Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-06/0-4471-3		

4. Title and Subtitle	5. Report Date
DURABILITY OF PREFORMED THERMOPLASTIC PAVEMENT MARKINGS FOR HORIZONTAL SIGNING APPLICATIONS	December 2005 Published: April 2006
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
Susan T. Chrysler, Steven D. Schrock and Timothy J. Gates	Report 0-4471-3

9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Texas Transportation Institute The Texas A&M University System College Station, Texas 77843-3135	11. Contract or Grant No. Project 0-4471

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Texas Department of Transportation Research and Technology Implementation Office P. O. Box 5080 Austin, Texas 78763-5080 URL: http://tti.tamu.edudocuments/0-4471-3.pdf	Technical Report: September 2002 – October 2005
	14. Sponsoring Agency Code

15. Supplementary Notes

Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.
Project Title: Evaluation of Horizontal Signing Applications
URL: http://tti.tamu.edu/documents/0-4471-3.pdf

16. Abstract

The results of two-year durability tests of preformed thermoplastic pavement marking materials are reported. A survey of material manufacturers is also presented. Pavement marking materials in the form of transverse lines, arrowheads, and sections of the letter S were installed at test decks on three Texas roadways. Small square sections of colored pavement marking materials were also tested for some of the manufacturers. Manufacturers' representatives performed the installations. Three types of pavement surface were tested: concrete, asphalt, and seal coat. Retroreflectivity and color measurements of the materials were made at the time of installation, after one year, and after two years. Thickness of the material was measured prior to installation and at the same time intervals using video microscopy of samples chiseled from the roadway.

17. Key Words	18. Distribution Statement
Horizontal Signing, Pavement Marking Symbols, Pavement Marking Materials, Durability Testing	No restrictions. This document is available to the public through NTIS: National Technical Information Service Springfield, Virginia 22161 http://www.ntis.gov

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	152	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

DURABILITY OF PREFORMED THERMOPLASTIC PAVEMENT MARKINGS FOR HORIZONTAL SIGNING APPLICATIONS

by

Susan T. Chrysler
Research Scientist
Center for Transportation Safety
Texas Transportation Institute

Steven D. Schrock, P.E.
Assistant Research Engineer
Transportation Operations Group
Texas Transportation Institute

and

Timothy J. Gates
Assistant Transportation Researcher
Transportation Operations Group
Texas Transportation Institute

Report 0-4471-3
Project 0-4471
Project Title: Evaluation of Horizontal Signing Applications

Performed in Cooperation with the
Texas Department of Transportation
and the
Federal Highway Administration

December 2005
Published: April 2006

TEXAS TRANSPORTATION INSTITUTE
The Texas A&M University System
College Station, Texas 77843-3135

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Federal Highway Administration (FHWA) or the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation. The researcher in charge of this project was Dr. Susan Chrysler. The engineer in charge of this project was Steven D. Schrock, P.E., Texas License #92982.
The materials included in this evaluation include several trademarked products, these are:

- Flametape™ registered trademark of Ennis Paint, Inc.
- PREMARK ™ registered trademark of Flint Trading, Inc.
- HotTape™ registered trademark of Avery Dennison Corporation
- ThermaLine™ registered trademark of LaFarge, Inc. This product line was sold to Ennis Paint, Inc. in June 2003.
- Rocbinda™ registered trademark of Jobling Purser, Ltd.
- DigiMark™ registered trademark of Digital Markings, Ltd.
- StreetPrint™ registered trademark of Integrated Paving Concepts, Inc.

The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufactures' names appear herein solely because they are considered essential to the object of this report.

ACKNOWLEDGMENTS

This project was conducted in cooperation with TxDOT and FHWA. The authors would like to acknowledge the support of Roy Wright of the Abilene District, who served as project director, Sally Wegman of the Houston District, who served as program coordinator, Greg Brinkmeyer of the Traffic Operations Division, who served as project advisor, and Wade Odell, the RTI Research Engineer. Jerry Howell and Herb Smart of the Construction Division also provided invaluable assistance with the durability testing. Dock Gee and Mike Manor of the Houston and Abilene Districts provided logistical support with test deck installations in those locations. This project enjoyed the great cooperation of the many pavement marking vendors who all provided their materials and installation technical service free of charge.

TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

CHAPTER 1:
PAVEMENT MARKING MATERIAL SELECTION

This report documents the durability testing of pavement marking materials intended for use in horizontal signing applications. A previous report describes tests of driver comprehension of these messages and field tests of the effects of horizontal signing on speed at rural curves and wrong-way movements on two-way frontage roads *(1)*.

A major task of the project was to place potential horizontal signing materials on a series of on-road test decks and evaluate their performance over time. Researchers performed two tasks to identify potential horizontal signing materials:

1. Survey product vendors/manufacturers for material recommendations.
2. Review and analyze recent National Transportation Product Evaluation Program (NTPEP) data.

VENDOR SURVEY

Researchers contacted vendors that were believed to possess material(s) suitable for use as horizontal signing. Vendors were asked to participate in a short survey, which was administered either via e-mail or over the phone in fall 2002. Appendix A includes a copy of the survey questionnaire. The purpose of the survey was to identify vendors that:

- could provide material(s) suitable for use on Portland cement concrete (PCC) or hot-mix asphalt concrete (HMAC) under severe traffic conditions,
- could provide material(s) suitable for use on surface treatments (i.e., seal coat) under low-medium traffic conditions, and
- were willing to provide materials and technical support for placement on a series of on-road test decks.

Table 1 summarizes the survey findings. Detailed responses from each individual vendor can also be found in Appendix A.

Table 1. Vendor Survey Summary.

Name	Contacted?	Survey Response?	Recommended Material
Ennis	Yes	Yes	Preformed Thermoplastic
LaFarge	Yes	Yes	Preformed Thermoplastic
Avery Dennison	Yes	Yes	Preformed Thermoplastic
Flint Trading	Yes	Yes	Preformed Thermoplastic
Rocbinda	Yes	No	Colored Aggregate Overlay
3M	Yes	Yes	Tape
ATM	Yes	Yes	Tape
Trelleborg	Yes	Yes	Tape
GRT	Yes	Yes	Tape
Highway Ceramic Products	Yes	No	Nonreflective Ceramic Tile
Swarco	Yes	Yes	Tape
Digital Markings Ltd.	Yes	Yes	Polyurethane Colored Graphic Sheet
BriteLine	Yes	Yes	N/A

NTPEP REPORTS

NTPEP is responsible for testing and evaluating products, materials, and devices that are commonly used by the American Association of State Highway and Transportation Officials (AASHTO) member departments of transportation. NTPEP is a major resource for comprehensive pavement marking evaluations performed at the national level. Although data are furnished in NTPEP reports, no approval, disapproval, or endorsements of products are made per NTPEP/AASHTO policy.

Texas Transportation Institute (TTI) researchers obtained and reviewed the following three recent NTPEP pavement marking reports:

- 2000 Urban California Test Deck (first year data), Report 02 NTPEP 216 (*2*);
- 2000 Pennsylvania Test Deck (first year data), Report 02 NTPEP 221 (*3*); and
- 1999 Mississippi Test Deck (second year data), Report 02 NTPEP 220 (*4*).

All materials included in a given NTPEP evaluation were evaluated on both a PCC roadway and an HMAC roadway. A detailed description of the NTPEP data sources can be found in Appendix B.

TTI research staff analyzed the first-year[1] retroreflectivity and durability data for applicable materials from each of the three NTPEP reports (*2*,*3*,*4*). TTI research staff rated a total of 36 materials produced by six manufacturers, which were limited to preformed thermoplastics and permanent preformed tapes.

Table 2 displays the vendor information for the NTPEP materials that were rated by the researchers.

Table 2. Product Vendor Information for NTPEP Data.

Vendor	Material Type	NTPEP Test Deck
Avery Dennison	Preformed Thermoplastic	2000 Penn, 1999 Miss
BriteLine	Permanent Tape	2000 Penn, 1999 Miss, 2000 Cal
Ennis	Preformed Thermoplastic	1999 Miss, 2000 Cal
Flint Trading	Preformed Thermoplastic	2000 Penn, 1999 Miss, 2000 Cal
LaFarge	Preformed Thermoplastic	2000 Penn, 1999 Miss, 2000 Cal
3M	Permanent Tape	2000 Penn, 2000 Cal

Materials were rated as "*good*," "*marginal*," or "*poor*" based on a combination of the retroreflectivity and durability performance in the wheelpath. Wheelpath data were selected for analysis due to the accelerated wear vs. non-wheelpath data. For consistency purposes, ratings applied to only white materials, and PCC and HMAC pavement surfaces received separate ratings. The TTI rating criteria are shown in Table 3.

Table 3. Rating Criteria for NTPEP Wheelpath Data.

	Rating Criteria*		
	Pass	Marginal	Fail
Retroreflectivity ($mcd/m^2/lx$)	>150	70-150	<70
Durability Rating** (0 min, 10 max)	9-10	7-8	≤6

*For materials with different ratings for retroreflectivity and durability, the lesser rating determined the overall rating.
**Durability rating equals the percent of material remaining on the surface divided by 10.

Based on the NTPEP data and the criteria described in Table 3, the researchers generated a list of the top performing potential horizontal signing materials.

[1] Second-year data were analyzed from the Mississippi deck.

Table 4 and Table 5 display all materials receiving "passing" ratings for PCC and HMAC surfaces, respectively.

Table 4. Top Performing Materials on PCC Pavements Based on NTPEP Data.

Material	Vendor	Product Number	NTPEP Location	Thick-ness (mil)	Surface Prep.	Primer/ Sealer	Bead Type
Preformed Thermo-plastic	Flint Trading	Premark 20/20 Flex –180-1003	Penn	135	Torch Heated	Pliobond 10	AASHTO M247 TY1
	Flint Trading	Premark Flex (OTD3-175-360)	Miss	N/A	N/A	N/A	N/A
	Flint Trading	Tilly 2 223-1001	Penn	175	Torch Heated	Pliobond 10	AASHTO M247 TY1
	LaFarge	LRMOOTL-40	Penn	160	N/A	PB 20	L511
	LaFarge	LRMOOTL-41	Penn	130	N/A	PB 20	L511
Durable Tape	3M	820	Penn	25	None	P-50	Pre-applied
	3M	820	Cal	N/A	N/A	Primer	Pre-applied
	3M	380-EX-PAT	Penn	N/A	None	P-50	Pre-applied

Notes: Information based on 2001-2002 NTPEP Deck Data.
NTPEP does not provide endorsement to any of the products listed in this table.
N/A = Data not available in NTPEP report.

Table 5. Top Performing Materials on HMAC Pavements Based on NTPEP Data.

Material	Vendor	Product Number	NTPEP Location	Thick-ness (mil)	Surface Prep.	Primer/ Sealer	Bead Type
Preformed Thermo-plastic	Flint Trading	Premark 20/20 Flex –180-1003	Penn	115	Torch Heated	None	AASHTO M247 TY1
	Flint Trading	Premark Flex (OTD3-175-360)	Miss	N/A	N/A	N/A	N/A
	Flint Trading	180-1003	Cal	125	N/A	Primer	N/A
	Flint Trading	Tilly 1 223-1000	Penn	140	Torch Heated	None	AASHTO M247 TY1
	Flint Trading	223-1000	Cal	125	N/A	Primer	N/A
	Flint Trading	Tilly 2 223-1001	Penn	115	Torch Heated	None	AASHTO M247 TY1
	Flint Trading	223-1001	Cal	125	N/A	Primer	N/A
	LaFarge	LRMOOTL-40	Penn	160	Torch Heated	None	L511
	LaFarge	LRMOOTL-41	Penn	130	Torch Heated	None	L511
	LaFarge	LRMOOTL-57	Cal	125	N/A	None	N/A
	Avery Dennison	W9099	Miss	N/A	N/A	N/A	N/A
Durable Tape	3M	820	Penn	25	None	P-50	Preapplied
	3M	820	Cal	N/A	N/A	Primer	Preapplied
	3M	380-EX-PAT	Penn	N/A	None	P-50	Preapplied
	3M	EXPAT	Cal	N/A	N/A	Primer	Preapplied

Notes: Information based on 2001-2002 NTPEP Deck Data.
NTPEP does not provide endorsement to any of the products listed in this table.
N/A = Data not available in NTPEP report.

CHAPTER 2:
TEST DECK INSTALLATION

The durability of materials that could be used in horizontal signing applications was assessed on three test decks in Texas. Because horizontal signs may include large symbols or text with curved edges, these designs were included in the test. Unlike most longitudinal lines, horizontal signs are placed in the wheel track, which is a more challenging environment for pavement marking materials. The wheel track poses more wear from tire hits and more oil tracking. Tire hits cause pavement markings to fail by wearing through the material and by wearing off the retroreflective elements. Oil tracking causes failures in daytime color and through chemical breakdown of the materials.

The measurements described in this chapter were repeated at one-year intervals for a period of two years.

TEST DECK MATERIALS AND CONFIGURATION

Based on the survey of manufacturers and contacts with TxDOT staff and vendors, researchers developed the final list of vendors and product lines. Not every vendor was able to attend every test deck installation. Additionally, not all vendors installed the same products at each test deck location. The individual deck descriptions in the next section include notes regarding deviation. Vendors were invited to provide 12 inch square samples of any special colored products that they wanted to include. Many vendors produce special colors for commercial applications such as fast-food drive through lanes and toll plaza lane markings. It was desirable to include these in this project so that future uses of color, such as in interstate route shields, could be expedited by having completed durability assessments. Most vendors supplied two thicknesses of their products for testing, nominally 90 mil and 125 mil. Flint Trading elected to test only the 125 mil thickness because results of its own internal testing do not support the use of a 90 mil product in these applications. Flint did occupy two test spots but repeated the 125 mil product in the second spot. LaFarge elected to test the two product thicknesses in the transverse line application only, expressing the opinion that results would apply to symbols as well. Table 6 summarizes the vendors and the materials tested.

Table 6. Vendor and Materials List.

Vendor	Symbol and Transverse Line Product 1	Symbol and Transverse Line Product 2	Colors Tested
Avery - Dennison	HotTape 125 mil	HotTape 90 mil	Yellow-Green, Blue
Ennis Paint	Flametape 125 mil	Flametape 90 mil, transverse line only	Red, Yellow-Green light, Yellow-Green dark, Blue
Flint Trading	PreMark 125 mil	PreMark 90 mil	Yellow-Green
LaFarge	Thermaline 125 mil	Thermaline 90 mil	Red, Yellow-Green, Blue, Purple
Jobling-Purser	Rocbinda aggregate	N/A	Red
Digital Markings	DigiMark 300 mil	N/A	None

It should be noted that in late June 2003 LaFarge Thermaline was acquired by Ennis Paint. In addition, Zumar Industries Inc. acquired the Hot Tape ™ thermoplastic business unit of Avery in 2004. The effect that this acquisition will have on future product offerings and testing is not clear at the time of this report.

A variety of symbol shapes were selected for inclusion in the test deck. Because wear and shear forces differ on transverse, longitudinal, curved, and pointed edges, each of these shapes were included. An arrow head, pointed in the direction of traffic so as not to confuse drivers, represented a pointed edge and the letter S represented a curved edge. To limit the overall longitudinal distance of the entire deck, only half of each symbol was included. Vendors provided the top half of a stock 9 foot lane-use arrow, as shown in Figure 3B-20 of the Manual on Uniform Traffic Control Devices (MUTCD). They also provided the top half of an 8 foot letter S, which is a stock item for school crossing markings. A 12 inch wide transverse line 10 feet in length was placed across the lane of travel. The 12 inch square color patches were placed outside of the wheel track toward the roadway edge. Standard yellow markings were not included in the test because their applications are limited to longitudinal markings. Figure 1 shows the layout and dimensions of the test area.

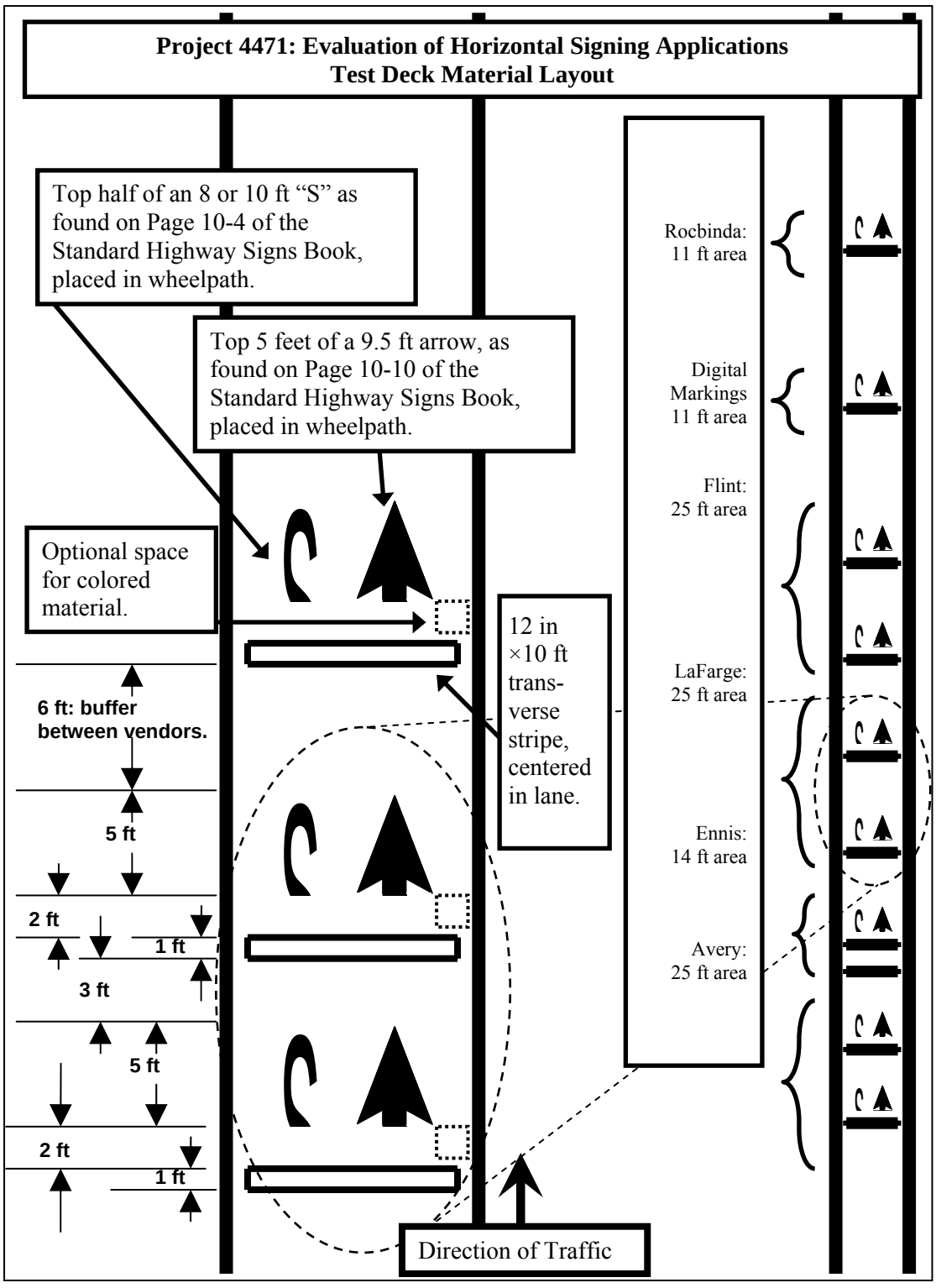

Figure 1. Test Deck Layout.

TEST INSTRUMENTS AND PROCEDURE

American Society for Testing and Materials (ASTM) test method D713-90 (5) was followed as appropriate for testing the durability of preformed thermoplastic materials. Because this test method does not address materials such as Rocbinda ™, adaptations were made where appropriate. A sign placed upstream of the test areas informed drivers of the upcoming pavement markings.

Before any materials were installed, TxDOT Construction Division staff measured and marked each vendor's test area (Figure 2).

Figure 2. TxDOT Staff Measuring Test Areas.

After each work area was defined, the manufacturer's representatives each measured and laid out the materials according to the diagram shown in Figure 1. These measurements are typical installation procedures for preformed symbols. A typical layout procedure is illustrated in Figure 3, which shows the Avery-Dennison representatives aligning transverse line pieces.

Figure 3. Layout of Preformed Sections before Application.

Material Thickness

Material thickness was measured with a caliper on the material before it was laid. Subsequent measurements were made by removing a section of the material and measuring the thickness using an electronic video microscope. Figure 4 shows the caliper measurement instrument. The caliper was moved across the materials, avoiding beads and nonskid particles, to estimate the average thickness of the thermoplastic layer of the material. Note that these measurements can only be made within an inch of the edge of the material because of the caliper size. Some compression of material could have occurred during the slitting process in manufacturing. In addition, most manufacturers' thickness specifications call for measurements from the top of the beads, whereas our measurements avoided beads for consistency.

Figure 4. Thickness Measurements on a Piece of Red Preformed Thermoplastic.

Size of Marking

The actual area of the installed material was measured, accurate to the quarter-inch, after the material was completely installed. Subsequent measurements of the quantity of material remaining allowed an assessment of road presence. While size measurements were being made, bead embedment was inspected on materials that showed obvious scorching. Figure 5 shows this procedure on installed material.

Figure 5. Bead Embedment Inspection Using a Jeweler's Loupe.

Retroreflectivity

The coefficient of retroreflected luminance (R_L) was measured using a Mirolux MX30 retroreflectometer. This instrument uses 30 m geometry and provides values in units of millicandelas per square-meter per lux (mcd/m^2/lx). Retroreflected luminance is a measurement of how much vehicle headlight can be returned to the driver's eye by the reflective elements in the pavement markings. For the white markings, both symbols and transverse lines, measurements were made at two to four different spots on each marking. For the colored squares, only one measurement was made due to the small size of the patch. Figure 6 shows staff performing luminance measurements.

Figure 6. Retroreflectivity Measurements.

Color Measurements

Daytime color was measured using a BYK-Gardner colorimeter (see Figure 7). This instrument measures hue, or chromaticity, which plots on an *x*,*y* chart of color space. Whiteness, or cap-Y, is also measured. Values of cap-Y range from 0 to 100, with 0 being perfect black and 100 being perfect white. Color shift, a standard quality assurance check, can be determined over time by looking at how these three values change. Fading of the colored sections is revealed by a change in the *x*,*y* position and/or a likely increase in the cap-Y as the pigments bleach. White material generally darkens over time due to dirt accumulation, resulting in lower cap-Y values. Tracking and oil drips also produce lower cap-Y values. Pigment bleaching in the yellow, as

well as other colors, may be overcome by dirt and oil accumulation to produce lower cap-Y values as well.

Figure 7. Color Measurement Instrument.

TEST DECK LOCATIONS

Appendix C lists the exact materials tested at each of the test deck locations. Appendix D contains photographs of each of the test decks including details of installation and inspection. The dates of installation and inspection are shown in Table 7. The following section provides an overview of the material installations.

Table 7. Installation and Inspection Dates for Test Decks.

	Abilene	Austin	Houston
Installation Date	9/18/2003	6/3/2003	7/29/2003
Year 1 Inspection	11/15/2004	6/6/2004	11/11/2004
Year 2 Inspection	10/3/2005	7/7/2005	8/3/2005

Asphalt Pavement: Austin

A test area was installed on U.S. Highway 183 northbound, just south of State Highway (SH) 71 in the Austin area on June 3, 2003. This test deck is an extension of an already existing TxDOT Construction Division testing area. The pavement is worn asphalt. The annual average daily Traffic (AADT) for this road is 6500 vehicles per lane per day. An overview of the completed test area is shown in Figure 8.

