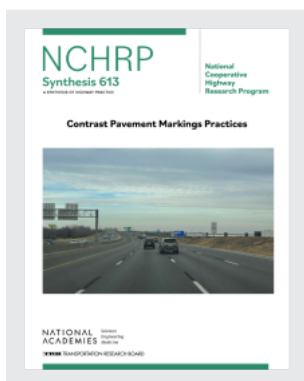


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## Contrast Pavement Markings Practices (2023)

### DETAILS

70 pages | 8.5 x 11 | PAPERBACK

ISBN 978-0-309-69923-5 | DOI 10.17226/27284

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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**NCHRP SYNTHESIS 613**

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**Contrast Pavement Markings Practices**

*A Synthesis of Highway Practice*

**Omar Smadi  
Neal Hawkins**  
IOWA STATE UNIVERSITY  
Ames, IA

*Subscriber Categories*

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Research sponsored by the American Association of State Highway and Transportation Officials  
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## NCHRP SYNTHESIS 613

Project 20-05, Topic 53-10

ISSN 0547-5570

ISBN 978-0-309-69923-5

Library of Congress Control Number 2023946423

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Business Office  
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## **ABOUT THE NCHRP SYNTHESIS PROGRAM**

Highway administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to highway administrators and engineers. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire highway community, the American Association of State Highway and Transportation Officials—through the mechanism of the National Cooperative Highway Research Program—authorized the Transportation Research Board to undertake a continuing study. This study, NCHRP Project 20-05, “Synthesis of Information Related to Highway Practices,” searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute an NCHRP report series, Synthesis of Highway Practice.

This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

## **FOREWORD**

By Jo Allen Gause

Staff Officer

Transportation Research Board

Contrast markings are used to improve the visibility of pavement markings by providing better contrast with the pavement surface. The use of contrast pavement markings (CPMs) by state departments of transportation (DOTs) has been growing in recent years. However, there is no national consensus on what design to use and when and where to install CPMs. The objective of this synthesis was to document the current practice of CPMs by DOTs.

Information for this study was gathered through a literature review, a survey of state DOTs, and follow-up interviews with selected DOTs. Case examples of four state DOTs provide additional information on the use of CPMs.

Omar Smadi and Neal Hawkins, Iowa State University, collected and synthesized the information and wrote the report. The members of the topic panel are acknowledged on page iv. This synthesis is an immediately useful document that records practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.



  
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Note: Photographs, figures, and tables in this report may have been converted from color to grayscale for printing. The electronic version of the report (posted on the web at [nap.nationalacademies.org](http://nap.nationalacademies.org)) retains the color versions.





# Contrast Pavement Markings Practices

Contrast pavement markings (CPM) improve the visibility of pavement markings by providing better contrast with the pavement surface, especially on lighter-colored pavements. During the day, the visibility of pavement markings is governed by the contrast of the marking with the pavement surface. White pavement markings tend to have lower contrast and thus are less visible on light-colored Portland cement concrete (PCC) pavement and faded asphalt pavement surfaces. Also, when the sun is at low azimuth angles, such as during sunrise and sunset, the sun's rays shine directly on the pavement markings, causing glare and thus reducing the visibility of the markings.

The use of CPM has been growing in recent years because of the desire to improve safety through better guidance and improved visibility for drivers along with improvements for autonomous vehicle operations. In 2002, in a survey conducted by AASHTO, out of the 35 state DOTs that responded, only 8 state DOTs (23%) were using CPM. In 2006, a survey by the Texas Transportation Institute found that 21 (60%) out of 35 state DOTs were using CPM. In the survey for this synthesis, 35 (81%) out of 43 agencies responding to the survey are using CPM.

The *Manual on Uniform Traffic Control Devices* (MUTCD) indicates that black is the standard color for use in enhancing the contrast of white and yellow pavement markings but does not offer guidance on when or where to use such markings or what design of CPM is recommended. Despite the increased use of CPM by state DOTs, no national consensus on what design or pattern to use and where and when to use CPMs has developed. A better understanding of the benefits and costs of installing CPMs is needed.

The objective of this synthesis was to document the current practice of CPM by state DOTs. The synthesis presents information on the following:

- When and where to use CPM
- Which CPM design configurations to use
- Documented benefits of CPM (e.g., safety, operations)
- Design factors, including autonomous vehicle sensing capabilities
- Effect on the durability of the pavement markings
- Use of different materials (e.g., binder and beads)
- Challenges and obstacles

To achieve the synthesis objective, the synthesis study team reviewed CPM literature, developed and implemented a state-of-the-practice survey, and completed case examples. With the cooperation and feedback of the NCHRP synthesis panel, the authors developed an online survey to distribute to the state DOTs via their respective members of the AASHTO Committee on Traffic Engineering. The authors received 43 responses—42 states and the District of Columbia (86% response rate).

## 2 Contrast Pavement Markings Practices

The major findings from the study are as follows:

- The survey results show more state DOTs are using CPM compared to the numbers indicated in the literature review. State DOTs are interested in enhancing safety by providing better visibility for human drivers while supporting autonomous vehicle operations—CPM help achieve this goal.
- Of the responding state DOTs, most install CPM on the divided highways with the lane lines being the most common use. The DOTs mostly install CPM on concrete to enhance the contrast of the white lane line with the light-colored pavement surface.
- Of the responding state DOTs installing CPM, 66% use the Bordered design. Recently, some DOTs have been shifting to the Lag/Shadow pattern because of input from original equipment manufacturers developing advanced driver-assistance systems (ADAS).
- Of the state DOTs that use CPM, six states track the performance of CPMs and four of those quantify the safety or performance benefits.

The synthesis identified some gaps in the current knowledge that might be addressed by additional research. Suggested research topics are described below:

- Determine the effect of CPM on safety. Increased visibility is assumed to improve safety. One study was completed in 2022 but with a very limited set of data and additional studies are needed.
- Durability and performance of CPM.
- Understand the effect of CPM designs on safety, autonomous vehicle operations, and performance.
- Studies on CPM color and glare.



## CHAPTER 1

# Introduction

Contrast pavement markings (CPM) improve the visibility of pavement markings by providing better contrast with the pavement surface, especially on lighter-colored pavements. During the daytime, the visibility of pavement markings is governed by the contrast of the marking with the pavement surface. White pavement markings tend to have lower contrast and thus are less visible on light-colored Portland cement concrete (PCC) and faded asphalt. Also, when the sun is at low azimuth angles, such as during sunrise and sunset, the sun's rays shine directly on the pavement markings, causing glare and thus reducing the visibility of the markings. The visibility of white markings and yellow markings on these light-colored surfaces and when daytime glare is present can be improved with the use of black contrast marking. The black contrast marking is part of a contrast pavement marking system—the combination of the black contrast marking and the white or yellow traditional pavement markings (see Figure 1). The MUTCD calls for black as the standard color for use in enhancing the contrast of white and yellow pavement markings but does not indicate when or where to use such markings or what design of CPM is recommended.

State DOTs are using CPM on different roadway systems; however, of the state DOTs using CPM, most are using them on divided highways (e.g., interstate highways and two or four-lane roads) and mostly for broken lane line or skip line markings. Other state DOTs will likely install CPM in the future. Several different CPM designs are being used (e.g., Boxed, Bordered, and Lag/Shadow), but more knowledge about practices for various roadways, drivers, and forms of autonomous vehicle technology is needed. Furthermore, the safety benefits of CPM designs have not been identified. The benefits of CPM may include (1) reducing the number of crashes stemming from lane departures and (2) better identification by autonomous vehicle technologies of lanes based on stripe location.

This synthesis documents current CPM practice by state DOTs and presents information on the following:

- When and where to use CPM
- Which configurations to use for CPM design
- Documented benefits of CPM (e.g., safety and operations)
- Design factors, including autonomous vehicle sensing capabilities
- Effect on the durability of the pavement markings
- Use of different materials (e.g., binder and beads)
- Challenges and obstacles

Working with the NCHRP synthesis panel, the authors developed an online survey for distribution to the state DOTs via the members of the AASHTO Committee on Traffic Engineering. There were 43 responses—42 states and the District of Columbia (86% response rate).

## 4 Contrast Pavement Markings Practices



**Figure 1. CPM on I-35 in Iowa (Photo credit: Omar Smadi 2023).**

The synthesis has five chapters and three appendices as follows:

- Chapter One contains introductory information, including background, objectives, and scope.
- Chapter Two summarizes the literature review, which was conducted to explore different CPM practices included in the synthesis; and lists references that may help future researchers and practitioners interested in this topic.
- Chapter Three documents the survey results from the 43 responding DOTs (42 states and the District of Columbia).
- Chapter Four provides an in-depth analysis of four different DOT practices related to contrast pavement markings. The examples highlight agency efforts on where, why, and how contrast markings are used in addition to quantifying safety benefits.
- Chapter Five summarizes the synthesis findings and offers suggestions on future research that may advance the CPM state of the practice within state DOTs.
- Appendix A shows the survey.
- Appendix B lists the survey responses.
- Appendix C offers selected agency CPM specification links.

# Literature Review

The authors found limited research on this topic, however, the material available provided a starting point. CPM use has been growing in recent years given the desire to enhance safety through better guidance and improved visibility to drivers and improvements for autonomous vehicle operations. In a survey conducted by AASHTO in 2002, only 8 state DOTs were using CPM out of 35 state DOTs who responded to the survey. In 2006, a survey by the Texas Transportation Institute found that 21 out of 35 state DOTs were using CPM.

## Common Uses of Contrast Markings

CPM can be used at any location where pavement marking visibility is poor, usually due to a light-colored surface such as Portland cement concrete (PCC) and faded asphalt. Generally, there is no constraint on CPM alignment. For example, Michigan DOT uses contrast markings for both special markings (e.g., arrows and legends) and lane lines (Ceifetz et al. 2017). However, some agencies allow or recommend CPM only for longitudinal delineations, for example, the City of Lenexa, Kansas (*Design Criteria and Plan Requirements For Public Improvement Plans 2019 Edition* 2020) explicitly limits use to longitudinal lines. Tennessee DOT's CPM guidelines allow CPM application only on concrete surfaces (Williamson 2022). Tennessee (*Special Provision Regarding Contrast Markings* 2021) has a more detailed specification for where contrast markings can be used:

- For new installation of pavement markings on multi-lane concrete roadways, bridges, and ramps, the Contrast Pavement Marking System shall consist of either a white and black or yellow and black pavement marking, and the Contrast Pavement Shadow Marking shall consist of a black spray thermoplastic pavement marking. The Contrast Pavement Marking System shall be used for the edge lines and dotted lines only and the Contrast Pavement Shadow Marking shall be used for the lane lines only.
- For new installation of pavement markings on 2 lane concrete roadways, bridges, and ramps, the Contrast Pavement Marking System shall consist of either a white and black or yellow and black pavement marking. The Contrast Pavement Marking System shall be used for all lines.

Illinois DOT has used CPM on some sections having PCC surfaces and uses only the Bordered pattern and only materials from one approved brand. Virginia DOT recommends using CPM for permanent lane lines and requires that contrast tape be used wherever temporary removable tape is being used in work zones if the speed limit is 45 mph or greater and one or more of the following exist (*Virginia DOT-Standards & Specifications: Pavement Markings* 2019):

- Concrete bridges longer than 300 feet
- Curved roadways/bridges
- Concrete roadways

## 6 Contrast Pavement Markings Practices

Because of the increased expense of application, CPM are often used only for white broken lane lines on divided highways with light-colored pavements. However, there is no standard for when CPM should or should not be placed. There are also no standards for the design of contrast marking to be placed (Carlson et al. 2007; TxDOT 2003).

### Design, Patterns, and Materials

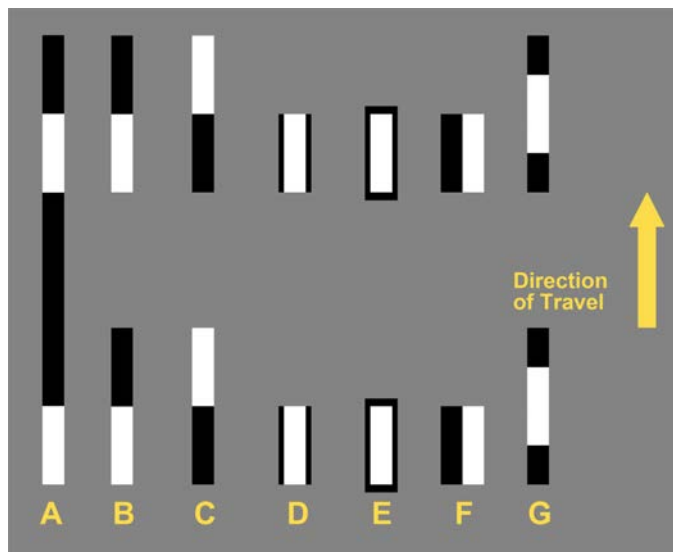
According to the *Manual on Uniform Traffic Control Devices for Streets and Highways* (MUTCD) (2009), where a light-colored pavement does not provide enough contrast with the markings, black can be used in combination with one of the following colors: yellow, white, red, blue, or purple. The MUTCD states that “When used in combination with one of the pavement marking colors, black is considered a contrast-enhancing system for the markings.” Therefore, although the MUTCD does not specify anything regarding the presence of retroreflective materials in the black portion of CPM, it is implied that retroreflective materials are not needed, given that the black portion of a contrast marking does not need to be visible at night (Carlson et al. 2007). State and local guidelines refer to the black portion of contrast marking as a non-reflective or opaque black film, and by non-reflective it is (at least in the reviewed documents) meant that the film does not contain beads. There has been no reference in the reviewed documents to any anti-glare or anti-reflective material in or on the black film. Despite the difference in application, this concern holds in the case of CPM. Therefore, caution must be taken when using black tapes because the surface appearance of the tapes can change as traffic wears the markings.

