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The Use of Raised Pavement Markings in Work Zone Applications – A Synthesis of Practice

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Abstract

Delineation of proper driving path to drivers is of significant importance in work zones, especially at nighttime or during inclement weather. With significant highway reconstruction under progress across the US and emphasis on getting the work done quickly, work zones with overnight lane closures are becoming common. Raised pavement markings (RPMs) coated with retro-reflective material offer increased visibility during nighttime and inclement weather, thereby potentially improving work zone safety. The use of RPMs in work zones appears to vary among state transportation agencies in work zones. A review and synthesis of practice for the application of RPMs in work zones was conducted via a survey to provide guidance on the use of RPMs in workzones.

The survey indicated that 40% of the responding DOTs use MUTCD specifications for the use of RPMs in workzones. The remaining 60% of the responding agencies have developed their own, more-specific, guidelines for RPM usage. However, there are differences in the specifications developed by the 60% of responding agencies. These differences are most likely the result of differences in agency needs and cost of RPMs. The research team recommends that transportation agencies that do not have specifications developed for RPM usage in workzones as yet, use the MUTCD specifications for RPM usage as a base-line. This will bring about some level of uniformity in RPM usage in workzones. Manufacturer recommendations, if different than MUTCD, can be compared and the more stringent set of specifications adopted for RPM usage in workzones. The information contained in this report can provide a starting point to those agencies that are interested in developing agency-specific guidelines on RPM usage in workzones.

The Use of Raised Pavement Markings in Work Zone Applications – A Synthesis of Practice

FINAL REPORT

Prepared for

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CHAPTER 1 – INTRODUCTION

1.1 Background

Delineation of proper driving path to drivers is of significant importance in work zones, especially at nighttime or during inclement weather when visibility is low. With significant highway reconstruction under progress across the US and emphasis on getting the work done quickly, work zones with overnight lane closures are becoming common. Adding to the safety issue is the growing older driver population, many of whom suffer from vision-related defects. Raised pavement markings (RPMs) coated with retro-reflective material offer increased visibility during nighttime and inclement weather, thereby potentially improving work zone safety. Some transportation agencies have started using RPMs for positive driver guidance in work zones.

1.2 Problem Statement

The use of RPMs in work zones appears to vary among state transportation agencies, especially in work zones. A review and synthesis of practice for the application of RPMs in work zones will provide guidance on provision of nighttime and inclement weather guidance to drivers in work zones using RPMs.

1.3 Research Objective

The objective of this research was to study and document the use of RPMs in work zones by different state department of transportation (DOT) agencies across the nation. Subsequent summary listing of the different practices and provision of guidance on the use of RPMs in workzones was also part of this study.

1.4 Research Methodology

The research methodology consisted of four steps. Step 1 involved conducting a literature review of published literature from various sources such as, Transportation Research Information System (TRIS), TRANSPORT database, and the Internet. Step 2 involved the development of a survey questionnaire administered via E-mail and telephone to state DOTs nationwide. The results of the questionnaire were then compiled and analyzed in the third step. In the fourth step, conclusions and recommendations based on the research results were developed as well as future research requirements identified.

1.5 Report Organization

This report consists of five chapters. This introductory chapter is followed by a chapter providing details on the literature review and information uncovered by the research team. Chapter 3 presents details of the survey questionnaire and data collection. Chapter 4 gives data analysis details while the last chapter presents the conclusions, recommendations and future research requirements.

CHAPTER 2 – LITERATURE REVIEW

Significant literature related to the advantages and disadvantages of using RPMs including rumble strips is available. However, literature on specific use of RMPs and rumble strips in work zones is sparse. This review pertaining to the delineation of work zones using RPMs including rumble strips was conducted to ascertain the extent and availability of information related to this topic. The research team conducted the literature review with specific reference to work zone applications, though some literature that is not specific to work zones but provides useful delineation guidelines is included.

