

Research Report
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Survey of Lane Delineation Methods

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16. Abstract The objective of this study was to summarize the nationwide experience pertaining to various lane delineation methods. The usage, cost, and problems associated with each alternative could then be analyzed for the purpose of determining an optimum marking program. A survey of the methods of lane delineation used across the United States was done by means of a questionnaire sent to each state. Responses were received from 46 states. Most of the information dealt with the following lane delineation methods: raised pavement markers, pavement tape, thermoplastic markings, and paint and beads.					
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Introduction

Past studies have involved an evaluation of alternate methods of lane delineation. These have included paint and beads (1, 2), raised pavement markers (3, 4, 5, 6), thermoplastic markings (7), and pavement tape (8). Lane delineation includes both centerline and edgeline

markings. The objective of this study was to summarize the nationwide experience pertaining to these various alternatives. The usage, cost, and problems associated with each alternative could then be analyzed for the purpose of determining an optimum marking program.

Survey Results

A questionnaire was sent to all 50 states (a copy of the questionnaire and cover letter is given in the APPENDIX). Responses were received from 46 states (92 percent). Following is a summary of responses in the five sections of the survey -- raised pavement markers, pavement tape, thermoplastic markings, paint and beads, and general. Information such as quantities installed represent data through the middle of 1980.

RAISED PAVEMENT MARKERS

The large majority of states have used raised pavement markers (raised markers) to some degree for lane delineation. Of 46 states, 38 (83 percent) indicated some experience with raised markers. Also, some experience with snowplowable markers was indicated in 32 states (70 percent). Almost all of the snowplowable markers were the Stimsonite marker -- either the Stimsonite 96 model or the older Stimsonite 99 model. Several states are also experimenting with a recessed marker. This involves placing a regular raised marker into a groove cut into the pavement so the top of the marker is flush with the pavement surface. Some states have placed the reflector used in the Stimsonite 96 marker in the groove. Use of this reflector reduces the depth of the groove. Use of the Konelite and catseye markers were each mentioned by one state.

Kentucky is conducting a research study involving an evaluation and comparison of five types of snowplowable markers -- Stimsonite 96, recessed, Kingray, Dura-Brite, and Prismo snowplowable markers. Several states have recently made test installations using the Dura-Brite marker. Modifications are currently being made to the Konelite marker, and this marker will be included later if it becomes available.

An estimate of the useful life of raised markers was also requested. Several northern states indicated the life was limited to the construction season or until the first snowplow operation. Excluding responses where use of snowplows was the limiting factor, an average useful life of 4 years was determined. Estimates of the useful life of snowplowable markers varied, and many respondents indicated they did not have sufficient data to make a response. The responses yielded an average useful life of 6 years for snowplowable markers. Several respondents indicated the life of the reflector would be less. In an economic comparison of regular versus snowplowable markers in heavily snowplowed areas, a more reasonable assumed life for regular markers would be 1 or 2 years.

There have been few studies to determine the effect raised markers may have had on accident reduction. Nine states indicated they had done such a study. The majority of these studies

found very little change in accident rates after installation of raised markers. An exception is a before-and-after accident study in Ohio at 184 high-hazard locations on rural roads (9). Accidents decreased in most categories and a favorable benefit-cost ratio resulted. It was concluded that raised markers are beneficial in reducing accidents at high-hazard locations. Also, a Kentucky study of raised markers installed on interstates indicated a reduction in accidents (6). Compared to a control section without markers, the section with markers showed a 20-percent reduction in wet-night accidents and a 10-percent reduction in dry-night accidents. These percentages were recommended for use in estimating the effectiveness of raised markers in systemwide installations. For the interstate system, this corresponded to a four-percent reduction in all accidents. This percentage would vary with the percentage of night accidents on a highway system. A benefit-cost ratio of 6.03 was found.

