yellowness Index, Initial (D65/10)*	ASTM E1349 / E313	196.92
Tensile Strength, Initial, psi (Modified Type I; 20"/min)	ASTM D638	4200 psi
Tensile Elongation, Initial, % (Modified Type I; 20"/min)	ASTM D638	426%
Color - After QUV, CIE*Lab (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / G154 (Cycle 1)	41.65L, 49.87a, 43.33b
Color - After QUV, CIE*Yxy (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / G154 (Cycle 1)	12.28Y, 0.5789x, 0.3527y
Color - ΔE to Initial (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1347 / E1349 / G154 (Cycle 1)	ΔE CIE*Lab = 6.85
Yellowness Index, (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)*	ASTM E1349 / E313 / G154	191.29
Tensile Strength, psi (Modified Type I; 20"/min) - (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	3935 psi avg
Tensile Elongation, % (Modified Type I; 20"/min) - (D65/10; After 1000 hr QUV : QUVA @ 0.89 IRR, 8 hrs UV @ 140°F; 4 hr Condensation @ 122°F)	ASTM D638 / G154 (Cycle 1)	414% avg
*HunterLab MiniScan EZ 45001.		

Evaluated By:

James M. Swickard, Coatings Laboratory Manager
FIU FlexStake Orange-Hunter (FL #1883) Research Study BVD29 TWO 977-29 (42417)

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