Concrete Pavement: Houston

A test area was installed on Interstate 10 westbound, between Mercury and East Loop 610 in July 2003. The pavement in this area is worn concrete. The AADT for this road is 33,600 vehicles per lane per day.

Chip-Seal Pavement: Abilene

A test area was installed in August 2003 on SH 351 in the Abilene District. The pavement was newly laid Grade 3 seal coat. The AADT for this road is 1875 vehicles per lane per day.

Figure 8. Austin Test Deck.

Most materials were installed using traditional flame application methods as shown in Figure 9, which shows representatives from Avery-Dennison using a propane torch to preheat the pavement. The different vendors used slightly different surface preparation techniques and torch types. Figure 10 shows two different types of propane torches being used to melt the preformed thermoplastic. Flint Trading is shown on the left, and Ennis Paint is shown on the right.

Figure 9. Preheating the Pavement with a Propane Torch.

Figure 10. Two Different Types of Propane Torches Used.

Two unusual application methods were used at the Austin installation. LaFarge was unable to provide their usual technical service support and instead used a crew from Integrated Pavement Concepts, Inc. This Canadian company specializes in pavement texturizing to simulate decorative brick. Their equipment heats up new or existing asphalt and then embosses a decorative pattern into the pavement. This same equipment can be used to preheat and melt preformed thermoplastic symbols. Figure 11 shows the equipment, called Streetprint ™. The heating element is the large bar near the engine. This heating element travels back and forth along the horizontal rods extending to the right in the photograph. The marked application area

for the LaFarge products is shown in Figure 12 as the machine prepared to preheat the pavement. Figure 13 shows the machine melting a transverse line. The device in the hand in view in the left of the photograph is an infrared thermometer used by all the installers to check the temperature of the pavement and materials during the installation process.

Figure 11. The Streetprint Machine.

Figure 12. The Streetprint Machine Preheating the Application Area.

Figure 13. The Streetprint Melting a Transverse Line.

The other unusual product and process was the Rocbinda colored road surfacing product from Jobling-Purser, Ltd. of England. This material is a polyurethane resin binder holding an aggregate stone mixture. The aggregate can be made of naturally or artificially colored rock. The installation procedure for symbols normally uses a premade stencil. For the installation for this project, symbols were marked using masking tape. Because of the difficulty of creating curved shapes by hand with tape, the top half of a letter Z shape was used in place of the letter S for this product.

Application of this segment, with two workers, took more than two hours. Using of a premade stencil could reduce this time somewhat. Figure 14 shows the symbols marked with tape and application of the polyurethane resin binder. The next step, shown in Figure 15, is placement of the aggregate. Note that with hand placement, wide variation in material thickness is possible. Great care was taken by the vendors to completely and uniformly cover the binder. The aggregate must be applied to the binder while it is still wet. Some material overage is expected in order to assure good coverage to the symbol's edge. Figure 16 shows the letter Z section just after the aggregate was spread. After the mixture sets up, the excess is swept off, as shown in Figure 17. The masking tape, or stencil if one is used, is then removed, as shown in Figure 18. In order to provide a contrast edge, a second masking is required after the main

symbol has completely set. A second batch of binder and darker aggregate is applied and, after it has cured, the masking tape is removed to produce an edged symbol as shown in Figure 19. In addition to the symbols, Rocbinda also provided a red-colored patch. The Rocbinda test segment was placed last in the lane of travel to prevent any loose aggregate from contaminating other products. The completed segment is shown in Figure 20.

Another unusual material tested was the DigiMark material, included in Abilene and Houston. Delivery of the material was delayed, and it was therefore not included in the Austin test installation. Figure 21 shows the DigiMark material newly installed in Abilene. This material is a full digitally printed sheet manufactured by Digital Marking, Inc. It is commonly used for floor advertising in retail stores. The material did not perform well at either test location. The Digital Markings and Rocbinda products do not contain retroreflective elements and are intended for use in areas with high mast lighting.

Figure 14. Rocbinda Masking and Binder Application.

Figure 15. Applying Aggregate to Rocbinda.

Figure 16. Rocbinda after Aggregate Application.

Figure 17. Sweeping Excess Aggregate.

Figure 18. Removing Masking from Symbols.

Figure 19. Detail of Completed Contrast Edging.

Figure 20. Completed Rocbinda Segment.

Figure 21. DigiMark Preformed Sheet.

CHAPTER 3:
RESULTS OF DURABILITY TESTING

This chapter presents a summary of the results. As noted earlier, Appendix C lists the exact materials tested at each of the test deck locations. Appendix D contains photographs of each of the test decks including detailed photos of damaged or failing materials. In a few instances, measurements were not obtained due to oversight in the field or data recording failures.

Most of the materials maintained road presence throughout the duration of the test. Material presence was documented through photographs and physical measurements. Appendix C indicates those locations where material failed to adhere to the pavement.

RETROREFLECTIVITY

Retroreflectivity was measured at two to four spots on each sample. The average values are reported for each sample. No standards exist on minimum required retroreflectivity for pavement marking symbols. The minimum value for a longitudinal line of nominal 4 inches width of 150 mcd is desired to assure nighttime visibility (6). It is not clear if this minimum is applicable to a large pavement marking symbol or word. It may be that, due to the size of the symbol, minimum reflectivity values for horizontal signing applications may be lower. There are no widely applied minimum reflectivity values for colored pavement markings, other than standard yellow.

To summarize the results, the retroreflectivity values for the transverse lines are shown for each of the test decks in Figure 22 through Figure 24. Most products showed a sharp drop in retroreflectivity in the first year. A few products increased in reflectivity, which may be attributed to new beads being exposed through wear. On the seal coat test deck in Abilene, many of the materials developed a glossy sheen, presumably due to abrasion from loose aggregate. This abrasion wore down the beads, resulting in lower reflectivity values than at the other test locations. Details of each of the test samples, including the symbols and colored patches, are provided in tables in Appendix E.

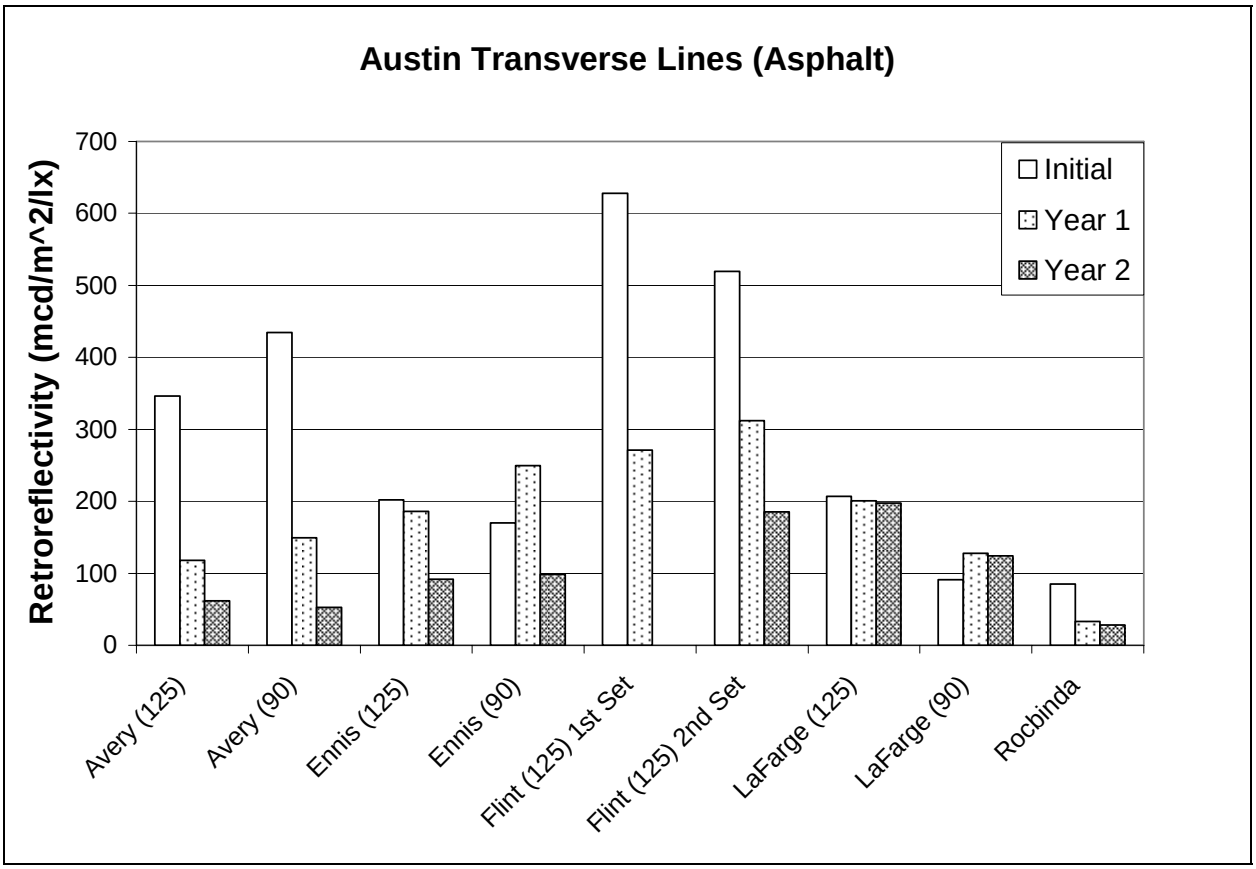

Figure 22. Retroreflectivity Values for White Transverse Lines for Asphalt Test Deck.

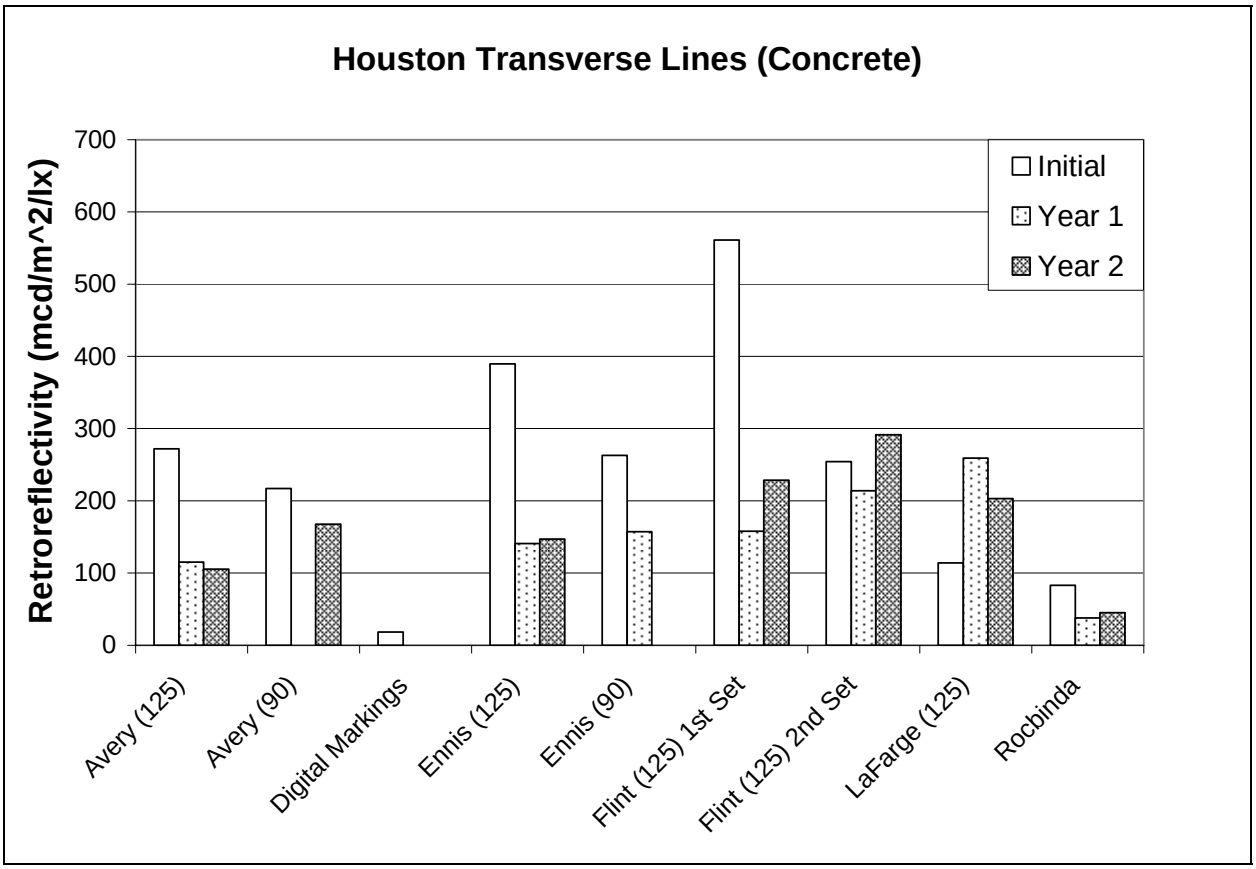

Figure 23. Retroreflectivity Values for White Transverse Lines on Concrete Test Deck.

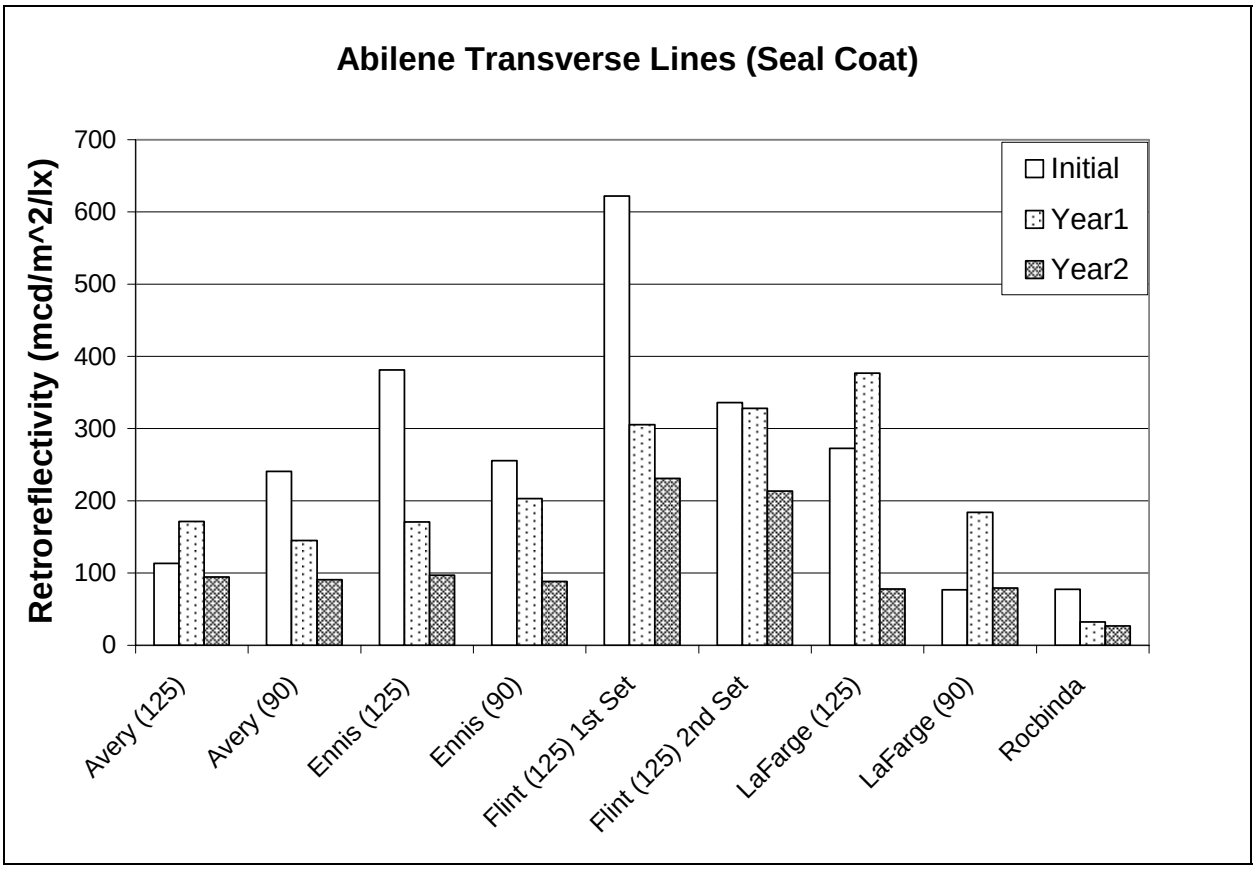

Figure 24. Retroreflectivity Values for White Transverse Lines for Seal Coat Test Deck.

THICKNESS

Thickness measurements for the Abilene seal coat pavement test deck for all measurement periods are presented in Figure 25 through Figure 27. These measurements were made initially using a manual caliper (see Figure 4). Subsequent measurements were made by chipping a piece of material off and bringing the sample to the TxDOT Construction Division laboratory for measurement on a electronic video microscope. This instrument uses image processing software to provide physical measurements of samples. A thickness measurement was made in several locations across the sample perpendicular to the surface. Figure 28 shows an image with the accompanying perpendicular line and measurement indication.

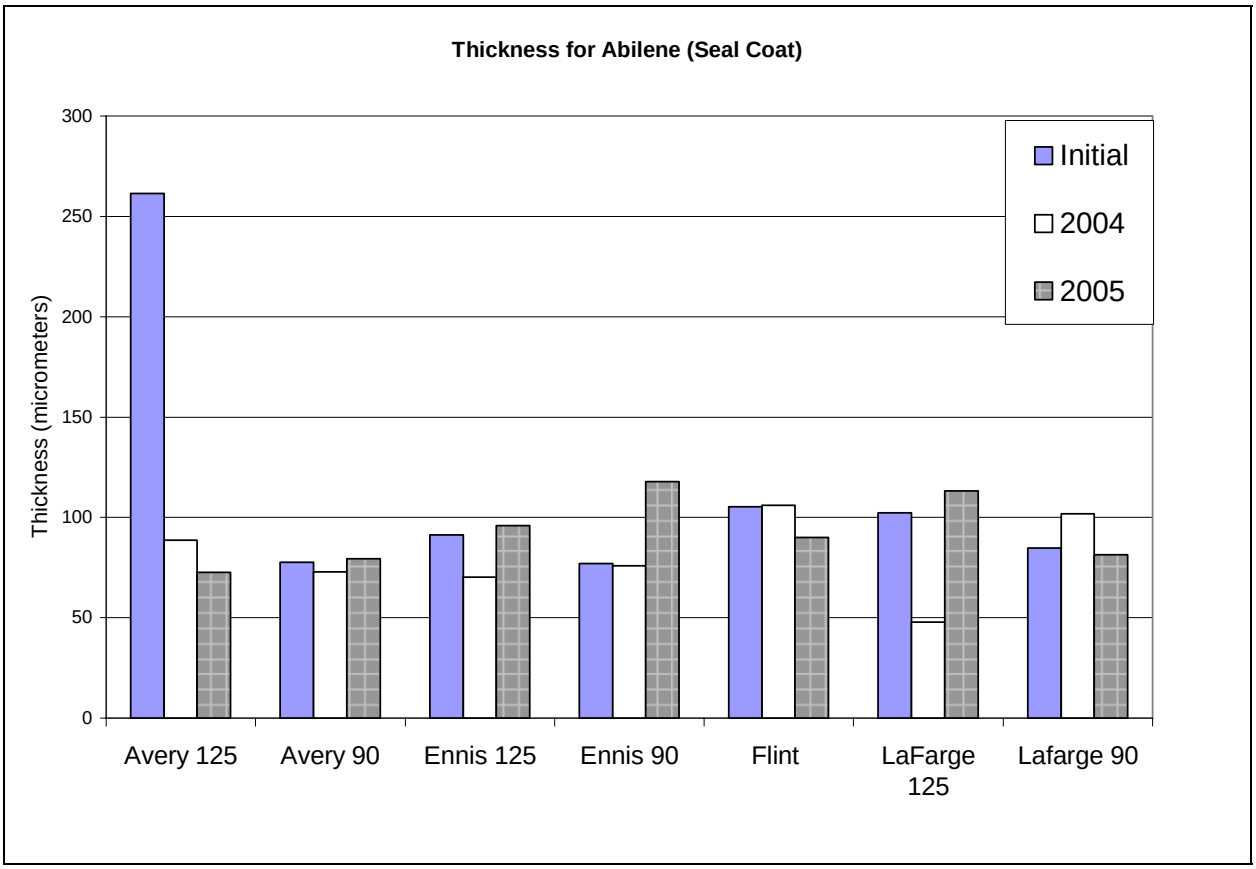

Figure 25. Thickness Data for Abilene Test Deck.

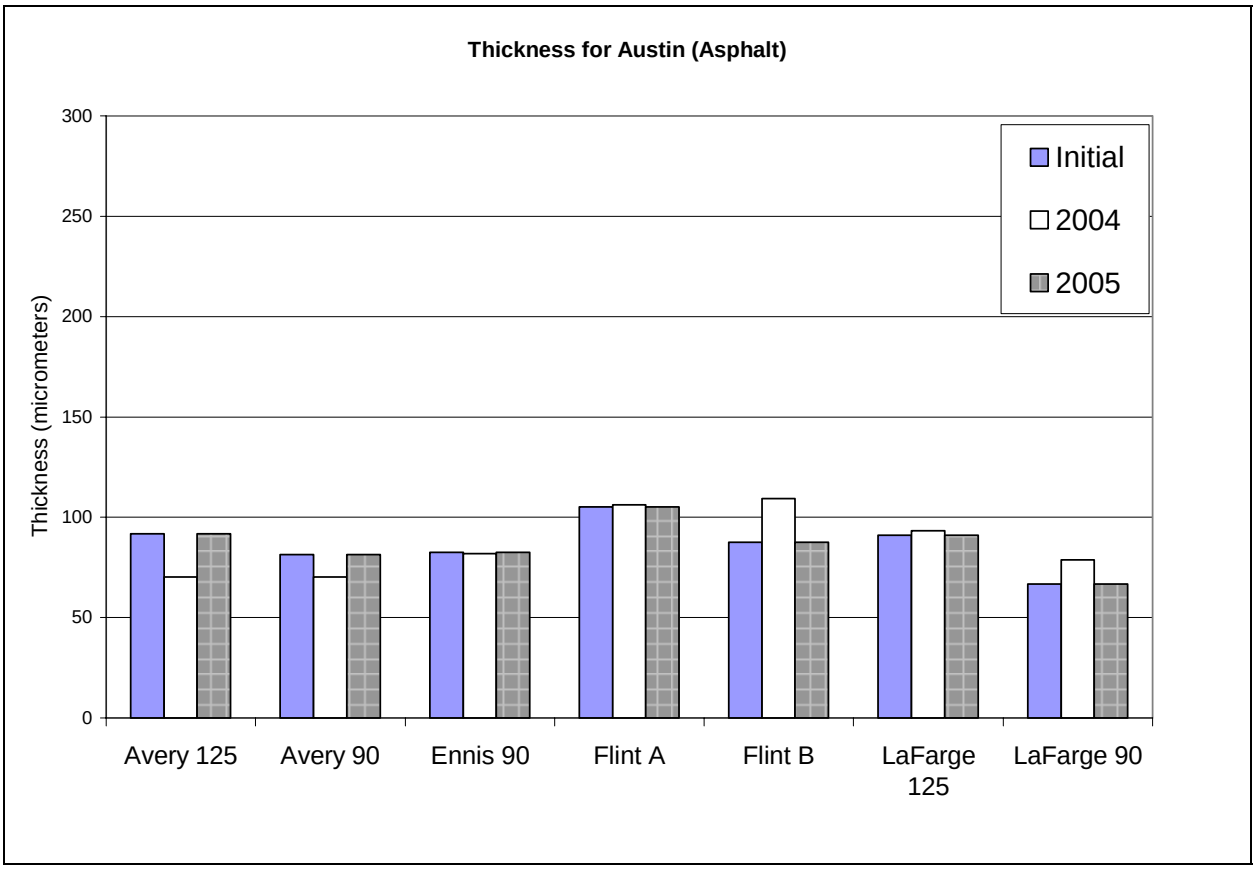

Figure 26. Thickness Data for Asphalt Test Deck.