As an example, Tennessee (*Special Provision Regarding Contrast Markings* 2021) provides some highly detailed guidelines for CPM. Some of the important items are as follows:

- The amount of pigment used in the black paint should follow the manufacturer’s recommendation as long as it provides a completely opaque black appearance and 70 hours of weatherometer exposure per ASTM G 155 using Exposure Cycle 1 with a quartz inner filter glass and Type “S” Borosilicate outer filter glass.
- The black material must be colorfast and anti-skid but the provisions do not specify the use of any anti-skid additives or recommend their use.
- The contrast markings must include white and black or yellow and black thermoplastic materials from the same manufacturer.
- Alternative materials (instead of thermoplastic) shall be selected from the Department’s Qualified Products List 1: Section B, Preformed Plastic Pavement Markings with a thickness of 90 mils minimum or List 1: Section C.2, Preformed Contrast Tape with a thickness of 80 mils minimum.

### Patterns and Designs

Various designs for CPM are shown in Figure 2. Table 1 shows what the Texas DOT districts did in 2006 in one column and the other states who responded to the survey in a different column. As seen in Table 1, the typical design types commonly used by the agencies are Boxed (Design E in Figure 2), Bordered (Design D in Figure 2), and Lag/Shadow and Lead (Designs B and C in Figure 2). The Boxed and Bordered designs are very similar, except that the Boxed design has black all around the marking whereas the Bordered only has black on the sides. The Lead and Lag/Shadow designs are black markings placed before or after standard white pavement markings. The most frequently used CPM design is the Bordered design where a white marking is highlighted with black markings along the longitudinal sides. Although driver preference seems to be for the Bordered design, the Lag/Shadow design is normally more cost-effective, considering the maintenance of the marking. The Bordered design is currently



**Figure 2. Design diagram of contrast markings (Carlson et al. 2007).**

created with tape products, which have a high initial cost. The Lag/Shadow design (as well as the Lead design) are non-tape alternatives. The Lead and Lag/Shadow designs present fewer maintenance issues than other non-tape applications. Limiting the number of CPM designs to Lead and Lag/Shadow has the potential to reduce driver confusion. Carlson et al. showed that some drivers do not understand the meaning of CPM (Carlson et al. 2007). In the survey by Williamson (2022), pattern selection by agencies was explored (with responses as shown in Figure 3), revealing that Border design was the most popular followed by Lead/Lag and Border with Lead/Lag.

**Boxed Design**

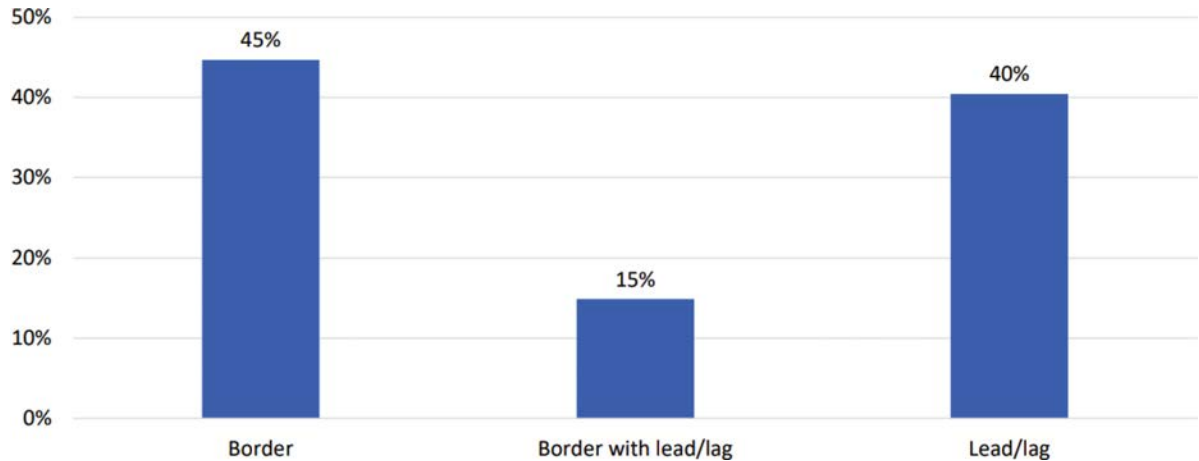
The Boxed design CPM is created by first applying a black marking to the roadway. This black marking must exceed the dimensions of the white marking to be applied. After the black marking is applied, the white marking is applied over the top of it, leaving a border around the white marking. Boxed contrast markings are only applicable to broken lane lines, as a box cannot be placed around edge lines (Carlson et al. 2007).

**Table 1. Design approaches taken by different states and TxDOT districts according to 2006 survey.**

Marking Design	TxDOT		All States	
A: Continuous Black	0	0%	1	3%
B: Lag/Shadow	5	23%	6	17%
C: Lead	2	9%	3	8%
D: Bordered	9	41%	17	47%
E: Boxed	4	18%	7	19%
F: Side by Side	0	0%	0	0%
G: Half Lead, Half Lag	1	5%	2	6%
Other	1	5%	0	0%



## 8 Contrast Pavement Markings Practices



**Figure 3.** Percent of agencies using each CPM pattern among the responders to Williamson's survey (Williamson 2022).

### Bordered Design

Currently, the Bordered design CPM is only available as a preformed tape design. The tape product has the marking color in the center with black stripes on either side. The marking color and the black border can both vary in width. The typical pattern of the tape is a 4- or 6-inch-wide white stripe with a 1.5-inch-wide black border on each side. Because the black is only on the sides of the marking, the markings can be placed as either skip or edge lines (Carlson et al. 2007). Texas DOT's guidelines specify a 1.5-inch-wide minimum border for the design of the patterns involving borders (Boxed and Bordered). Similarly, the City of Lenexa, Kansas, specifies the total width of the preformed contrast tape as being 3 inches wider than the standard width of the pavement marking specified (with 1.5 inches on both sides of the white or yellow marking) (*Design Criteria and Plan Requirements For Public Improvement Plans 2019 Edition* 2020).

### Lead and Lag (Shadow) Designs

The Lead and Lag (Shadow) design has a typical pavement marking either followed by a black marking or preceded by a black marking. Like the Boxed design, this design is only applicable to broken lane lines. The black marking can be the same width or wider than the actual pavement marking. In some cases, the black portion may connect the two white broken lane lines, creating a solid marking of white broken lane lines connected with black lines (i.e., continuous contrast marking) (Carlson et al. 2007).

### Use Cases and Benefits

In Williamson's survey, 10% of the responding agencies listed crash reduction as a benefit of using CPM, 53% identified driver comfort as a benefit, and 37% mentioned other benefits. However, none of the responding agencies had quantified the crash reductions resulting from the CPM application. Texas DOT's experience using CPM indicated visibility-improving benefits during heavy rain and hurricanes (Williamson 2022).

Table 2 shows the reasons for using CPM according to the responses of different states and TxDOT districts (Carlson et al. 2007).

**Table 2. Reasons for using CPM obtained from the 2006 survey.**

Reason for Using Contrast Markings	TxDOT		All States	
	Count	Percentage	Count	Percentage
Improve Safety	11	46%	14	44%
Public Request	0	0%	1	3%
Trial/Experimental	5	21%	9	28%
Other areas have used them	0	0%	0	0%
Other	8	33%	8	25%

Hawkins et al. (2002) suggested CPM application as a way to enable an all-white pavement marking system by mitigating the low-visibility problem of white markings on concrete or faded pavements.

## Machine Vision and Pavement Markings

Machine vision is a technology that uses cameras and image-processing algorithms to detect and interpret visual information from the environment. Machine vision research in the context of pavement markings typically involves developing algorithms and systems that can detect and interpret various types of markings on roads (e.g., broken lane lines, crosswalks, and symbols). Machine vision can be used in various applications, including autonomous vehicles, intelligent transportation systems, and advanced driver-assistance systems (ADAS). Lane detection and tracking as well as road surface markings detection and recognition are an integral part of ADAS. The aforementioned applications provide helpful, accurate information to the driver and help reduce driving errors (e.g., unintended lane departure), thereby decreasing the number of accidents and improving safety (Gupta and Choudhary 2018). Some of the key challenges in this area of research include dealing with variations in lighting conditions and dealing with markings that have faded or that do not contrast sufficiently with the pavement surface.

CPM may provide benefits for autonomous vehicles and driving assistance systems as part of the machine vision systems used in these vehicles. Of the agencies responding to Williamson's survey, 22% mentioned autonomous vehicles as a reason for using CPM (compared to the 78% that mentioned visibility as the primary reason) (Williamson 2022). A research project completed by Texas A&M Transportation Institute (Pike et al. 2018) studied the influence of pavement marking characteristics on the ability of machine vision systems to detect pavement markings. The study evaluated the detection confidence rating given to a non-contrast and a contrast version of the same [white] pavement marking by a machine vision system on board the vehicle. The results of this study showed a mixed outcome as the contrast markings had better detection confidence ratings in one direction and weaker results in the other which may have been due to glare on the black contrast marking. However, the authors noted that these results are specific to the studied sample of pavement markings and the specific location of the study, suggesting that further research is required to provide more reliable conclusions about the machine vision detectability of CPM. The black material was found not to be detectable by the machine vision system, scoring a detection confidence rating of zero. As a result, it was suggested that the Lead-Lag pattern (10 feet of white marking followed by 10 feet of black marking) may not be beneficial to the machine vision system evaluated in this study. The study of CPM detection by machine vision was limited because it was not the main focus of the research project. Only two samples were studied, so the results cannot be generalized.



## CHAPTER 3

# Survey on the State of the Practice

This chapter summarizes the survey responses from state DOTs on the use of CPM. The survey consisted of 32 questions, with 27 of those being closed-ended.

Surveys were sent to the voting members of the AASHTO Committee on Traffic Engineering. A total of 43 DOTs responded to the survey (42 state DOTs and the District of Columbia), yielding a response rate of 86%. However, not all 43 DOTs responded to every question.

The results are organized below by topic areas:

- Use of CPM
- Installation Practices
- Design Details
- Specifications
- Costs, Performance Monitoring, and Maintenance

A copy of the survey instrument is provided in Appendix A, and a summary of the agencies' responses can be found in Appendix B. The survey responses reported below may reflect different interpretations of the questions and represent a snapshot in time for an evolving state of practice.

### **Use of CPM**

Several questions asked the state DOTs about their current, past, or planned use of CPM. At the time of the questionnaire, 35 agencies reported using CPM, 4 agencies were not using CPM but had in the past, and 4 agencies do not use CPM at all (with 1 agency considering CPM in the future to improve daytime visibility). These findings are shown in Figure 4.

The four agencies that indicated they do not use contrast markings but have in the past provided the following reasons for discontinuing use:

- Budget (three agencies)
- Durability issues (one agency)
- Adds complexity to the installation (one agency)

Agencies reported that they install CPM based on their statewide policy, a specific project, or special use cases, including very light-colored bridge surfaces. Most state DOTs responding to the survey (83%) reported having installed CPM for 6 or more years. Only 15 (43%) out of the 35 state DOTs that use CPM indicated they have a statewide policy regarding CPM installations. The remaining state DOTs indicated they use CPM as part of special projects.

Agencies were asked if they are using CPM for improved daytime visibility, autonomous vehicle operations, both, or some other reason. Most agencies responding to the survey (74%)

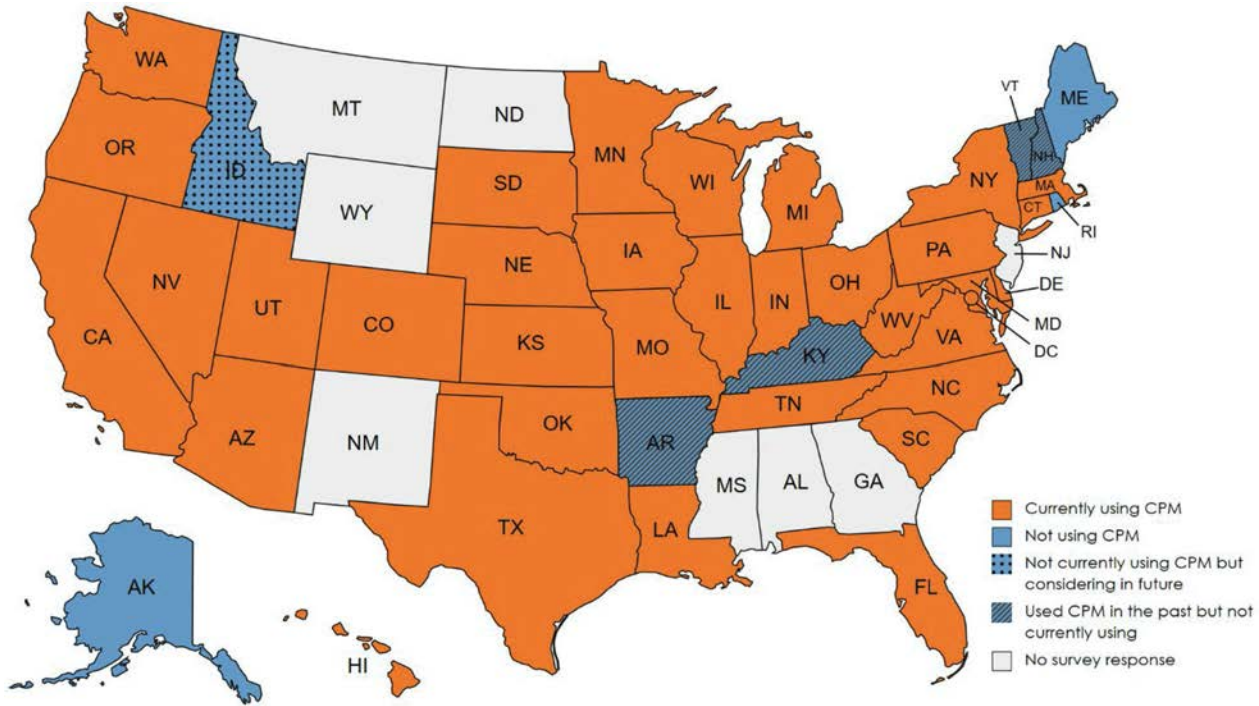


Figure 4. State DOTs use of CPM (43 responses).

use CPM to improve daytime visibility and 26% use CPM to both improve daytime visibility and support autonomous vehicle operations.

### Installation Practices

Agencies are applying CPM to a range of project types with 85% being on new construction projects, 68% when restriping existing roads, and 26% when applying CPM to existing markings (Figure 5).

