Evaluation of Durable Lane Delineation Materials (Interim Report)

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**Abstract**

The objective of the study is to evaluate the cost-effectiveness of available marking materials by means of field tests and to develop a policy for material selection of lane delineation based on these tests. Materials tested included: 100 percent solid epoxy paint, polyester paint, extruded thermoplastic, 3M Stamark tape, 3M Bisymmetric tape, EPOFLEX, solvent epoxy paint, and chlorinated rubber paint. Most test installations have been in place for over two years, and this interim report summarizes findings for that period. The evaluation will continue for another 18 months with recommendations presented in a final report.

Based on current data, expanded use is warranted for: 1) polyester paint on lower volume asphalt roadways and 2) extruded thermoplastic on higher volume asphalt highways with lighting.
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EVALUATION OF DURABLE LANE
DELINEATION MATERIALS
(INTERIM REPORT)

by

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in cooperation with
Transportation Cabinet
Commonwealth of Kentucky

and

Federal Highway Administration
US Department of Transportation

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ACKNOWLEDGEMENTS

This report was prepared with the guidance of the following members of the Study Advisory Committee:

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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Installations</td>
<td>1</td>
</tr>
<tr>
<td>Data Collection</td>
<td>3</td>
</tr>
<tr>
<td>Results</td>
<td>3</td>
</tr>
<tr>
<td>100 Percent Solid Epoxy Paint</td>
<td>3</td>
</tr>
<tr>
<td>Polyester Paint</td>
<td>5</td>
</tr>
<tr>
<td>Extruded Thermoplastic</td>
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</tr>
<tr>
<td>3M Stamark Tape</td>
<td>6</td>
</tr>
<tr>
<td>3M Bisymmetric Tape</td>
<td>7</td>
</tr>
<tr>
<td>EPOFLEX</td>
<td>7</td>
</tr>
<tr>
<td>Solvent Epoxy Paint</td>
<td>8</td>
</tr>
<tr>
<td>Chlorinated Rubber Paint</td>
<td>8</td>
</tr>
<tr>
<td>Summary and Conclusions</td>
<td>9</td>
</tr>
<tr>
<td>100 Percent Solid Epoxy Paint</td>
<td>9</td>
</tr>
<tr>
<td>Polyester Paint</td>
<td>9</td>
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<td>Extruded Thermoplastic</td>
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<td>10</td>
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<td>Solvent Epoxy Paint</td>
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<td>Chlorinated Rubber Paint</td>
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INTRODUCTION

Traffic paints, typically an alkyd formulation, have been used as lane delineation on Kentucky highways for decades. In the past few years, more durable marking materials have been developed. These include epoxy and polyester paints, preformed tapes, and thermoplastics. These materials could prove to be more cost-effective than typical traffic paint on certain types of highways. There is a need to field test the various materials and evaluate their performances. Based on field performances and the costs of the materials, a plan detailing where certain materials should be used could be developed.

The objective of this study is to evaluate the cost-effectiveness of available durable marking materials by means of field tests and to develop a policy for material selection of lane delineation based on these tests. Most test installations have been in place for over two years, and this interim report summarizes the findings for that period. The evaluation will continue for another 18 months with recommendations presented in a final report.

INSTALLATIONS

Various types of materials to be evaluated were placed under several contracts. All but two of the materials were placed in Kentucky and the other two in Indiana. Following is a list and brief description of the eight materials included in the analysis:

1. 100 percent solid epoxy paint
   This material is a two-component, chemically-reacted system that is 100 percent solids. The two parts are mixed by pumps on the striping equipment. The old paint stripe was removed prior to placing the epoxy. Line thickness was 15 mils wet and dry. A no-track time of 10 minutes was specified and cones were used for protection. Beads were applied at about 23 pounds per gallon for reflectivity as a means to prevent tracking. Two types of epoxy paints were used. They were manufactured by Polycarb and Prismo.