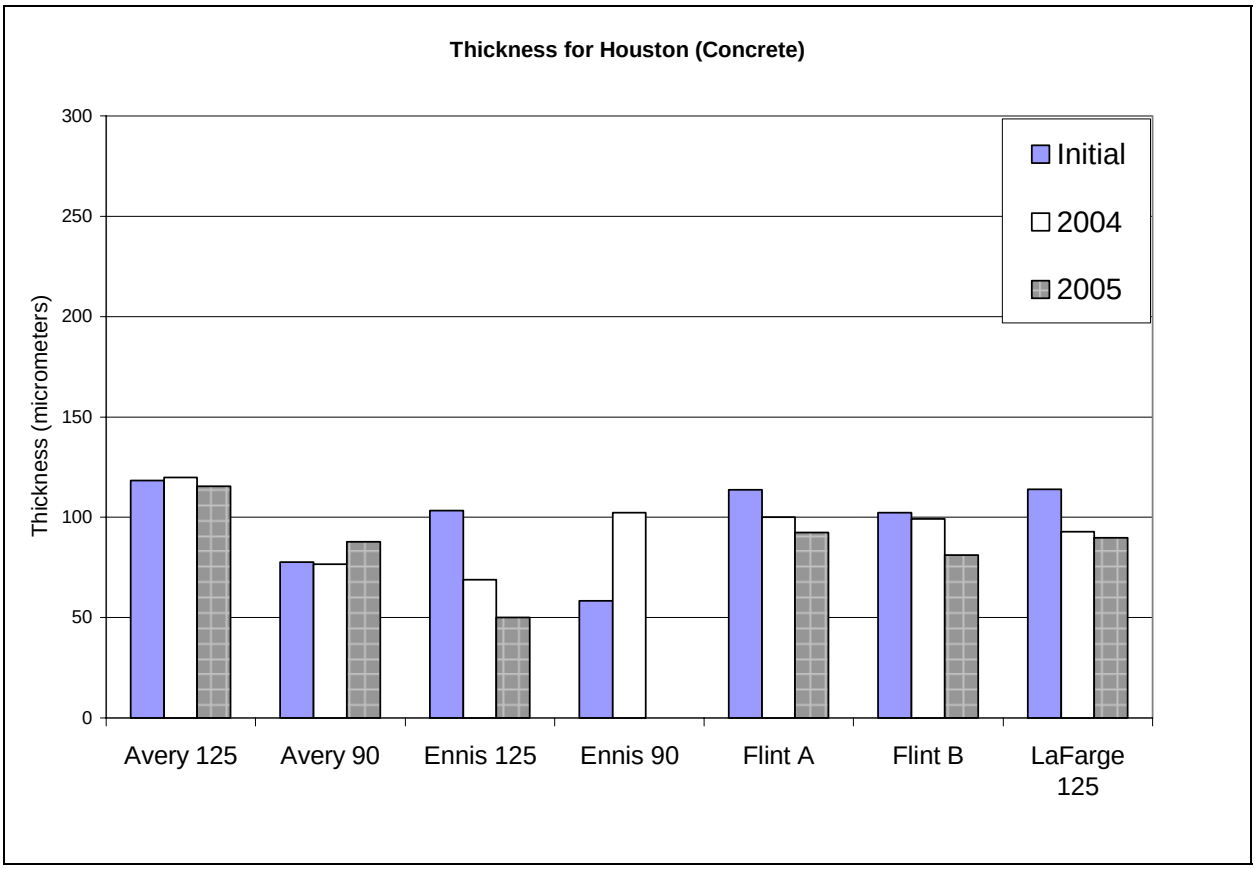

Figure 27. Thickness Data for Concrete Test Deck.

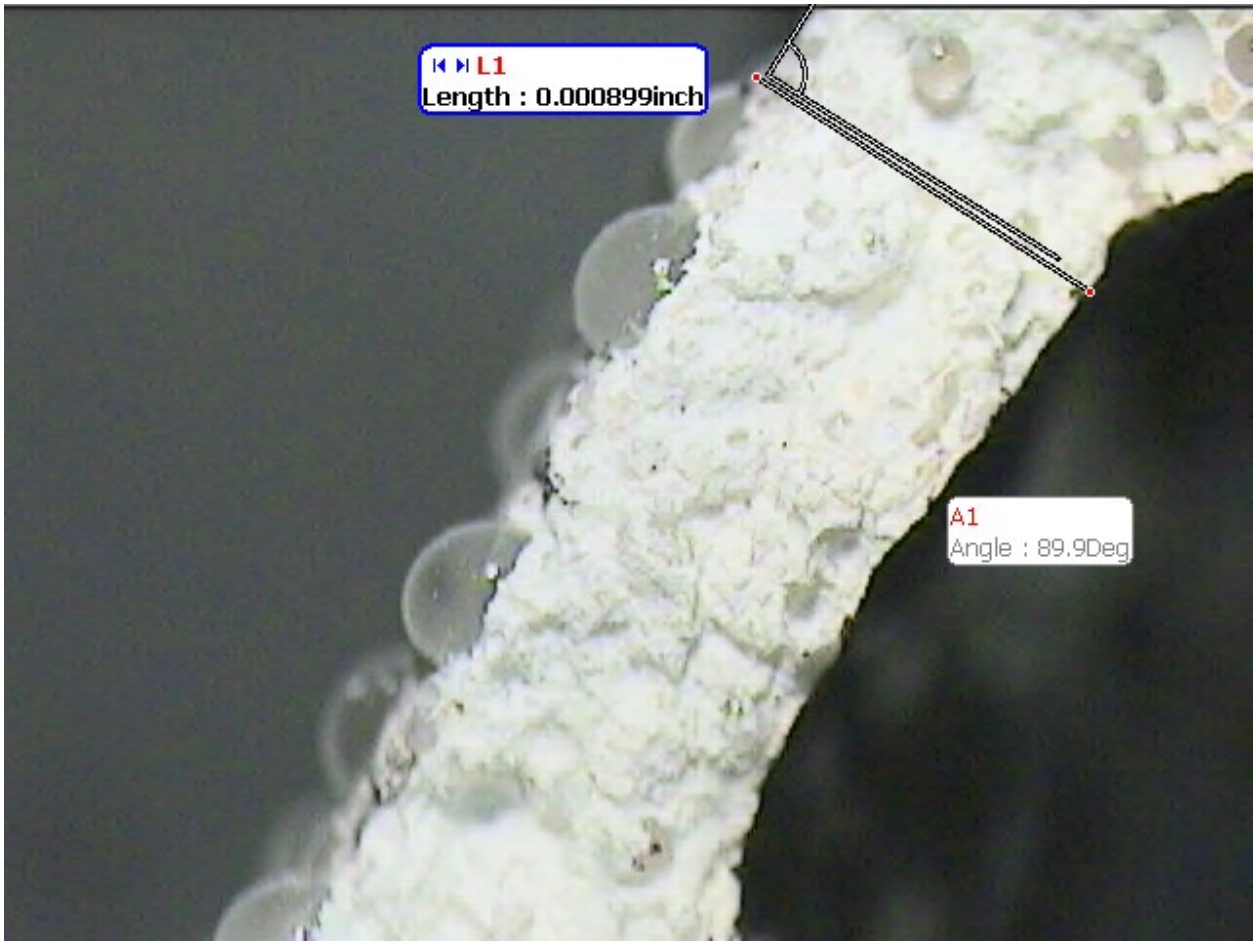

Figure 28. Microscope Image of a Thickness Measurement.

COLOR MEASUREMENTS

Daytime and nighttime color requirements for pavement markings are specified in an amendment to the Code of Federal Regulations published in 2002 (*7*). The colorimeter instrument used in this project measured daytime color only. Color is specified in three-dimensional color space with *x*,*y* coordinates denoting the hue and Y ("cap-Y") denoting the saturation, where a cap-Y value of 100 is perfect white, and a value of 0 is perfect black. White pavement markings must have a minimum cap-Y value of 35. There are color coordinates provided in the 2002 document for white and yellow pavement markings. These coordinates are similar to the color coordinates for retroreflective sign sheeting material, but are not identical. Color specification boxes are shown in Figure 29 for the four pavement marking colors specified by FHWA. The boxes for daytime color of retroreflective sign sheeting for yellow-green and

purple are provided for reference. The third dimension, not shown on this chromaticity chart, is the cap-Y value. These data will be presented later in separate charts.

Chromaticity values for all the white markings are shown in Figure 30. This close-up of the white region of color space illustrates that all of the white markings, except one sample from the asphalt test deck, remained in the white box throughout the two years of the test. Individual results for each product at each test location are presented in Appendix F.

The results for the red markings are shown in Figure 31 as a close-up of the red region of color space. Note that the majority of the markings are not in the color box at the end of the two-year test period. The Rocbinda red markings were not in the red box initially. The direction of movement is toward the center, or white region, of color space, indicating that the markings are beginning to bleach. To the naked eye, the markings still appeared red at the two-year inspection time.

The same data for the blue markings are shown in Figure 32. Two of the products were not in the color box at the time of the installation. All of the products were outside of the box at the Year 1 inspection and continued to move toward the white region through the second year.

The data for yellow-green and purple markings are not shown in graphical form because FHWA has not provided color boxes for these special colors. The data are presented, along with the details on all the markings, in Appendix F. Like the red markings, the direction of color shift for the blue markings faded toward white during the test period.

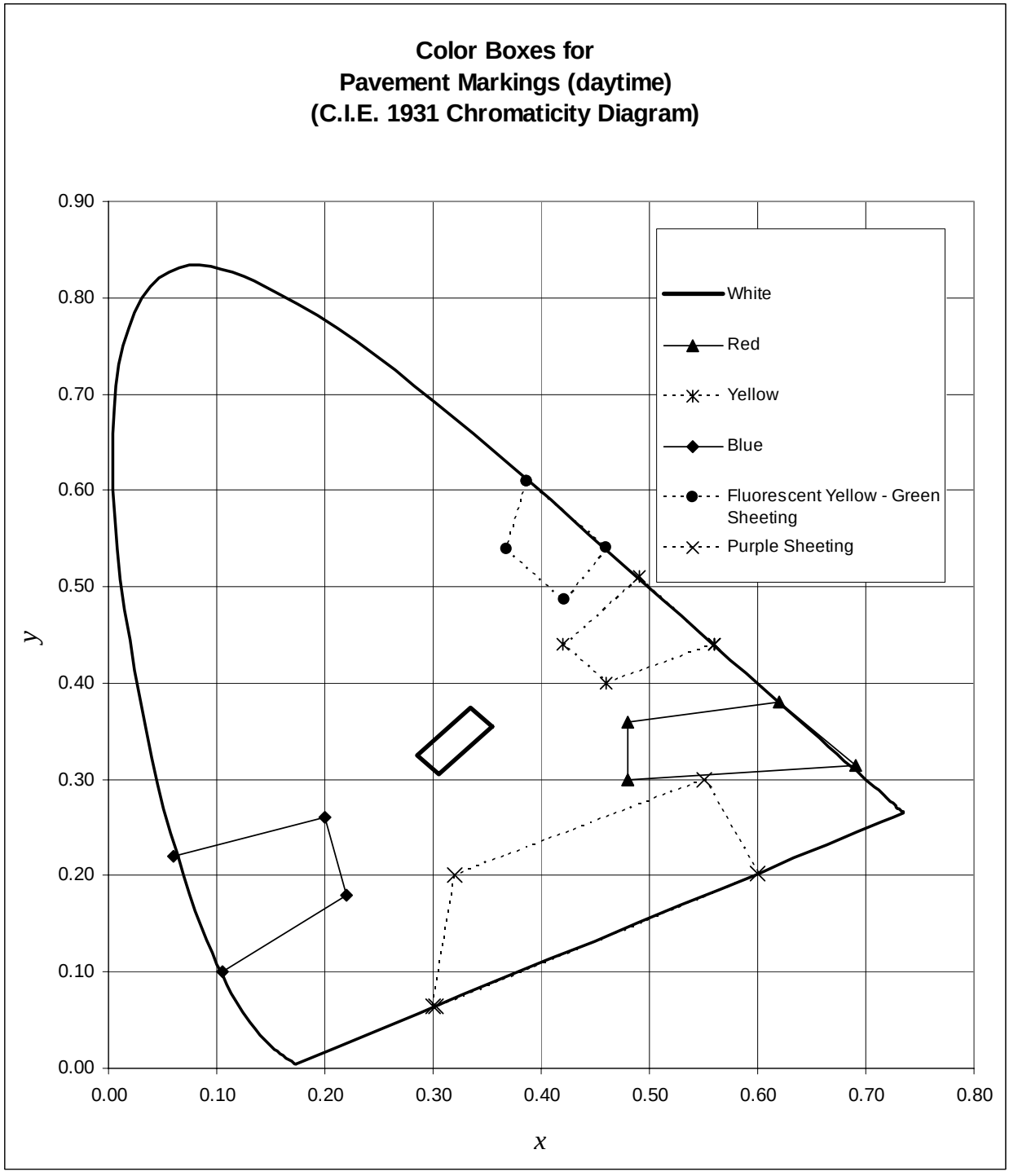

Figure 29. Daytime Color Boxes.

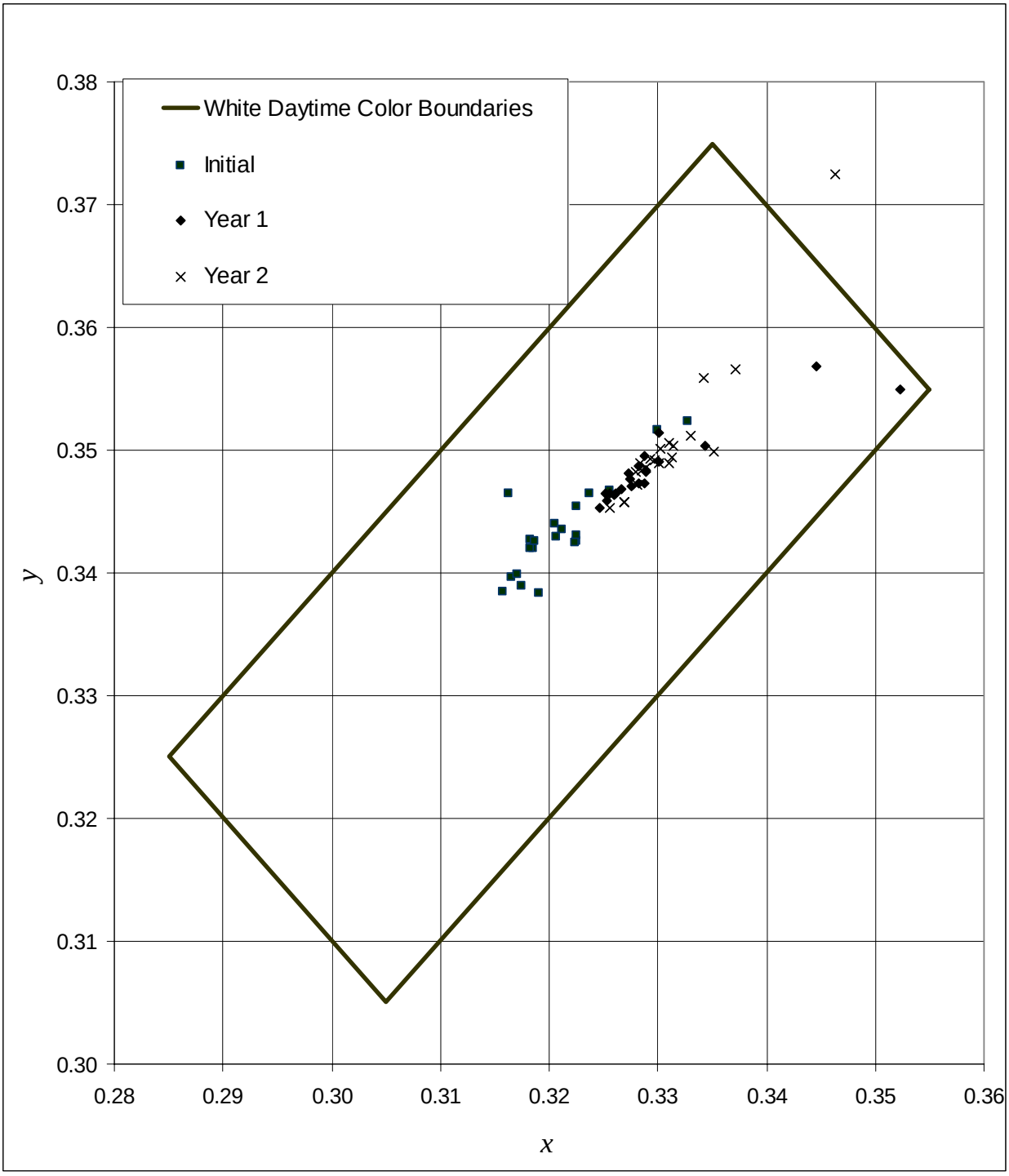

Figure 30. Chromaticity Values for White Markings.

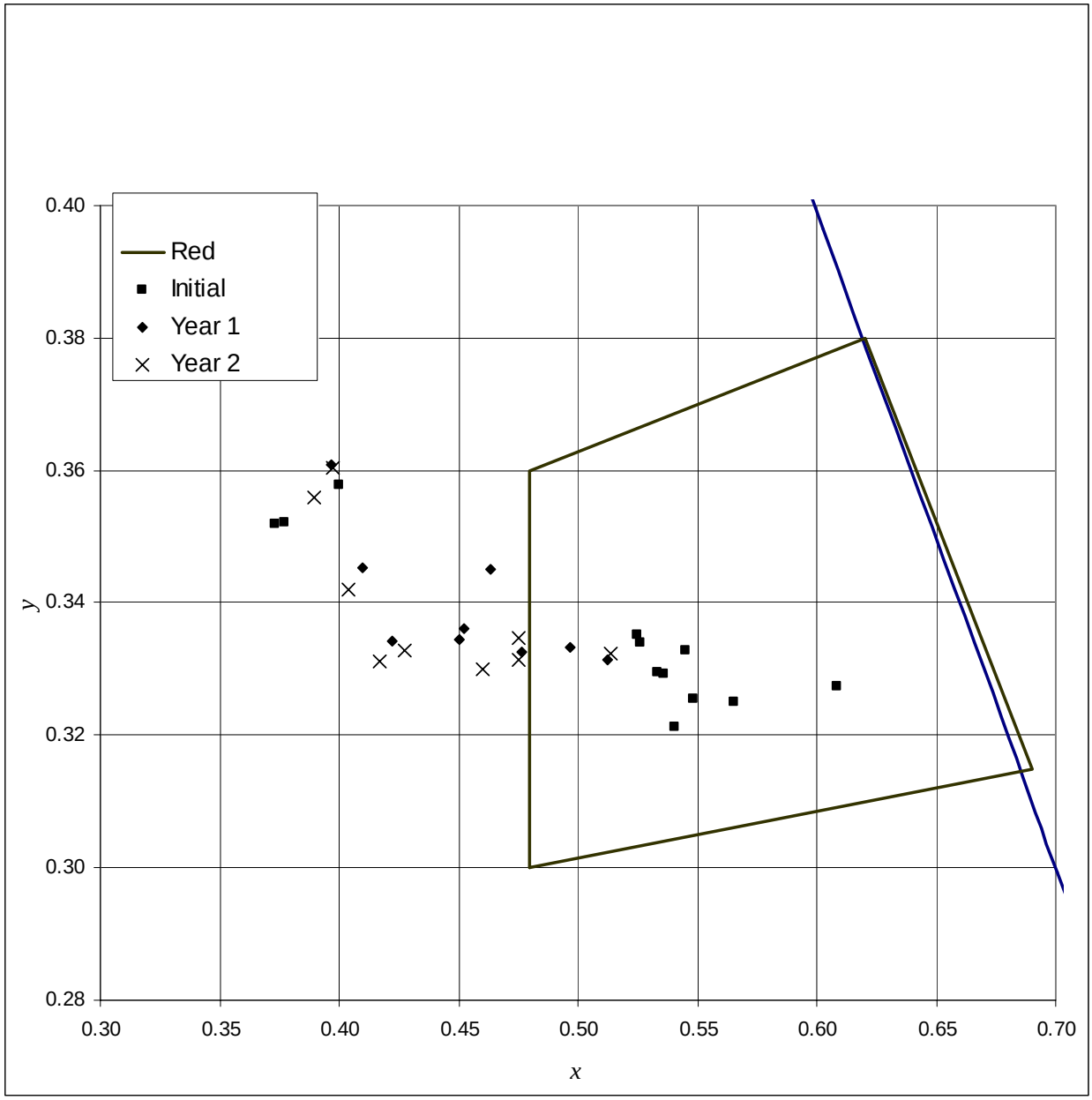

Figure 31. Chromaticity Values for Red Markings.

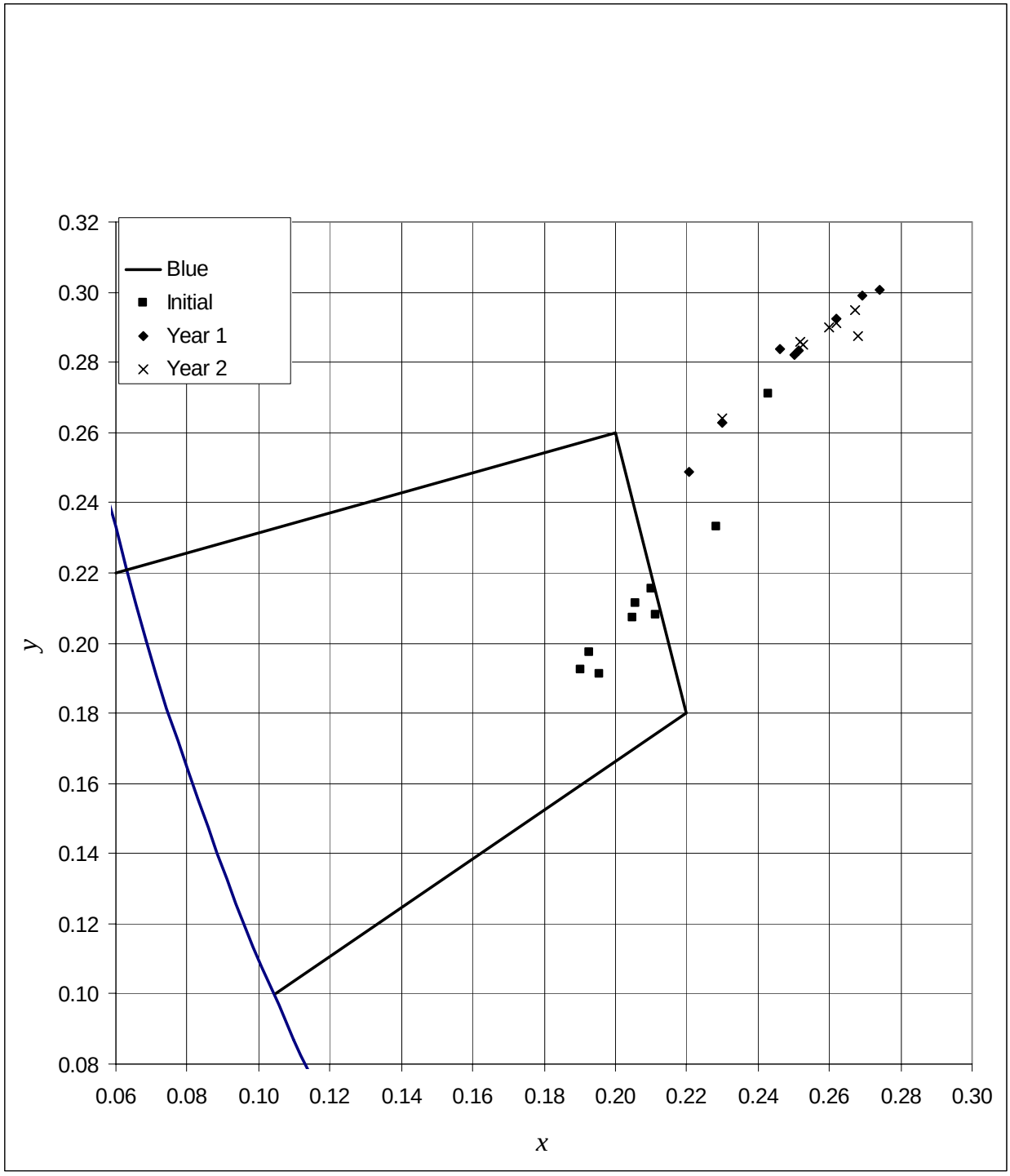

Figure 32. Chromaticity Values for Blue Markings.