Table 3 identifies the reported state of practice in terms of where CPM are being applied by roadway type and then category, pavement surface type, and line type. Most state DOTs

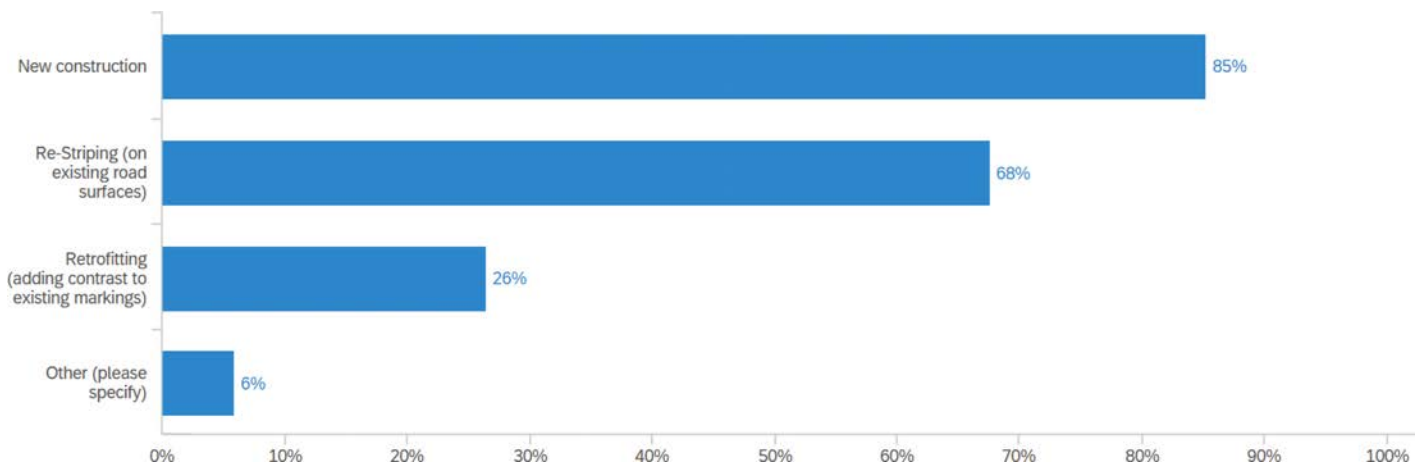


Figure 5. Response to "What categories of projects have contrast pavement markings? (Select all that apply)" (34 responses).

**Table 3. Response to “Where does your agency apply contrast markings? (select all that apply)” (35 responses).**

Road Type	Road Category		Pavement Type		Line Type		
	Urban	Rural	Asphalt	Concrete	Broken	Edge	Dotted
Interstate	80%	69%	6%	100%	94%	20%	60%
Non-Interstate Divided (Freeways)	69%	57%	3%	83%	80%	20%	51%
Non-Interstate Undivided 3+ Lanes	49%	40%	3%	60%	57%	14%	37%
Non-Interstate Undivided 2 Lane	23%	26%	3%	40%	37%	11%	31%
Ramps	40%	31%	0%	51%	46%	14%	37%

responding to the survey (80%) are installing CPM on urban interstate roadways with the trend being on concrete roadway surfaces and most commonly for broken lane lines. Of the state DOTs responding to the survey, 60% are applying CPM on their interstate dotted lane lines.

Agencies were asked to describe any other criteria used to identify where CPM are installed. Of the state DOTs responding to the survey, 60% noted using CPM for concrete pavement bridge decks, 52% are applying CPM when installing long-life pavement markings, and 32% are using traffic volume levels as a factor for installation (Figure 6).

## Design Details

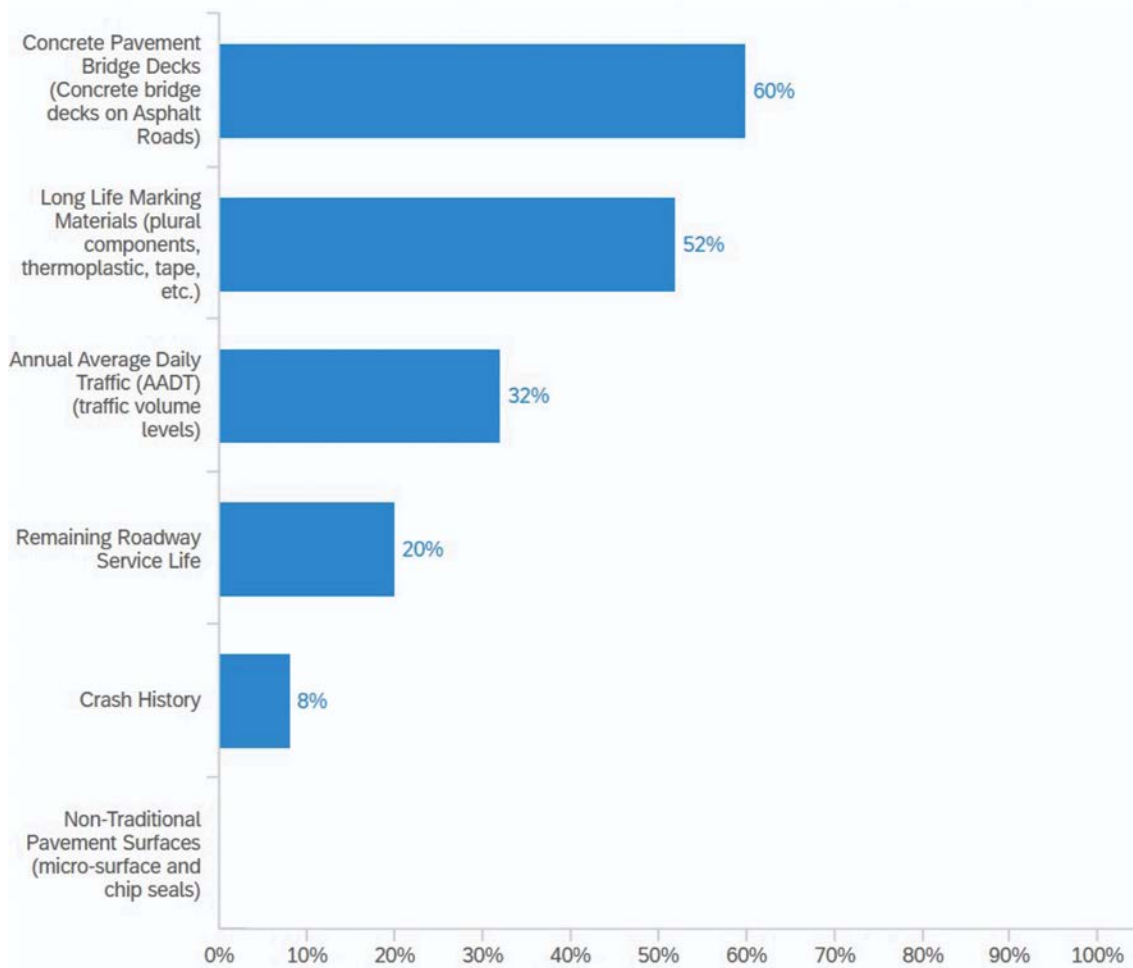
No standard patterns or styles for CPM exist. As of the time of this questionnaire, 66% of respondents indicated using the Bordered pattern followed by 57% using the Lag/Shadow contrast style (Figure 7). One agency also noted using the Bordered style with a Lag. Another agency uses the Lag/Shadow design on broken lane lines with the Bordered style being optional for edge lines.

Respondents were asked to indicate if their agency has used different CPM types in the past and if so, why did they change. Of the survey respondents, 30% indicated using different CPM styles in the past with some of the reasons being as follows:

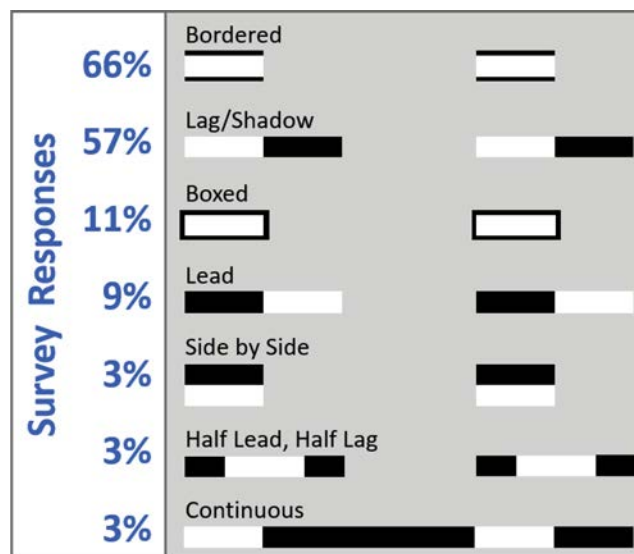
- Previously used Bordered, changed based on the material being used
- Previously used Bordered, groove width took additional time and work which increased the cost to install patterned cold plastic tape
- Established a new standard to use Lag/Shadow

The survey included a question on dimensions for both the Bordered (66% of responses) and Boxed (11% of responses) types of CPM. Figure 8 identifies these dimensions for both CPM types. The overwhelming majority use a width of 1.5 inches for all dimensions, regardless of the pavement marking width. Three agencies are using 1- or 2-inch widths for each dimension.

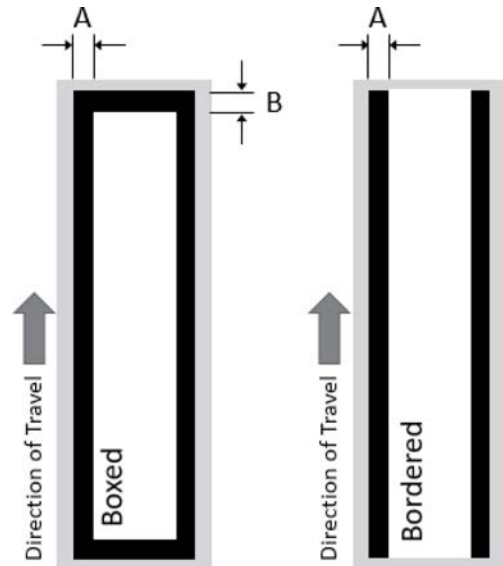
Agencies were asked about how CPM are installed with 46% using “only surface-applied,” 34% using “only recessed within a groove,” and the remaining agencies using a combination of both choices (Figure 9). All the state DOTs only installing CPM within a groove are considered snowplow states (i.e., CO, CT, IA, IL, IN, KS, MA, MN, MI, NE, SD, and WI). The state DOTs that indicated using both recessed and surface-applied CPMs include CA, MO, NV, OR, PA, and UT. These states are not completely snowplow states but have to deal with winter maintenance operations in some parts of their states. Recessing pavement markings improves durability by protecting the pavement marking system from damage from traffic or winter maintenance operations.



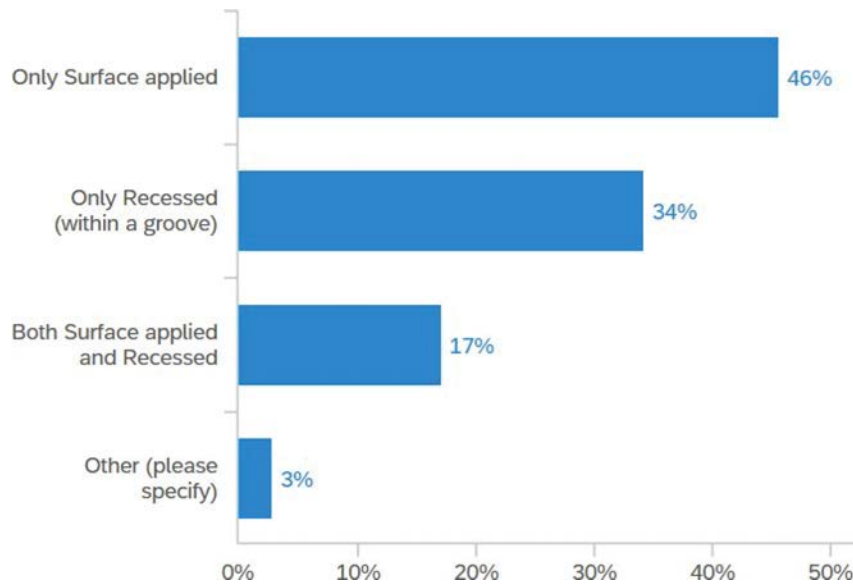
**Figure 6.** Responses to “Does your agency use any of the following criteria to identify where contrast pavement markings are installed? (select all that apply)” (25 responses).



**Figure 7.** Responses to “What contrast marking types are currently used by your agency? (select all that apply)” (35 responses).



**Figure 8. Graphic used for the question “If your agency uses either Boxed or Bordered contrast markings, as shown here, please provide the dimensions for both measurements ‘A’ and ‘B’ (in inches) specific to a 4-inch wide and a 6-inch wide pavement marking.”**



**Figure 9. Responses to “Does your agency install contrast markings on the surface or within a recessed groove?” (35 responses).**

## Specifications

This section summarizes agency practice in terms of CPM specifications including whether or not an agency has a CPM specification, marking materials used, anti-skid materials, retro-reflectivity, and color. Even if a DOT responded that they do not have specifications for CPM, it is the authors' understanding that all DOTs have pavement marking specifications for materials and installation. This section covers just the specifics of the details related to the black contrast marking and not the contrast marking system.