2. Polyester paint
   This material is a two-component, thermosetting material consisting of a resin and a catalyst. Two separate systems and guns are required on the striping equipment. A minimum thickness of 16 mils was specified. The wet and dry thicknesses would be approximately the same. A pressure-regulated air jet was used to remove all debris from the pavement in advance of the spray guns. Glass beads were applied by pressure at a rate of 15 pounds per gallon. Air temperature had to be above 40 degrees Fahrenheit. No-track time is 8 to 12 minutes on a normal sunny day; therefore, line protection is required. Two types of polyester paints were used. They were manufactured by Glidden-Durkee and Baltimore Paint.
3. Extruded thermoplastic

Hot-applied thermoplastics are thick pavement marking materials consisting of resin binder, reflective glass beads, coloring agents, and inorganic filler. The extruded thermoplastic was placed at a thickness of 90 mils using a die. A maximum drying time of 15 minutes was specified. The thermoplastic material was manufactured by Pave-Mark.

4. 3M Stamark tape

This is a preformed tape or a retroreflective film consisting of plastic material, pigments, and glass beads. It is manufactured by 3M. Beads are distributed throughout the film and form a layer bonded on the surface. The thickness was 60 mils. Tape was overlayed on existing pavements. According to the manufacturer, this tape is a highly durable, conformable, and a moderately reflective marking designed for use as words and symbols, lane lines, edge lines, and channelizing lines on newly resurfaced roads.

5. 3M bisymmetric tape

This is a preformed tape having a metal-foil backing, a pigmented surface layer, and 1.75 refractive index glass beads. It is manufactured by 3M. Thickness was about 25 mils. Tape was overlayed on existing pavements. According to the manufacturer, this tape is a highly reflective and moderately durable marking material designed primarily for use on streets having lower traffic volumes and free rolling traffic.

6. EPOFLEX

This is an epoxy thermoplastic material consisting of a binder, pigment, a calcium carbonate filler, and premixed glass beads. The material is sprayed at a temperature not to exceed 460 degrees Fahrenheit and at a thickness of 20 mils, which is also the dry-film thickness. Beads are applied at a rate of about 6 pounds per gallon. No coning is necessary since no-track time is less than five seconds. The EPOFLEX was manufactured by Pave-Mark.

7. Solvent epoxy paint

Epoxy paints use two-component epoxy mixed with a reaction-blocking solvent. In the presence of solvent, the mixture remains liquid up to 10 days. When sprayed at 15 mils wet, it dries to about 10 mils. About 6 pounds of pressure-applied beads per gallon of paint are typically used. At a temperature of 75 degrees Fahrenheit, it has a no-track time of 3 to 5 minutes. Solvent epoxy paint manufactured by Saf-T-Mark, Prismo, and Polycarb was used.

8. Chlorinated rubber traffic paint

This typical traffic paint includes the paint binder and solvent as well as pigment and glass beads. The paint is applied at 15 mils wet, which dries to about 8 mils. Pressure-applied beads are applied at a rate of 4 pounds per gallon of paint. Chlorinated-rubber resins were used. The paint was manufactured by Ennis Paint Company.
DATA COLLECTION

Data collection included three areas: 1) durability, 2) reflectivity, and 3) appearance. The method of conducting road service tests as described in ANSI/ASTM D 713-69 was used as a guide. It describes the rating of traffic paint in terms of appearance, durability, and nighttime visibility. Both daytime and nighttime photographs were taken to document the durability, reflectivity, and appearance evaluations.

Durability and appearance of the various materials were evaluated visually. The durability evaluation related to the ability of the material to remain on the surface. The appearance evaluation dealt with color of the white or yellow lines as compared to their original color and as compared to a desirable color. Reflectivity readings were measured using a portable retroreflectometer (PRR). Nighttime observations were also conducted.

RESULTS

Following is a discussion of the results of the evaluations, individually, for the various marking materials. Typical prices, in terms of installed cost per linear foot of a 4-inch line, for the various materials are given in Table 1. These prices were based upon discussions with various highway agency officials and company representatives as well as data contained in the literature. A summary of the portable retroreflectometer (PRR) data is given in Table 2. Measurements are presented by year. The measurements were taken several times during the year and averaged. It has been estimated that a PRR reading of less than 80 for white and less than 60 for yellow would be considered unacceptable.

100 PERCENT SOLID EPOXY PAINT

Four separate installations involving solid epoxy paint were placed in the summer of 1982 by three separate contractors. Three of the contracts involved lane marking on state-maintained streets in three major metropolitan areas in the state: Fayette County, Jefferson County, and the northern Kentucky counties of Boone, Kenton, and Campbell. The other contract involved pavement markings at various narrow bridge locations throughout the eastern half of Kentucky.