Color stability can be described by describing color change from an initial value to a later measurement as a vector in this three-dimensional color space. This vector is delta-E and represents the distance between two points in color space. As such, it represents changes in chromaticity (x,y) as well as hue value (cap-Y). The delta-E values for each of the materials are presented in Appendix F. They were calculated from the initial, new color readings compared to the Year 1 and Year 2 readings. In addition to the delta-E values, the tables in Appendix F report a Pass/Fail grade for each colored material depending on whether the color stayed in the color box specified by FHWA over the two-year period.

Another way to examine the color data is to examine the cap-Y values for the white markings. These values serve as an indication of darkening due to dirt accumulation. The test decks were represented different pavement types, in part, to discover the effect of pavement type on dirt accumulation. Figure 33 through Figure 35 illustrate cap-Y values for each product for the three pavement types tested. For the seal coat and asphalt pavements, the cap-Y values of the majority of the products fall below the minimum value of 35 that the FHWA recommends for new markings. These low cap-Y values can become an issue for daytime visibility because a lower value of cap-Y corresponds to a gray appearance, which may not provide adequate contrast with the surrounding pavement.

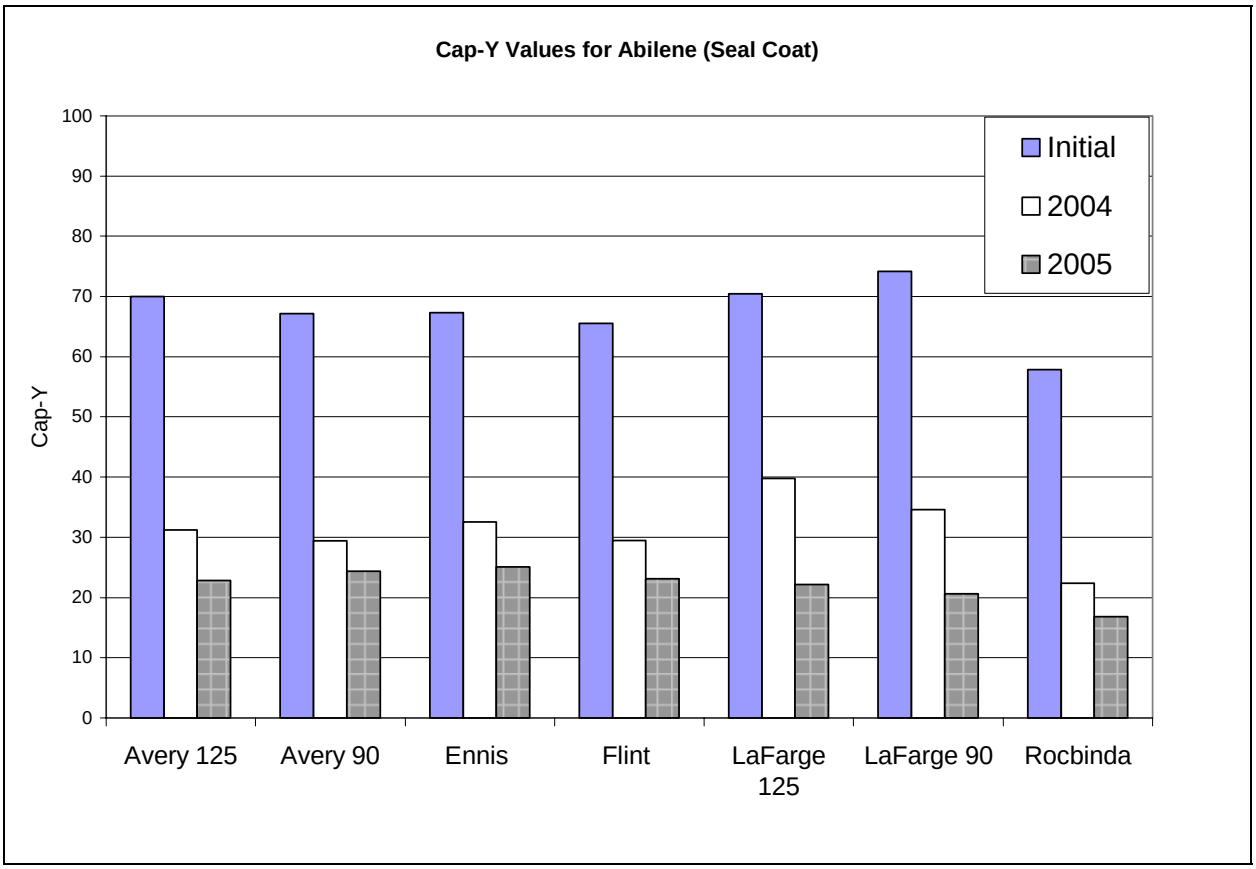

Figure 33. Cap-Y Values for White Markings on Seal Coat Pavement.

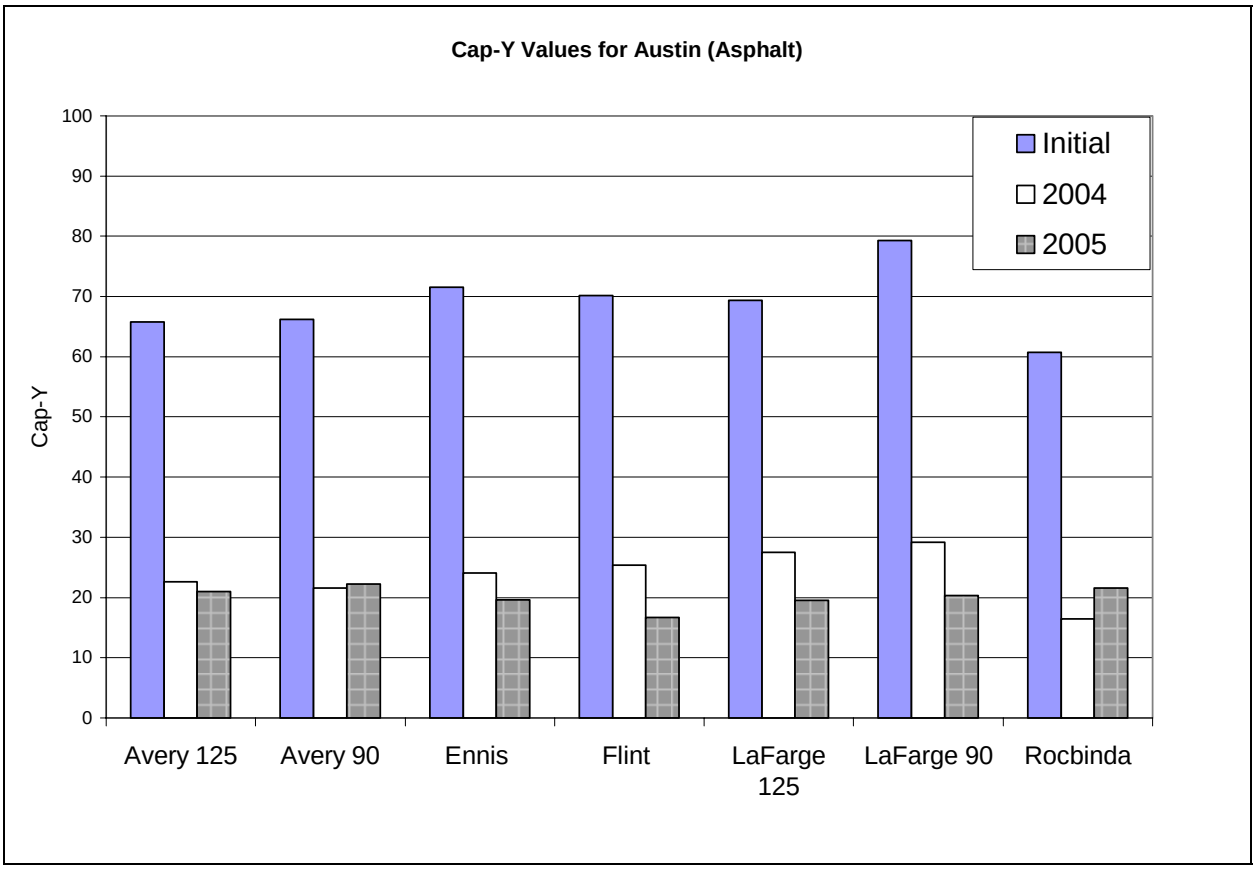

Figure 34. Cap-Y Values for White Markings on Asphalt Pavement.

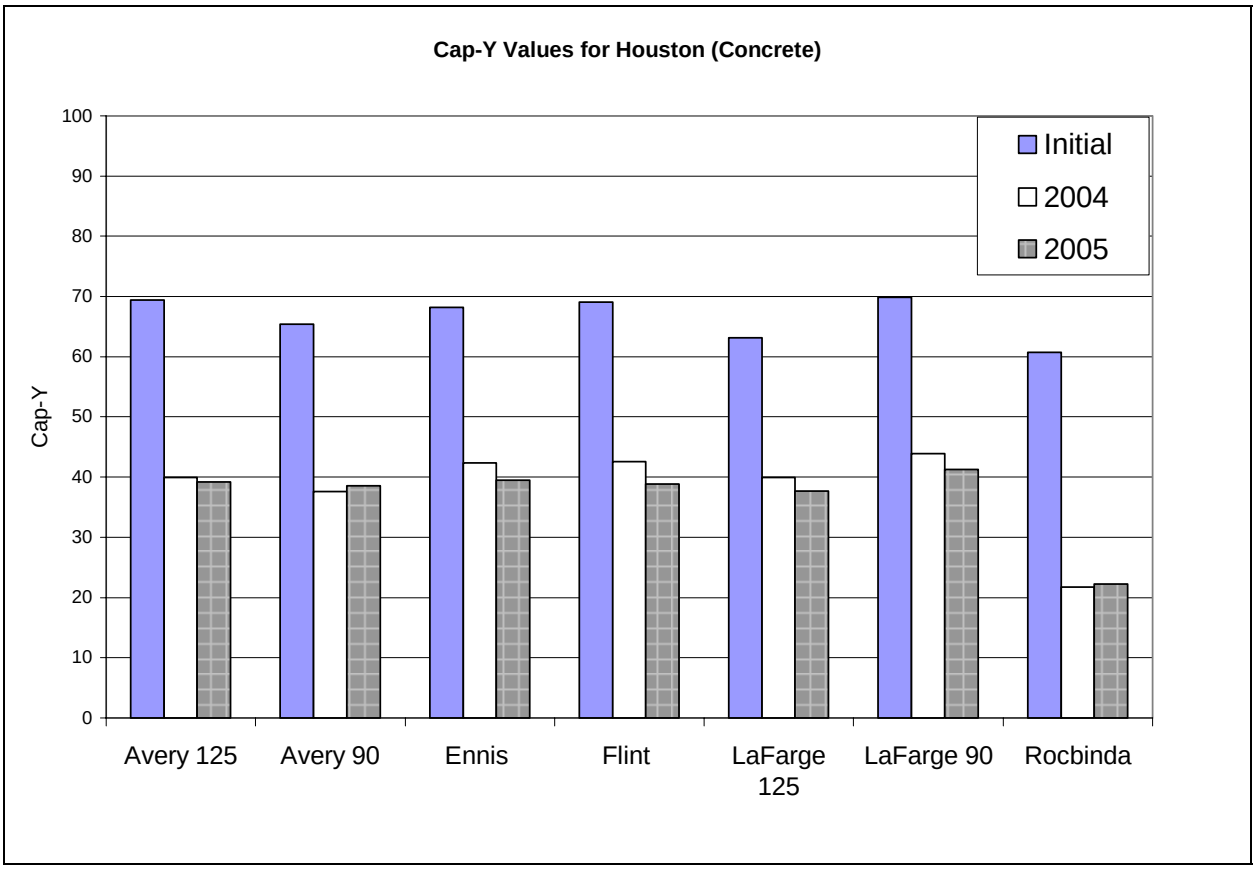

Figure 35. Cap-Y Values for White Markings on Concrete Pavement.

CHAPTER 4:
RECOMMENDATIONS FOR ADDITIONS OR REVISIONS TO TXDOT'S TRAFFIC CONTROL STANDARDS SHEETS

An earlier part of this project examined the operational effects of a variety of horizontal signing applications. These efforts were documented in an earlier report *(1)*. These earlier studies showed small and mixed results for applications to reduce speeds at horizontal curves on rural two-lane roads. The project monitoring committee did not feel that these results supported widespread application of any of these treatments. The application of directional arrows to reduce wrong-way movements on two-way frontage roads, however, showed very promising results. At the request of the project monitoring committee, the researchers have developed a typical layout diagram for application of directional arrows. This layout can be found in Appendix G.

CHAPTER 5:
CONCLUSIONS AND RECOMMENDATIONS

Preformed thermoplastic materials are recommended for horizontal applications with the following considerations:

- Confirm that the product has been tested on an AASTHO NTPEP test deck.
- Assure proper installation surface preparation as recommended by vendors (sweeping, etc.), particularly if larger sheets of preformed materials will be installed.
- Avoid overheating and scorching the material during installation.
- Use materials within one year of purchase to avoid discoloration before installation.
- When use is desired on chip seal pavement, consider using a product with a black border to enhance contrast. Products tested in this project became dirty when installed two weeks after the application of a of seal coat.
- New products and manufacturers are continually entering the market; users should work with the Construction Division Materials and Testing Laboratory and the TxDOT New Products committee to get the best estimate of performance before installation.

REFERENCES

1. Chrysler, S.T., and S.D. Schrock. *Field Evaluations and Driver Comprehension Studies of Horizontal Signing*. Research Report 4471-2, Texas Transportation Institute, College Station, TX, 2005.

2. *2000 NTPEP Pavement Marking Field Performance History & Lab Test Results on Select Products, 2000 Urban California Test Deck.* Report 02 - NTPEP 216. National Transportation Product Evaluation Program, American Association of State Highway and Transportation Officials, Washington, D.C., October 2001.

3. *First Year Field Performance & Laboratory Test Results of Pavement Marking Materials, 2000 Pennsylvania Test Deck.* Report 02 – NTPEP 221. National Transportation Product Evaluation Program, American Association of State Highway and Transportation Officials, Washington, D.C., February 2002.

4. *Second Year and Final Report of Field Performance Evaluation of Pavement Marking Materials, 1999 Mississippi Test Deck.* Report 02 – NTPEP 220. National Transportation Product Evaluation Program, American Association of State Highway and Transportation Officials, Washington, D.C., February 2002.

5. *Standard Practice for Conducting Road Service Tests on Fluid Traffic Marking Materials. ASTM D 713-90 (1998).* ASTM International, West Conshohocken, Pennsylvania, 1998.

6. Zwahlen, H.T., and T. Schnell. Minimum In-Service Retroreflectivity of Pavement Markings. In *Transportation Research Record 1715,* Transportation Research Board, National Research Council, Washington, D.C., 2000, pp. 60–70.

7. Federal Register. Volume 67, No. 147, July 31, 2002. FHWA Docket No. FHWA-99-6190 Final Rule. *Traffic Control Devices on Federal-Aid and Other Streets and Highways; Color Specifications for Retroreflective Sign and Pavement Marking Materials.*

APPENDIX A:
VENDOR SURVEYS

INDUSTRY SURVEY FOR HORIZONTAL SIGNING

Company: 3M

Name: Jeff Low

Phone: 512-415-2658

Email: _____

1. What specific types of durable pavement marking materials does your company recommend for use as horizontal signing applications placed in the travel lanes on **urban concrete or asphalt** roadway surfaces with **high traffic** (average daily traffic > 100,000 vehicles)? Please list materials that are suitable for the following applications:

A. Route Shields
Product ID numbers or name: _____
Type of material: _____
How is the material applied? _____
Approximate contracted cost for materials and application: _____
Recommended thickness: _____
Range of ambient air temperatures for application: _____
Approx. no-track drying time: _____
Recommended surface preparation: _____
Recommended primer/sealer (if any): _____

B. Symbols/Words
Product ID numbers or name: 380
Approximate contracted cost for materials and application: _____
Recommended thickness: _____
Range of ambient air temperatures for application: _____
Approx. no-track drying time: _____
Recommended surface preparation: _____
Recommended primer/sealer (if any): _____

C. Transverse Lines
Product ID numbers or name: 380
Approximate contracted cost for materials and application: _____
Recommended thickness: _____
Range of ambient air temperatures for application: _____
Approx. no-track drying time: _____
Recommended surface preparation: _____
Recommended primer/sealer (if any): _____

2. What specific types of durable pavement marking materials does your company recommend for use as horizontal signing applications (e.g. words, symbols, transverse bars) placed in the travel lanes on **rural asphalt or chipseal** roadway surfaces with **low-medium traffic**? Please list materials that are suitable for the following applications:

A. Symbols/Words

Product ID numbers or name: _____
Approximate contracted cost for materials and application: _____
Recommended thickness: _____
Range of ambient air temperatures for application: _____
Approx. no-track drying time: _____
Recommended surface preparation: _____
Recommended primer/sealer (if any): _____

B. Transverse Lines

Product ID numbers or name: _____
Approximate contracted cost for materials and application: _____
Recommended thickness: _____
Range of ambient air temperatures for application: _____
Approx. no-track drying time: _____
Recommended surface preparation: _____
Recommended primer/sealer (if any): _____

3. Have any of the materials listed above been included in a NTPEP (or similar) evaluation and if so, does a publication exist?

NTPEP

Penn '00: 820 Tape - Concrete = Good, Asphalt = Good
380 Tape (Experimental) - Concrete = Good, Asphalt = Good

Cal '00: 820 Tape - Concrete = Marginal, Asphalt = Good

4. Please provide contact information for agencies that have used your products for route shield markings or other innovative applications.

5. Please provide us with a website or product information pamphlets.

INDUSTRY SURVEY FOR HORIZONTAL SIGNING

Company: Trelleborg

Name: Dan Nivone

Phone: 775-843-3547

Email: dannavone@aol.com

6. What specific types of durable pavement marking materials does your company recommend for use as horizontal signing applications placed in the travel lanes on **urban concrete or asphalt** roadway surfaces with **high traffic** (average daily traffic > 100,000 vehicles)? Please list materials that are suitable for the following applications:

A. Route Shields

Product ID numbers or name: City Tape (need a huge order to get custom order)
Type of material: Permanent tape (thermoplastic) with adhesive
How is the material applied? By hand
Approximate contracted cost for materials and application:
Recommended thickness: 90 mil
Range of ambient air temperatures for application: 40º
Approx. no-track drying time:
Recommended surface preparation: Clean and dry
Recommended primer/sealer (if any): Primer on concrete

B. Symbols/Words

Product ID numbers or name: City Tape
Approximate contracted cost for materials and application: $125 per symbol
Recommended thickness: 90 mil
Range of ambient air temperatures for application: 40º
Approx. no-track drying time:
Recommended surface preparation: Clean and dry
Recommended primer/sealer (if any): Primer on concrete

C. Transverse Lines

Product ID numbers or name: City Tape
Approximate contracted cost for materials and application: 4" - $0.58 per foot
Recommended thickness: 90 mil
Range of ambient air temperatures for application: 40º
Approx. no-track drying time:
Recommended surface preparation: Clean and dry
Recommended primer/sealer (if any): Primer on cone

7. What specific types of durable pavement marking materials does your company recommend for use as horizontal signing applications (e.g. words, symbols, transverse bars) placed in the travel lanes on **rural asphalt or chipseal** roadway surfaces with **low-medium traffic**? Please list materials that are suitable for the following applications:

A. Symbols/Words
Product ID numbers or name: City Tape
Approximate contracted cost for materials and application: _____
Recommended thickness: 90 mil
Range of ambient air temperatures for application: _____
Approx. no-track drying time: _____
Recommended surface preparation: _____
Recommended primer/sealer (if any): _____

B. Transverse Lines
Product ID numbers or name: City Tape
Approximate contracted cost for materials and application: _____
Recommended thickness: 90 mil
Range of ambient air temperatures for application: _____
Approx. no-track drying time: _____
Recommended surface preparation: _____
Recommended primer/sealer (if any): _____

8. Have any of the materials listed above been included in a NTPEP (or similar) evaluation and if so, does a publication exist?

   Mississippi 2002
   PennDot 2002

9. Please provide contact information for agencies that have used your products for route shield markings or other innovative applications.

   NONE

10. Please provide us with a website or product information pamphlets.

    www.roadtape.com

INDUSTRY SURVEY FOR HORIZONTAL SIGNING

Company: ATM

Name: Ron Sims

Phone: 601-260-3175

Email: rsims2001@yahoo.com

11. What specific types of durable pavement marking materials does your company recommend for use as horizontal signing applications placed in the travel lanes on **urban concrete or asphalt** roadway surfaces with **high traffic** (average daily traffic > 100,000 vehicles)? Please list materials that are suitable for the following applications:

A. Route Shields

Product ID numbers or name: Custom ATM 400
Type of material: They can make custom colored and shaped products
How is the material applied? Would need CAD drawings
Approximate contracted cost for materials and application:
Recommended thickness: Probably use ATM 300 products
Range of ambient air temperatures for application:
Approx. no-track drying time:
Recommended surface preparation:
Recommended primer/sealer (if any):

B. Symbols/Words

Product ID numbers or name: ATM 400 white & yellow 4" up to 24"
Approximate contracted cost for materials and application: $ 96.30 per 90' roll (4"), $3.21 per sft for symbols
Recommended thickness: 90 mil - for higher shear areas
Range of ambient air temperatures for application: 40º and rising
Approx. no-track drying time: N/A
Recommended surface preparation:
Recommended primer/sealer (if any): Pressure sensitive adhesive is on the material

C. Transverse Lines

Product ID numbers or name: SAME
Approximate contracted cost for materials and application:
Recommended thickness:
Range of ambient air temperatures for application:
Approx. no-track drying time:
Recommended surface preparation:
Recommended primer/sealer (if any):

12. What specific types of durable pavement marking materials does your company recommend for use as horizontal signing applications (e.g. words, symbols, transverse bars) placed in the travel lanes on **rural asphalt or chipseal** roadway surfaces with **low-medium traffic**? Please list materials that are suitable for the following applications:

A. Symbols/Words

Product ID numbers or name: ATM 300: 60 mil - or - ATM 180 45 mil
Approximate contracted cost for materials and application: $59.00 per 90' roll, $51.13 per 90' roll
Recommended thickness: _____
Range of ambient air temperatures for application: _____
Approx. no-track drying time: _____
Recommended surface preparation: _____
Recommended primer/sealer (if any): Pressure sensitive adhesive

B. Transverse Lines

Product ID numbers or name: ATM 300 or ATM 180
Approximate contracted cost for materials and application: _____
Recommended thickness: _____
Range of ambient air temperatures for application: _____
Approx. no-track drying time: _____
Recommended surface preparation: _____
Recommended primer/sealer (if any): _____

13. Have any of the materials listed above been included in a NTPEP (or similar) evaluation and if so, does a publication exist?