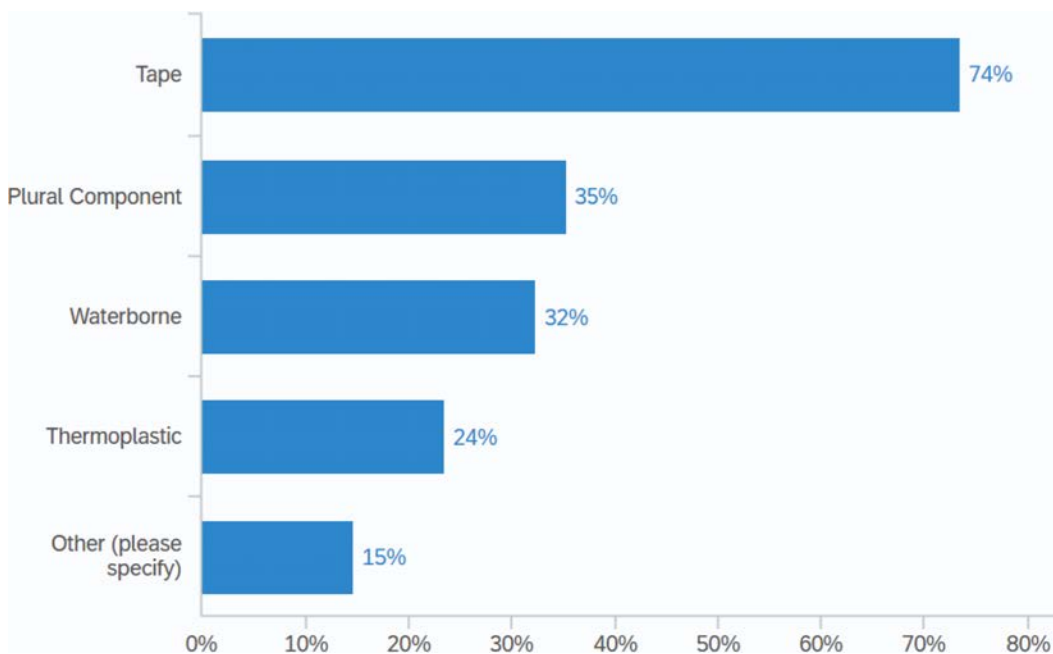
Of the agencies using CPM (35 responses) 57% report having a specification. (Appendix C provides web links to the nine state DOTs that provided that information.)

Respondents identified the types of pavement marking materials used for CPM (see Figure 10) and 74% reported using tape followed by plural components and waterborne at 35% and 32% respectively. The survey data indicate that when the primary marking material is not waterborne, agencies are installing the CPM within a groove.

When agencies were asked if they specify the same pavement marking material for the contrast marking as is used for the adjacent white or yellow pavement marking, 61% indicated "Yes," 9% "No," and the remaining 30% answered "Sometimes."

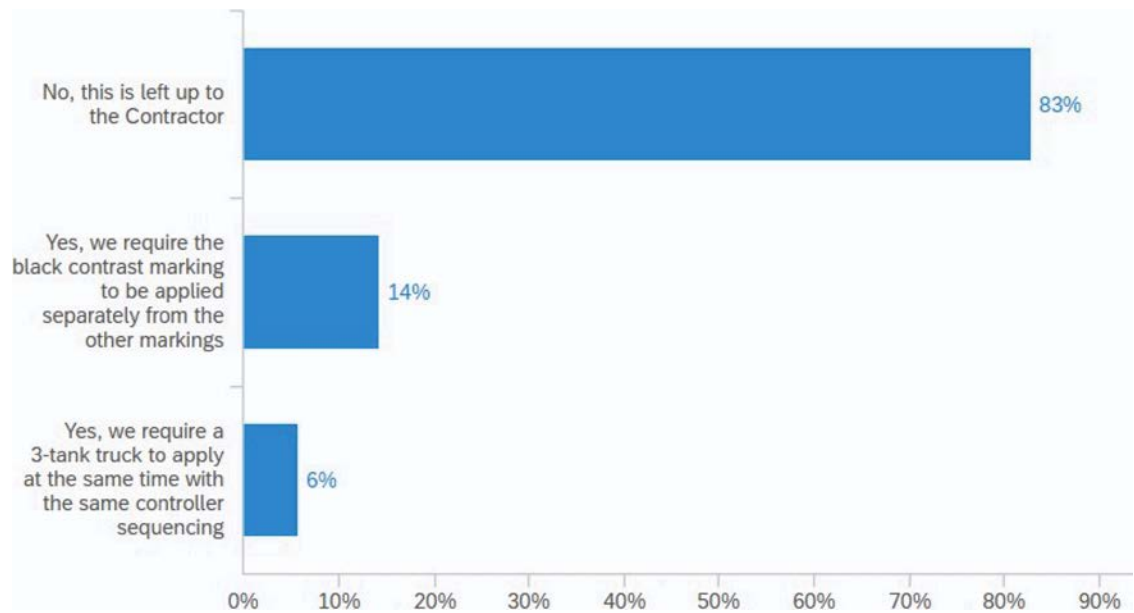
Typically, the black contrast marking includes an abrasive material as an anti-skid agent. Of the respondents, 86% report using anti-skid materials and 14% do not. Only 30% of the agencies using anti-skid materials specify the type of materials to be used.

Specifications for white and yellow pavement markings typically include a minimum retro-reflectivity value as well as a requirement to be within a specific color box. Because CPMs should not be retroreflective, agencies were asked if they specify a maximum retroreflectivity and color. Only 2 out of 34 agencies specify that the black CPM "should not be retroreflective" without indicating a retroreflectivity value. Specific to color, 6 out of 33 agencies are specifying a color box requirement for the black CPM.



**Figure 10.** Responses to "Identify the types of pavement marking materials used for contrast pavement markings (select all that apply)" (34 responses).





**Figure 11.** Responses to “Does your agency have installation requirements specific to how black contrast markings are installed? (select all that apply)” (35 responses).

CPM requires contractors to apply another color (black) which, due to truck capacity, materials used, and other reasons, creates a situation where black markings are applied separately to the standard white and yellow markings. Trying to match an existing stripe complicates installations and can affect quality. State DOTs were asked about their requirements specific to how CPMs are installed. Most state DOTs (83%) do not have installation requirements and instead rely on the contractor or manufacturers’ recommendation (see Figure 11).

## Performance, Costs, and Maintenance

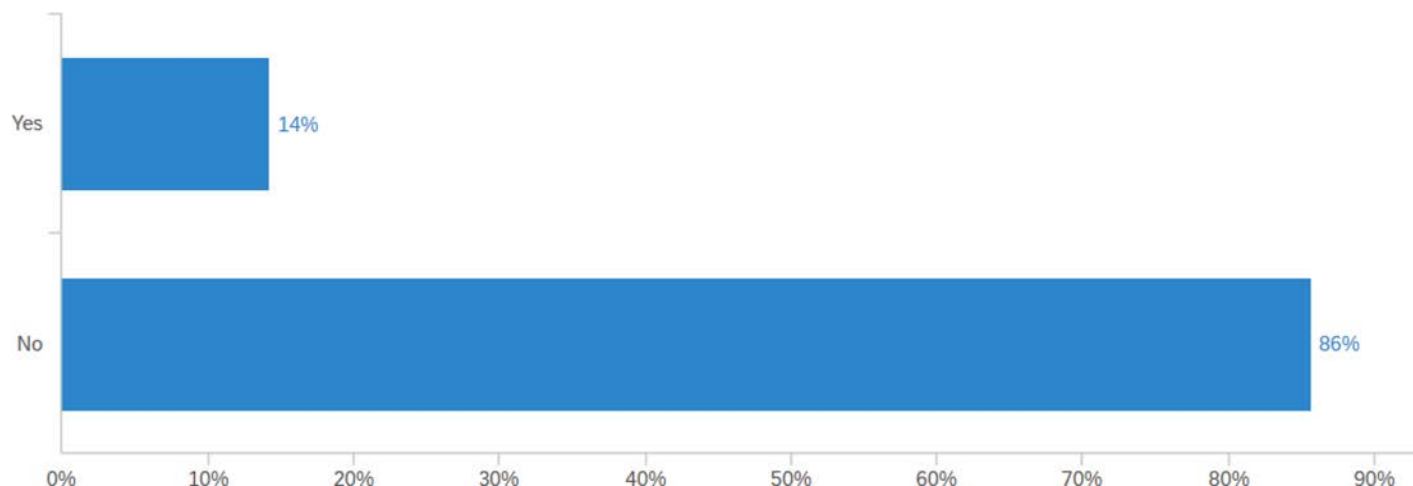
As agencies consider, or refine, their CPM practices, it is important to understand the state of practice when it comes to performance (durability), additional costs, and maintenance (restriping). The survey addressed two topics in terms of performance: (1) whether agencies collect data on CPM durability as measured by presence and (2) whether durability differs based on the type of CPM used. Only 14% of agencies reported monitoring the performance of CPMs in terms of marking presence (see Figure 12).

Agencies were also asked if the type of contrast marking used affects durability. Figure 13 shows that 47% believe there is no impact and 9% believe there is. The remaining 44% have either not tracked, are unsure, or only use one type and have no basis for comparison.

Agencies were asked if they have conducted any studies to evaluate the benefits of contrast markings from either a user or performance perspective. Agency responses by the type of study and responding agency were as follows:

- Safety impact of contrast markings (IL, IN)
- Public opinion of contrast markings (AZ, KS)
- Long-term performance of contrast markings (CO, MA)
- Comparison of different contrast marking types (CA, IN, KS, TN)

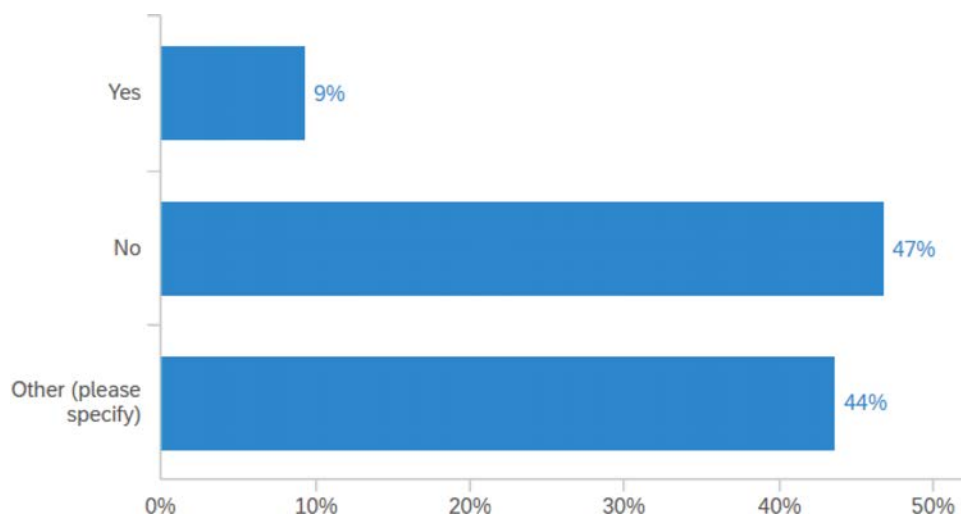
The additional cost of CPM is a critical consideration for most agencies deciding whether to install CPM or not. Agencies were asked if they track the cost for the installation of contrast



**Figure 12. Responses for “Does your agency collect data on contrast marking durability (presence)?” (35 responses).**

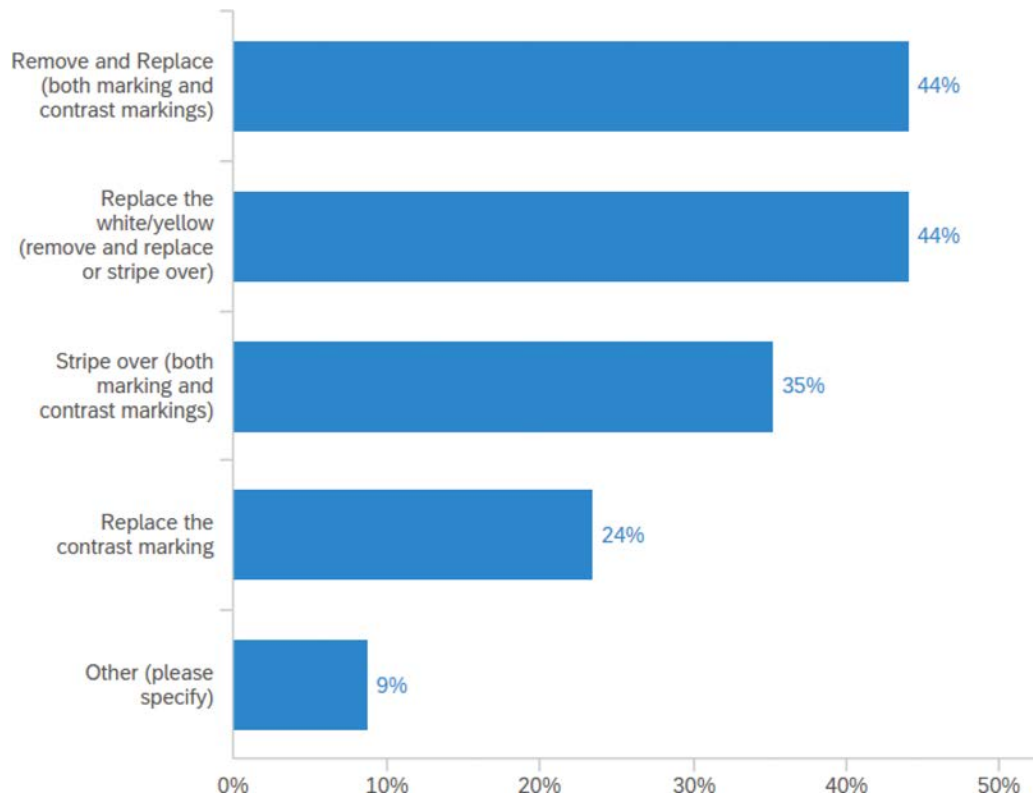
markings and if so, to provide the percent of extra cost required as compared to the same non-contrast marking. Of the responding agencies, 16 agencies indicated tracking CPM costs, but only 8 agencies provided numbers. Six agencies indicated cost differences less than or equal to 65% (this most likely represents the additional material cost for the contrast marking). The other two agencies indicated a 200% increase in CPM when using tape—this may indicate that those agencies switched to tape when using contrast pavement marking and the additional cost is not just for the contrast markings. Because the information provided on cost may be influenced by agencies changing pavement marking material type and line width when installing CPMs, it is difficult to draw definite conclusions about this.

CPM complicates pavement marking restriping. Agencies were asked to identify how they refresh pavement markings that include CPM. Figure 14 shows that nearly half of the agencies using CPM either remove and replace all markings or remove and replace only the white and yellow (not black) markings; 35% stripe over all markings during restriping activities; 24% report only replacing the contrast marking when required; and 9% noted varied practices based on the pavement marking material type and whether the existing stripe is recessed or surface applied.