2.1. Information from Reviewed Literature

According to the Manual on Uniform Traffic Control Devices (MUTCD, 2003), the needs and control of all road users through a temporary traffic control zone shall be an essential part of highway construction, utility work, maintenance operations, and management of traffic incidents. It suggests the use of rumble strips and RPMs in work zones to enhance safety and defines rumble strips and RPMs as:

Rumble strips are a series of intermittent, narrow, transverse areas of textured slightly raised or depressed road surface that are installed to alert, through noise and vibration, road users to unusual traffic conditions. *RPMs* are devices with minimum height of about 10mm (0.39 inch) mounted on or in a road surface that is intended to be used as a positioning guide or to supplement or substitute for pavement marking.

MUTCD (2003) provides standard specifications for installation of RPMs in work zones. If used to substitute for broken line segments, at least two retroreflective markers shall be placed,

one at each end of a segment 2–5 foot in length. For segments longer than 5 feet, a group of three markers shall be equally spaced at no more than N/8. The value for N for a broken or dotted line shall equal the length of one line segment plus one gap whereas for a solid line, N shall equal the N for the broken or dotted lines that might be adjacent to or might extend the solid line. The color of RPMs under both daylight and nighttime conditions shall conform to the color of the pavement marking it is substituting. The MUTCD suggests options for using RPMs as vehicle positioning guides with other longitudinal markings, supplements for other markings, and substitutes for pavement markings.

Spencer (1978) examined the use of RPMs for work zone delineation in Arkansas. The study reported that RPMs provided excellent wet weather and nighttime reflectivity and appeared to be an effective means of maintaining safe traffic flow in work zones. In a similar study conducted by Niessner (1978), the practices of nine state highway agencies concerning the use of RPMs for temporary delineation in work zones were evaluated. The nine state highway agencies reported that the RPMs provided excellent nighttime temporary delineation, particularly on wet roads. In addition, the delineation was low cost and required little or no maintenance. Niessner reported that accident reductions were recorded in two projects utilizing RPMs. Officials in the majority of the states said that they would continue to use the RPMs in work zones after the study had been concluded.

Pigman and Agent (1983) conducted an evaluation of commercially available snowplowable markers under similar traffic and snowplow operations. Five different markers as shown in Figure 2.1 were tested during a period of 16 months for both reflectivity and durability during wet and dry conditions. Two test locations consisting of four-lane divided highways were selected in Kentucky, where snowplow operations were conducted on the markers with a metal