Over seven million linear feet of solid epoxy paint were applied under the four contracts. The contract cost varied from 24.3 to 25.6 cents per foot. These prices were midway of the typical price range of 20 to 30 cents per linear foot. The contract specified that at least 65 percent of the pavement be exposed prior to application, which required removing the old painted line. The old line was typically ground off as shown in Figure 1. The pavement condition before paint application is shown in Figure 2. On the Lexington project, an effort was made to remove all existing paint, resulting in the removal of some pavement. The epoxy line was therefore placed slightly below the top of the pavement (Figure 3), which had an adverse effect when moisture was present.
As previously noted, a large quantity of beads were placed on the stripe. That reduced the no-track time and also increased reflectivity. Beads were applied using either a free-fall dispenser (Figure 4) or by pressure through bead guns (Figure 5).

As shown by PRR measurements in Table 2, the initial reflectivity was good compared to the other materials and has been maintained as well as any other material in areas where durability has not been a problem. Shown in Figures 6 and 7 are nighttime photographs of the same section of roadway in 1982 and 1984, respectively. After approximately two years in service, the reflectivity remained adequate. This was revealed through nighttime observation and PRR measurements. Other nighttime photographs showing good reflectivity exhibited by the solid epoxy paint are shown in Figures 8 and 9.

The previous nighttime photographs show areas in which durability problems did not exist. However, varying levels of durability problems were experienced on each of the four solid epoxy contracts. All problems were attributed to improper mixing of the two epoxy components. The problem was related to not controlling pressure on the pumps on the striping equipment. The problem was first noticed and was more severe in the northern Kentucky area. As shown in Figure 10, the first evidence of a problem is a brown discoloration of the stripe. This discoloration appears at a regular interval along the stripe, which corresponds to the cycle of the pump that is not properly proportioning the two components. Spots become darker, as shown in Figure 11, as the material softens. Eventually, the dark (soft) portion of the line will wear off (Figure 12). Daytime and nighttime photographs of one roadway section that experienced this problem are shown in Figures 13 and 14. The sensitive nature of this problem may be seen in that two solid yellow lines were placed side by side, and one line experienced the durability problem while the other did not. An extreme example of the problem is shown in Figures 15 and 16, which shows striping a few weeks and about two years after placement, respectively.

A 90-day proving period was specified in the contracts. Any 2,000-foot section that experienced more than 10 percent failure was to be replaced. The only replacement required was part of the northern Kentucky installation, although durability problems were observed in the Jefferson County project during the 90-day proving period. Several miles of epoxy lines were replaced in northern Kentucky in 1983. The PRR measurements for the replaced lines were very similar to that for the original stripes when they were new and after one year in service. One problem in some instances was a lack of bond between the new and old stripe (Figure 17). This was probably related to poor adhesion of the remaining old stripe to the pavement. While major durability problems have not been detected in the replaced lines after one year in service, evidence of the same problem observed on the original lines may be seen in Figures 18 and 19. The left-hand yellow line is showing signs of discoloration at regular intervals; this will likely worsen over time.

Stripes placed as part of the Fayette County project presented less severe problems. No problems were detected during the 90-day proving
period and no significant problem was noted during the first year. Inspections after two years of service indicated more sections were developing discoloration, which was evident much earlier in the other projects.

Problems were also observed in the appearance of the solid epoxy lines, specifically the white lines. The appearance of the markings was good immediately after placement, as shown in Figure 20. The yellow line has generally retained a good appearance after two years in service (Figure 21). However, the yellow is not as bright as that provided by typical traffic paint (Figure 22). The dull appearance of the white stripe in daytime is shown in Figure 23. The grayish color of the white line is more of a problem on concrete (as shown in Figure 24) where the color of the line blends in with the pavement surface.

POLYESTER PAINT

Polyester paint was first used in Jefferson County in the summer of 1982 with a project completed at a contract price of 7.4 cents per linear foot. This price is the lowest of any of the durable materials. Some sections had been restriped in 1983 and 1984 under the same contract. The striping equipment is shown in Figure 25.