When asked about warrants for the use of raised markers, twelve respondents noted their state did use some type of warrant. Some warrants were specific; others were very general. Most of the warrants dealt with volumes or type of location or highway. Accident data were listed as a factor with priority given to sites with specific accident types such as nighttime or head-on accident problems. However, no specific accident rates or numbers were given. Following is a summary of warrants listed.

1. A minimum ADT (average daily traffic) of 750 is required.
2. Reflective markers are used on all state highways except in snow removal areas. Ceramic markers used on all freeways and paint and reflective markers on all other routes.
3. Follow FHPM 6-8-3-1 (10). This federal-aid highway program manual recommends use of raised markers on all new interstates, other freeways, and other high-speed highways with three or more through lanes in each direction. Also, use of raised reflective and nonreflective markers as a

supplement or in lieu of painted lines on previously constructed interstate highways was listed. Reflective markers may be used to supplement painted lines in rural areas where there is less than three through lanes in each direction.

4. Snowplowable markers are to be used as a supplemental method of delineation. They are used in areas of frequent inclement weather and in areas of low roadway illumination. They are not used at locations scheduled for resurfacing or reconstruction during the next four-year period or at locations that are illuminated. Normally, such roads should have an ADT of not less than 2,500 for two-lane roads and 6,000 for four-lane roads.
5. Use raised markers on four-lane highways, four-lane construction sections, and two-lane construction detours.
6. Use raised markers in conjunction with thermoplastic stripe, which is used on highways with an ADT of 1,500 or greater.
7. Use is based on ADT, type of location, and accident data.
8. Snowplowable markers are placed on multilane roads with 10,000 ADT or more and on selected hazardous curves.
9. Snowplowable markers should be used to supplement pavement markings at identified locations and sections having nighttime accidents, potential accident locations, and freeways and expressways. Potential accident locations include: horizontal curves with degree of curvature of five degrees or greater, narrow bridge with a clear roadway width greater than 18 feet but less than or equal to the approach pavement width plus 4 feet, one-lane bridge with a clear roadway width less than or equal to 18 feet, entrance and exit gores, intersection with left-turn lane on one or more approaches (signalized or stop control), multilane undivided highway, and pavement transitions

(two to four lane and four to two lane).

10. Use raised markers on roads with a minimum ADT of 10,000 on two-lane roads and 20,000 on four-lane roads, an elevation below 15,000 feet, and an experience of problems during fog or rain.
11. Use of raised markers requires a minimum ADT of 4,500, four or more lanes, four to five years remaining pavement life, roadway at least three months old, and inadequate street lighting.
12. Snowplowable markers are considered for lane lines on unlighted expressway sections having 10,000 or more ADT and either a concrete or new asphalt surface.

Respondents were asked to estimate the number and cost of reflective, nonreflective, and snowplowable markers placed in their state. Some respondents listed the number of markers installed in a one- or two-year period, others estimated the total number installed. Thus, it was not possible to obtain an estimate of the total number of markers that have been installed. However, it was obvious several million (over 10 million) reflective markers have been placed in the United States and a few million non-reflective markers have been placed. The largest number of reflective markers have been installed in California. Also, over one million snowplowable markers have been installed nationwide with the largest quantities installed in Ohio. Average cost per marker was calculated for each type: \$2.80 for reflective markers, \$1.85 for nonreflective markers, and \$15.60 for snowplowable markers. These costs include installations made for the past few years, so current costs would be higher. The cost for snowplowable markers was for the Stimsonite marker, primarily the Stimsonite 96 marker. A more accurate current cost for the Stimsonite 96 marker would be about \$20 per marker when installed in large quantities. The only other type of snowplowable marker that has been installed in quantities sufficiently large to estimate a cost is the recessed marker. Contract cost per marker for this type of marker has generally been in the

\$8 to \$9 range.