**Figure 13. Responses to “Does the type of contrast marking used (lag, box, bordered, etc.) impact durability?” (32 responses).**

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**Figure 14.** Responses to “What are your agency practices in terms of maintaining pavement markings with contrast? (select all that apply)” (34 responses).

# Case Examples for DOT State of the Practice

This chapter presents four case examples that were selected based on responses to the survey and follow-up interviews. These examples highlight agency efforts on where, why, and how contrast markings are used in addition to quantifying safety benefits.

## Kansas Department of Transportation

The Kansas DOT (KDOT) began using CPM in 2009. In the last 6 years with advancements in the striping industry, KDOT has taken a more active role in using CPM across the state. These initial efforts focused on pavement marking tapes using Lag/Shadow contrast stripe, as well as plural component pavement markings on concrete surfaces, along specific (high crash rate) safety corridors. In 2022, these early projects represented roughly 5% of the contrast markings on the road.

KDOT's current practice is focused on plural components and patterned cold plastic tape marking materials with a Lag/Shadow contrast stripe. The agency has continued to install contrast pavement markings based on specific projects and criteria, including concrete surfaces along four-lane divided, high-traffic-volume routes (mostly interstate).

KDOT uses contrast pavement markings to improve visibility for today's drivers and to support vehicles equipped with Advanced Driver-Assistance Systems (ADAS), specifically lane-keeping and lane-departure warning systems. To support ADAS development, KDOT installed contrast markings and wider gore areas along a 24-mile section that is available for any ADAS provider to use. This test section includes white broken lines 15 feet long followed by a 15-foot black contrast stripe in addition to wider gore area markings.

KDOT has received unsolicited positive feedback on rural and urban contrast pavement marking projects involving concrete surfaces. For the rural interstate condition, KDOT included black CPM on a plural component project for the first 12 miles into the state from the Colorado border. A practitioner emailed KDOT and mentioned how well the Lag/Shadow CPM stood out against snowfall after the roadway was cleared by KDOT's Maintenance crews. The individual also expressed appreciation for the use of contrast striping to help individuals stay in their lanes when the sun was at a low angle and the white markings are not as visible in other weather conditions. The urban example came from KC SCOUT (which is Kansas City's traffic management system). An individual noted that the CPM were "incredibly helpful" in trying to stay in their lane during a rain event.

KDOT includes Lag/Shadow CPM on both restriping projects (on existing road surfaces) and for new construction. The effort is focused on providing CPM for concrete road surfaces. CPM are always considered where long-life plural component or patterned cold plastic tape marking materials are installed within a recess or groove, both of which often imply roadway surfaces that have a sufficient remaining service life.

## Kansas DOT

- *Lag/Shadow contrast markings on both liquid and preformed plastic (tape) projects*
- *Contractors using 3-tank trucks (yellow, white, black) for line quality and production*
- *Require Contractors to provide initial retroreflectivity*
- *Third-party statewide retroreflectivity measurements each spring*
- *Require Contractor training and certifications*
- *Contractor quality control requirement for 180 days*

KDOT reports working with contractors over time to improve the quality of CPM installations. Early efforts to install black markings had contractors making more than a pass along the contractor's layout lines to spray the white markings and then to make another pass for the black. The separate applications created issues in aligning the two colors linearly and in making sure the black material started immediately after the white with a full 8 feet of black material installed per stripe color. As KDOT expanded CPM practices statewide, three to four contractors purchased or built 3-color tank trucks (i.e., white, yellow, black) with each color run through the onboard paint-gun control system so that each color is turned on and off at a precise time and the linear stripe alignment is consistent as compared to two separate applications. KDOT is very satisfied with how these new 3-tank installations have improved the quality of CPM installations.

KDOT requires that the black contrast marking materials match the white plural or patterned cold plastic tape materials with the black contrast stripes requiring anti-skid/glare media. KDOT does not specify the application rate for these materials but simply requires a non-glare surface. Contrast markings are also used on most patterned cold plastic tape projects, typically "All-Weather" for longitudinal as well as broken lane lines, dotted extension lines, and lane drop markings.

KDOT estimates that adding contrast striping increases costs by an additional 50% for each line type that uses black contrast. Pavement marking maintenance and restriping includes removing and replacing all pavement markings (regardless of color).

KDOT does not collect data specific to CPM durability (presence) over time, however, the agency is focused on pavement marking quality and requires the following:

- Marking material manufacturer warranty
- Manufacturer certification of the contractor
- Contractor satisfaction of specific training and certification requirements of organizations such as the American Traffic Safety Services Association (ATSSA)
- Contractor provision of initial retroreflectivity values as measured between 12 hours and 14 days after installation
- Contractor-responsibility for quality control during the 180-day observation period on all striping projects

KDOT hires a third-party company to measure the entire system each spring which supports the following:

- Maintenance of minimum pavement marking retroreflectivity per FHWA
- Contractor quality review
- KDOT Maintenance and Construction staff review of district retroreflectivity deficiencies
- KDOT staff planning and budgeting for pavement marking projects funded through the Highway Safety Improvement Program and their overall construction program

The Kansas DOT Pavement Marking Specification can be found at: <https://www.ksdot.org/Assets/wwwksdotorg/bureaus/burConsMain/specprov/2015/PDF/15-08020-r01.pdf>

## Illinois Department of Transportation

The Illinois DOT (IDOT) has used CPM for more than 6 years. IDOT efforts to date have focused solely on Preformed Plastic Type B (pavement marking tape) using a 1.5-inch Bordered black contrast.

Contrast markings are not included with every pavement marking tape project—this decision is left up to each district. Typical applications include light-colored pavements, at intersections

### Illinois DOT

- *Bordered style contrast markings only for Preformed Plastic (tape) projects*
- *Have developed significant pavement marking installation guidance and will consider adding contrast in the future*
- *Recently completed a study on the safety benefits of contrast markings and a benefit-cost analysis tool*

or locations having complicated geometry, or in areas that require unusual traffic maneuvers. IDOT's overall approach to using contrast markings is to improve daytime visibility on both new construction and when restriping existing roadways. Lighter concrete surfaces are the most common application but occasionally a district has used contrast when restriping faded asphalt roadway.

IDOT has installed pavement marking tape products for more than 20 years and prefers that all tapes be installed within a recessed groove, cut into the pavement, or inlaid in asphalt for snow plow protection. Their current "General Guidelines for the Use of Pavement Marking Materials on State Highways" provides guidance on selecting the optimum types of pavement marking materials to be placed and maintained on the state highway system both by state forces and contract work. "Optimum marking materials" are those that are compatible with the site, provide an appropriate service life, and are cost-effective. This policy describes the various factors that influence the performance of pavement markings and based on these variables, presents tables of recommended materials.

Given that contrast markings are only allowed on tape projects, all manufacturing, material, anti-skid materials, or installation requirements follow the Preformed Plastic Type B specifications.

IDOT recognizes that contrast markings could be used with other marking materials (liquid markings) but that it is more complicated than with tapes and their policy does not currently allow it. IDOT does not specify a maximum retroreflectivity threshold for the contrast portion of pavement marking tapes.

IDOT is aware of the national dialog specific to contrast marking use, patterns, and widths and shares the desire to support vehicles with higher levels of assistance like lane-departure warnings.

In considering contrast marking guidance, IDOT funded the report "Crash Modification Factors for Contrast Pavement Markings on Light-Colored Pavement" which evaluates the safety benefits of CPM and developed a benefit-cost analysis tool for use in project selection. Some of the key study elements and findings are reproduced here:

- The findings suggest contrast pavement markings reduce roadway departure crashes between 5% and 29%.
- Based on the findings, CPM are believed to be effective at reducing roadway departure crashes on the three high-speed roadway configurations tested—four, six, and eight lanes—in urban and suburban areas. CPM provide crash reductions resulting in economic savings related to crash costs that greatly outweigh the additional cost of contrast pavement markings.
- The benefit-cost analysis tool developed provides a quantitative analysis in dollars regarding economic savings resulting from the use of CPM.

IDOT is considering how to incorporate the CPM research findings into the next update of the Pavement Marking Policy guidance.

## Iowa Department of Transportation

In the past, the Iowa DOT only used CPM in conjunction with a few projects that included preformed plastic tape. These projects were for short segments of urban interstate and on concrete-surfaced roadways. In these cases, the Bordered contrast marking was manufactured as part of the broken lane line (white skip).

Roughly 5 years ago, the Iowa DOT's Pavement Marking Task Force began planning for when, where, and how to start using longer-lasting liquid pavement marking materials (versus waterborne), including wider 6-inch stripes, wet reflective media, and contrast markings. With

## Iowa DOT

- *Lag/Shadow contrast markings on liquid striping projects*
- *Recessed contrast markings installed for broken lane lines on Interstate*
- *Contrast markings used for both new construction projects and contractor restriping work*
- *Established an Interstate Marking Program that includes funds to add contrast striping on the interstate and frees DOT crews to spend more time painting all of the non-interstate roads*

lane-departure crashes as a persistent leading crash type, a goal was to improve visibility for all drivers today; to support national efforts to provide wider, consistent, and more visible markings that enable Advanced Driver-Assistance Systems (ADAS); and to install pavement markings that can support even higher levels of automation in the future.

Given that the Iowa DOT has an unusually high percentage of concrete-surfaced roads (roughly 50%), the Task Force recognized the need and opportunity to increase the use of CPM with a focus on the broken lane lines on light-colored pavements (both concrete and light-colored asphalt). Through consultation with neighboring states and discussions across the DOT, the group established strategies for pavement markings specific to both maintenance and new construction projects.

The key concept was to transition away from DOT crews applying waterborne paint on the interstate system every year. This takes up considerable time and resources (e.g., it is done annually), requires unusual work hours within urban areas, and has the highest differential in speeds between the workers and the traveling public. The goal was to transition to a contractor-applied multi-component interstate program that extends the restripe cycle to at least 3 and hopefully 4 or more years and which includes a Lag/Shadow stripe and wet reflective media for the broken lane lines. This strategy improves the interstate (which carries the highest volume and percentage of trucks) and, more importantly, allows the DOT paint crews to spend more time on non-interstate roads where the probability of death or serious injury to a driver leaving the roadway is much higher.

The DOT then developed, for new construction, a multi-component pavement marking specification that included 6-in-wide recessed markings, wet reflective media for all new longitudinal lines, and a Lag/Shadow contrast for the broken lane lines.

Regarding maintenance striping, the DOT funded the Interstate Pavement Marking Program to contract out specific segments of the interstate system for restriping each year. Each installation will include the removal of the existing markings, installation of the 6-in-wide multi-component markings, recessed broken lane lines with wet reflective media as well as a Lag/Shadow contrast marking. Every mile covered through this program allows the six local district crews to spend more time painting the non-interstate roads, trying different strategies with high-build waterborne marking materials, and addressing areas having safety performance issues.

The Iowa DOT selected the Lag/Shadow style of CPM as a result of input from national conversations among practitioners and for practical reasons (i.e., knowing that these broken lane lines, which include wet reflective media, would need to be recessed within a groove for snow plow protection). The Bordered contrast style would result in groove widths of over 9 inches in contrast to Lag/Shadow being the 6-inch line width plus some tolerance. Also, the Pavement Marking Task Force thought that having a 6-in-wide by 10-ft-long black contrast line provided improved delineation for light-colored concrete surfaces and especially at low sun angles.

The Iowa DOT does not require a maximum retroreflectivity for the black contrast marking but does require that the black should satisfy color chip 37038 of Federal Standard 595B and have similar quality as the white and yellow multi-component pavement markings. The anti-skid material is required for all shadow line markings applied at a minimum rate of 15 pounds per gallon. The Iowa DOT specification can be found at [https://iowadot.gov/specifications/dev\\_specs/2015/DS-15097.pdf](https://iowadot.gov/specifications/dev_specs/2015/DS-15097.pdf)

### **Colorado DOT**

- *Started with 4-inch preformed tape using the Bordered contrast and then transitioned to 6 inch and provided an option to use Lag/Shadow*
- *Contrast used on all lighter-colored pavements (PCC)*
- *Preformed tape skip line markings are recessed in a groove*
- *Annual evaluation of pavement marking presence and retroreflectivity*

### **Colorado Department of Transportation**

The Colorado DOT (CDOT) began using 4-in-wide preformed patterned pavement marking tape in 1998 for all skip (broken lane) lines statewide. For light-colored PCC roadways, a 1.5-inch contrast black border was included for visibility.

In 2019, ahead of national trends, CDOT modified its specification by increasing all pavement marking widths from 4 to 6 inches and adding the option of Lag/Shadow contrast marking style to the existing Bordered style. For the Denver Metro District (Region 1), it took roughly 3 years to convert all of the skip lines to the Lag/Shadow contrast markings. Figure 15 shows the two styles for the same section of the roadway.

CDOT wanted to keep groove widths to 7 inches wide (6-inch wide tape with a half-inch extra on each side) and worked with the tape manufacturers to produce the Lag/Shadow style, as opposed just to Bordered. All preformed pavement marking tapes are placed within a 140-mil groove.

To date, nearly all (94%) of skip line pavement markings statewide, on concrete surfaces, include a contrast marking (see Figure 16).

CDOT measures the retroreflectivity of state pavement markings each June using a private contractor. CDOT also hires a private contractor for pavement marking grooving.

Additional CDOT pavement marking information can be found at <https://www.codot.gov/safety/traffic-safety/design/signing-and-markings>



**Figure 15. Contrast marking comparison for the same roadway before (left) using 4-inch wide tape with a Bordered contrast style and now (right) 6-inch wide tape using the Lag/Shadow contrast style (Colorado DOT).**



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***Figure 16. Typical CDOT pavement markings for light-colored concrete surfaces where a 6-inch wide preformed pavement marking tape is used for the centerline skips along with a Lag/Shadow contrast (black) tape marking (Colorado DOT).***

# Summary of Findings

This chapter covers insights from the literature review, summarizes the results of the state-of-the-practice survey, and presents possible research areas to support the application of CPM in the future.