    ATM 300 and 400 are in NTPEP evaluations, not sure of locations Texas

14. Please provide contact information for agencies that have used your products for route shield markings or other innovative applications.

    Call Brenda Robbins contact the main office, some stuff with border authority in N.Y.

15. Please provide us with a website or product information pamphlets.

    www.trafficmarking.com - facility management page

INDUSTRY SURVEY FOR HORIZONTAL SIGNING

Company: Avery Dennison

Name: Bill Quincy

Phone: 512-219-8600

Email: _____

16. What specific types of durable pavement marking materials does your company recommend for use as horizontal signing applications placed in the travel lanes on **urban concrete or asphalt** roadway surfaces with **high traffic** (average daily traffic > 100,000 vehicles)? Please list materials that are suitable for the following applications:

A. Route Shields

Product ID numbers or name: "Hot Tape" - many colors
Type of material: Preformed thermo
How is the material applied? By torch
Approximate contracted cost for materials and application: I cuts
Recommended thickness: 125 mil
Range of ambient air temperatures for application: Any (must preheat pavement)
Approx. no-track drying time:
Recommended surface preparation: Heat pavement (300º), clean and dry
Recommended primer/sealer (if any): Primers on polished surfaces only

B. Symbols/Words

Product ID numbers or name: Hot Tape
Approximate contracted cost for materials and application: $1.25 per sft
Recommended thickness:
Range of ambient air temperatures for application:
Approx. no-track drying time: Takes about 10 min per arrow
Recommended surface preparation:
Recommended primer/sealer (if any):

C. Transverse Lines

Product ID numbers or name: Hot tape
Approximate contracted cost for materials and application: $1.25 per sft
Recommended thickness:
Range of ambient air temperatures for application:
Approx. no-track drying time:
Recommended surface preparation:
Recommended primer/sealer (if any):

17. What specific types of durable pavement marking materials does your company recommend for use as horizontal signing applications (e.g. words, symbols, transverse bars) placed in the travel lanes on **rural asphalt or chipseal** roadway surfaces with **low-medium traffic**? Please list materials that are suitable for the following applications:

A. Symbols/Words

Product ID numbers or name: Hot tape
Approximate contracted cost for materials and application: _____
Recommended thickness: 125 mil
Range of ambient air temperatures for application: _____
Approx. no-track drying time: _____
Recommended surface preparation: _____
Recommended primer/sealer (if any): _____

B. Transverse Lines

Product ID numbers or name: Hot tape
Approximate contracted cost for materials and application: _____
Recommended thickness: 125 mil
Range of ambient air temperatures for application: _____
Approx. no-track drying time: _____
Recommended surface preparation: _____
Recommended primer/sealer (if any): _____

18. Have any of the materials listed above been included in a NTPEP (or similar) evaluation and if so, does a publication exist?

NTPEP

Penn '00: Pavemark (P.F. Thermo) - Concrete = Marginal, Asphalt = Marginal
Hot Tape (P.F. Thermo) - Concrete = Marginal, Asphalt = Marginal

Miss '99: Hot Tape (P.F. Thermo) - Concrete = Marginal, Asphalt = Marginal

19. Please provide contact information for agencies that have used your products for route shield markings or other innovative applications.

20. Please provide us with a website or product information pamphlets.

Have them

INDUSTRY SURVEY FOR HORIZONTAL SIGNING

Company: Brite Line

Name: Mike Forth

Phone: 303-816-2187

Email: _____

21. What specific types of durable pavement marking materials does your company recommend for use as horizontal signing applications placed in the travel lanes on **urban concrete or asphalt** roadway surfaces with **high traffic** (average daily traffic > 100,000 vehicles)? Please list materials that are suitable for the following applications:

A. Route Shields
Product ID numbers or name: No response
Type of material: _____
How is the material applied? _____
Approximate contracted cost for materials and application: _____
Recommended thickness: _____
Range of ambient air temperatures for application: _____
Approx. no-track drying time: _____
Recommended surface preparation: _____
Recommended primer/sealer (if any): _____

B. Symbols/Words
Product ID numbers or name: _____
Approximate contracted cost for materials and application: _____
Recommended thickness: _____
Range of ambient air temperatures for application: _____
Approx. no-track drying time: _____
Recommended surface preparation: _____
Recommended primer/sealer (if any): _____

C. Transverse Lines
Product ID numbers or name: _____
Approximate contracted cost for materials and application: _____
Recommended thickness: _____
Range of ambient air temperatures for application: _____
Approx. no-track drying time: _____
Recommended surface preparation: _____
Recommended primer/sealer (if any): _____

22. What specific types of durable pavement marking materials does your company recommend for use as horizontal signing applications (e.g. words, symbols, transverse bars) placed in the travel lanes on **rural asphalt or chipseal** roadway surfaces with **low-medium traffic**? Please list materials that are suitable for the following applications:

A. Symbols/Words
Product ID numbers or name: _____
Approximate contracted cost for materials and application: _____
Recommended thickness: _____
Range of ambient air temperatures for application: _____
Approx. no-track drying time: _____
Recommended surface preparation: _____
Recommended primer/sealer (if any): _____

B. Transverse Lines
Product ID numbers or name: _____
Approximate contracted cost for materials and application: _____
Recommended thickness: _____
Range of ambient air temperatures for application: _____
Approx. no-track drying time: _____
Recommended surface preparation: _____
Recommended primer/sealer (if any): _____

23. Have any of the materials listed above been included in a NTPEP (or similar) evaluation and if so, does a publication exist?

NTPEP

Penn ’00: Brite Line 2000 - Concrete = Fail, Asphalt = Fail
Brite Line 1000 – Concrete = Fail, Asphalt = Fail

Miss ’99: Brite Line 3000 - Concrete = Fail, Asphalt = Fail
Brite Line 3001 – Concrete = Fail, Asphalt = Fail

Cal ’00: Brite Line 2000 - Concrete = Fail, Asphalt = Fail

24. Please provide contact information for agencies that have used your products for route shield markings or other innovative applications.

25. Please provide us with a website or product information pamphlets.

INDUSTRY SURVEY FOR HORIZONTAL SIGNING

Company: Digital Markings. Ltd.

Name: Nick Nedas

Phone: 770-650-1541

Email:

26. What specific types of durable pavement marking materials does your company recommend for use as horizontal signing applications placed in the travel lanes on **urban concrete or asphalt** roadway surfaces with **high traffic** (average daily traffic > 100,000 vehicles)? Please list materials that are suitable for the following applications:

A. Route Shields

Product ID numbers or name: Digimark (modified polyurethane resin with bitumen adhesive)
Type of material: 4 color graphic sheet - like billboard on roadway
How is the material applied? Comes as one sheet - applied like a tape
Approximate contracted cost for materials and application:
Recommended thickness: 2 millimeters
Range of ambient air temperatures for application: Any condition
Approx. no-track drying time:
Recommended surface preparation: Clean and dry
Recommended primer/sealer (if any): Primer on concrete

B. Symbols/Words

Product ID numbers or name: None
Approximate contracted cost for materials and application:
Recommended thickness:
Range of ambient air temperatures for application:
Approx. no-track drying time:
Recommended surface preparation:
Recommended primer/sealer (if any):

C. Transverse Lines

Product ID numbers or name: None
Approximate contracted cost for materials and application:
Recommended thickness:
Range of ambient air temperatures for application:
Approx. no-track drying time:
Recommended surface preparation:
Recommended primer/sealer (if any):

27. What specific types of durable pavement marking materials does your company recommend for use as horizontal signing applications (e.g. words, symbols, transverse bars) placed in the travel lanes on **rural asphalt or chipseal** roadway surfaces with **low-medium traffic**? Please list materials that are suitable for the following applications:

A. Symbols/Words

Product ID numbers or name: None
Approximate contracted cost for materials and application: _____
Recommended thickness: _____
Range of ambient air temperatures for application: _____
Approx. no-track drying time: _____
Recommended surface preparation: _____
Recommended primer/sealer (if any): _____

B. Transverse Lines

Product ID numbers or name: None
Approximate contracted cost for materials and application: _____
Recommended thickness: _____
Range of ambient air temperatures for application: _____
Approx. no-track drying time: _____
Recommended surface preparation: _____
Recommended primer/sealer (if any): _____

28. Have any of the materials listed above been included in a NTPEP (or similar) evaluation and if so, does a publication exist?

    Not yet

29. Please provide contact information for agencies that have used your products for route shield markings or other innovative applications.

    None in U.S. - New Product

30. Please provide us with a website or product information pamphlets.

    We have informational flyers

INDUSTRY SURVEY FOR HORIZONTAL SIGNING

Company: Ennis

Name: Susan MaKosh

Phone: 866-247-2283

Email: _____

31. What specific types of durable pavement marking materials does your company recommend for use as horizontal signing applications placed in the travel lanes on **urban concrete or asphalt** roadway surfaces with **high traffic** (average daily traffic > 100,000 vehicles)? Please list materials that are suitable for the following applications:

A. Route Shields

Product ID numbers or name: Flametape (blue, red, white, yellow)
Type of material: Performed thermo (alkyd)
How is the material applied? torch
Approximate contracted cost for materials and application: _____
Recommended thickness: 90 mil
Range of ambient air temperatures for application: _____
Approx. no-track drying time: _____
Recommended surface preparation: preheat
Recommended primer/sealer (if any): No primer at all on any surface

B. Symbols/Words

Product ID numbers or name: Flametape
Approximate contracted cost for materials and application: _____
Recommended thickness: 90 mil
Range of ambient air temperatures for application: _____
Approx. no-track drying time: _____
Recommended surface preparation: _____
Recommended primer/sealer (if any): _____

C. Transverse Lines

Product ID numbers or name: Flametape
Approximate contracted cost for materials and application: _____
Recommended thickness: 90 mil
Range of ambient air temperatures for application: _____
Approx. no-track drying time: _____
Recommended surface preparation: _____
Recommended primer/sealer (if any): _____

32. What specific types of durable pavement marking materials does your company recommend for use as horizontal signing applications (e.g. words, symbols, transverse bars) placed in the travel lanes on **rural asphalt or chipseal** roadway surfaces with **low-medium traffic**? Please list materials that are suitable for the following applications:

A. Symbols/Words
Product ID numbers or name: Flametape
Approximate contracted cost for materials and application: _____
Recommended thickness: 90 mil
Range of ambient air temperatures for application: _____
Approx. no-track drying time: _____
Recommended surface preparation: _____
Recommended primer/sealer (if any): _____

B. Transverse Lines
Product ID numbers or name: Flametape
Approximate contracted cost for materials and application: _____
Recommended thickness: 90 mil
Range of ambient air temperatures for application: _____
Approx. no-track drying time: _____
Recommended surface preparation: _____
Recommended primer/sealer (if any): _____

33. Have any of the materials listed above been included in a NTPEP (or similar) evaluation and if so, does a publication exist?

NTPEP

Miss '99: Flametape - Concrete = Fail, Asphalt = Marginal

Cal '00: Flametape - Concrete = Fail, Asphalt = Fail

34. Please provide contact information for agencies that have used your products for route shield markings or other innovative applications.

Steve Hellmuth – STI striping

35. Please provide us with a website or product information pamphlets.

We have them

INDUSTRY SURVEY FOR HORIZONTAL SIGNING

Company: ____Flint_____

Name: ____Adam Clinton_____

Phone: ____(336) 475-6600_____

Email: _____

36. What specific types of durable pavement marking materials does your company recommend for use as horizontal signing applications placed in the travel lanes on **urban concrete or asphalt** roadway surfaces with **high traffic** (average daily traffic > 100,000 vehicles)? Please list materials that are suitable for the following applications:

A. Route Shields

Product ID numbers or name: "Premark" (also Visigrip-skid resistant material)
Type of material: 125 mil preformed thermo. (ester modified rosin)
How is the material applied? Torch (no preheating of road necessary)
Approximate contracted cost for materials and application: ımber of cuts
Recommended thickness: 125 mils
Range of ambient air temperatures for application: any (don't need to preheat pavement)
Approx. no-track drying time: 15 – 20 minutes to put shield down
Recommended surface preparation: Dry and clean
Recommended primer/sealer (if any): Prime concrete

B. Symbols/Words

Product ID numbers or name: Premark
Approximate contracted cost for materials and application: Arrow = $104 per 125 mil
Recommended thickness: 125 mils
Range of ambient air temperatures for application: _____
Approx. no-track drying time: _____
Recommended surface preparation: _____
Recommended primer/sealer (if any): _____

C. Transverse Lines

Product ID numbers or name: Premark
Approximate contracted cost for materials and application: _____
Recommended thickness: 125 mils
Range of ambient air temperatures for application: _____
Approx. no-track drying time: _____
Recommended surface preparation: _____
Recommended primer/sealer (if any): _____

37. What specific types of durable pavement marking materials does your company recommend for use as horizontal signing applications (e.g. words, symbols, transverse bars) placed in the travel lanes on **rural asphalt or chipseal** roadway surfaces with **low-medium traffic**? Please list materials that are suitable for the following applications:

A. Symbols/Words

Product ID numbers or name: Premark
Approximate contracted cost for materials and application: _____
Recommended thickness: 90 mils – 125 mils
Range of ambient air temperatures for application: _____
Approx. no-track drying time: _____
Recommended surface preparation: _____
Recommended primer/sealer (if any): _____

B. Transverse Lines

Product ID numbers or name: Premark
Approximate contracted cost for materials and application: _____
Recommended thickness: 90 mils – 125 mils
Range of ambient air temperatures for application: _____
Approx. no-track drying time: _____
Recommended surface preparation: _____
Recommended primer/sealer (if any): _____

38. Have any of the materials listed above been included in a NTPEP (or similar) evaluation and if so, does a publication exist?

NTPEP

Penn '00: Various Preformed Thermo - Concrete = Good, Asphalt = Good

Miss '99: Premark Flex (P.F. Thermo) - Concrete = Marginal, Asphalt = Marginal
Premark 20/20 Flex (P.F. Thermo) - Concrete = Fail, Asphalt = Fail

Cal '00: Various Preformed Thermo - Concrete = Fail, Asphalt = Good

39. Please provide contact information for agencies that have used your products for route shield markings or other innovative applications.

City of Houston I-45 downtown (on city street)
@ Travis and Commerce

40. Please provide us with a website or product information pamphlets.

www.flinttrading.com

INDUSTRY SURVEY FOR HORIZONTAL SIGNING

Company: GRT

Name: Sherry Taylor

Phone: (800) 643 – 0134

Email: _____

41. What specific types of durable pavement marking materials does your company recommend for use as horizontal signing applications placed in the travel lanes on **urban concrete or asphalt** roadway surfaces with **high traffic** (average daily traffic > 100,000 vehicles)? Please list materials that are suitable for the following applications:

A. Route Shields
Product ID numbers or name: None
Type of material: _____
How is the material applied? _____
Approximate contracted cost for materials and application: _____
Recommended thickness: _____
Range of ambient air temperatures for application: _____
Approx. no-track drying time: _____
Recommended surface preparation: _____
Recommended primer/sealer (if any): _____

B. Symbols/Words
Product ID numbers or name: None
Approximate contracted cost for materials and application: _____
Recommended thickness: _____
Range of ambient air temperatures for application: _____
Approx. no-track drying time: _____
Recommended surface preparation: _____
Recommended primer/sealer (if any): _____

C. Transverse Lines
Product ID numbers or name: Rubber Series 2000 (removable tape) - only product available (white & yellow only)
Approximate contracted cost for materials and application: 4" - $0.56 per foot 5" - $0.70 6" - $0.84
Recommended thickness: _____
Range of ambient air temperatures for application: See pamphlet
Approx. no-track drying time: N/A
Recommended surface preparation: See pamphlet
Recommended primer/sealer (if any): Adhesive is on tape - sometimes primer should be used

42. What specific types of durable pavement marking materials does your company recommend for use as horizontal signing applications (e.g. words, symbols, transverse bars) placed in the travel lanes on **rural asphalt or chipseal** roadway surfaces with **low-medium traffic**? Please list materials that are suitable for the following applications:

A. Symbols/Words
Product ID numbers or name: SAME
Approximate contracted cost for materials and application: _____
Recommended thickness: _____
Range of ambient air temperatures for application: _____
Approx. no-track drying time: _____
Recommended surface preparation: _____
Recommended primer/sealer (if any): _____

B. Transverse Lines
Product ID numbers or name: SAME
Approximate contracted cost for materials and application: _____
Recommended thickness: _____
Range of ambient air temperatures for application: _____
Approx. no-track drying time: _____
Recommended surface preparation: _____
Recommended primer/sealer (if any): _____

43. Have any of the materials listed above been included in a NTPEP (or similar) evaluation and if so, does a publication exist?

Utah
Penn 2001

44. Please provide contact information for agencies that have used your products for route shield markings or other innovative applications.

None

45. Please provide us with a website or product information pamphlets.

www.roadstripe.com - We have pamphlets

INDUSTRY SURVEY FOR HORIZONTAL SIGNING

Company: LaFarge

Name: Dave Vallanni Kevin Francis

Phone: (404) 767 – 0569 x33 (570) 546 - 6041

Email:

46. What specific types of durable pavement marking materials does your company recommend for use as horizontal signing applications placed in the travel lanes on **urban concrete or asphalt** roadway surfaces with **high traffic** (average daily traffic > 100,000 vehicles)? Please list materials that are suitable for the following applications:

A. Route Shields

Product ID numbers or name: ColorLine (a.k.a. thermaline in colors)
Type of material: P.F. thermo (unique polymer), 90 mils or 125 mils
How is the material applied? Torch @ 400 – 450 deg. (recommend push cart torch)
Approximate contracted cost for materials and application: depending on color
Recommended thickness: 4" (about 50 cents per foot)
Range of ambient air temperatures for application: Any temp with torch (either preheat or non-preheat pavement)
Approx. no-track drying time: N/A
Recommended surface preparation: Dry & heat
Recommended primer/sealer (if any): On concrete

B. Symbols/Words

Product ID numbers or name: ColorLine/thermaline
Approximate contracted cost for materials and application:
Recommended thickness: 125 mil
Range of ambient air temperatures for application:
Approx. no-track drying time:
Recommended surface preparation:
Recommended primer/sealer (if any):

C. Transverse Lines

Product ID numbers or name: ColorLine/thermaline - Also have sprayed or extruded "normal" DMS8220 thermo
Approximate contracted cost for materials and application:
Recommended thickness: 125 mil
Range of ambient air temperatures for application:
Approx. no-track drying time:
Recommended surface preparation:
Recommended primer/sealer (if any):

47. What specific types of durable pavement marking materials does your company recommend for use as horizontal signing applications (e.g. words, symbols, transverse bars) placed in the travel lanes on **rural asphalt or chipseal** roadway surfaces with **low-medium traffic**? Please list materials that are suitable for the following applications:

A. Symbols/Words

Product ID numbers or name: ColorLine

Approximate contracted cost for materials and application: 60 mil or 90 mil

Recommended thickness: _____

Range of ambient air temperatures for application: _____

Approx. no-track drying time: _____

Recommended surface preparation: _____

Recommended primer/sealer (if any): _____

B. Transverse Lines

Product ID numbers or name: _____

Approximate contracted cost for materials and application: _____

Recommended thickness: _____

Range of ambient air temperatures for application: _____

Approx. no-track drying time: _____

Recommended surface preparation: _____

Recommended primer/sealer (if any): _____

48. Have any of the materials listed above been included in a NTPEP (or similar) evaluation and if so, does a publication exist?

NTPEP

Penn ’00: Various Preformed Thermo - Concrete = Good, Asphalt = Good

Miss ’99: Various Preformed Thermo - Concrete = Marginal, Asphalt = Marginal

Cal ’00: Various Preformed Thermo - Concrete = Fail, Asphalt = Marginal

49. Please provide contact information for agencies that have used your products for route shield markings or other innovative applications.

50. Please provide us with a website or product information pamphlets.

www.lafargegroadmarking.com

INDUSTRY SURVEY FOR HORIZONTAL SIGNING

Company: Swarco

Name: Dick Racs

Phone: 254-562-9879

Email: _____

51. What specific types of durable pavement marking materials does your company recommend for use as horizontal signing applications placed in the travel lanes on **urban concrete or asphalt** roadway surfaces with **high traffic** (average daily traffic > 100,000 vehicles)? Please list materials that are suitable for the following applications:

A. Route Shields

Product ID numbers or name: None
Type of material:
How is the material applied?
Approximate contracted cost for materials and application:
Recommended thickness:
Range of ambient air temperatures for application:
Approx. no-track drying time:
Recommended surface preparation:
Recommended primer/sealer (if any):

B. Symbols/Words

Product ID numbers or name: Director 90 (permanent tape) white/yellow
Approximate contracted cost for materials and application: $2.10 per sft
Recommended thickness: 90 mil
Range of ambient air temperatures for application: 50-55º
Approx. no-track drying time:
Recommended surface preparation: Clean and dry
Recommended primer/sealer (if any): Prime concrete

C. Transverse Lines

Product ID numbers or name: Director 90 (permanent) white/yellow
Approximate contracted cost for materials and application: $2.10 per sft (360' roll of 4", 90' roll of 12')
Recommended thickness: 90 mil
Range of ambient air temperatures for application: 50-55º
Approx. no-track drying time:
Recommended surface preparation: Clean and dry
Recommended primer/sealer (if any): Prime concrete

52. What specific types of durable pavement marking materials does your company recommend for use as horizontal signing applications (e.g. words, symbols, transverse bars) placed in the travel lanes on **rural asphalt or chipseal** roadway surfaces with **low-medium traffic**? Please list materials that are suitable for the following applications:

A. Symbols/Words
Product ID numbers or name: Director 60
Approximate contracted cost for materials and application: _____
Recommended thickness: _____
Range of ambient air temperatures for application: _____
Approx. no-track drying time: _____
Recommended surface preparation: _____
Recommended primer/sealer (if any): _____

B. Transverse Lines
Product ID numbers or name: Director 60
Approximate contracted cost for materials and application: _____
Recommended thickness: _____
Range of ambient air temperatures for application: _____
Approx. no-track drying time: _____
Recommended surface preparation: _____
Recommended primer/sealer (if any): _____

53. Have any of the materials listed above been included in a NTPEP (or similar) evaluation and if so, does a publication exist?

Yes

54. Please provide contact information for agencies that have used your products for route shield markings or other innovative applications.