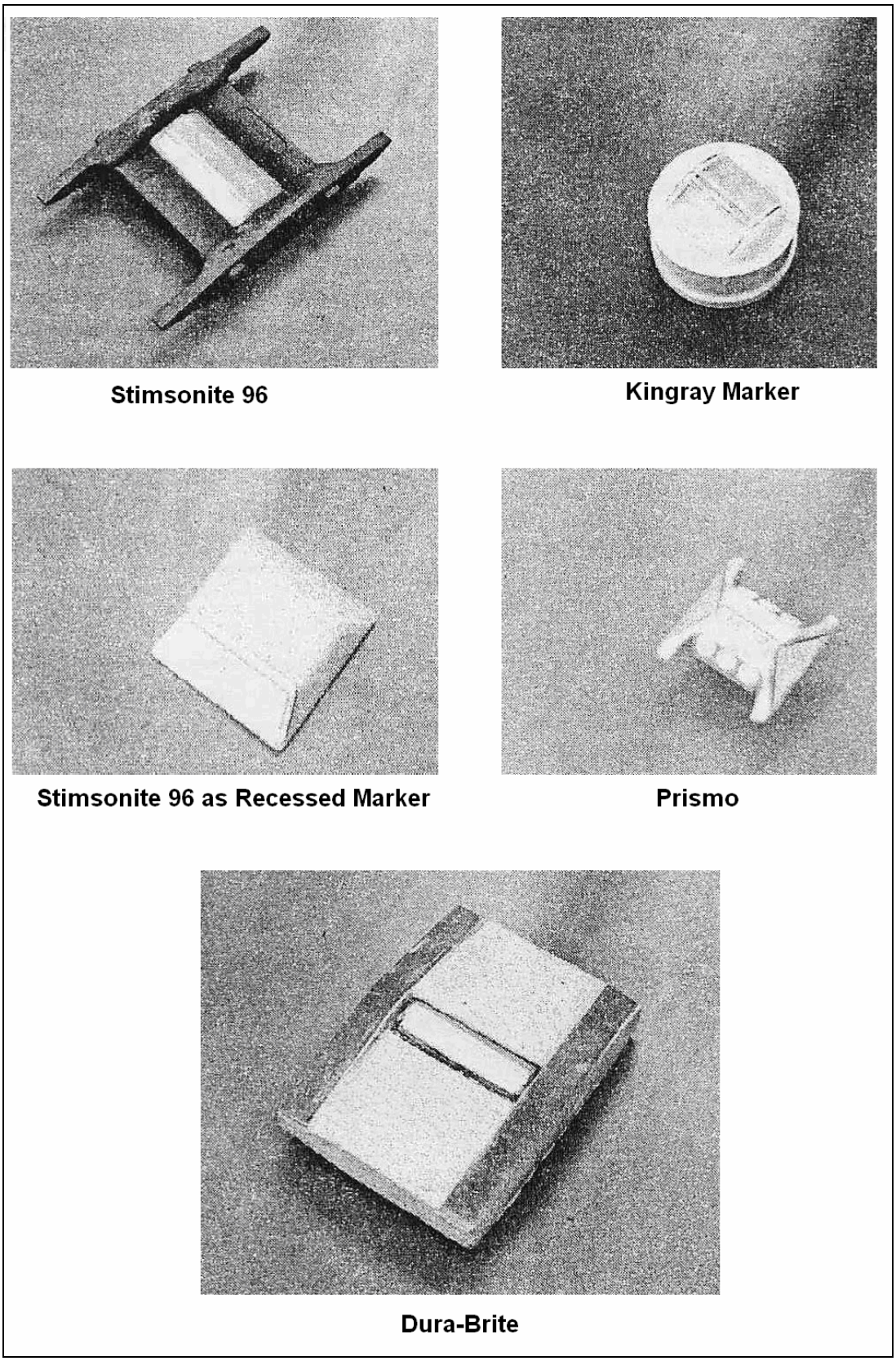

Figure 2.1. Markers tested by Pigman and Agent (1983)

plow. The markers were also tested for wear due to traffic movements. The results showed that Stimsonite 96, Dura-brite, and recessed markers were acceptable because all three maintained adequate reflectivity throughout the study period and proved durable when subjected to snowplow operations. Nevertheless, the authors recommended the recessed markers as being the most functional and cost-effective.

Davis (1986) carried out a similar study on six different types of marker to identify one that could withstand construction zone traffic as well as provide good visibility and durability. Features that met the day and night marker adequacy criteria included: a streamlined profile, a microscopic cube corner, a sealed prismatic air cell, a cube-corner reflex or multiple-glass lens reflector, and a balance between the reflector area and casing area exposed to drivers. Two of the six marker systems satisfied the criteria for selection – a hollow acrylic marker with a sealed prismatic air cell reflector such as the Stimsonite 66B by the American corporation, and a combination of a dome-shaped polyester marker such as the Titan TM-40 by Traffic Safety Supply Company for day visibility and a filled ADS shell marker with a cube-corner reflex such as the Ray-O-Lite by I.T.L. industries for night vision.

Zwahlen (1987) conducted research in which optimal spacing for raised reflective pavement markers (RRPMs) were determined along tangent sections and on interchange ramps of Interstate highways. Initially, theoretical optimal spacing was determined using photometric calculations for the tangent sections, assuming clear and slightly degraded atmospheric conditions (i.e., rain intensity of 1.0 inch/hour), and by using geometric calculations for the interchange ramps to determine maximum driver viewing distance. A field evaluation, using an instrumented car and test driver, was conducted on these theoretical optimal spacing. The tests were conducted at night on four unlit tangent sections and on four unlit interchange ramps of

Interstate 70, east of Columbus, Ohio. On the basis of the results, the author recommended a maximum RRPM spacing of 120 ft for the lane line at tangent sections of Interstate highways and no RRPMs for interchange ramps along Interstate highways.