PRR measurements and nighttime observations showed the white material maintained its reflectivity better than the yellow. The yellow stripes were subject to more wear since they were used as centerline while the white material was used as edgeline. Nighttime photographs taken in 1982, 1983, and 1984 of one section of roadway striped with polyester paint are shown in Figures 26, 27, and 28, respectively. The edgeline had not been restriped since 1982 while the yellow was restriped in 1983 and 1984. The 1984 PRR measurements showed a slight increase over that recorded in 1983, the result of additional paint applications.

No significant durability problems were experienced when the polyester paint was placed over pavement or old paint. Shown in Figure 29 is a new installation. The same location two years later is shown in Figure 30 (it had been restriped in 1983). The only durability problem was when new polyester was placed over old polyester paint as shown in Figure 31. The new paint did not adhere well at first to the old paint. This was related to a formulation problem, which was resolved in later restriping installations.

While the polyester paints generally did not appear as bright as typical white or yellow traffic paints, their appearances were adequate. Again, the only appearance problem encountered was related to the formulation used when restriping over old polyester. When the formulation was originally changed, solvent was added so it would dry quicker and would not chip as previously shown in Figure 31. This problem was solved but the paint remained tacky, allowing it to become contaminated with dirt, resulting in off-color lines as shown in Figure 32. This problem was solved by using another formulation from a different paint manufacturer.
Most markings were placed on low-volume streets; therefore, performance on high-volume streets is unknown. Also, all material was placed on asphalt since work conducted in other states reported durability problems when polyester paint was placed on concrete.

EXTRUDED THERMOPLASTIC

One project involving extruded thermoplastic was completed in the summer of 1982. The project involved pavement markings at narrow bridge locations throughout the western portion of the state. Slightly over one million linear feet of centerline and edgeline were placed at a cost of 47 cents per linear foot. The unit price was high due to excessive travel necessary between various bridge locations. A more typical price would be 25 to 35 cents per linear foot, as noted in Table 1. As shown in Figure 33, the material was extruded through a die and then beads were sprayed onto the material.

As shown in Table 2, white lines have maintained reflectivity well while yellow lines have suffered a significant loss in reflectivity. This is seen in Figures 34 and 35, which show the same bridge location a few months and about two years after placement of the markings. The white edgeline on the right in Figure 35 has been covered with patching material. Loss of reflectivity of the yellow line may be explained by Figure 36. As shown in that figure, the surface of the line contains numerous small holes. The holes may have resulted from placing the material at an excessive temperature, which allowed surface beads to sink into the material.

No significant durability problems have been experienced. All material was placed on bituminous pavements. None was placed on portland cement concrete because of previously reported durability problems. A photograph of a typical installation approximately two years after placement is shown in Figure 37.

The lines have maintained their original color and appearance quite well. This is shown in Figures 38 and 39. The small holes in the surface of the yellow line do not adversely affect appearance when viewed from a distance of over a few feet.

3M STAMARK TAPE

A project involving the use of 3M Stamark tape as lane delineation was completed in Jefferson County in the summer of 1982. The contract unit price per linear foot was $0.98 for yellow and $1.10 for white 4-inch lines. That was the most expensive of all materials evaluated. The tape was placed using equipment shown in Figure 40.

PRR measurements presented in Table 2 show that the Stamark tape had a very high initial reflectivity, but that level of reflectivity was not maintained. Nighttime photographs, Figures 41 and 42, show the tape a few weeks and approximately two years after placement, respectively. The photographs were taken at the same location. Shown in Figures 43 and 44 are roadways on which both Stamark tape and polyester paint were
used. The superior reflectivity of the white polyester paint is evident.

There were no problems with durability or appearance of the Stamark tape. As may be seen in Figures 45 and 46, after two years in service, the lines have remained intact and maintained their color. While the stripe shown in Figure 46 provides a good daytime line, it does not provide nighttime delineation, as shown in Figure 44.

3M BISYMMETRIC TAPE

This tape was placed as a lane line along a few blocks of one street in Lexington in September 1982. The street has an ADT of slightly over 20,000. A typical price per linear foot of 4-inch stripe would be in the range of 50 to 60 cents.

PRR measurements indicated this tape had the highest initial reflectivity of any material, as shown by Figure 47. After one year, its reflectivity was still high (Figure 48), but it dropped dramatically after the second year (Figure 49) to approximately the level of the Stamark tape.

The durability and appearance of this tape was satisfactory. Photographs of the tape a few months and approximately two years after placement are shown in Figures 50 and 51, respectively. The tape was placed on both concrete and asphalt and exhibited good durability on both.