N/A

55. Please provide us with a website or product information pamphlets.

www.swarco.com

APPENDIX B:
NTPEP FIELD TESTING PROCEDURES FOR PAVEMENT MARKINGS

A major resource for comprehensive pavement marking evaluations performed at the national level is the National Transportation Product Evaluation Program (NTPEP). NTPEP is responsible for testing and evaluating products, materials, and devices that are commonly used by the American Association of State Highway and Transportation Officials (AASHTO) member departments of transportation (DOTs). NTPEP evaluations of pavement marking materials are usually performed both in field and laboratory environments, with an emphasis on field performance of materials. Manufacturers voluntarily submit products for testing by NTPEP. NTPEP evaluations culminate in a formal report that is written by the state DOT in which the field evaluation was performed and is published and distributed by AASHTO. Test data are furnished in the report; however, per NTPEP/AASHTO policy, no approval, disapproval, or endorsements of products are made.

TTI researchers obtained and reviewed the following three recent NTPEP pavement marking reports:

- 2000 Urban California Test Deck (first year data), Report 02 NTPEP 216 *(2)*;
- 2000 Pennsylvania Test Deck (first year data), Report 02 NTPEP 221 *(3)*; and
- 1999 Mississippi Test Deck (second year data), Report 02 NTPEP 220 *(4)*.

Each of the three reports was obtained because they included up-to-date performance data for pavement marking materials installed on both HMAC and PCC roadway surfaces. The California report was of particular interest due to the high traffic volumes through the test sections. Table 8 displays a summary of the characteristics of each site.

Table 8. NTPEP Site Characteristics.

Criteria		2000 Urban California	2000 Pennsylvania	1999 Mississippi
Location	Concrete	US 50 (WB[a]), Sacramento	I-80 (EB[b]), Williamsport	US 78 (WB[a]), New Albany
	Asphalt	US 50 (WB[a]), Sacramento	I-80 (WB[a]), Williamsport	US 78 (EB[b]), Tupelo
ADT	Concrete	160,000	10,000	20,000
	Asphalt	160,000	10,000	15,000
Material Installation Date		August 2000	July 2000	July 1999
Snowplowing?		No	Yes	No
Total Number of Materials Evaluated		33	180	100
Material Types		Thermo, Preformed Thermo, Permanent Tape, Polyurea, Modified Urethane	Paint, Thermo, Preformed Thermo, Permanent Tape, Removable Tape, Epoxy, Polyurea, Modified Urethane, Methyl Methacrylate, Experimental Products	Paint, Thermo, Preformed Thermo, Permanent Tape, Removable Tape, Epoxy

[a] WB = westbound
[b] EB = eastbound

In each evaluation, NTPEP field testing was performed according to the procedures developed by the NTPEP Subcommittee for Pavement Marking Materials, which are based on ASTM D 713-90: Standard Practice for Conducting Road Service Tests on Fluid Traffic Marking Materials. In each evaluation, all pavement marking materials were installed on both bituminous asphalt surface and Portland cement concrete surface. The material manufacturers, under the supervision of the lead agency, were responsible for placement of their respective striping materials. Multiple beaded transverse lines were placed for each material sample. Lines extended across the right lane from the left side of the right edgeline to the left side of the lane line. Primers/sealers were used with selected thermoplastic and tape materials.

In each case, the marking materials were evaluated based on the field testing procedures described in ASTM D 713-90. The lead agency for each evaluation performed all field data collection. Field data were initially collected within the first few days after application.

Subsequent data collection was performed at monthly intervals for the first year after application and at quarterly intervals during the second year[1]. The following field data were collected for each material sample during each data collection event:

- subjective rating of the durability and appearance,
- quantitative retroreflectivity measurement (30 m geometry [for consistency with earlier text]), and
- quantitative color measurement[2].

Subjective ratings of durability were made by a team of trained evaluators. Retroreflectivity measurements were made using a portable handheld retroreflectometer with 30 m geometry. Durability and retroreflectivity measurements were obtained in two locations for each transverse sample line:

- within the 18 inch left wheel path area to approximate maximum wear conditions and
- within the 9 inch area at the lane line to approximate normal wear conditions.

Material durability was determined by estimating the percentage of the stripe remaining (non-exposed substrate) at each of the two locations on the line. Durability ratings were assigned by taking 10 percent of the percentage remaining (e.g., 60 percent remaining equals a durability rating of 6). Durability ratings were therefore reported on an integer scale from 0 to 10.

[1] The California and Pennsylvania reports include first-year data only, as second-year data have not yet been reported. The Mississippi report includes only second-year data.
[2] Color measurements were not necessarily performed during every data collection event.

APPENDIX C:
MATERIALS INSTALLED AND MEASUREMENTS TAKEN

Tables 9 through 17 in this appendix document the types of materials installed at each location. In addition, the status of each sample and the measurements taken are indicated. In some cases, the material failed to adhere to the pavement and was missing at the time of measurement. In other cases, the researchers failed to get a valid measurement due to oversight or equipment malfunction in the field.

A check mark (√) denotes that a sample was present and measurements were taken. A dash (-) denotes that no sample was provided of that type. An O denotes that the sample had failed and was missing from the test deck. An X denotes missing data due to researcher or equipment error.

Table 9. Results for Avery (125).

Vendor Name:	**Avery (125)**								
Test:	Retroreflectivity								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Arrow	√	√	√	√	√	√	√	√	√
Letter S	√	X	√	√	√	√	√	√	√
Transverse Line	√	√	√	√	√	√	√	√	√
Yellow Green	-	-	-	√	√	√	√	X	√
Red	-	-	-	-	-	-	√	X	√
Blue	-	-	-	√	√	√	√	X	√
Green	-	-	-	-	-	-	-	-	-
Purple	-	-	-	-	-	-	-	-	-
Test:	Thickness								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Transverse Line	√	√	√	√	√	√	√	√	√
Test:	Color								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Arrow	√	√	√	√	√	√	√	√	√
Letter S	√	X	√	√	√	√	√	√	√
Transverse Line	√	√	√	√	√	√	√	√	√
Yellow Green	-	-	-	√	√	√	-	-	-
Red	-	-	-	-	-	-	-	-	-
Blue	-	-	-	√	√	√	-	-	-
Green	-	-	-	-	-	-	-	-	-
Purple	-	-	-	-	-	-	-	-	-

Table 10. Results for Avery (90).

Vendor Name:	**Avery (90)**								
Test:	Retroreflectivity								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Arrow	√	√	√	√	√	√	√	√	√
Letter S	√	√	√	√	√	√	√	√	√
Transverse Line	√	√	√	√	√	√	√	X	√
Yellow Green	√	√	√	√	√	√	-	-	-
Red	√	√	√	-	-	-	-	-	-
Blue	√	√	√	√	√	√	-	-	-
Green	-	-	-	-	-	-	-	-	-
Purple	-	-	-	-	-	-	-	-	-
Test:	Thickness								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Transverse Line	√	√	√	√	√	√	√	√	X
Test:	Color								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Arrow	√	√	√	√	√	√	√	√	√
Letter S	√	X	√	√	√	√	√	√	√
Transverse Line	√	√	√	√	√	√	√	√	√
Yellow Green	√	√	√	√	√	√	√	√	√
Red	√	√	√	-	-	-	√	√	√
Blue	√	√	√	√	√	√	√	√	√
Green	-	-	-	-	-	-	-	-	-
Purple	-	-	-	-	-	-	-	-	-

Table 11. Results for Ennis.

Vendor Name:	**Ennis**								
Test:	Retroreflectivity								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Arrow	√	√	√	√	√	√	√	√	√
Letter S	√	√	√	√	√	√	√	√	O
Transverse Line (90 mil)	√	√	√	√	√	√	√	√	O
Transverse Line (125 mil)	√	√	√	√	√	√	√	√	√
Yellow Green	√	√	√	√	√	X	√	O	O
Red	√	√	√	√	√	X	√	O	O
Blue	√	√	√	√	√	X	√	O	O
Green	√	√	√	√	√	X	√	O	O
Purple	-	-	-	-	-	-	-	-	-
Test:	Thickness								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Transverse Line (90 mil)	√	√	√	-	-	-	√	√	X
Transverse Line (125 mil)	-	-	-	√	√	√	-	-	-
Test:	Color								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Arrow	√	√	√	√	√	√	√	√	√
Letter S	√	X	√	√	√	√	√	√	O
Transverse Line (90 mil)	√	√	√	√	X	X	√	O	O
Transverse Line (125 mil)	√	√	√	√	√	√	√	√	√
Yellow Green	-	-	-	√	X	√	√	√	O
Red	-	-	-	√	X	√	√	O	O
Blue	-	-	-	√	X	√	√	O	O
Green	-	-	-	√	X	√	√	O	O
Purple	-	-	-	-	-	-	-	-	-

Table 12. Results for Flint (125) 1st Set.

Vendor Name:	**Flint (125) 1st Set**								
Test:	Retroreflectivity								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Arrow	√	√	√	√	√	√	√	√	√
Letter S	√	√	√	√	√	X	√	√	√
Transverse Line	√	√	√	√	√	X	√	√	√
Yellow Green	√	√	√	√	√	√	√	√	√
Red	√	√	√	-	-	-	√	√	√
Blue	-	-	-	-	-	-	-	-	-
Green	-	-	-	-	-	-	-	-	-
Purple	-	-	-	-	-	-	-	-	-
Test:	Thickness								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Transverse Line	√	√	√	√	√	√	√	√	√
Test:	Color								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Arrow	√	√	√	√	√	√	√	√	√
Letter S	√	X	√	√	√	√	√	√	√
Transverse Line	√	√	√	√	√	√	√	√	√
Yellow Green	√	√	√	√	X	√	√	√	√
Red	√	√	√	-	-	-	√	√	√
Blue	-	-	-	-	-	-	-	-	-
Green	-	-	-	-	-	-	-	-	-
Purple	-	-	-	-	-	-	-	-	-

Table 13. Results for Flint (125) 2nd Set.

Vendor Name:	**Flint (125) 2nd Set**								
Test:	Retroreflectivity								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Arrow	√	√	√	√	√	√	√	√	√
Letter S	√	√	√	√	√	√	√	√	√
Transverse Line	√	√	√	√	√	√	√	√	√
Yellow Green	√	√	√	√	√	√	√	√	√
Red	√	√	√	-	-	-	√	√	√
Blue	-	-	-	-	-	-	-	-	-
Green	-	-	-	-	-	-	-	-	-
Purple	-	-	-	-	-	-	-	-	-
Test:	Thickness								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Transverse Line	-	-	-	√	√	√	√	√	√
Test:	Color								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Arrow	√	√	√	√	√	√	√	√	√
Letter S	√	X	√	√	√	√	√	√	√
Transverse Line	√	√	√	√	√	√	√	√	√
Yellow Green	√	√	√	X	√	√	√	√	√
Red	√	√	√	-	-	-	√	√	√
Blue	-	-	-	-	-	-	-	-	-
Green	-	-	-	-	-	-	-	-	-
Purple	-	-	-	-	-	-	-	-	-

Table 14. Results for LaFarge (90 mil).

Vendor Name:	**LaFarge (90 mil)**								
Test:	Retroreflectivity								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Arrow	√	√	√	√	√	√	√	√	√
Letter S	√	√	√	√	√	√	√	√	√
Transverse Line	√	√	√	√	√	√	-	-	-
Yellow Green	√	√	√	√	√	√	-	-	-
Red	√	√	√	√	√	√	-	-	-
Blue	√	√	√	√	√	√	-	-	-
Green	-	-	-	-	-	-	-	-	-
Purple	√	√	√	√	√	√	-	-	-
Test:	Thickness								
	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Transverse Line	√	√	√	√	√	√	-	-	-
Test:	Color								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Arrow	√	√	√	√	√	X	√	√	√
Letter S	√	X	√	√	√	√	√	√	√
Transverse Line	√	√	√	√	√	√	-	-	-
Yellow Green	X	X	√	√	√	√	-	-	-
Red	X	X	√	√	√	√	-	-	-
Blue	X	X	√	√	√	√	-	-	-
Green	-	-	-	-	-	-	-	-	-
Purple	X	X	√	√	√	√	-	-	-

Table 15. Results for LaFarge (125 mil).

Vendor Name:	**LaFarge (125 mil)**								
Test:	Retroreflectivity								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Arrow	√	√	√	-	-	-	√	√	√
Letter S	√	√	√	√	√	√	√	√	√
Transverse Line	√	√	√	√	√	√	√	√	√
Yellow Green	-	-	-	-	-	-	-	-	-
Red	-	-	-	-	-	-	√	√	X
Blue	-	-	-	-	-	-	√	√	X
Green	-	-	-	-	-	-	√	√	√
Purple	-	-	-	-	-	-	√	X	√
Test:	Thickness								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Transverse Line	√	√	√	√	√	√	√	√	√
Test:	Color								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Arrow	√	√	√	X	X	√	√	√	X
Letter S	√	X	√	√	√	√	√	√	√
Transverse Line	√	√	√	√	√	√	√	√	√
Yellow Green	√	√	X	-	-	-	√	√	√
Red	√	√	X	-	-	-	√	√	X
Blue	√	√	X	-	-	-	√	√	X
Green	-	-	-	-	-	-	-	-	-
Purple	√	√	X	-	-	-	√	√	√

Table 16. Results for Digital Markings.

Vendor Name:	**Digital Markings**								
Test:	Retroreflectivity								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Arrow	-	-	-	-	-	-	√	X	X
Letter S	-	-	-	-	-	-	√	X	X
Transverse Line	-	-	-	-	-	-	√	X	X
Yellow Green	-	-	-	-	-	-	-	-	-
Red	-	-	-	-	-	-	-	-	-
Blue	-	-	-	-	-	-	-	-	-
Green	-	-	-	-	-	-	-	-	-
Purple	-	-	-	-	-	-	-	-	-
Test:	Thickness								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Transverse Line	-	-	-	-	-	-	√	X	X
Test:	Color								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Arrow	-	-	-	-	-	-	√	X	X
Letter S	-	-	-	-	-	-	√	X	X
Transverse Line	-	-	-	-	-	-	√	X	X
Yellow Green	-	-	-	-	-	-	-	-	-
Red	-	-	-	-	-	-	-	-	-
Blue	-	-	-	-	-	-	-	-	-
Green	-	-	-	-	-	-	-	-	-
Purple	-	-	-	-	-	-	-	-	-

Table 17. Results for Rocbinda.

Vendor Name:	**Rocbinda**								
Test:	Retroreflectivity								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Arrow	√	√	√	√	√	√	√	√	√
Letter S	√	√	√	√	√	√	√	√	√
Transverse Line	√	√	√	√	√	√	√	√	√
Yellow Green	-	-	-	-	-	-	-	-	-
Red	√	√	√	X	√	√	X	X	√
Blue	-	-	-	-	-	-	-	-	-
Green	-	-	-	-	-	-	-	-	-
Purple	-	-	-	-	-	-	-	-	-
Test:	Thickness								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Transverse Line	X	X	X	X	X	X	X	X	X
Comments:	Could not measure thickness due to application methods								
Test:	Color								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Arrow	√	√	√	√	√	√	√	√	√
Letter S	√	X	√	√	√	√	√	√	√
Transverse Line	√	√	√	√	√	√	√	√	√
Yellow Green	-	-	-	-	-	-	-	-	-
Red	√	√	√	√	X	X	√	X	√
Blue	-	-	-	-	-	-	-	-	-
Green	-	-	-	-	-	-	-	-	-
Purple	-	-	-	-	-	-	-	-	-

APPENDIX D:
PHOTOGRAPHS OF TEST DECKS

Figures 36 through 167 document the installation and durability of the test materials.

ABILENE TEST DECK SEAL COAT

Avery Products

Figure 36. Project Overview, 2003, Abilene.

Figure 37. Avery 125 Installation, 2003, Abilene.

Figure 38. Avery 125, New, 2003, Abilene.

Figure 39. Avery 125, 1 Year, 2004, Abilene.

Figure 40. Avery 125, 2 Years, 2005, Abilene.

Figure 41. Avery 125 Arrow, 1 Year, 2004, Abilene.

Figure 42. Avery 125 Arrow, 2 Years, 2005, Abilene.

Figure 43. Avery 90, New, 2003, Abilene.

Figure 44. Avery 90, 1 Year, 2004, Abilene.

Figure 45. Avery 90, 2 Years, 2005, Abilene.

Figure 46. Avery 90 Arrow, 1 Year, 2004, Abilene.

Figure 47. Avery 90 Arrow, 2 Years, 2005, Abilene.

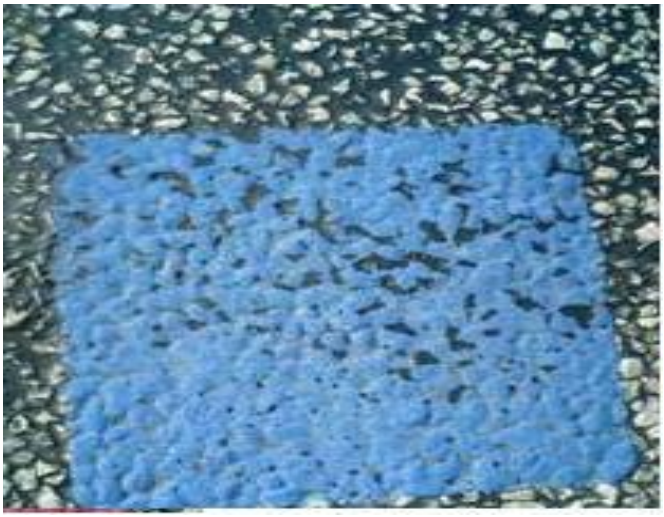

Figure 48. Avery 90 Blue, 1 Year, 2004, Abilene.

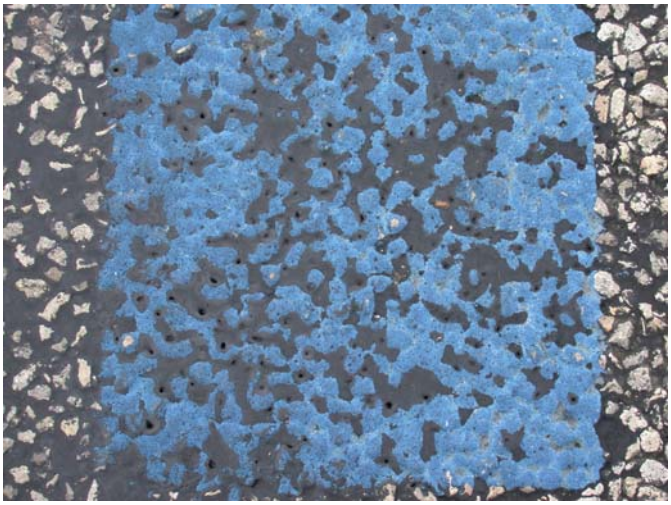

Figure 49. Avery 90 Blue, 2 Years, 2005, Abilene.

Ennis Products

Figure 50. Ennis, New, 2003, Abilene.

Figure 51. Ennis, 1 Year, 2004, Abilene.

Figure 52. Ennis, 2 Years, 2005, Abilene.

Figure 53. Ennis Arrow, 1 Year, 2004, Abilene.

Figure 54. Ennis Arrow, 2 Years, 2005, Abilene.

Figure 55. Ennis Transverse, 1 Year, 2004, Abilene.

Figure 56. Ennis Transverse, 2 Years, 2005, Abilene.

Flint Products

Figure 57. Flint (125) First Set, New, 2003, Abilene.

Figure 58. Flint (125) First Set, 1 Year, 2004, Abilene.

Figure 59. Flint (125) First Set, 2 Years, 2005, Abilene.

Figure 60. Flint (125) First Set Arrow, 1 Year, 2004, Abilene.

Figure 61. Flint (125) First Set Arrow, 2 Years, 2005, Abilene.

Figure 62. Flint (125) Second Set, New, 2003, Abilene.

Figure 63. Flint (125) Second Set, 1 Year, 2004, Abilene.

Figure 64. Flint (125) Second Set, 2 Years, 2005, Abilene.

Figure 65. Flint (125) Second Set Arrow, 1 Year, 2004, Abilene.

Figure 66. Flint (125) Second Set Arrow, 2 Years, 2005, Abilene.

LaFarge Products

Figure 67. LaFarge (125) Installation, 2003, Abilene.

Figure 68. LaFarge (90) Installation, 2003, Abilene.

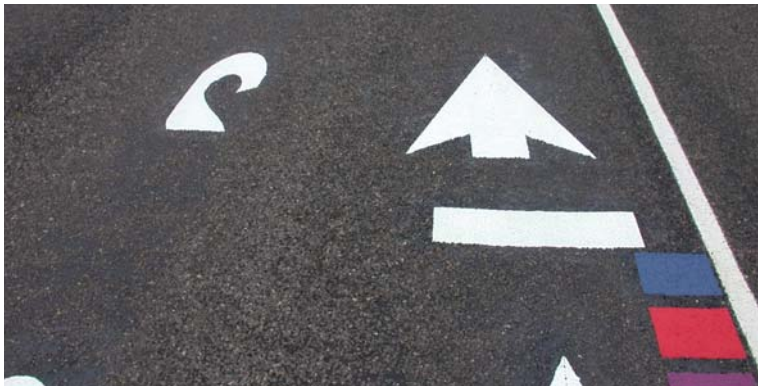

Figure 69. LaFarge (125), New, 2003, Abilene.

Figure 70. LaFarge (125), 1 Year, 2004, Abilene.

Figure 71. LaFarge (125), 2 Years, 2005, Abilene.

Figure 72. LaFarge (125) Arrow, 1 Year, 2004, Abilene.

Figure 73. LaFarge (125) Arrow, 2 Years, 2005, Abilene.

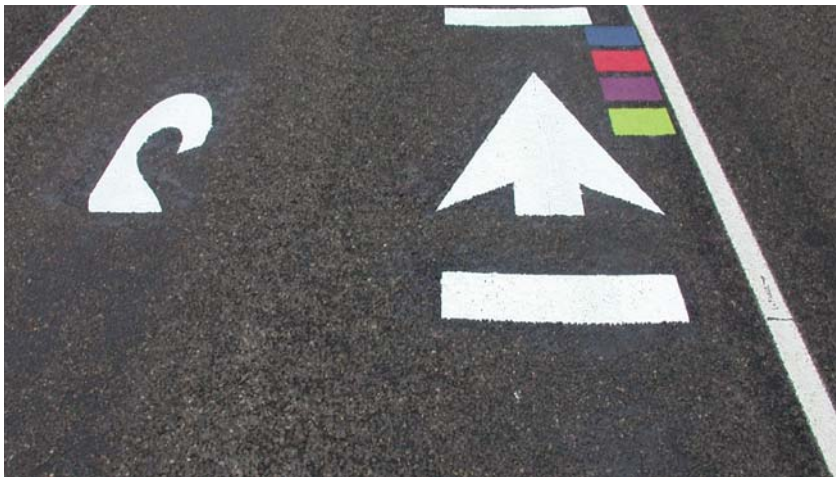

Figure 74. LaFarge (90), New, 2003, Abilene.

Figure 75. LaFarge (90), 1 Year, 2004, Abilene.

Figure 76. LaFarge (90), 2 Years, 2005, Abilene.

Figure 77. LaFarge (90) Arrow, 1 Year, 2004, Abilene.

Figure 78. LaFarge (90) Arrow, 2 Years, 2005, Abilene.

Digital Markings Products

Figure 79. Digital Markings, New, 2003, Abilene.

Figure 80. Digital Markings, 1 Year, 2004, Abilene.