CPM are used to improve the visibility of pavement markings by providing better contrast with the pavement surface, especially on lighter-colored pavements. The objective of this synthesis was to document the current practice of CPM by state DOTs. The scope of this synthesis study focuses primarily on the following questions related to the use of CPM:

- When and where to use CPM?
- What is the most common design of contrast pavement marking used by state DOTs?
- What are the documented benefits of contrast pavement markings?
- Why are agencies using contrast pavement markings (e.g., autonomous vehicle sensing capabilities, visibility)?
- Do contrast pavement markings impact the durability of the pavement markings?
- What materials are used (binder and beads)?
- What challenges and obstacles exist regarding the use of CPM?

These questions were used to create five categories, which were then used to develop a logical flow for the survey as follows:

- Use of CPM
- Installation practices
- Design details
- Specifications
- Performance, cost, and maintenance

To accomplish the study objectives and to draw conclusions on the state of the current practice of CPM, the authors reviewed available literature, developed and implemented a survey of current practices, and developed case examples from four state DOTs.

## Overall Findings

The literature review showed increased use of CPM by state DOTs. The survey conducted for this synthesis also found increased use of CPM. Out of the 43 agencies responding to the synthesis survey, 35 indicated they are using CPM with 1 state DOT intending on using it in the future—this is over 81% of the responding agencies.

The study revealed gaps in terms of state practices. The roadway characteristics where CPM is used vary by state and the design of CPM used also varies. Little literature exists on the

benefits of CPM. All of these areas are candidates for further research to increase understanding of CPM and the benefits of CPM.

The survey results showed that most of the responding DOTs use CPM mostly on the interstates for broken lane lines and the majority on concrete pavements. The most common design is either Bordered or Lag/Shadow surface applied. Practices vary by state. The choice of materials seems to be driven by the CPM design used. Most of the responding agencies using the Bordered design use tape as the primary pavement marking material for CPM installation. The Lag/Shadow pattern allows a wider selection of different types of pavement marking materials. Materials such as plural components, waterborne, and thermoplastic are used for CPM installation in almost equal proportions by the state DOTs. Most of the responding state DOTs still use tape for their CPMs.

When it comes to installation practices, the overwhelming majority of the responding DOTs using CPM leave it up to the contractor to decide how CPM are installed (83%) with the remaining agencies either specifying how the black marking is installed or specifying the type of equipment used. As CPM use increases, more specifications will be developed to control the quality of CPM.

When addressing the performance, costs, and maintenance practices of CPMs, the responding DOTs provided little information. Few of the agencies measure the performance of CPM. Those agencies that are (9% of the respondents) have not done any studies on the long-term performance of CPM. When it comes to additional costs for installing CPM, increases ranged from 25% to 200%, depending on the pavement marking materials used.

Additional work is needed to further understand these issues and provide guidance to the agencies on material selection and performance.

Addressing the benefits of CPM, the responding DOTs had little information to provide regarding safety impacts. Two DOTs indicated they have conducted safety studies (IDOT and INDOT), but only the IDOT study was documented (see the IDOT case study) with a 5% to 29% reduction in roadway departure crashes due to CPM. Other areas such as public opinion of CPM, long-term performance, and comparisons of the different CPM designs and their effect on safety and performance remain unexplored.

## **Suggestions for Future Research**

Work on this synthesis has identified several gaps in current knowledge that could be addressed by the following suggested research topics.

- Safety impacts of CPM. Anecdotal evidence suggests that CPM improves visibility and will eventually enhance safety in terms of reductions in crashes. One study documented those safety benefits using data from six state DOTs for a total of 70 miles of roadways. Additional studies, in which more state DOTs are represented and more roadways are included, are needed. The increased use of CPM as shown in this synthesis should facilitate the availability of more data to conduct these kinds of studies. With more miles of roadways with CPM, researchers can examine multiple factors, including CPM design type and roadway characteristics.
- CPM durability and performance by material type and CPM design. Few state DOTs are monitoring the performance of CPMs. As the survey showed, there is a wide range of pavement marking materials used for CPM installation and also a range of CPM designs. Studies are needed to assess the long-term performance of CPM durability (presence and color) by material type and CPM design. Multiple agencies have programs to monitor pavement marking performance in general—these agencies will be equipped to conduct such studies in the future.

- Determining which CPM design types are most effective. When the state DOTs discussed why they use CPM, the majority (74%) said visibility and 24% said both visibility and autonomous vehicle operations. Given that multiple CPM designs are being used by state DOTs and no consensus exists on what is the most effective for either visibility or autonomous vehicle operations, research studies to address these issues would be helpful. Original equipment manufacturers who develop guidance systems for autonomous vehicle operations like advanced driver-assistance systems (ADAS) for lane-keeping or lane warning indicated that Lag/Shadow CPM is best viewed by their systems. Additional work needs to be conducted by the state DOTs to provide information on these critical issues.
- Studies on CPM color and glare. Out of the 35 state DOTs that indicated using CPM, only 2 specify the maximum retroreflectivity level of the black marking and 6 specify the color box for CPM. Studies are needed to determine (1) the effect of these two factors on the long-term performance of CPM and (2) the impacts on visibility and contrast when it comes to safety and autonomous driving.



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## A P P E N D I X A

# The Survey

## Current Practice of Contrast Pavement Markings

Introduction

**NCHRP SYNTHESIS 20-05/Topic 53-10**

**Identifying the Current Practice of contrast pavement markings by Departments of Transportation**

Dear Agency Representative,

The Transportation Research Board (TRB), through the National Cooperative Highway Research Program (NCHRP), under the sponsorship of the American Association of State Highway and Transportation Officials (AASHTO), and in cooperation with the Federal Highway Administration (FHWA) is preparing a synthesis report to identify current practice of Contrast Pavement Markings.

The purpose of this questionnaire is to identify and summarize the use of contrast pavement markings by DOTs. The results of the survey will be incorporated into a synthesis of highway agency practice which includes a literature review, case-studies based on follow-up interviews with selected agencies, identified information gaps, and suggested research to address these gaps. The overall intent is to help agencies evaluate and improve their current contrast pavement marking practices.

This survey is being sent to each state highway agency for distribution to applicable employees. If you are not the appropriate person at your agency to complete this questionnaire, please forward this request to the correct person.

Please complete and submit this survey by May 31, 2022. We estimate that it should take no more than 15 minutes to complete.

Thank you for your time and expertise in completing this important questionnaire.

A-2 Contrast Pavement Markings Practices

Qi. Please provide your Name

Qii. Please provide your Agency Name

Qiii. Please provide your Email address (work)

Q1. Has your agency ever used contrast pavement markings?

Yes (1)

No (2)

*Skip To: Q4 If Q1 = Yes*

Q2. Is your agency considering contrast pavement markings in the future?

Yes (1)

No (2)

*Skip To: End of Survey If Q2 = No*

*Display This Question:*

*If Q2 = Yes*

Q3. Why is your agency considering contrast pavement markings?

Improved Daytime Visibility (Safety) (1)

Autonomous Vehicles (AV) operations (2)

Both (3)

Other (please specify) (4) \_\_\_\_\_

*Skip To: End of Survey If Q3 = Improved Daytime Visibility (Safety)*

*Skip To: End of Survey If Q3 = Autonomous Vehicles (AV) operations*

*Skip To: End of Survey If Q3 = Both*

*Skip To: End of Survey If Q3 = Other (please specify)*

Q4. Does your agency currently use contrast pavement markings?

Yes (1)

No (2)

*Skip To: Q6 If Q4 = Yes*

Q5. Please indicate why contrast pavement markings were discontinued. (select all that apply)

Durability Issues (Black contrast marking) (1)

Budget (Additional Cost) (2)

Installation (Adds complexity) (3)

Benefit (No perceived benefit) (4)

Other (please specify) (5) \_\_\_\_\_

*Skip To: End of Survey If Q5 = Durability Issues (Black contrast marking)*

*Skip To: End of Survey If Q5 = Budget (Additional Cost)*

*Skip To: End of Survey If Q5 = Installation (Adds complexity)*

*Skip To: End of Survey If Q5 = Benefit (No perceived benefit)*

*Skip To: End of Survey If Q5 = Other (please specify)*



**A-4** Contrast Pavement Markings Practices

Q6. My agency installs contrast pavement markings based on:

- Trial Basis (1)
- Specific Projects (2)
- Statewide policy (3)
- Other (please specify) (4) \_\_\_\_\_

Q7. How long has your agency been using contrast pavement markings?

- 1 year (1)
- 2 years (2)
- 3 years (3)
- 4 years (4)
- 5 years (5)
- 6 or more years (6)

Q8. Why does your agency use contrast pavement markings?

- Improved Daytime Visibility (Safety) (1)
- Autonomous Vehicles (AV) operations (2)
- Both (3)
- Other (please specify) (4) \_\_\_\_\_

Q9. What categories of projects have contrast pavement markings? (select all that apply)

- New construction (1)
- Restriping (on existing road surfaces) (2)
- Retrofitting (adding contrast to existing markings) (3)
- Other (please specify) (4) \_\_\_\_\_

Q10. Where does your agency apply contrast markings? (select all that apply). Other factors are considered in future questions.

	<b>Roadway Settings (Urban) (1)</b>	<b>Roadway Settings (Rural) (2)</b>	<b>Pavement Type (Asphalt) (3)</b>	<b>Pavement Type (Concrete) (4)</b>	<b>Line Type (Broken Lane Line) (5)</b>	<b>Line Type (Edge Lines) (6)</b>	<b>Line Type (Dotted Line) (7)</b>
Interstate (1)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Non-Interstate Divided (Freeways) (2)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Non-Interstate Undivided 3+ Lanes (3)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Non-Interstate Undivided 2 Lane (4)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Ramps (5)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

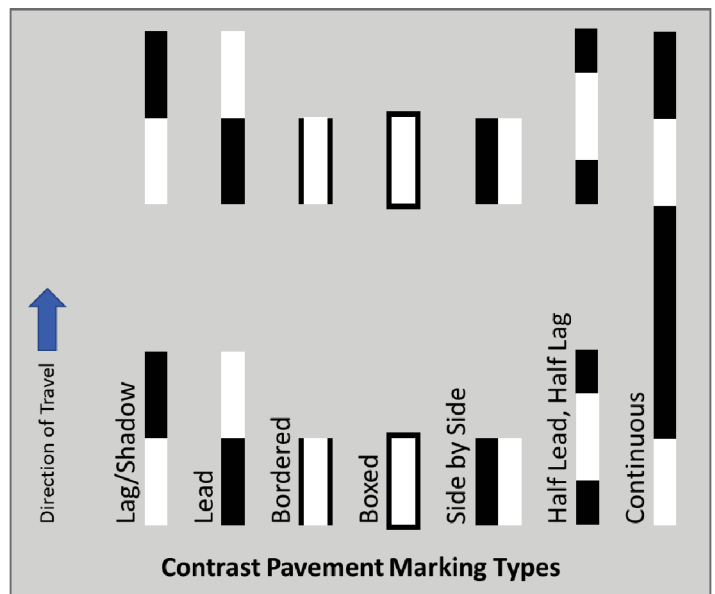
**A-6** Contrast Pavement Markings Practices

Q11. Does your agency use any of the following criteria to identify where contrast pavement markings are installed? (select all that apply)

- Annual Average Daily Traffic (AADT) (traffic volume levels) (1)
- Concrete Pavement Bridge Decks (Concrete bridge decks on Asphalt Roads) (2)
- Non-Traditional Pavement Surfaces (micro-surface and chip seals) (3)
- Remaining Roadway Service Life (4)
- Crash History (5)
- Long-Life Marking Materials (plural components, thermoplastic, tape, etc.) (6)

Q12. What contrast marking types are currently used by your agency? Based on the figure below (select all that apply).

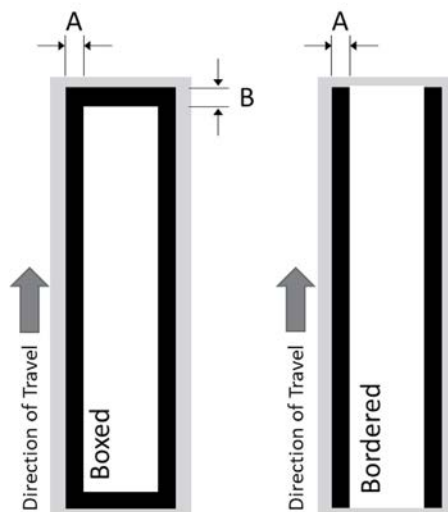
- Lag/Shadow (1)
- Lead (2)
- Bordered (3)
- Boxed (4)
- Side by Side (5)
- Half Lead, Half Lag (6)
- Continuous (7)
- Other (please specify) (8) \_\_\_\_\_



Q13. Has your agency used different contrast marking types in the past?

- No (1)
- Yes (what types based on the figure above, and why did this change?) (2)

Q14.1. If your agency uses either Boxed or Bordered contrast markings, as shown here, please provide the dimensions for both measurements "A" and "B" (in inches) specific to a **4-inch wide** pavement marking.



- Boxed:** Dimension "A" (in inches) (1)  
\_\_\_\_\_
- Boxed:** Dimension "B" (in inches) (2)  
\_\_\_\_\_
- Bordered:** Dimension "A" (in inches) (3)  
\_\_\_\_\_

Q14.2. If your agency uses either Boxed or Bordered contrast markings, as shown here, please provide the dimensions for both measurements "A" and "B" (in inches) specific to a **6-inch wide** pavement marking.

- Boxed:** Dimension "A" (in inches) (1)  
\_\_\_\_\_
- Boxed:** Dimension "B" (in inches) (2)  
\_\_\_\_\_
- Bordered:** Dimension "A" (in inches) (3)  
\_\_\_\_\_

## A-8 Contrast Pavement Markings Practices

Q15. Does your agency install contrast markings on the surface or within a recessed groove?

- Only Surface applied (1)
- Only Recessed (within a groove) (2)
- Both Surface applied and Recessed (3)
- Other (please specify) (4) \_\_\_\_\_

Q16. Does your agency have installation requirements specific to how black contrast markings are installed? (select all that apply)

- Yes, we require a 3-tank truck to apply at the same time with the same controller sequencing (1)
- Yes, we require the black contrast marking to be applied separately from the other markings (2)
- No, this is left up to the Contractor (3)
- Other (please specify) (4) \_\_\_\_\_

Q17. Does your agency specify the type of anti-skid materials used for the black contrast marking?