EPOFLEX

Even though no epoxy thermoplastic (EPOFLEX) was placed in Kentucky, the material has been used in several states in the past few years, and it is included herein for information. To evaluate this material, inspections were made of installations in Indiana. In the summer of 1983, Indiana awarded contracts in three highway districts totalling over one million linear feet at costs ranging from 14 to 17 cents per linear foot. A photograph of the equipment used to apply the material is shown in Figure 52 and a close-up photograph of a new line is shown in Figure 53.

PRR measurements were obtained in 1983 and then one year later. Reflectivity of this material, especially the yellow, was not as high initially as other materials. Beads were applied at a rate of 7 pounds per gallon, which is lower than that for the solid epoxy and polyester paint but slightly higher than that used in typical traffic paint (usually 4 to 6 pounds per gallon). A nighttime photograph after a few weeks in service is shown in Figure 54. Measurements after about one year in service showed that the reflectivity had been reduced to low levels.

Significant durability problems were experienced after less than one year in service. A photograph after a few weeks in service is shown in Figure 55. Photographs taken after about one year in service (Figure
SOLVENT EPOXY

This is another type of marking material that has been used in several states, but not in Kentucky. As with EPOFLEX, an inspection was made of an installation in Indiana. In the summer of 1983, three projects involving about 1.7 million linear feet of this material, were completed at a cost ranging from about 9 to 13 cents per linear foot.

PRR measurements taken a few weeks after placement indicated very low reflectivity. A close visual inspection revealed the beads were originally embedded properly but had been lost. The bead pockets were clearly visible. A daytime photograph of the appearance of a yellow epoxy centerline is shown in Figure 57. No additional inspections were conducted because of bead retention failure.

CHLORINATED RUBBER PAINT

The Kentucky Department of Highways used a chlorinated rubber based traffic paint for the 1982 striping season and that was included in the evaluation. Placement of this stripe is shown in Figure 58. Beads were applied under pressure at a rate of about 4 pounds per gallon. The bead gun was aimed so that paint and beads hit the pavement surface at about the same time. That procedure was used to obtain proper bead embedment.

PRR measurements indicated the initial reflectivity was relatively high but had decreased dramatically after about one year in service. Nighttime photographs in Figures 59 and 60 show lines a few months and about one year after placement, respectively. Test sections were restriped after one year in service, so no additional data were available. No durability or appearance problems were experienced during the one-year period.
SUMMARY AND CONCLUSIONS

100 PERCENT SOLID EPOXY PAINT

This material had the highest reflectivity of any of the paints. However, durability and appearance problems preclude widespread future use until it is demonstrated that those problems have been solved. The durability problem was related to equipment problems, specifically improper mixing of the two epoxy components. The major appearance problem was the dull daytime appearance of the lines. This material has been used extensively in other states and the manufacturer of the paint indicated that the two problems have been remedied. Another test installation is warranted to determine whether future use of the material is justified.

POLYESTER PAINT

Polyester paint had the lowest price of any of the durable materials. Reflectivity was adequate, although not as good as solid epoxy. Some durability and appearance problems were detected but were solved by changing the paint formulation. Future use of this material is warranted on low-volume asphalt streets and highways. Additional testing is needed to determine whether this material may be used on high-volume roadways. Also, since there has been restriping in 1983 and 1984, there is a need for continued monitoring.

EXTRUDED THERMOPLASTIC

Initial reflectivity was high, but considerable loss in reflectivity was experienced later. No durability or appearance problems were noted. The locations included in the evaluation were low-volume roadways. An upcoming project will involve an alkyd extruded thermoplastic on a high-volume interstate. This material has the potential for use on higher-volume asphalt streets and highways. Unless reflectivity characteristics are improved, its use would be limited to lighted roadways. Price per linear foot for large installations would enhance its use on high-volume roadways.

3M STAMARK TAPE

This was the most expensive of all materials evaluated. While there were no durability and appearance problems, reflectivity decreased dramatically. Its cost and poor reflectivity would limit its use to high-volume lighted roadways. The lower price of extruded thermoplastics would probably render use of expensive preformed tapes as lane delineation not cost-effective.