In recent years, raised markers with a pressure-sensitive adhesive backing have been marketed. Twenty-two respondents indicated they had used this type of marker. Favorable comments were generally noted when the marker was used as a temporary marker in construction zones. However, several problems were noted and should be considered before this type marker is used. Problems arise if the marker is not placed on a smooth surface since the pad would not be in contact with the pavement at some places. It was also noted this marker adhered better to asphalt than concrete, and difficulties with installations on concrete pavements were listed as a problem area. Durability problems also existed when installations were made at lower than recommended temperatures (under about 50 degrees F). Problems involving movement of the markers occurred when they were installed on curves or in areas with turning movements or weaves. One respondent indicated these markers were good in areas not exposed to traffic and another noted that vehicles striking the edge of the marker would loosen the marker and cause failure. These markers are reclaimed in one state by installing new adhesive pads.

A durability problem associated with the placement of raised markers on new asphalt was noted by two states. When raised markers were installed on new asphalt, markers were lost as a result of failure of the asphalt pavement. Therefore, it was recommended that raised markers should not be installed on new asphalt pavement for a specified period of time after paving. One state recommended waiting nine months to a year, while the other recommended a delay of at least 60 days. Another recommendation in this area was to allow one year for weathering before placing markers on asphalt pavement that had received an application of an asphalt rejuvenating agent.

PAVEMENT TAPE

The majority of states have used, to some degree, pavement tape (preformed pliant polymer) as a method of lane delineation. Of the 46 respondents, 27 (59 percent) indicated some experience

with pavement tape. The tapes used were made by two manufacturers. The most common tape used is Stamark, made by the 3M Corporation. The other tape commonly used is the Prismo Plastix. The Stamark tape has a thickness of 60 mils; the Prismo tapes are available in thicknesses of 60 or 90 mils. Use of pavement tape for lane delineation is relatively new with a few million feet installed nationwide at an average cost of about 90 cents per linear foot of 4-inch stripe. The largest reported installations were in Maryland. Latest cost figures for the 60-mil tape are in the 70-to-80 cents per linear foot range for a 4-inch stripe. The average useful life estimated by the respondents was four years. The useful life can be increased if the tape is inlaid rather than surface applied. The inlay method is used on new asphalt surfaces. This involves rolling the tape into the hot asphalt. Several states have used this procedure. The overlay method is used on existing asphalt and concrete surfaces. Of those responding to whether a binder (primer) was used, 25 percent indicated that one had been.

Ten respondents listed either specific or general warrants used by their state when considering the use of pavement tape. The warrants dealt mainly with traffic volumes and pavement type. Also, a requirement that the roadway be lighted was listed in two warrants. Following is a summary of warrants that were listed:

1. Tape is used in new urban construction projects having an ADT over 7,000.
2. Tape is used where it is not cost effective to send striping crews long distances for small installations.
3. Tape is used only on bituminous surfaces that will not be resurfaced within five years.
4. Tape is used at locations not scheduled for resurfacing within the next four years. On roads where traffic lanes are at least 12 feet wide, the ADT must be 5,000 vehicles or more per lane. On roads where traffic lanes are less than 12 feet wide, the ADT may be less than 5,000 per lane if there is past experience of

excessive line wear.

5. Tape is used on two-lane roads having volumes in excess of 5,000 vehicles per day and on urban freeways.
6. The minimum ADT should be 2,000. Tape is not permitted on edgelines.
7. Tape is used when the ADT is 1,500 or more and as an alternate to hot-sprayed thermoplastic.
8. Tape is used on new and existing portland cement concrete pavements in good condition. Tape may be used on projects on lighted highways where the retroreflectivity of the marking is not as important and small quantities are involved so its use is expected to result in a lower cost.
9. Tape is used at urban signalized intersections.
10. Tape may be used in urban areas on well-lighted roads with an ADT greater than 11,000 and a speed limit of 35 mph or less. For asphalt pavements, the tape should be inlaid.

Generally, the durability of pavement tapes was rated as good whether a binder was or was not used. However, two respondents noted unsatisfactory performance when a binder was not used. The major durability problem appears to be loss of reflectivity. Loss of reflectivity in less than one year was noted. Another problem involved damage caused by snowplowing and studded tires. One state limits installations to the 60-mil thickness using the inlaid process to minimize damage from plowing. The pavement surface may cause a problem; poor durability on old pavements and open-graded surfaces was reported. Adhesion failure was noted by one respondent at installations made during cool weather or at very heavy volume locations. Failure under shear and a problem with tape moving on the pavement were also listed. In one instance, a problem with removal of the tape by vandals was noted.