Shepard (1990) investigated vehicle guidance through work zones by evaluating the effectiveness of two primary components of traffic control relative to delineation. First, a comparison of the steady-burn lights now used on top of temporary concrete barriers was made with experimental reflectorized panels. Second, the addition of closely spaced, RPMs as a supplement to striping was made. The study, conducted in Virginia, was limited to work zones on the Interstate and four-lane highways at locations were the roadway alignment deviated from the original alignment. Once the RPMs were installed as supplements to lane striping, vehicle speed and placement relative to the lane line next to the concrete barrier were noted. The results showed that RPMs were most effective during night/wet conditions because water significantly reduced the retroreflection capabilities of pavement striping, leaving the RPM protruding above the water as the primary source of reflected light. The author further recommended using RPMs at 4–5 foot spacing in areas with curves and/or transitions and 8–10 foot apart on tangent sections.

Rumble strips can also be an effective form of RPMs that can alert drivers to road conditions that require special attention. However, the cold-mix asphalt forms, currently used by many DOTs demand significant time and effort in their application. Meyer (2000) evaluated orange removable rumble strips for their characteristics relative to the standard asphalt rumble strips. The study conducted at a bridge repair site in Kansas, involved comparing vehicle speeds, effort necessary to install and remove the strips, and a subjective effectiveness with respect to noise and vibration from the strips as perceived by drivers of the various types of vehicles. The

results showed that the orange rumble strips were easily installed and removed. Furthermore, the strips were able to significantly reduce both the mean and 85th percentile speeds. This reduced speed was also an indication that the orange color of the strips contributed to the desired effect. The ease of installation and removal coupled with the positive effect afforded mostly by the orange color made this an appealing traffic control device for work zones.

Morgan (2003) conducted a research to verify if the specifications for rumble strips used by the New York DOT (NYDOT) met the specifications of five other DOTs. The research also examined several work zones to determine if the current NYDOT specifications were appropriate or required refinement. The specifications for rumble strips used by the five DOTs that were examined are summarized in Table 2.1. To examine if NYDOT specifications for rumble strips were adequate or required refinement, nineteen work zones fitted with various combinations of rumble strips were tested. The results indicated that the NYDOT specifications met those of the different DOTs though a small amount of refinement was required to their current specifications. Based on the results of the research, Morgan concluded that rumble strips of 10 ± 3 mm should be placed in sets of 6 that are spaced not more than 2.7 m apart and preferably at irregular intervals with spacing determined by speed limit. The installation shall follow manufacturer or department specifications and the use shall only be warranted where audible and tactile warnings are necessary.

There are a number of commercial vendors dealing in RPMs and rumble strips. These include: Hallen Products, New Century Northwest LLC, Advanced Traffic Markings (ATM) and 3M Corporation. Products that are supplied by these vendors are fairly similar in specifications and are detailed in Table 2.2.

Table 2.1. Rumble strip specifications

State DOT	Specifications
California	Uses raised asphalt strips ≤ 0.75 in. or Indented ≤ 1.0 in. They are placed across the full width of the lane.
Illinois	Uses raised high-strength Polycarbonate strips; 0.5 in. high and 3.5 in. wide with tapered edge towards the approaching traffic. They use 6 strips evenly spaced over 25 ft. placed 200 ft. before each work zone.
Pennsylvania	Uses raised 4.5 in. high and 4 in. wide asphalt strips that are placed in-situ on asphalt overlay. A set of 15-20 strips are spaced 12 in. apart extending into the shoulders. The sets are spaced intermittently at 200 ft. between sets 1 and 2; 100 ft. between sets 2, 3, and 4; and 50 ft. between 4, 5, and 6.
Kentucky	Uses raised 8 in. wide asphalt strips that are placed in sets of 10 at varied distances. The height and width depend on the speed, therefore speeds of 45 mph or less; strips are 0.25 in. to 0.38 in. and speed greater than 45 mph; strips are 0.38 in. to 0.5 in. high at 24 in. spacing. The sets are spaced placed at 1.5 mi., 1.0 mi., 0.6 mi., 0.3 mi., and 0.1 mi. distances.
Ohio	Uses raised or grooved strips both at maximum 0.5 in. high or deep. The number of strips in a set and spacing of sets both depend on the speed limit. They use 10 sets with 8 to 16 strips per set that are placed in groups of 3, 4, and then 3 more sets with varying distances of 100 ft. to 200 ft.
Indiana	Uses buzz strips (i.e. thermal plastic rumble strips)
New Mexico & South Dakota	Uses high-strength Polycarbonate material that is 3.5 in. wide and 0.5 in. high. They have an additional feature of the tapered edge not being smooth but, stepped to increase the noise. They are placed in sets of 6 at 10 in. spacing 200 ft. before the work zone.