3M BISYMMETRIC TAPE

This tape had the highest initial reflectivity of all materials tested. The reflectivity decreased dramatically after two years on a relatively high-volume street. The durability and appearance of this tape was satisfactory. The cost of this tape is substantially less than
the Stamark type of tapes and use may be warranted on low-to moderate-volume streets having no lighting.

**EPOFLEX**

The EPOFLEX installation suffered significant durability problems after less than one year in service. Problems have been experienced in several states and further placement has been delayed until the problems, which appear to be related to the application equipment and material formulation, have been resolved. Further testing may be warranted later.

**Solvent Epoxy**

The inspection inspected had a complete loss of beads within a few weeks after placement. This would probably be related to either a problem with application or formulation. This material has been used successfully in other states, but additional testing would be necessary before it could be used in Kentucky.

**Chlorinated Rubber Traffic Paint**

This paint is substantially less expensive than the more durable markings. It will provide adequate reflectivity and durability for varying time periods based on traffic volumes. In most rural areas, it will provide a service life of one year. At high-volume locations, it must be restriped at least once per year. Its appearance is very good, having bright white and yellow colors.

**RECOMMENDATIONS**

Based on current data, expanded use is warranted for: 1) polyester paint on lower-volume asphalt roadways and 2) extruded thermoplastic on higher-volume asphalt roadways with lighting. A very high percentage of state-maintained highways are low volume; therefore, polyester paint could be used. About 80 percent of the total mileage included on the statewide roadway volume file has an ADT under 2,500.

The high cost of tapes, especially Stamark-type tapes, precludes widespread use. Furthermore, the Stamark tape could be used only where the roadway was lighted. No further use of the 100 percent solid epoxy, EPOFLEX, or solvent epoxy paint is recommended until such time that additional testing proves problems have been resolved.
## TABLE 1. TYPICAL PRICES OF MARKING MATERIALS (MATERIALS AND INSTALLATION)

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TABLE 2. SUMMARY OF PORTABLE RETROREFLECTOMETER (PRR) DATA

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* Measurements increased as a result of additional paint applications.
** No data for this time period.
Figure 1. Removing Old Paint Stripe.

Figure 2. Pavement Condition after Grinding.
Figure 3. Groove Due to Excessive Grinding.

Figure 4. Application of Solid Epoxy Using Free-Fall Bead Dispenser.
Figure 5. Application of Solid Epoxy with Beads Applied by Pressure through Several Bead Guns.

Figure 6. Reflectivity of Solid Epoxy after a Few Months in Service (KY 17 in Kenton County).
Figure 7. Reflectivity of Solid Epoxy after About Two Years in Service (KY 17 in Kenton County).

Figure 8. Reflectivity of Solid Epoxy after About One Year in Service (US 60 in Fayette County).
Figure 9. Reflectivity of Solid Epoxy after About Two Years in Service (KY 1974 in Fayette County).

Figure 10. Beginning of Brown Discoloration of Solid Epoxy Stripe.
Figure 11. Very Dark Discoloration of Solid Epoxy Stripe.

Figure 12. Wear on Solid Epoxy Edgeline after About 18 Months in Service (KY 18 in Boone County).
Figure 13. Wear on Solid Epoxy Centerline after About One Year in Service (KY 1998 in Campbell County).

Figure 14. Loss of Reflectivity Resulting from Wear of Solid Epoxy Centerline (KY 1998 in Campbell County).
Figure 15. Reflectivity of Solid Epoxy Line Immediately after Installation (KY 1968 in Fayette County).

Figure 16. Loss of Reflectivity after About Two Years in Service Resulting from Wear to Solid Epoxy Line (KY 1968 in Fayette County).
Figure 17. Lack of Bond between New and Old Epoxy Stripes.

Figure 18. Replaced Solid Epoxy Line after About One Year in Service Showing beginning of Brown Discoloration (KY 1632 in Campbell County).
Figure 19. Reflectivity of Replaced Solid Epoxy Line after About One Year in Service Showing beginning of Wear (KY 1632 in Campbell County).

Figure 20. Appearance of Solid Epoxy Line Immediately after Placement (KY 17 in Kenton County).
Figure 21. Appearance of Yellow Solid Epoxy Line after Two Years in Service (KY 1974 in Fayette County).

Figure 22. Comparison of Yellow Color of Solid Epoxy Line and Typical Traffic Paint (Foreground).
Figure 23. Dull Daytime Appearance of White Solid Epoxy Line (Foreground) Compared to Typical Traffic Paint.