THERMOPLASTIC MARKINGS

The use of either hot-sprayed or extruded thermoplastics has been

widespread as a method of lane delineation. Thirty-three (72 percent) of the respondents indicated experience with thermoplastics. Use has been extensive with several thousand miles of thermoplastics installed in a few states. Hot-sprayed thermoplastic was used in most cases (about 90 percent of the installations that were reported by type). The average cost was about 20 cents per linear foot for hot-sprayed and about 45 cents per foot for extruded thermoplastics. The cost was fairly consistent, except for small projects where the cost was equal to or above the price of pavement tape. The estimated useful life of extruded thermoplastics was slightly higher (4 to 5 years) than for hot-sprayed thermoplastics (3 to 4 years). Most installations were on bituminous asphalt pavements rather than portland cement concrete pavements.

Warrants for installation of thermoplastic markings were listed by 16 respondents. They dealt primarily with volumes and pavement type. Following is a summary of these warrants:

1. Thermoplastics are used on two-lane roads with an ADT of at least 3,000 and any roadway with four or more lanes.
2. FHWA criteria given in "Traffic Control Devices Handbook -- An Operating Guide" (11) are used. This publication, which refers to research conducted by the Bureau of Public Roads in 1967, provides a guide for determining whether paint or thermoplastic is the most economical striping material. The ADT per lane, highway type, pavement type, and mean annual snowfall were used to determine whether thermoplastics or paint were more economical.
3. Follow FHPM 6-8-3-1 (10), which requires a justification for thermoplastics based either on cost-effectiveness or an inability to maintain conventional paint markings on a year-round basis in an area where there is a demand for improved traffic flow and safety under winter conditions.
4. Place thermoplastics on bituminous pavements where the ADT is 2,500

or greater. Portland cement concrete (PCC) pavements must be in place and cured one year before thermoplastic installations are permitted.

5. Locations must not be scheduled for resurfacing within the next four years. On roads where traffic lanes are at least 12 feet wide, the ADT must be 5,000 vehicles or more per lane. On roads where traffic lanes are less than 12 feet wide, the ADT may be less than 5,000 per lane if there is past experience of excessive line wear.
6. Thermoplastics are used on high volume, two-lane roads with a volume in excess of 5,000 ADT and on urban freeways.
7. Use is based on volume (ADT) required for thermoplastic striping to be more economical than conventional paint striping. For both white and yellow lines on bituminous pavements, an ADT of 15,000 for two-lane roads, 28,000 for four-lane roads, and 38,000 for six-lane roads is required. Higher volumes were necessary on portland cement concrete pavements. For white lines on such pavements, the required ADT increases to 26,000 for a two-lane highway, 46,000 for a four-lane highway, and 65,000 for a six-lane highway. For yellow lines on portland cement concrete pavements, the required ADT increases dramatically to 52,000 for a two-lane highway, 93,000 for a four-lane highway, and 120,000 for a six-lane highway.
8. Thermoplastics are used on all resurfacing and reconstruction of roadways with an ADT of 15,000 or greater.
9. A minimum of 2,000 ADT is required. Use is not permitted on edgelines. Thermoplastics are installed on bituminous surfaces only.
10. A minimum of 1,500 ADT is required, and thermoplastics are used as an alternate to cold thermoplastic.
11. Use thermoplastics at all high-

volume intersections and other areas where markings are important.