Table 2.2. Products available from commercial vendors

Product	Specifications
1. ATM removable rumble strips 2. 3M Starmark Series 750 wet reflective tape.	Self-adhesive rubber-based strips that create visual, audible and physical alerts to drivers of a change in traffic patterns and draw attention to caution signs or road construction. Easy to install on both asphalt and concrete pavements. Strips remain visible in rain and are designed for the duration of the construction season.
3. Hallen Products Model H1010HP RRPM	Marker consists of iron casting to which is attached a replaceable 3M snowplowable marker insert for reflecting light from a single or opposite directions. The reflector features polycarbonate prismatic optics, abrasion resistant lens, and impact resistant polycarbonate body. The product is 10” long, 4.9” wide, 1.9” high, and is 0.41” above road-surface when installed.
4. Avery Denison Model 66 RRPM	Features a domed-top design which improves daytime marker conspicuity. The dome extends the extent of drivers’ line of sight.
5. New Century NORTHWEST LLC	Made of high impact material with corner-cube reflector lenses of Methylmethacrylate sonic welded within the marker. It has a reflective area of 1.5 square inches.

2.2. Literature Summary

In summary, the literature review indicated that RPMs (i.e., rumble strips and RRPMs) provide a visible, audible, and physical feature that alerts drivers to changes in traffic patterns and draws their attention to caution signs or road construction. RRPMs provide wet weather and nighttime reflectivity, thus alerting drivers to changes in road patterns at nighttime or during adverse weather. Although removable rumble strips are visible in wet and dry conditions, RRPMs have superior visibility in wet conditions. Both are easily installed and removed and can

potentially improve highway safety. While placement specifications vary among the DOTs however, the MUTCD provides some standards. Most of the literature that was reviewed discussed the advantages and disadvantages of using RPMs and little or no details on the installation of such devices.

CHAPTER 3 – SURVEY DESIGN AND DATA COLLECTION

This chapter presents details on the design of the survey questionnaire and how it was administered to collect data for this study. Also included in this chapter are details of the data collection procedure.

3.1. Survey Questionnaire Design

The survey questionnaire was intended to be administered to an individual(s) within a state DOT that was responsible for either work zone safety or the use of RPMs. The questionnaire was designed so that it can be administered by either phone or E-mail using a minimum amount of the respondents' time but getting the intended information. The questionnaire, attached in Appendix A, consisted of three parts with an estimated 20-minute completion time. The first part of the questionnaire consisted of question 1 and focused on contact and job information related to the respondent. The purpose was to maintain a record of the respondent for purposes of future communication and reference.

The second part consisted of questions 2–11 and focused on use of RPMs in work zones. The objective of this part was to determine if the responding DOT used RPMs in work zones and if so, what factors led to the decision to use RPMs. It was also necessary within this part of the survey to assess the responding agency expectations from using RPMs in work zones and whether those expectations were met. Information related to work zone safety improvements resulting from RPM usage, their advantages and disadvantages were also requested in this part of the survey.

The last part of the questionnaire consisting of questions 12–14 focused on the specifications and costs of RPM usage in work zones. The objective was to determine the specifications (i.e., type and spacing) that each responding DOT followed when using RPMs in work zones. Information on the costs of installation, maintenance, and supplying vendor was sought in this part of the survey.

3.2. Data Collection Procedure

The questionnaire was sent to forty-nine state DOTs within the US with particular attention to DOTs located in the Midwest. Data were gathered during a period of approximately two months. Collection efforts were initiated via e-mail with individual DOTs, explaining this research and asking for contact information of a person in the agency responsible for RPM usage. Once the contact person was identified in a DOT (see contact list in Appendix B), the survey questionnaire and an explanation of this research was e-mailed to that person. If no response was received in a week, a follow-up telephone call was made to the contact person to obtain response to the survey via telephone. If no reply was received after the lapse of a month, a second effort using a reminder e-mail and yet another follow-up telephone call was made. Efforts to obtain a response from each DOT that had not responded to the survey were made for approximately two months. Appendix B contains a log of the research team's efforts to solicit responses from non-responding DOTs. At the end of two months, a 39% (19/49) response rate to the survey was achieved. Figure 3.1 presents a map showing the states that responded to the survey questionnaire while Table B.1 in Appendix B lists the nineteen responding DOTs and job titles of the contact personnel providing the responses for each DOT. From Figure 3.1, it is clear that the survey achieved fairly good coverage of the nation.