Figure 24. Appearance of White Solid Epoxy Line on Concrete Pavement after Two Years in Service (KY 1934 in Jefferson County).
Figure 25. Placement of Polyester Paint.

Figure 26. Reflectivity of Polyester Paint a Few Weeks after Placement (Bashford Manor Lane in Jefferson County).
Figure 27. Reflectivity of Polyester Paint About One Year after Placement of White Edgeline (Bashford Manor Lane in Jefferson County).

Figure 28. Reflectivity of Polyester Paint About Two Years after Placement of White Edgeline (Bashford Manor Lane in Jefferson County).
Figure 29. New Polyester Paint Installation (Deering Road in Jefferson County).

Figure 30. Polyester Paint after About Two Years in Service (Deering Road in Jefferson County).
Figure 31. Lack of Adhesion of Polyester Paint Placed on Old Polyester Paint Line.

Figure 32. Dark Color Resulting from Dirt Contamination of Polyester Line.
Figure 33. Placement of Extruded Thermoplastic Line.

Figure 34. Reflectivity of Extruded Thermoplastic Line a Few Months after Placement (US62 in Harrison County).
Figure 35. Reflectivity of Extruded Thermoplastic Line after About Two Years in Service (US62 in Harrison County).

Figure 36. Small Holes in Surface of Yellow Extruded Thermoplastic Line.
Figure 37. Extruded Thermoplastic Lines after Two Years in Service (KY 1032 in Harrison County).

Figure 38. Appearance of Yellow Extruded Thermoplastic Line after About Two Years in Service (KY 1032 in Harrison County).
Figure 39. Appearance of White Extruded Thermoplastic Line after About Two Years in Service (KY 1032 in Harrison County).

Figure 40. Placement of 3M Stamark Tape.
Figure 41. Reflectivity of Stamark Tape a Few Weeks after Placement (Hikes Lane in Jefferson County).

Figure 42. Reflectivity of Stamark Tape about Two Months after Placement (Hikes Lane in Jefferson County).
Figure 43. Comparison of Reflectivity of Stamark Tape (White Lane Line and Yellow Edgeline) with Polyester Paint (White Edgeline) after About Two Years in Service (Fegenbush Lane in Jefferson County).

Figure 44. Comparison of Reflectivity of Stamark Tape (Yellow Centerline) with Polyester Paint (White Edgeline) after About Two Years in Service (Watterson Trail in Jefferson County).
Figure 45. Appearance of White Stamark Tape Lane Line after About Two Years in Service (Fegenbush Lane in Jefferson County).

Figure 46. Appearance of Yellow Stamark Centerline after About Two Years in Service (Watterson Trail in Jefferson County).
Figure 47. Reflectivity of 3M Bisymmetric Tape (Lane Lines) a Few Months after Placement (US 27 in Fayette County).

Figure 48. Reflectivity of 3M Bisymmetric Tape (Lane Lines) after About One Year in Service (US 27 in Fayette County).
Figure 49. Reflectivity of 3M Bisymmetric Tape (Lane Lines) after About Two Years in Service (US 27 in Fayette County).

Figure 50. Appearance of 3M Bisymmetric Tape a Few Months after Placement (US 27 in Fayette County).
Figure 51. Appearance of 3M Bisymmetric Tape after About Two Years in Service (US 27 in Fayette County).

Figure 52. Equipment Used to Place EPOFLEX.
Figure 53. Appearance of New EPOFLEX line.

Figure 54. Reflectivity of EPOFLEX line a Few Weeks after Placement (State Route 135 in Harrison County, Indiana).
Figure 55. EPOFLEX Installation after a Few Weeks in Service (State Route 135 in Harrison County, Indiana).

Figure 56. Durability Problem with EPOFLEX after About One Year in Service (State Route 135 in Harrison County, Indiana).
Figure 57. Appearance of Solvent Epoxy Yellow Centerline after a Few Weeks in Service (US 150 in Harrison County, Indiana).

Figure 58. Placement of Chlorinated Rubber Paint.
Figure 59. Reflectivity of Chlorinated Rubber Paint a Few Months after Placement (US 127 in Mercer County).

Figure 60. Reflectivity of Chlorinated Rubber Paint after About One Year in Service (US 27 in Fayette County).