12. Use thermoplastics on newly placed bituminous top courses and existing bituminous top courses in good condition.
13. An ADT of 10,000 or above is required.
14. Use thermoplastics for lane lines when ADT is 6,000 or more per lane.
15. A minimum ADT of 4,500, four or more lanes, four to five years remaining pavement life, and a roadway surface at least three months old are required.
16. Use thermoplastics on asphalt pavements only. For rural areas, only spray-type thermoplastic may be used on roads with an ADT from 2,000 to 15,000, and either spray or extruded thermoplastic may be used for roads with an ADT above 15,000. Extruded thermoplastic may be used only when placed concurrent with the asphalt. For urban areas, only spray-type thermoplastic may be used on roads with an ADT of 1,500 to 11,000, and either spray or extruded thermoplastic may be used for roads with an ADT above 11,000.

The major durability problem associated with thermoplastic markings occurred on portland cement concrete pavements. This lack of durability has resulted in some states using thermoplastics only on bituminous surfaces. Durability also decreased on asphalt pavements that were not in good condition. Several respondents mentioned damage done by snowplows and studded tires. Poor materials, improper installation, or lack of quality control were listed as contributing factors to poor durability. Loss of reflectivity was listed in two instances. An abrasion failure under heavy traffic was reported.

A procedure has been used to inlay hot-sprayed thermoplastic. It involved grooving the pavement and placing the thermoplastic marking in the groove so it was flush with the surface. This procedure lead to improved durability, as was observed for inlaid pavement tapes.

However, installation cost for the inlaid thermoplastic markings was reported to be about three dollars per linear foot.

PAINT AND BEADS

The respondents were asked to specify which type paint, classified by drying time, was used primarily in their state. The most common paint was fast dry (dry time of from 2 to 7 minutes) with 18 respondents (39 percent) listing this type. One-half of the states using fast-dry paint had a no-track time of from 2 to 3 minutes. Quick-dry paint (dry time of 30 to 120 seconds) was the second most common type (15 states, 33 percent). Conventional paint (dry time over 7 minutes) was used primarily in ten states (22 percent); instant-dry paint (dry time less than 30 seconds) was only listed by three respondents (six percent).

Forty percent of the respondents replying to the question concerning bead embedment indicated they were experiencing problems obtaining proper embedment. Problems with bead embedment were related directly to the type of paint used. All respondents using instant-dry paint experienced a problem with bead embedment. The percent having this problem decreased from 50 percent for states using quick-dry paint to 33 percent for those using fast-dry paint to 20 percent for those using conventional paint. This problem is reduced as the dry time is increased. Several methods have been used to improve bead embedment. The primary method has involved altering the position of the bead gun so the beads hit the pavement closer to the paint or in some cases, the beads hit the paint spray above the pavement. Using a thicker paint film has also been tried. Adjusting the bead graduation to provide for a smaller percentage of fines, using silane-coated beads, and increasing bead pressure have also been tried. Changing the paint application temperature as well as the paint formula were also listed. Kentucky is currently conducting a study of this problem. Test stripes of different thicknesses have been placed using different bead-gun positions. After an optimum procedure of obtaining bead embedment is found, an evaluation of several types of paint-stripe beads will be performed.

The respondents also listed the average cost (cents per foot in place) of their paint stripe. Excluding Hawaii and Alaska, the average cost was 2.8 cents per foot. Hawaii and Alaska reported very large striping costs that were probably related to small mileages striped and the states' location. When the costs were weighted according to the mileage in each state, a cost of 3.1 cents per foot was obtained. Therefore, a good overall estimate of the average cost of a paint stripe would be three cents per foot. Forty-five of the respondents answered the questions concerning the cost and mileage of paint stripes. The total mileage was about 700,000 miles or an average of about 15,000 miles per state. This mileage varied significantly from state to state. Using this average would indicate that, nationwide, about 750,000 miles of roadway are striped annually. Considering two edgelines and a centerline, a rough estimate of the annual nationwide cost for paint striping for lane delineation would be around 250 million dollars.