- Yes (1)
- No (2)
- Anti-skid materials are not used (3)
- Other (please specify) (4) \_\_\_\_\_

Q18. Identify the types of pavement marking materials used for contrast markings. (select all that apply)

- Waterborne (1)
- Plural Component (2)
- Thermoplastic (3)
- Tape (4)
- Other (please specify) (5) \_\_\_\_\_

Q19. Does your agency use the same pavement marking material for the contrast marking as is used for the adjacent white or yellow pavement marking?

- Yes (1)
- No, (please specify) (2) \_\_\_\_\_
- Sometimes (please explain) (3) \_\_\_\_\_

Q20. Does your agency track the cost for the installation of contrast markings?

- Yes, (please provide the percent of extra cost required for contrast compared to the same non-contrast markings) (1) \_\_\_\_\_
- No (2)

Q21. Does your agency specify a maximum retroreflectivity threshold for contrast markings?

- Yes, (provide value in millicandela per meter squared per lux) (1) \_\_\_\_\_
- No (2)

## A-10 Contrast Pavement Markings Practices

Q22. Does your agency specify the color box (black) requirements for contrast markings?

- Yes (1)
- No (2)

Q23. What are your agency practices in terms of maintaining pavement markings with contrast? (select all that apply)

- Stripe over (both marking and contrast markings) (1)
- Remove and Replace (both marking and contrast markings) (2)
- Replace the white/yellow (remove and replace or stripe over) (3)
- Replace the contrast marking (4)
- Other (please specify) (5) \_\_\_\_\_

Q24. Does your agency collect data on contrast marking durability (presence)?

- Yes (1)
- No (2)

Q25. Does the type of contrast marking used (Lag, Box, Bordered, etc.) impact durability?

- Yes (1)
- No (2)
- Other (please specify) (3) \_\_\_\_\_

Q26. Has your agency conducted any of the below studies? (select all that apply)

- Safety impact of contrast markings (1)
- Public opinion of contrast markings (2)
- Long-term performance of contrast markings (3)
- Comparison of different contrast marking types (4)
- Other (please specify) (5) \_\_\_\_\_

Q27. Does your agency have a specification for contrast pavement markings?

- No (1)
- Yes (Please provide a link) (2) \_\_\_\_\_





# Agency Survey Responses

## Survey participants:

1. Alaska Department of Transportation and Public Facilities
2. Arizona Department of Transportation
3. Arkansas Department of Transportation
4. California Department of Transportation
5. Colorado Department of Transportation
6. Connecticut Department of Transportation
7. Delaware Department of Transportation
8. District of Columbia Department of Transportation
9. Florida Department of Transportation
10. Hawaii Department of Transportation
11. Idaho Transportation Department
12. Illinois Department of Transportation
13. Indiana Department of Transportation
14. Iowa Department of Transportation
15. Kansas Department of Transportation
16. Kentucky Transportation Cabinet
17. Louisiana Department of Transportation and Development
18. Maine Department of Transportation
19. Maryland Department of Transportation
20. Massachusetts Department of Transportation
21. Michigan Department of Transportation
22. Minnesota Department of Transportation
23. Missouri Department of Transportation
24. Nebraska Department of Transportation
25. Nevada Department of Transportation
26. New Hampshire Department of Transportation
27. New York State Department of Transportation
28. North Carolina Department of Transportation
29. Ohio Department of Transportation
30. Oklahoma Department of Transportation
31. Oregon Department of Transportation
32. Pennsylvania Department of Transportation
33. Rhode Island Department of Transportation
34. South Carolina Department of Transportation
35. South Dakota Department of Transportation
36. Tennessee Department of Transportation

**B-2** Contrast Pavement Markings Practices

37. Texas Department of Transportation
38. Utah Department of Transportation
39. Vermont Agency of Transportation
40. Virginia Department of Transportation
41. Washington State Department of Transportation
42. West Virginia Department of Transportation
43. Wisconsin Department of Transportation

State	Q1. Has your agency ever used contrast pavement markings?	Q2. Is your agency considering contrasts in the future?	Q3. Why is your agency considering contrast pavement markings?	Q4. Does your agency currently use contrast pavement markings?	Q5. Please indicate why contrast pavement markings were discontinued
AK	No	No			
AR	Yes			No	Additional Cost
AZ	Yes			Yes	
CA	Yes			Yes	
CO	Yes			Yes	
CT	Yes			Yes	
DC	Yes			Yes	
DE	Yes			Yes	
FL	Yes			Yes	
HI	Yes			Yes	
IA	Yes			Yes	
ID	No	Yes	Improved Daytime Visibility (Safety)		
IL	Yes			Yes	
IN	Yes			Yes	
KS	Yes			Yes	
KY	Yes			No	Very few concrete pavements
LA	Yes			Yes	
MA	Yes			Yes	
MID	Yes			Yes	
ME	No	No			
MI	Yes			Yes	
MN	Yes			Yes	
MO	Yes			Yes	
NC	Yes			Yes	
NE	Yes			Yes	
NH	Yes			No	Durability issues and additional cost
NV	Yes			Yes	
NY	Yes			Yes	
OH	Yes			Yes	
OK	Yes			Yes	
OR	Yes			Yes	
PA	Yes			Yes	
RI	No	No			
SC	Yes			Yes	
SD	Yes			Yes	
TN	Yes			Yes	
TX	Yes			Yes	
UT	Yes			Yes	
VA	Yes			Yes	
VT	Yes			No	Budget and installation complexity
WA	Yes			Yes	
WI	Yes			Yes	
WV	Yes			Yes	

**B-4** Contrast Pavement Markings Practices

The remaining tables are only for the agencies that currently use contrast pavement markings (35 agencies).

State	Q6. My agency installs contrast pavement markings based on	Q7. How long has your agency been using contrast pavement markings?	Q8. Why does your agency use contrast pavement markings?		
			Improved Daytime Visibility (Safety)	Autonomous Vehicles Operations	Both
AZ	Specific Projects	3 years	X		
CA	Specific Projects	6 or more years			X
CO	Specific Projects	6 or more years	X		
CT	Specific Projects	6 or more years	X		
DC	Specific Projects	6 or more years	X		
DE	Statewide policy	6 or more years	X		
FL	Statewide policy	6 or more years	X		
HI	Specific Projects	6 or more years	X		
IA	Specific Projects	3 years			X
IL	Specific Projects	5 years	X		
IN	Specific Projects	1 year	X		
KS	Specific Projects	6 or more years			X
LA	Statewide policy	6 or more years	X		
MA	Statewide policy	6 or more years	X		
MD	Statewide policy	6 or more years	X		
MI	Statewide policy	6 or more years			X
MN	Statewide policy	6 or more years	X		
MO	Statewide policy	6 or more years	X		
NC	Specific Projects	6 or more years	X		
NE	Specific Projects	6 or more years	X		
NV	Specific Projects	6 or more years	X		
NY	Specific Projects	6 or more years	X		
OH	Specific Projects	5 years	X		
OK	Statewide policy	6 or more years	X		
OR	Specific Projects	6 or more years	X		
PA	Statewide policy	6 or more years	X		
SC	Specific Projects	6 or more years	X		
SD	Specific Projects	6 or more years	X		
TN	Specific Projects	5 years			X
TX	Statewide policy	6 or more years	X		
UT	Statewide policy	6 or more years			X
VA	Statewide policy	6 or more years	X		
WA	Specific Projects	6 or more years			X
WI	Statewide policy	6 or more years	X		
WV	Statewide policy	6 or more years	X		

State	Q9. What categories of projects have contrast pavement markings?			
	New construction	Restriping (on existing road surfaces)	Retrofitting (adding contrast to existing markings)	Other
AZ	X			
CA	X	X		
CO	X	X		
CT	X	X		
DE	X	X	X	
DC	X	X		
FL	X	X		
IL	X	X		
IN	X			
IA	X	X		
KS	X	X		
LA	X	X		
MD	X	X		
MA	X			
MI	X		X	
MO	X			
MN	X	X		
NC	X	X		
NE	X	X		
NV	X			
NY		X		
OH	X	X	X	
OK	X	X		
OR	X	X	X	
PA				
SC	X	X		
SD	X		X	
HI			X	
TX	X	X	X	
TN				Special Projects
UT	X	X	X	
VA	X			
WA	X			
WI	X	X		
WV		X	X	

**B-6** Contrast Pavement Markings Practices

State	Where does your agency apply contrast markings on the Interstate?						
	Roadway Settings		Pavement Type		Line Type		
	Urban	Rural	Asphalt	Concrete	Broken Lane Lines	Edge Lines	Dotted Line
AZ				X	X		
CA	X	X		X	X		X
CO	X			X	X		X
CT	X	X		X	X		X
DC				X			X
DE	X	X		X	X	X	X
FL	X	X		X	X		X
HI	X	X		X	X		
IA	X	X	X	X	X		
IL	X	X		X	X	X	X
IN	X			X	X	X	X
KS	X	X		X	X		X
LA	X	X		X	X		
MA				X	X	X	
MD				X	X		X
MI	X	X		X	X		X
MN	X	X		X	X		X
MO	X	X		X	X		X
NC	X	X		X	X		
NE	X	X		X	X		
NV				X	X	X	
NY	X			X			X
OH	X	X		X	X		
OK	X	X		X	X		X
OR				X	X		X
PA	X	X		X	X		
SC	X	X		X	X		
SD	X	X		X	X		X
TN	X	X		X	X	X	X
TX				X	X		
UT	X	X		X	X		X
VA	X	X		X	X	X	X
WA	X			X	X		
WI	X	X	X	X	X		X
WV	X	X		X	X		

State	Where does your agency apply contrast markings on Non-Interstate Divided (Freeways)?						
	Roadway Settings		Pavement Type		Line Type		
	Urban	Rural	Asphalt	Concrete	Broken Lane Lines	Edge Lines	Dotted Line
AZ	X			X	X		
CA	X	X		X	X		X
CO							
CT	X	X		X	X		X
DC				X			X
DE	X	X		X	X	X	X
FL	X	X		X	X		X
HI							
IA							
IL	X	X		X	X	X	X
IN	X			X	X	X	X
KS	X	X		X	X		X
LA	X	X		X	X		
MA				X	X	X	
MD				X	X		X
MI	X	X		X	X		X
MN	X	X		X	X		X
MO	X	X		X	X		X
NC	X	X		X	X		
NE	X	X		X	X		
NV				X	X	X	
NY							
OH	X	X		X	X		
OK	X			X	X		X
OR							
PA	X	X		X	X		
SC							
SD	X	X		X	X		X
TN	X	X		X	X	X	X
TX				X	X		
UT	X	X		X	X		X
VA	X	X		X	X	X	X
WA	X			X	X		
WI	X	X	X	X	X		X
WV	X	X		X	X		



**B-8** Contrast Pavement Markings Practices

State	Where does your agency apply contrast markings on Non-Interstate Undivided (3+ Lanes)?						
	Roadway Settings		Pavement Type		Line Type		
	Urban	Rural	Asphalt	Concrete	Broken Lane Lines	Edge Lines	Dotted Line
AZ	X			X	X		
CA	X	X		X	X		X
CO	X			X	X		X
CT							
DC				X			X
DE	X	X		X	X	X	X
FL	X	X		X	X		X
HI							
IA							
IL	X	X		X	X	X	X
IN							
KS							
LA	X	X		X	X		
MA				X	X	X	
MD				X	X		X
MI	X	X		X	X		X
MN	X	X		X	X		
MO	X	X		X	X		X
NC							
NE							
NV							
NY							
OH	X	X		X	X		
OK							
OR							
PA	X	X		X	X		
SC							
SD							
TN	X	X		X	X	X	X
TX				X	X		
UT	X	X		X	X		X
VA	X	X		X	X	X	X
WA	X			X	X		
WI	X	X	X	X	X		X
WV							

State	Where does your agency apply contrast markings on Non-Interstate Undivided (2 Lanes)?						
	Roadway Settings		Pavement Type		Line Type		
	Urban	Rural	Asphalt	Concrete	Broken Lane Lines*	Edge Lines	Dotted Line
AZ							
CA	X	X		X	X		X
CO							
CT							
DC				X			X
DE	X	X		X	X	X	X
FL							
HI							
IA							
IL	X	X		X	X	X	X
IN							
KS							
LA	X	X		X	X		
MA				X	X	X	
MD				X	X		X
MI				X	X		X
MN	X	X		X	X		X
MO	X	X		X	X		X
NC							
NE							
NV							
NY							
OH							
OK							
OR							
PA							
SC							
SD							
TN	X	X		X	X	X	X
TX				X	X		
UT		X		X	X		X
VA							
WA							
WI	X	X	X	X	X		X
WV							

\* Some broken lane lines on 2-lane roads might be for the passing lane

**B-10** Contrast Pavement Markings Practices

State	Where does your agency apply contrast markings on Ramps?						
	Roadway Settings		Pavement Type		Line Type		
	Urban	Rural	Asphalt	Concrete	Broken Lane Lines	Edge Lines	Dotted Line
AZ							
CA	X			X	X		
CO	X			X			X
CT							
DC				X			X
DE	X	X		X	X	X	X
FL	X	X		X	X		X
HI							
IA							
IL	X	X		X	X	X	X
IN							
KS	X	X		X	X		X
LA							
MA				X	X	X	
MD				X	X		X
MI				X	X		X
MN							
MO	X	X		X	X		X
NC							
NE							
NV				X			
NY							
OH	X	X		X	X		
OK	X				X		
OR							
PA							
SC	X	X		X	X		
SD	X	X		X	X		X
TN	X	X		X	X	X	X
TX							
UT	X	X		X	X		X
VA	X	X		X	X	X	X
WA							
WI							
WV							