Figure 81. Digital Markings, 2 Years, 2005, Abilene.

Rocbinda

Figure 82. Rocbinda, New, 2003, Abilene

Figure 83. Rocbinda, 1 Year, 2004, Abilene.

Figure 84. Rocbinda, 2 Years, 2005, Abilene.

Figure 85. Rocbinda Seven, 1 Year, 2004, Abilene.

Figure 86. Rocbinda Seven, 2 Years, 2005, Abilene.

Figure 87. Rocbinda Arrow, 1 Year, 2004, Abilene.

Figure 88. Rocbinda Arrow, 2 Years, 2005, Abilene.

AUSTIN TEST DECK ON ASPHALT

Figure 89. Project Overview, 2003, Austin.

Avery Products

Figure 90. Avery Application, 2003, Austin.

Figure 91. Avery 1, New, 2003, Austin.

Figure 92. Avery 1, 1 Year, 2004, Austin.

Figure 93. Avery 1, 2 Years, 2005, Austin.

Figure 94. Avery 2, New, 2003, Austin.

Figure 95. Avery 2, 1 Year, 2004, Austin.

Figure 96. Avery 2, 2 Years, 2005, Austin.

Ennis Products

Figure 97. Ennis Application, 2003, Austin.

Figure 98. Ennis, New, 2003, Austin.

Figure 99. Ennis, 1 Year, 2004, Austin.

Figure 100. Ennis, 2 Years, 2005, Austin.

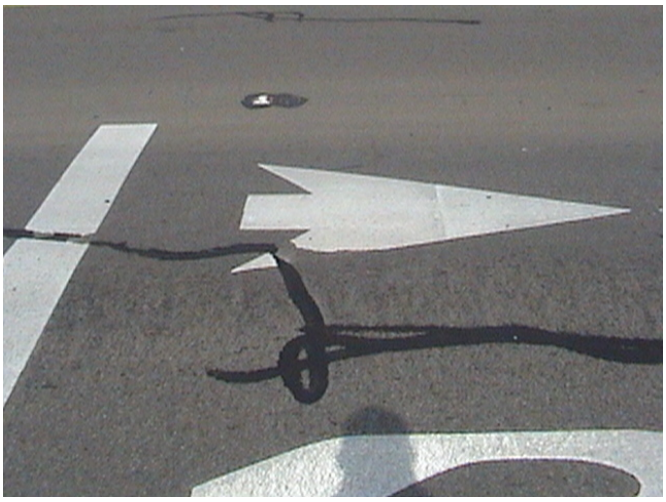

Figure 101. Ennis Arrow, 1 Year, 2004, Austin.

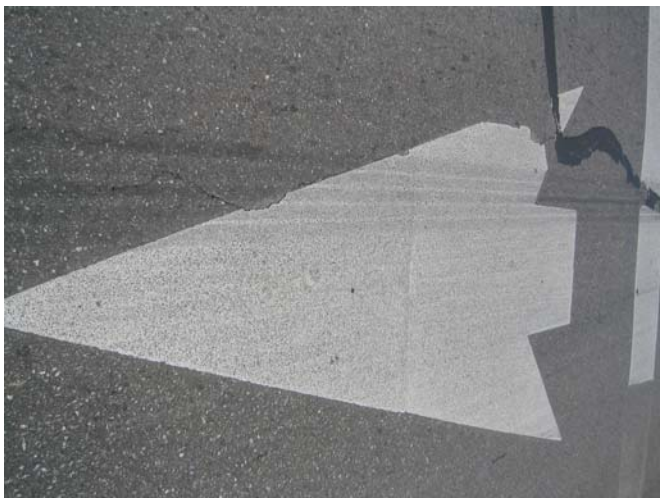

Figure 102. Ennis Arrow, 2 Years, 2005, Austin.

Flint Products

Figure 103. Flint 1, New, 2003, Austin.

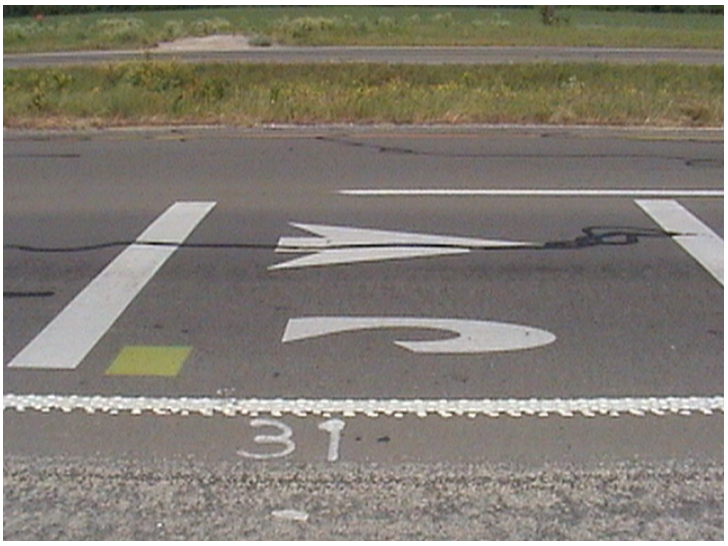

Figure 104. Flint 1, 1 Year, 2004, Austin.

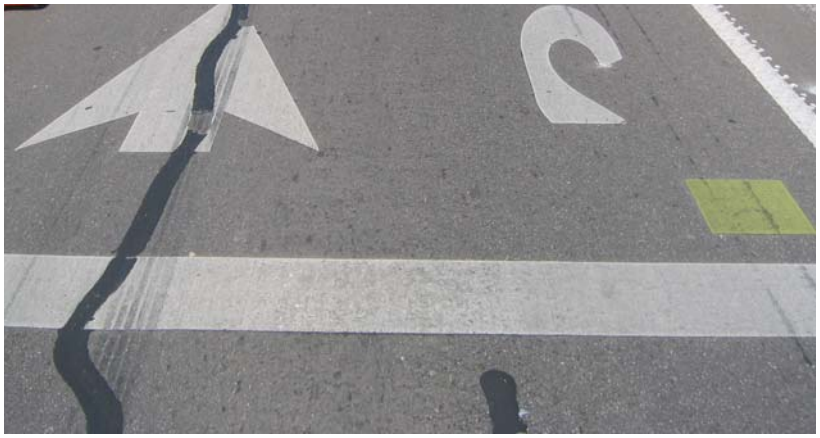

Figure 105. Flint 1, 2 Years, 2005, Austin.

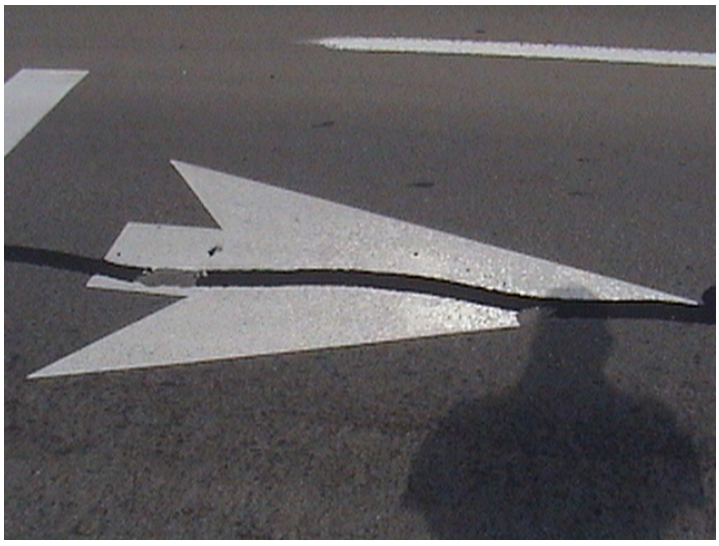

Figure 106. Flint 1 Arrow, 1 Year, 2004, Austin.

Figure 107. Flint 1 Arrow, 2 Years, 2005, Austin.

Figure 108. Flint 2, New, 2003, Austin.

Figure 109. Flint 2, 1 Year, 2004, Austin.

Figure 110. Flint 2, 2 Years, 2005, Austin.

LaFarge Products

Figure 111. LaFarge 125, New, 2003, Austin.

Figure 112. LaFarge 125, 1 Year, 2004, Austin.

Figure 113. LaFarge 125, 2 Years, 2005, Austin.

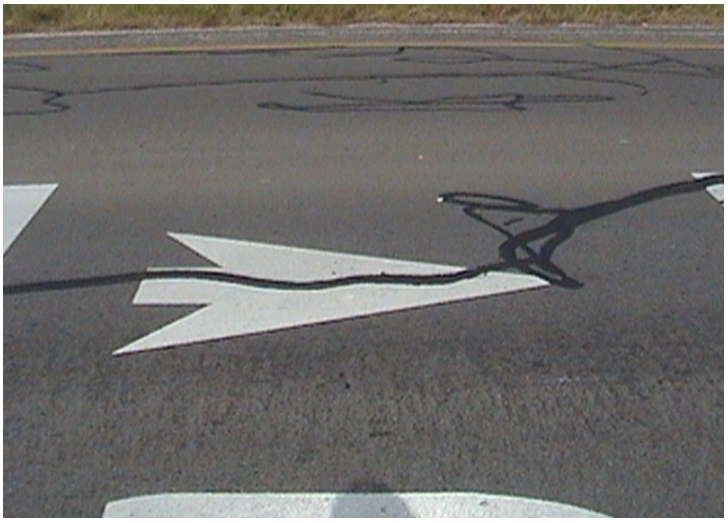

Figure 114. LaFarge 125, Arrow, 1 Year, 2004, Austin.

Figure 115. LaFarge 125, Arrow, 2 Years, 2005, Austin.

Figure 116. LaFarge 90, New, 2003, Austin.

Figure 117. LaFarge 90, 1 Year, 2004, Austin.

Figure 118. LaFarge 90, 2 Years, 2005, Austin.

Rocbinda Products

Figure 119. Rocbinda 1, New, 2003, Austin.

Figure 120. Rocbinda 1, 1 Year, 2004, Austin.

Figure 121. Rocbinda 1, 2 Years, 2005, Austin.

Figure 122. Rocbinda 1 Arrow, 2 Years, 2005, Austin.

Figure 123. Rocbinda 1 Transverse, 2 Years, 2005, Austin.

HOUSTON TEST DECK CONCRETE

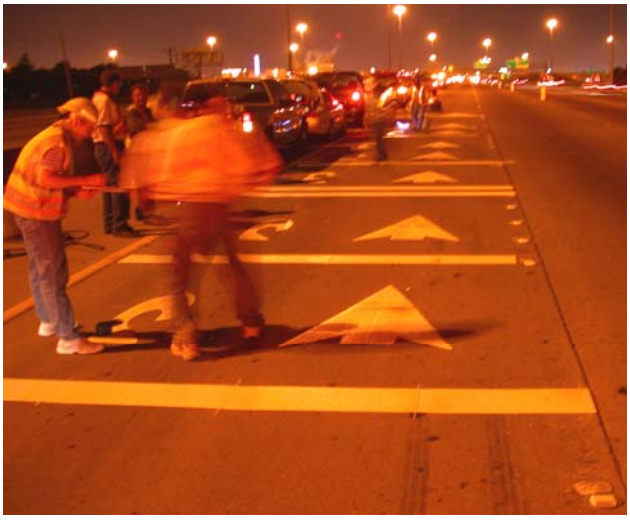

Figure 124. Project Overview, Houston.

Avery Products

Figure 125. Avery 90, New, 2003, Houston.

Figure 126. Avery 90, 1 Year, 2004, Houston.

Figure 127. Avery 90, 2 Years, 2005, Houston.

Figure 128. Avery 125, New, 2003, Houston.

Figure 129. Avery 125, 1 Year, 2004, Houston.

Figure 130. Avery 125, 2 Years, 2005, Houston.

Ennis Products

Figure 131. Ennis, New, 2003, Houston.

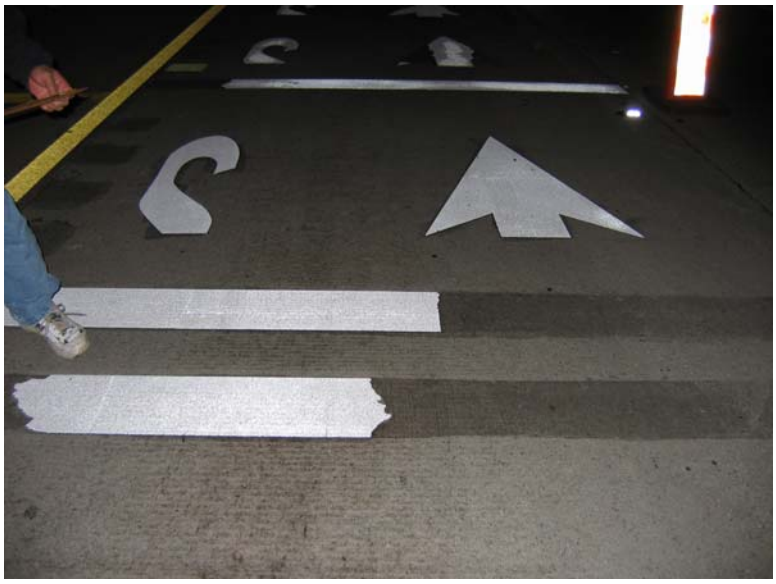

Figure 132. Ennis, 1 Year, 2004, Houston.

Figure 133. Ennis, 2 Years, 2005, Houston.

Figure 134. Ennis Transverse, 1 Year, 2004, Houston.

Figure 135. Ennis Transverse, 2 Years, 2005, Houston.

Figure 136. Ennis Arrow, 2 Years, 2005, Houston.

LaFarge Products

Figure 137. LaFarge 125, New, 2003, Houston.

Figure 138. LaFarge 125, 1 Year, 2004, Houston.

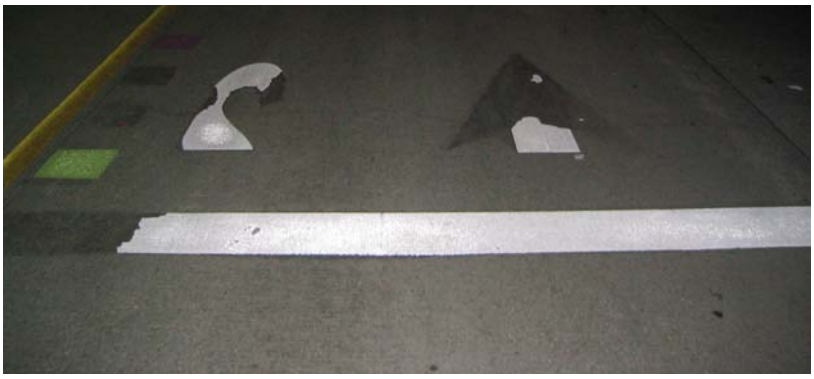

Figure 139. LaFarge 125, 2 Years, 2005, Houston.

Figure 140. LaFarge 125 S and Colors, 1 Year, 2004, Houston.

Figure 141. LaFarge 125 S and Colors, 2 Years, 2005, Houston.

Figure 142. LaFarge 125 Arrow, 1 Year, 2004, Houston.

Figure 143. LaFarge 125 Arrow, 2 Years, 2005, Houston.

Figure 144. LaFarge 90, New, 2003, Houston.

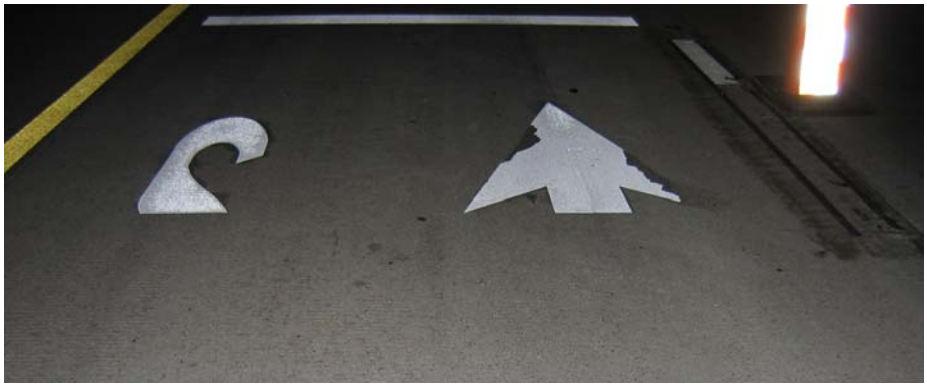

Figure 145. LaFarge 90, 1 Year, 2004, Houston.

Figure 146. LaFarge 90, Arrow, 2 Years, 2005, Houston.

Flint Products

Figure 147. Flint 1, New, 2003, Houston.

Figure 148. Flint 1, 1 Year, 2004, Houston.

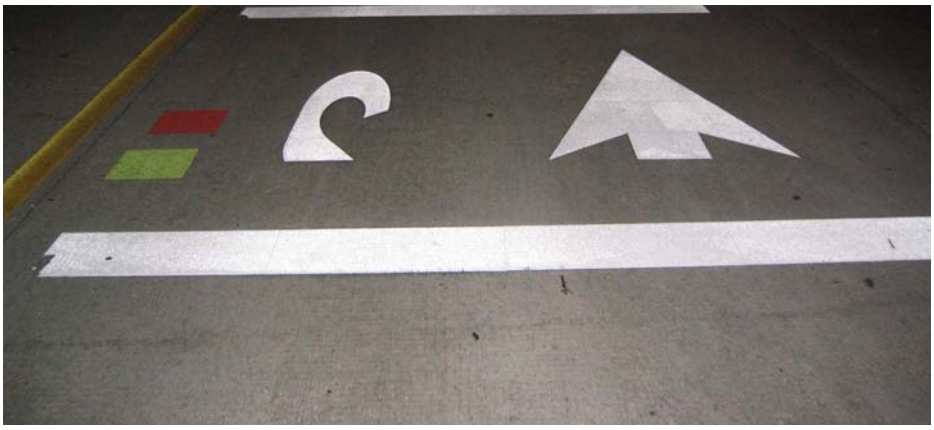

Figure 149. Flint 1, 2 Years, 2005, Houston.

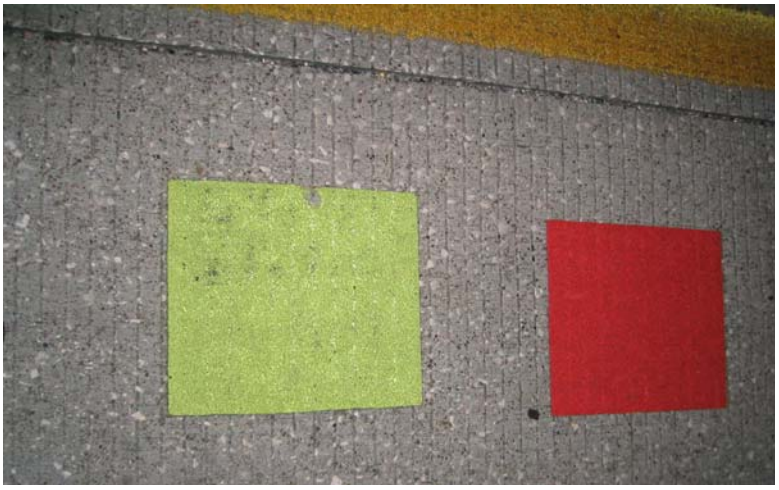

Figure 150. Flint 1 Yellow and Red, 2 Years, 2005, Houston.

Figure 151. Flint 1 Transverse, 2 Years, 2005, Houston.

Figure 152. Flint 2, New, 2003, Houston.

Figure 153. Flint 2, 1 Year, 2004, Houston.

Figure 154. Flint 2, 2 Years, 2005, Houston.

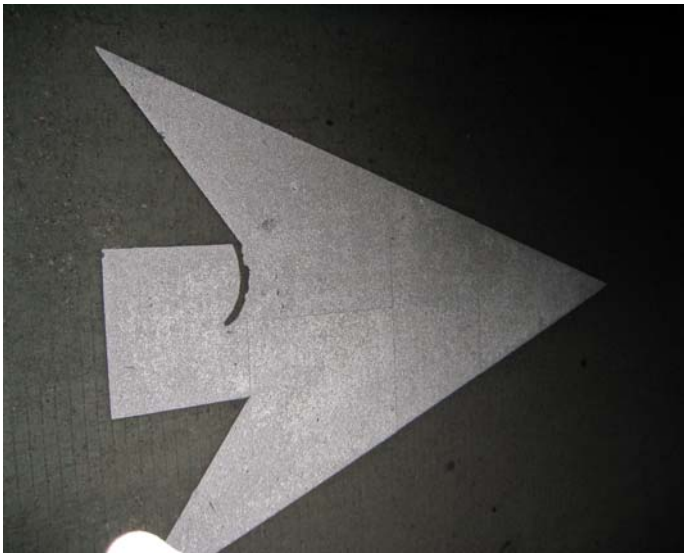

Figure 155. Flint 2 Arrow, 2 Years, 2005, Houston.

Digital Markings Products

Figure 156. Digital Markings, New, 2003, Houston.

Figure 157. Digital Markings, 1 Year, 2004, Houston.

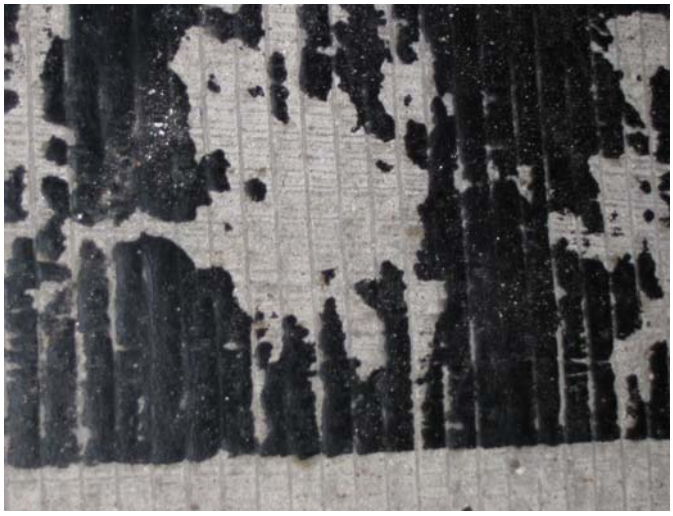

Figure 158. Digital Markings Close Up, 1 Year, 2004, Houston.

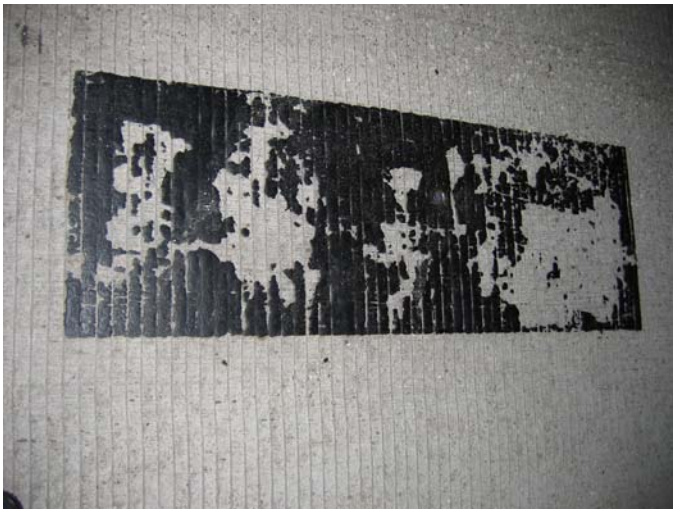

Figure 159. Digital Markings Transverse, 1 Year, 2004, Houston.

Figure 160. Digital Markings, 2 Years, 2005, Houston.