GENERAL

One question pertained to the types of temporary markings used for lane delineation in construction zones. Temporary marking tape was used most often, followed closely by paint. The tape commonly used is a foil-backed, construction grade tape costing between 15 and 20 cents per linear foot of 4-inch stripe. This type of tape, as well as paint, causes a problem in the event it must be removed. The most frequent methods used for removal of pavement markings are chemicals, grinding, high-pressure water jet, high-temperature burning, hydroblasting (sand and water), and sandblasting (12). An expensive alternate tape that may be removed easily is available. This tape is the detour grade Stamark tape used by a few states. The current price is about one dollar per linear foot of 4-inch stripe. The use of temporary traffic paint (latex paint) was listed by one respondent. Raised markers are the other common type of delineation used in construction zones. Specifically, the use of raised markers with a pressure-sensitive adhesive backing has been common since they are easily removed compared to

markers applied with epoxy.

A recent study evaluated the use of other types of temporary markers to delineate a road and to serve as guidance for paint striping in lieu of conventional spotting (13). Both reflectorized and nonreflectorized markers were tested. The markers were made of a polyvinyl chloride material. Reflective tape was used on the reflectorized marker. The markers were installed with either adhesive or nails. The durability of the markers was poor, with loss of reflectivity in less than one week. Further work will be done in an attempt to develop a reflectorized marker that will function effectively for a minimum of 14 days. The nonreflectorized markers will continue to be used as a method for retaining the centerline.

Eighteen respondents noted their states had used special methods of lane delineation at high-accident locations. The most common method was raised markers. A few research studies specifically evaluated the use of raised markers at high-hazard locations (5, 9, 14). Also listed were the use of thermoplastic markings, pavement tape, and altered painting schemes such as using a 6-inch rather than 4-inch edgeline.

Eight respondents stated they had used epoxy and polyester materials as lane delineation. Epoxy paint, epoxy thermoplastic, and polyester paint have been used. The polyester material is a two-part system comprised of a resin and a catalyst (15). The components are applied separately; the resin is applied and the catalyst is sprayed over the resin. Possible advantages are an increased service life, increased night and wet visibility, and a cost competitive with regular traffic paint. It has been reported that the cost of application of the polyester paint was similar to regular paint when applied at an equivalent dry-film thickness (16). A major disadvantage is a slow no-track time that makes coning necessary. This factor adds to the total cost of polyester paint. The epoxy paint used is a two-part adhesive with both a resin and a hardener that must be mixed before spraying. Epoxy paint has been recommended for use on high-volume roads in at least one state (17). The costs of application of epoxy paints is greater than that of regular traffic paint, but it

exhibits increased durability. Costs listed in the literature for application of epoxy paint range from about 20 to 50 cents per foot of 4-inch stripe. Epoxy thermoplastic is a relatively new type of thermoplastic marking that uses an epoxy resin to produce a stripe having excellent

properties of adhesion, elasticity, and bead retention (18). As a thermoplastic, it is a 100-percent solids system that is applied at about 450 degrees F as a liquid. It is applied by spraying, and a 15-mil line may be applied with a no-track time of 5 seconds.

Summary

RAISED PAVEMENT MARKERS

1. The large majority of states (83 percent) indicated they had used raised markers. Most states (70 percent) indicated some experience with snowplowable markers. Almost all past installations used the Stimsonite marker; however, several new snowplowable markers are being tested and some significant installations of recessed markers have been completed.
2. The average useful life of raised markers was estimated at 4 years, excluding snowplow damage. The average useful life of snowplowable markers was estimated as 6 years.
3. Most studies indicated little change in accident statistics after installation of raised markers. Exceptions were an Ohio study of installations at high-hazard locations (9) and a Kentucky study of installations on interstates (6).
4. Several states gave warrants for the use of raised markers. Most of the warrants dealt with volumes or type of location or highway.
5. The average cost per marker has been \$2.80 for reflective markers, \$1.85 for nonreflective markers, and \$15.60 for snowplowable markers. These costs include installations made over the past few years; therefore, current costs would be higher. For example, the cost of \$15.60 per marker for snowplowable markers was primarily for the Stimsonite marker, and the current installed cost of a Stimsonite 96 marker is about \$20.
6. Many states have used raised markers with a pressure-sensitive adhesive backing, primarily in construction zones. Favorable comments were generally noted; however, several

problems were noted and should be considered before this type of marker is used.