State	Q11. Does your agency use any of the following criteria to identify where contrast pavement markings are installed?					
	AADT	Concrete bridge decks on Asphalt Roads	On Micro-surface and Chip seals	Remaining Roadway Service Life	Crash History	Long-Life Marking Materials
AZ	X					X
CA						
CO	X	X				
CT		X				
DC		X				
DE		X				
FL		X				
HI						
IA						X
IL						
IN	X			X		X
KS				X		X
LA	X					
MA		X				
MD		X				
MI						X
MN		X				X
MO		X				
NC						X
NE				X		X
NV						
NY						
OH						
OK		X				X
OR						
PA		X				X
SC		X				X
SD						
TN					X	
TX						
UT						
VA	X	X				
WA	X	X		X	X	X
WI	X			X		X
WV	X	X				

**B-12** Contrast Pavement Markings Practices

State	Q12. What contrast marking types are currently used by your agency?							
	Lag/Shadow	Lead	Bordered	Boxed	Side by Side	Half Lead/Lag	Continuous	Other (please specify)
AZ			X					
CA		X	X					
CO	X		X					
CT			X					
DC			X	X				
DE	X		X		X			
FL	X							
HI		X						
IA	X							
IL			X					
IN	X		X					
KS	X							
LA	X		X					
MA			X					
MD			X					
MI	X							
MN			X					
MO			X					
NC	X		X					
NE	X							
NV			X					
NY	X							
OH	X		X	X				
OK	X							
OR	X			X				
PA	X							
SC	X		X					
SD			X					
TN	X		X					Lag/Shadow on broken lane lines
TX	X		X					Bordered with Lag
UT	X		X	X		X	X	
VA			X					
WA	X							
WI			X					
WV		X						

State	Q13. Has your agency used different contrast marking types in the past?	Q14.1. If your agency uses either Boxed or Bordered contrast markings provide the dimensions for 4-inch wide pavement markings	Q14.2. If your agency uses either Boxed or Bordered contrast markings provide the dimensions for 6-inch wide pavement markings
AZ	No	Bordered: 2.0 inches	Bordered: 2.0 inches
CA	No		Bordered: 2.0 inches
CO	No		Bordered: 1.5 inches
CT	No		Bordered: 1.5 inches
DC			
DE	Yes		Bordered: 1.5 inches
FL	No		
HI	No		
IA	No		
IL	No	Bordered: 1.5 inches	Bordered: 1.5 inches
IN	No	Bordered: 1.5 to 2.0 inches	Bordered: 1.5 to 2.0 inches
KS	Yes. Bordered. Groove width took additional time and work which increased the cost to install Patterned Cold Plastic Tape.		Bordered: 2.0 inches
LA	No	Bordered: 1.5 inches	Bordered: 1.5 inches
MA	Yes. Lag/Shadow	Bordered: 1.5 inches	Bordered: 1.5 inches
MD	No	Bordered: 1.5 inches	Bordered: 1.5 inches
MI	Yes. Tried Bordered. Contrast could not be maintained when we striped over the white marking at the end of its service life.		
MN	Yes. Lag/Shadow	Bordered: 1.5 inches	Bordered: 1.5 to 2.0 inches
MO	No	Bordered: 1.5 inches	Bordered: 1.5 inches
NC	No	Bordered: 1.5 inches	Bordered: 1.5 inches
NE	Yes. Bordered: Moved away from it due to cost.	Bordered: 1.0 inches	Bordered: 1.0 inches
NV	No		
NY	No		
OH	No		Boxed and Bordered: 1.5 inches
OK	No		
OR		Bordered: 1.0 inches	
PA	No		
SC	No		Bordered: 1.5 inches
SD	No	Bordered: 1.5 inches	
TN	Yes		Bordered: 1.5 inches
TX	No	Bordered: 1.5 inches	Bordered: 2.0 inches
UT	Yes		
VA	No	Bordered: 1.5 inches	Bordered: 1.5 inches
WA	Yes. Lead and Bordered		
WI	No	Bordered: 1.5 inches	
WV	Yes. Bordered. Change based on pavement marking material being used.		Bordered: 1.5 inches

State	Q15. Does your agency install contrast markings on the surface or within a recessed groove?	Q16. Does your agency have installation requirements specific to how black contrast markings are installed?	Q17. Does your agency specify the type of anti-skid materials used for the black contrast marking?
AZ	Only Surface applied		
CA	Both Surface applied and Recessed	Yes, we require the black contrast marking to be applied separately from the other markings.	No
CO	Only Recessed (within a groove)	No, this is left up to the Contractor	Yes
CT	Only Recessed (within a groove)	No, this is left up to the Contractor	No
DC	Only Surface applied	Yes, we require the black contrast marking to be applied separately from the other markings	No
DE	Only Surface applied	Yes, we require the black contrast marking to be applied separately from the other markings	Yes
FL	Only Surface applied	No, this is left up to the Contractor	Anti-skid materials are not used
HI	Only Surface applied	No, this is left up to the Contractor	No
IA	Only Recessed (within a groove)	No, this is left up to the Contractor	No
IL	Only Recessed (within a groove)		Yes
IN	Only Recessed (within a groove)		No
KS	Only Recessed (within a groove)	Yes, we require a 3-tank truck to apply at the same time with the same controller sequencing	Yes
LA	Only Surface applied	No, this is left up to the Contractor	Yes
MA	Only Recessed (within a groove)	No, this is left up to the Contractor	Anti-skid materials are not used
MD	Only Surface applied		Yes
MI	Both Surface applied and Recessed	No, this is left up to the Contractor	Anti-skid materials are not used
MN	Only Recessed (within a groove)	No, this is left up to the Contractor	No
MO	Both Surface applied and Recessed	No, this is left up to the Contractor	Anti-skid materials are not used
NC	Only Surface applied	No, this is left up to the Contractor	Anti-skid materials are not used
NE	Only Recessed (within a groove)	Yes, we require a 3-tank truck to apply at the same time with the same controller sequencing	Yes
NV	Both Surface applied and Recessed	No, this is left up to the Contractor	No
NY	Only Surface applied	No, this is left up to the Contractor	Yes
OH	Only Surface applied	No, this is left up to the Contractor	No
OK	Only Surface applied	No, this is left up to the Contractor	No
OR	Both Surface applied and Recessed	No, this is left up to the Contractor	
PA	Both Surface applied and Recessed	No, this is left up to the Contractor	Yes
SC	Only Surface applied	No, this is left up to the Contractor	No
SD	Only Recessed (within a groove)	No, this is left up to the Contractor	No
TN	Only in Trial Projects		Yes
TX	Only Surface applied		No
UT	Both Surface applied and Recessed	Yes, we require the black contrast marking to be applied separately from the other markings. Tape is different.	
VA	Only Surface applied		No
WA	Only Surface applied	No, this is left up to the Contractor	No
WI	Only Recessed (within a groove)	No, this is left up to the Contractor	No
WV	Only Surface applied	No, this is left up to the Contractor	Anti-skid materials are not used

State	Q18. Identify the types of pavement marking materials used for contrast markings					Q19. Does your agency use the same pavement marking material for the contrast marking as is used for the adjacent white or yellow pavement marking?
	Waterborne	Plural Component	Thermoplastic	Tape	Other	
AZ				X		Sometimes
CA	X			X		No. All contrast stripes are waterborne paint except when using tape.
CO				X		Yes
CT				X		Yes
DC	X		X	X		
DE		X		X		Yes
FL						No
HI			X			No
IA		X				Yes
IL				X		Yes
IN				X		Sometimes
KS		X		X		Yes
LA			X	X		Sometimes
MA				X		Yes
MD				X		Yes
MI	X			X		Sometimes
MN		X	X	X		Yes
MO	X					Yes
NC	X	X		X		No. Depends on the project
NE		X				Yes
NV						Yes
NY		X				Yes
OH	X	X	X	X		Yes
OK		X				Yes
OR	X			X		Yes
PA	X	X				Yes
SC		X		X		Yes
SD			X	X		Yes
TN			X	X	Spray Thermo for retrofits	Yes
TX			X	X	Prefabricated for Bordered	Yes
UT	X			X		
VA				X		Yes
WA	X			X		Sometimes
WI		X		X		Yes
WV	X					No



**B-16** Contrast Pavement Markings Practices

State	Q20. Does your agency track the cost for the installation of contrast markings?	Q21. Does your agency specify a maximum retroreflectivity threshold for contrast markings?	Q22. Does your agency specify the color box (black) requirements for contrast markings?
AZ	Yes	No	No
CA	No	No	Yes
CO	Yes	No	No
CT	Yes	No	No
DC	Yes	No	
DE	No	No	No
FL	No	No	No
HI	No	No	No
IA	No	No	No
IL	Yes (50 to 75 %)	No	No
IN	Yes (22 %)	No	No
KS	Yes (50 %)		No
LA	No	No	No
MA	No	No	No
MD	Yes	No	No
MI	Yes (50 %)	No	No
MN	Yes (200 %)	No	No
MO	No	No	No
NC	No	Yes. Black is required to be non retroreflective	No
NE	Yes	No	Yes
NV	No	No	Yes
NY	No	No	No
OH	No	No	No
OK	No	No	No
OR	No	No	No
PA	No	No	Yes
SC	Yes	No	No
SD	Yes (200% for Tape, 27 % for Thermoplastic)	No	No
TN	No	No	Yes
TX	Yes (65% for 4" 80% for 6")	No	Yes
UT		No	
VA	Yes (45 %)	No	No
WA	Yes	Yes. Black is required to be non retroreflective	No
WI	No	No	No
WV	No	No	No

State	Q23. What are your agency practices in terms of maintaining pavement markings with contrast?				
	Stripe over (both marking and contrast markings)	Remove and Replace (both marking and contrast markings)	Replace the white/yellow	Replace the contrast marking	Other
AZ				X	
CA	X				
CO		X			
CT					
DC		X			
DE	X	X	X		
FL	X	X	X		
HI				X	
IA	X				
IL				X	
IN			X		
KS		X			
LA		X			Since we only use contrast on PCCP, markings must be removed and replaced
MA		X		X	
MD	X		X	X	
MI			X		
MN		X	X		
MO			X		MoDOT does not have a policy to maintain contrast markings
NC		X		X	
NE		X			
NV			X		
NY	X				
OH	X		X		
OK	X	X			
OR			X		
PA	X		X	X	
SC		X			
SD		X			
TN					We do not specify
TX	X	X	X	X	
UT					Depends on material and if the materials are inlaid
VA			X		When contrast tape is aged
WA			X		
WI	X	X	X		
WV	X				

**B-18** Contrast Pavement Markings Practices

State	Q24. Does your agency collect data on contrast marking durability (presence)?	Q25. Does the type of contrast marking used (Lag, Box, Bordered, etc.) impact durability?
AZ	Yes	Yes
CA	No	No
CO	Yes	Yes
CT	No	
DC	No	No
DE	No	No
FL	No	No
HI	No	No
IA	No	No
IL	No	Not Applicable
IN	No	Not Applicable
KS	No	Yes
LA	No	Not Applicable
MA	No	No
MD	Yes	Not Applicable
MI	No	
MN	No	No
MO	No	No
NC	Yes	
NE	No	No
NV	No	No
NY	No	
OH	No	
OK	No	
OR	No	No
PA	No	
SC	No	No
SD	No	No
TN	No	No
TX	No	No
UT	No	
VA	No	No
WA	Yes	Yes
WI	No	
WV	No	No

State	Q26. Has your agency conducted any of the below studies?				
	Safety impact of contrast markings	Public opinion of contrast markings	Long-term performance of contrast markings	Comparison of different contrast marking types	Other
AZ		X			Annual evaluation through Maintenance
CA				X	
CO			X		
CT					
DC					
DE					
FL					
HI					
IA					
ID					
IL	X				
IN	X			X	
KS		X		X	
KY					
LA					
MA			X		
MD					
ME					
MI					
MN					
MO					
NC					
NE					
NH					
NV					
NY					
OH					
OK					
OR					
PA					
RI					
SC					
SD					
TN				X	
TX					
UT					
VA					
VT					
WA					
WI					
WV					





## APPENDIX C

## CPM Specification Links

The links provided below are as they were conveyed in the survey and may not work as time goes by.

California:

<https://dot.ca.gov/-/media/dot-media/programs/design/documents/rss-a04-15-22-2018-a11y.pdf>  
(Section 84)

Colorado:

<https://www.codot.gov/business/designsupport/cdot-construction-specifications/2021-construction-specifications/2021-specs-book/2021-division-700>

Illinois:

<https://public.powerdms.com/IDOT/documents/1945348/Standard%20Specifications%20for%20Road%20and%20Bridge%20Construction%202022> (See Sections 780 and 1095 for Pavement Markings)

Iowa:

[https://iowadot.gov/specifications/dev\\_specs/2015/DS-15097.pdf](https://iowadot.gov/specifications/dev_specs/2015/DS-15097.pdf)

Kansas:

<https://www.ksdot.org/Assets/wwwksdotorg/bureaus/burConsMain/specprov/2015/PDF/15-08020-r01.pdf>

Michigan:

<https://mdotjboss.state.mi.us/TSSD/getTSDocument.htm?docGuid=34acbe4b-97a7-425f-8351-9e172f726bbf&fileName=PAVE-906-C.pdf>

Missouri:

[https://www.modot.org/sites/default/files/documents/2022%20Missouri%20Standard%20Specific%20-%20MHTC%20%28Jul%202022%29\\_final.pdf](https://www.modot.org/sites/default/files/documents/2022%20Missouri%20Standard%20Specific%20-%20MHTC%20%28Jul%202022%29_final.pdf) (See section 620.60)

Pennsylvania:

- <https://www.dot.state.pa.us/public/PubsForms/Publications/Pub%2046.pdf>
- <https://www.dot.state.pa.us/public/PubsForms/Publications/PUB%20111.pdf>
- [https://www.dot.state.pa.us/public/PubsForms/Publications/Pub\\_408/408\\_2020/408\\_2020.pdf](https://www.dot.state.pa.us/public/PubsForms/Publications/Pub_408/408_2020/408_2020.pdf)

Tennessee:

<https://www.tn.gov/content/dam/tn/tdot/construction/special-provisions/Const-716CPM.pdf>



*Abbreviations and acronyms used without definitions in TRB publications:*

A4A	Airlines for America
AAAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI-NA	Airports Council International-North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FAST	Fixing America's Surface Transportation Act (2015)
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
GHSA	Governors Highway Safety Association
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S. DOT	United States Department of Transportation



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ISBN 978-0-309-69923-5



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