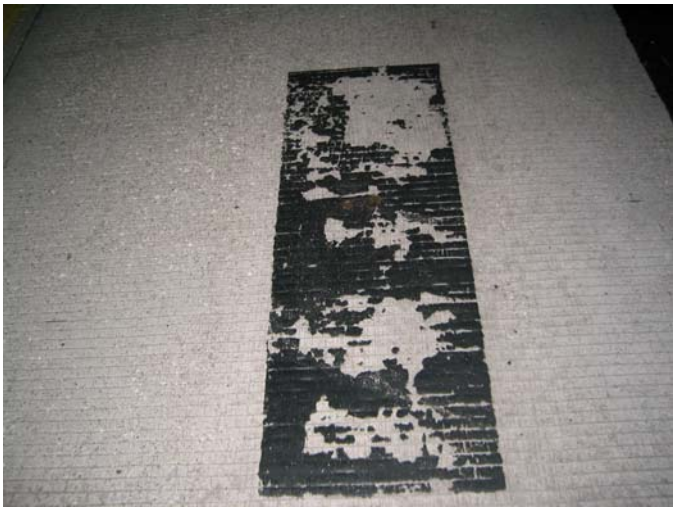

Figure 161. Digital Markings Close up, 2 Years, 2005, Houston.

Rocbinda Products

Figure 162. Rocbinda, New, 2003, Houston.

Figure 163. Rocbinda, 1 Year, 2004, Houston.

Figure 164. Rocbinda, 2 Years, 2005, Houston.

Figure 165. Rocbinda Transverse, 1 Year, 2004.

Figure 166. Rocbinda, 1 Year, 2004, Houston.

Figure 167. Rocbinda Transverse, 2 Years, 2005, Houston.

APPENDIX E:
RETROREFLECTIVITY DATA BY PRODUCT AND LOCATION

Tables 18 through 25 document retroreflectivity results. A dash (-) denotes that no sample was provided of that type. An X denotes missing data. An O denotes that the sample had failed and was missing from the test deck.

Table 18. Retroreflectivity Data for Avery (125 mil).

Vendor Name:	**Avery (125 mil)**								
Test:	Retroreflectivity (R_L in units of mcd / m^2 /lx)								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Arrow	116	125	71	310	70	54	161	123	80
Letter S	111	X	53	346	74	50	137	107	81
Transverse Line	113	171	95	346	118	62	272	115	105
Yellow Green	-	-	-	80	66	23	25	X	50
Red	-	-	-	-	-	-	5	X	11
Blue	-	-	-	1	9	6	2	X	11
Green	-	-	-	-	-	-	-	-	-
Purple	-	-	-	-	-	-	-	-	-
Comments:	Some samples were inadvertently overlooked in Year 2 data measurements in the field								

Table 19. Retroreflectivity Data for Avery (90 mil).

Vendor Name:	**Avery (90 mil)**								
Test:	Retroreflectivity (R_L in units of mcd / m^2 /lx)								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Arrow	283	139	91	450	69	38	175	171	107
Letter S	366	129	56	363	72	40	126	151	125
Transverse Line	241	145	91	434	149	52	217	0	168
Yellow Green	33	79	36	86	71	22	-	-	-
Red	2	9	12	-	-	-	-	-	-
Blue	2	11	8	2	8	5	-	-	-
Green	-	-	-	-	-	-	-	-	-
Purple	-	-	-	-	-	-	-	-	-
Comments:									

Table 20. Retroreflectivity Data for Ennis.

Vendor Name:	**Ennis**								
Test:	Retroreflectivity (R_L in units of mcd / m^2 /lx)								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Arrow	284	140	73	223	124	61	285	155	97
Letter S	323	142	68	271	99	54	133	471	O
Transverse Line (90 mil)	256	203	89	170	250	99	263	157	O
Transverse Line (125 mil)	381	171	97	202	186	92	390	141	147
Yellow Green	-	-	-	68	53	O	45	O	O
Red	-	-	-	9	46	O	71	O	O
Blue	-	-	-	10	34	O	37	O	O
Green	-	-	-	56	49	O	150	O	O
Purple	-	-	-	-	-	-	-	-	-
Comments:									

Table 21. Retroreflectivity Data for Flint 1st Set.

Vendor Name:	**Flint 1st Set**								
Test:	Retroreflectivity (R_L in units of mcd / m^2 /lx)								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Arrow	372	297	134	724	126	126	560	161	245
Letter S	430	333	159	760	127	X	539	197	443
Transverse Line	622	305	231	628	271	X	561	158	229
Yellow Green	48	115	98	272	88	73	94	51	68
Red	8	40	29	-	-	-	9	27	28
Blue	-	-	-	-	-	-	-	-	-
Green	-	-	-	-	-	-	-	-	-
Purple	-	-	-	-	-	-	-	-	-
Comments:									

Table 22. Retroreflectivity Data for Flint 2nd Set.

Vendor Name:	**Flint 2nd Set**								
Test:	Retroreflectivity (R_L in units of mcd / m^2 /lx)								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Arrow	328	318	196	636	157	108	549	182	238
Letter S	557	276	133	605	126	75	367	192	478
Transverse Line	336	328	214	520	312	185	254	214	291
Yellow Green	75	118	86	124	124	41	37	61	111
Red	9	37	27	-	-	-	4	28	27
Blue	-	-	-	-	-	-	-	-	-
Green	-	-	-	-	-	-	-	-	-
Purple	-	-	-	-	-	-	-	-	-
Comments:									

Table 23. Retroreflectivity Data for LaFarge 90 mil.

Vendor Name:	**LaFarge 90 mil**								
Test:	Retroreflectivity (R_L in units of mcd / m^2 /lx)								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Arrow	104	180	68	89	136	124	552	132	136
Letter S	93	209	62	113	89	138	261	192	193
Transverse Line	77	184	79	91	128	124	-	-	-
Yellow Green	17	101	85	21	40	62	-	-	-
Red	10	43	34	16	40	17	-	-	-
Blue	10	33	24	11	33	13	-	-	-
Green	-	-	-	-	-	-	-	-	-
Purple	10	44	29	21	23	20	-	-	-
Comments:									

Table 24. Retroreflectivity Data for LaFarge 125 mil.

Vendor Name:	**LaFarge 125 mil**								
Test:	Retroreflectivity (R_L in units of mcd / m^2 /lx)								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Arrow	125	165	71	-	-	-	217	135	93
Letter S	165	179	68	201	152	147	105	129	147
Transverse Line	273	377	78	207	201	198	114	259	203
Yellow Green	-	-	-	-	-	-	116	82	104
Red	-	-	-	-	-	-	41	18	0
Blue	-	-	-	-	-	-	42	14	0
Green	-	-	-	-	-	-	-	-	-
Purple	-	-	-	-	-	-	25	0	16
Comments:									

Table 25. Retroreflectivity Data for Rocbinda.

Vendor Name:	**Rocbinda**								
Test:	Retroreflectivity (R_L in units of mcd / m^2 /lx)								
Location:	Abilene			Austin			Houston		
	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2	Initial	Yr 1	Yr 2
Arrow	78	39	21	83	32	30	90	46	51
Letter S	77	41	20	68	29	25	89	45	51
Transverse Line	78	32	27	85	33	28	83	38	45
Yellow Green	-	-	-	-	-	-	-	-	-
Red	21	13	12	0	11	9	0	0	12
Blue	-	-	-	-	-	-	-	-	-
Green	-	-	-	-	-	-	-	-	-
Purple	-	-	-	-	-	-	-	-	-
Comments:									

APPENDIX F:
COLOR DATA

Delta-E values (DE) were calculated compared to initial color values and are reported in Tables 26 through 33. Pass/Fail (P/F) grades were assigned based on whether the product stayed within the FHWA color box at the end of two years. A product received a failing grade for failing in terms of the chromaticity values or the cap-Y values. Grades could not be assigned for yellow-green and purple markings (N/A) because no FHWA specifications exist for these colors.

A dash (-) denotes that no sample was provided of that type. An X denotes missing data. A O denotes that the product had failed and the sample was missing.

Table 26. Color Data for Avery (125).

Vendor Name:	**Avery (125)**								
Test:	Color								
Location:	Abilene			Austin			Houston		
	Yr 1 DE	Yr 2 DE	P/F	Yr 1 DE	Yr 2 DE	P/F	Yr 1 DE	Yr 2 DE	P/F
Arrow	24.45	32.87	**F**	30.97	30.78	**F**	15.02	17.99	P
Letter S	X	32.65	**F**	30.02	31.07	**F**	19.54	19.68	P
Transverse Line	23.66	31.14	**F**	29.86	34.36	**F**	18.96	16.93	P
Yellow Green	-	-	-	43.94	54.76	**F**	-	-	-
Red	-	-	-	-	-	-	-	-	-
Blue	-	-	-	21.2	22.18	**F**	-	-	-
Green	-	-	-	-	-	-	-	-	-
Purple	-	-	-	-	-	-	-	-	-

Table 27. Color Data for Avery (90).

Vendor Name:	**Avery (90)**								
Test:	Color								
Location:	Abilene			Austin			Houston		
	Yr 1 DE	Yr 2 DE	P/F	Yr 1 DE	Yr 2 DE	P/F	Yr 1 DE	Yr 2 DE	P/F
Arrow	24.86	28.68	**F**	30.81	28.73	**F**	12.83	11.51	P
Letter S	X	32.51	**F**	34.17	32.61	**F**	22.00	22.41	**F**
Transverse Line	23.40	26.78	**F**	29.98	31.45	**F**	19.23	17.82	P
Yellow Green	29.06	30.85	N/A	44.33	46.75	N/A	5.85	8.24	N/A
Red	21.15	31.29	**F**	X	X		21.37	16.61	**F**
Blue	18.61	21.39	**F**	22.21	23.17	**F**	10.50	10.84	**F**
Green	-	-	-	-	-	-	-	-	-
Purple	-	-	-	-	-	-	-	-	-

Table 28. Color Data for Avery (90).

Vendor Name:	**Ennis**								
Test:	Color								
Location:	Abilene			Austin			Houston		
	Yr 1 DE	Yr 2 DE	P/F	Yr 1 DE	Yr 2 DE	P/F	Yr 1 DE	Yr 2 DE	P/F
Arrow	16.88	29.47	P	29.09	36.01	**F**	9.44	O	P
Letter S	X	27.73	P	33.42	36.03	**F**	12.66	12.24	P
Transverse Line (125)	19.54	27.60	P	29.71	36.45	**F**	14.83	20.18	P
Transverse Line (90)	25.42	30.88	**F**	30.16	36.93	**F**	19.26	O	
Yellow Green	-	-	-	28.01	27.51	N/A	56.75	O	**F**
Red	-	-	-	31.25	31.98	**F**	-	-	-
Blue	-	-	-	21.05	19.62	**F**	-	-	-
Green	-	-	-	44.21	42.21		-	-	-
Purple	-	-	-	-	-	-	-	-	-

Table 29. Color Data for Flint 1st Set.

Vendor Name:	**Flint 1st Set**								
Test:	Color								
Location:	Abilene			Austin			Houston		
	Yr 1 DE	Yr 2 DE	P/F	Yr 1 DE	Yr 2 DE	P/F	Yr 1 DE	Yr 2 DE	P/F
Arrow	21.53	31.84	**F**	29.98	35.56	**F**	14.93	18.17	P
Letter S	X	28.67	**F**	30.74	35.69	**F**	17.91	21.73	**F**
Transverse Line	21.49	29.87	**F**	29.94	37.72	**F**	18.32	17.42	P
Yellow Green	28.56	33.42	N/A	48.58	49.79	N/A	17.34	18.73	N/A
Red	22.47	15.85	**F**	-	-	-	25.56	26.28	P
Blue	-	-	-	-	-	-	-	-	-
Green	-	-	-	-	-	-	-	-	-
Purple	-	-	-	-	-	-	-	-	-

Table 30. Color Data for Flint 2nd Set.

Vendor Name:	**Flint 2nd Set**								
Test:	Color								
Location:	Abilene			Austin			Houston		
	Yr 1 DE	Yr 2 DE	P/F	Yr 1 DE	Yr 2 DE	P/F	Yr 1 DE	Yr 2 DE	P/F
Arrow	23.06	32.85	**F**	29.05	33.41	**F**	14.21	16.83	P
Letter S	X	26.54	**F**	29.15	37.67	**F**	16.51	20.40	P
Transverse Line	24.52	29.72	**F**	30.58	37.16	**F**	15.31	16.62	P
Yellow Green	23.39	27.28	N/A	-	-	-	23.85	21.76	N/A
Red	24.03	23.86	**F**	-	-	-	21.74	22.56	P
Blue	-	-	-	-	-	-	-	-	-
Green	-	-	-	-	-	-	-	-	-
Purple	-	-	-	-	-	-	-	-	-

Table 31. Color Data for LaFarge (125).

Vendor Name:	**LaFarge (125)**								
Test:	Color								
Location:	Abilene			Austin			Houston		
	Yr 1 DE	Yr 2 DE	P/F	Yr 1 DE	Yr 2 DE	P/F	Yr 1 DE	Yr 2 DE	P/F
Arrow	17.93	33.99	**F**	-	-	-	13.95	O	**F**
Letter S	X	32.71	**F**	25.92	32.74	**F**	14.82	15.93	P
Transverse Line	16.83	33.00	**F**	26.48	34.48	**F**	14.64	14.43	P
Yellow Green	24.54	25.40	N/A	-	-	-	16.05	16.60	N/A
Red	19.02	22.67	**F**	-	-	-	17.86	O	**F**
Blue	15.65	13.89	**F**	-	-	-	12.55	O	**F**
Green	-	-	-	-	-	-	-	-	-
Purple	7.34	8.41	N/A	-	-	-	6.29	7.93	N/A

Table 32. Color Data for LaFarge (90).

Vendor Name:	**LaFarge (90)**								
Test:	Color								
Location:	Abilene			Austin			Houston		
	Yr 1 DE	Yr 2 DE	P/F	Yr 1 DE	Yr 2 DE	P/F	Yr 1 DE	Yr 2 DE	P/F
Arrow	23.82	37.37	**F**	31.28	36.69	**F**	18.93	16.19	P
Letter S	X	36.78	**F**	33.08	42.62	**F**	12.80	19.09	P
Transverse Line	23.48	35.69	**F**	30.20	40.86	**F**	-	-	-
Yellow Green	-	-	-	44.08	46.14	N/A	-	-	-
Red	-	-	-	29.60	29.97	**F**	-	-	-
Blue	-	-	-	19.12	18.60	**F**	-	-	-
Green	-	-	-	-	-	-	-	-	-
Purple	-	-	-	9.40	17.77	N/A	-	-	-

Table 33. Color Data for Rocbinda.

Vendor Name:	**Rocbinda**								
Test:	Color								
Location:	Abilene			Austin			Houston		
	Yr 1 DE	Yr 2 DE	P/F	Yr 1 DE	Yr 2 DE	P/F	Yr 1 DE	Yr 2 DE	P/F
Arrow	30.00	34.52	**F**	31.26	28.02	**F**	29.63	28.70	**F**
Letter S	X	32.97	**F**	28.92	28.99	**F**	25.37	24.29	**F**
Transverse Line	24.12	31.16	**F**	49.25	29.51	**F**	31.05	31.55	**F**
Yellow Green	-	-	-	-	-	-	-	-	-
Red	5.28	5.68	**F**	-	-	-	X	11.79	**F**
Blue	-	-	-	-	-	-	-	-	-
Green	-	-	-	-	-	-	-	-	-
Purple	-	-	-	-	-	-	-	-	-

APPENDIX G: RECOMMENDATIONS FOR ADDITIONS OR REVISIONS TO TXDOT'S TRAFFIC CONTROL STANDARDS SHEETS

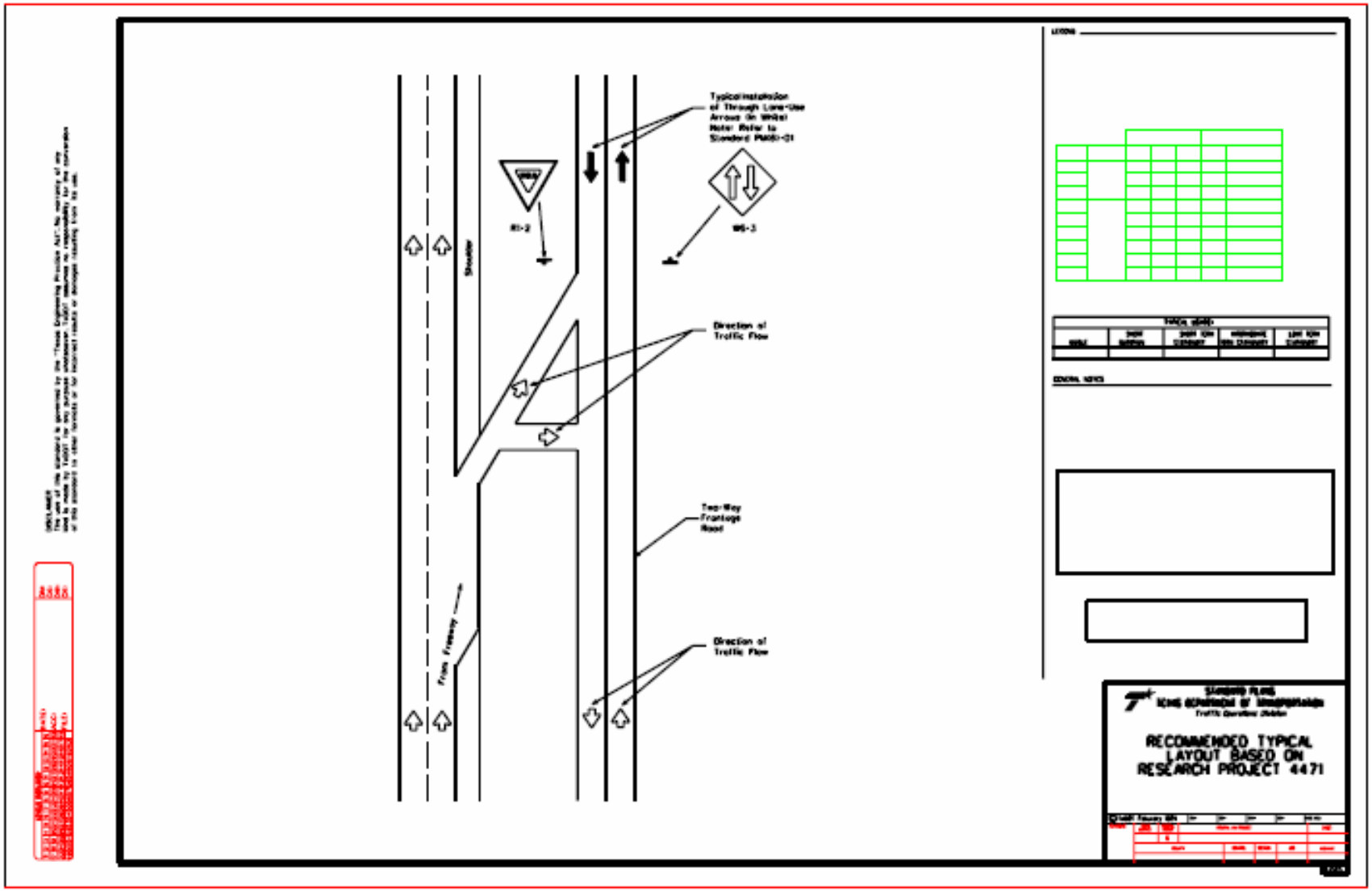

Figure 168. Proposed Plan for Typical Installation of Through Lane-Use Arrows at Two-Way Frontage Road Locations.

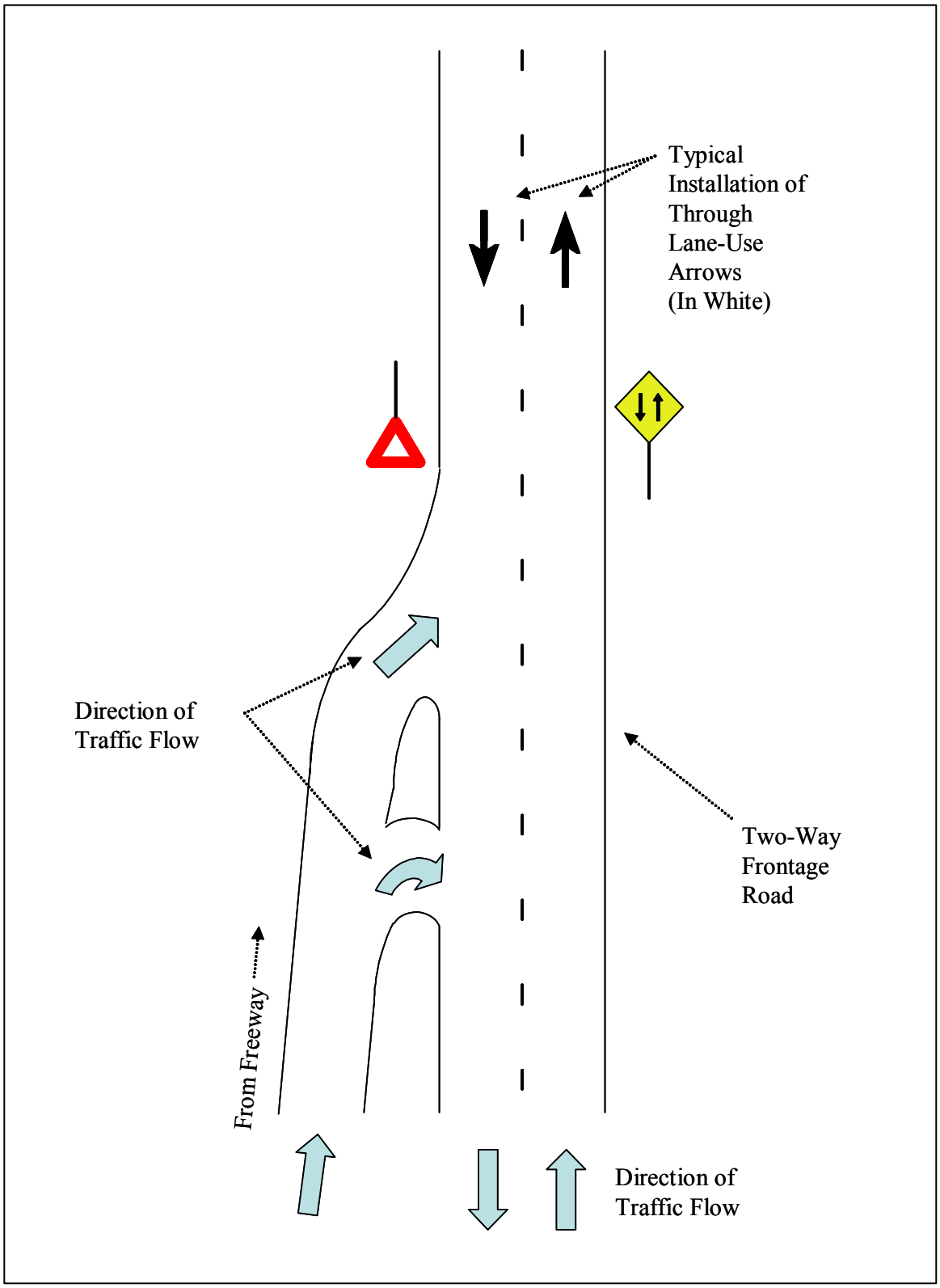

Figure 169. Detailed View of Typical Installation of Through Lane-Use Arrows at Two-Way Frontage Road Locations.