PAVEMENT TAPE

1. The majority of states (59 percent) have used pavement tape (preformed pliant polymer) as lane delineation. The most common tape was the Stamark brand made by 3M Corporation. The other tape used was the Prismo Plastix tape.
2. Latest cost figures for the 60-mil tape are in the 70-to-80 cents per linear foot range for a 4-inch stripe. The average estimated useful life was 4 years.
3. Warrants used for pavement tape dealt mainly with traffic volumes and pavement type. Also, a requirement that the roadway be lighted was listed in two warrants.
4. The major durability problem noted with pavement tapes has been a loss of reflectivity. Use of tape has been limited to lighted areas where the retroreflectivity of the marking is not as important. Another problem involved damage caused by snowplowing and studded tires.

THERMOPLASTIC MARKINGS

1. The use of hot-sprayed or extruded thermoplastics (primarily hot-sprayed) has been widespread as a method of lane delineation with usage noted by 72 percent of the states.
2. The average cost per linear foot was about 20 cents for hot-sprayed and about 45 cents for extruded thermoplastics. The estimated useful life of extruded thermoplastics was

slightly higher (4 to 5 years) than for hot-sprayed thermoplastics (3 to 4 years).

3. Warrants for installation of thermoplastic markings dealt primarily with volumes and pavement type. Use was limited to bituminous surfaces in several instances.
4. The major durability problem associated with thermoplastic markings occurred on portland cement concrete pavements that resulted in future usage only on bituminous surfaces in some states. Damage by snowplows and studded tires was noted by several respondents.

PAINT AND BEADS

1. When classified by drying time, the most common paint used was fast dry (dry time from 2 to 7 minutes) followed closely by quick dry (dry time of 30 to 120 seconds).
2. Forty percent of the respondents indicated they were experiencing problems obtaining proper bead embedment. Problems were directly related to type paint used. Bead embedment problems increased as the paint drying time decreased. The major method used to improve bead embedment is to alter the position of the bead gun so the beads hit closer

to the paint or, in some cases, the beads hit the paint spray above the pavement. Other methods include using a thicker paint film, adjusting the bead gradation, using silane-coated beads, increasing bead pressure, and changing the paint application temperature or paint formula.

3. The average cost of a paint stripe was about three cents per foot.

GENERAL

1. The most commonly used lane delineation in construction zones was the foil-backed construction-grade tape that costs between 15 and 20 cents per linear foot of 4-inch stripe. Paint was also commonly used. Removal of tape or paint has been a problem. A removable tape is available, but its cost is about one dollar per linear foot of 4-inch stripe. Raised markers are another common type of delineation used in construction zones.
2. Raised markers were the most common marking used to provide additional delineation at high-accident locations.
3. Epoxy paint, epoxy thermoplastic, and polyester paint were listed as additional lane delineation materials used in some states.

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Appendix
Questionnaire and Cover Letter

Dear Mr. _____ :

For the past several years, the Division of Research of the Kentucky Department of Transportation has been involved in the evaluation of alternate methods of lane delineation. These have included paint and beads, raised pavement markers, thermoplastic markings, and pavement tape. We are currently investigating problems with bead embedment in quick-dry paint and durability of raised pavement markers, snowplowable pavement markers, and various types of pavement tape. Also, we are beginning a study involving a comparison of the various lane delineation methods. For the purposes of this study, lane delineation includes both centerline and edgeline markings. In this study, we plan to summarize information pertaining to the various alternatives and analyze their advantages and disadvantages with the objective of determining an optimum marking program.

An important phase of our study involves a survey of lane delineation methods used in other states. We are attempting to determine some basic information about the types of lane delineation used across the country. We would appreciate your help in completing the attached questionnaire. Several questions concerning the quantities, average costs, and useful lives of the various methods of lane delineation will require estimates. We are interested in comparing the usage and cost-effectiveness of the lane delineation methods; so your best estimates for these questions will be very helpful.

Thank you very much for your assistance. You may indicate on the questionnaire whether you desire to receive a copy of the results of this survey and the subsequent research report.

Sincerely,

Kenneth R. Agent
Research Engineer Chief

SURVEY OF LANE DELINEATION METHODS
(Includes centerline and edgeline markings)

STATE _____

RAISED PAVEMENT MARKERS

1. Does your state use raised pavement markers for lane delineation? Yes____ No____ If no, skip to question 8.

2. Are snowplowable pavement markers used? Yes____ No____
If yes, what type(s) are used?

3. Considering durability, estimate the useful life (years) of:
 raised pavement markers _____
 snowplowable pavement markers _____

4. Has your state conducted any studies to determine the effect raised pavement markers have had on accidents? Yes____ No____ If yes, what results have you found?

5. Has your state established warrants for the use of raised pavement markers? Yes____ No____ If yes, what are the warrants?

6. Estimate the total number of each of the following types of markers installed in your state and the approximate cost per marker for each type.

Type	Approximate Cost per Marker	Approximate Number Installed
Reflective (Mono- or Bi-directional)	_____	_____
Nonreflective	_____	_____
Snowplowable:		
Type _____	_____	_____
_____	_____	_____

7. Have raised pavement markers with a pressure-sensitive adhesive backing been used? Yes____ No____
If yes, what has been your experience with these markers?

PAVEMENT TAPE

8. Does your state use pavement tape for lane delineation (permanent installations rather than in construction zones)? Yes____ No____ If no, skip to Question 12.
9. Estimate the quantity, average cost, and useful life for the types of tape which have been used. Indicate if a binder was used.

Type (Manufacturer, Brand Name, etc.)	Approximate Cost (Cents per foot)	Approximate Linear Feet Installed	Estimated Useful Life	Binder Used (Yes or No)
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

10. Has your state established warrants for the use of pavement tape for lane delineation? Yes____ No____ If yes, what are the warrants?

11. What durability problems have you encountered with the pavement tapes? Specify if a binder was or was not used.

THERMOPLASTIC MARKINGS

12. Does your state use thermoplastic markings for lane delineation? Yes___ No___ If no, skip to Question 16.

13. Estimate the quantity installed, average cost, and useful life for the types of thermoplastic markings that have been used. List by pavement type.

Type (Extruded, hot-sprayed)	Approximate Cost (Cents per foot)	Approximate Linear Feet Installed	Estimated Useful Life (Years)	Pavement Type
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

14. Has your state established warrants for the use of thermoplastic markings for lane delineation? Yes___ No___
If yes, what are the warrants?

15. What durability problems have been encountered?

PAINT AND BEADS

16. What type of paint does your state primarily use? (Instant Dry (less than 30 sec.), Quick Dry (30 to 120 sec.), Fast Dry (2 to 7 min.), Conventional (over 7 min.)). If more than one paint type is used, list the type used the most.

17. What no-track time is specified? _____
18. Have you experienced problems with proper bead embedment in the paint? Yes____ No____ If yes, what methods of improvement have been used?
- _____
- _____
19. What has been the average cost (cents per foot in place) of your paint stripe? _____
20. Approximately how many miles of roadway are striped each year? _____

GENERAL

21. What types of temporary markings are used for lane delineation in construction zones?
- _____
- _____
22. Has your state used special methods of lane delineation at high-accident locations? Yes____ No____ If yes, what types are used?
- _____
- _____
23. Does your state use any lane delineation methods other than paint and beads, raised pavement markers, thermoplastic markings, and pavement tape? Yes____ No____ If yes, what other methods are used?
- _____
- _____
24. Has your state conducted any recent studies involving an evaluation of any type of lane delineation? Yes____ No____ If yes, we would appreciate receiving a copy of any studies that are available.

Check if you are interested in receiving a copy of the
results of this survey and/or subsequent research report.

Survey Summary _____

Research Report _____