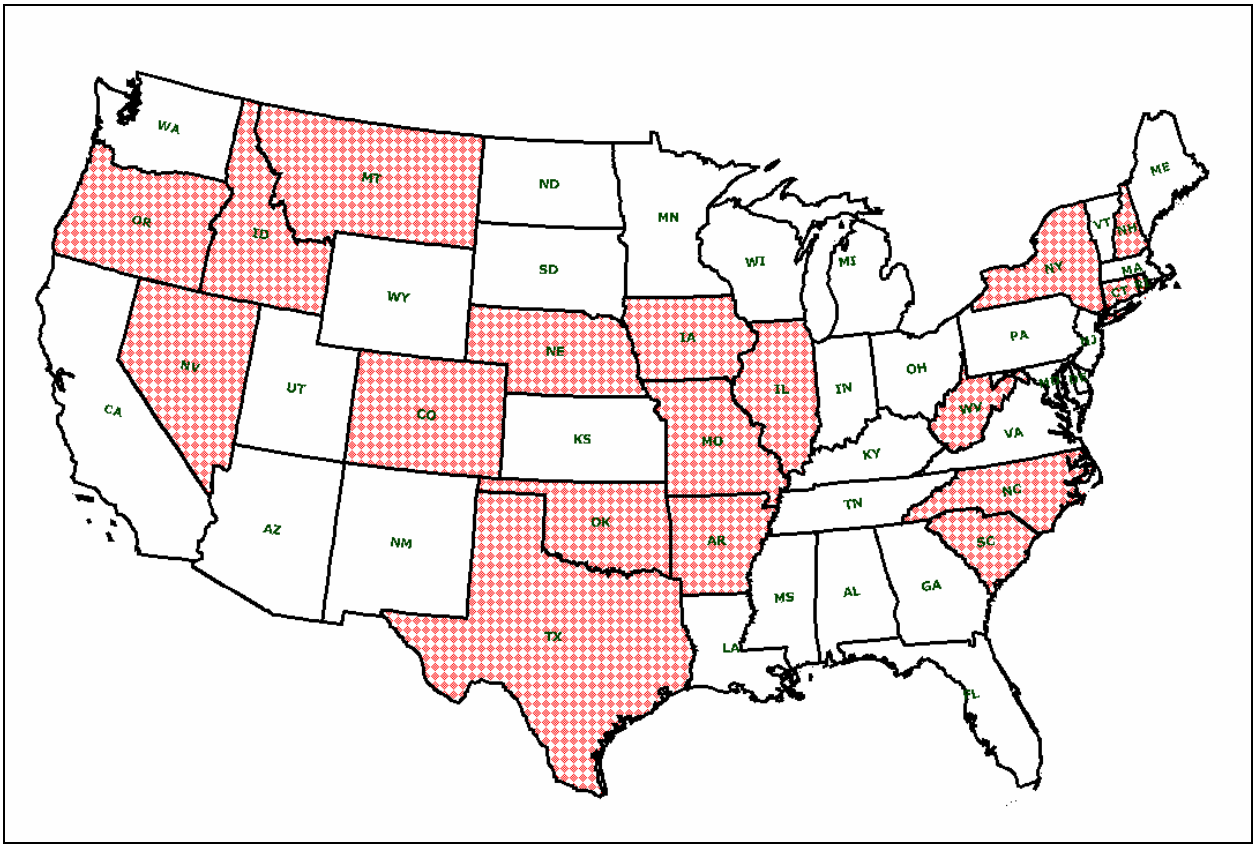

Figure 3.1. Map showing states that responded to the survey questionnaire

CHAPTER 4 – RESULTS

The responses to each questionnaire were entered into a spreadsheet, which is provided in Appendix C. Descriptive statistics, frequencies, and percentages for responses were calculated. Responses to questions 2 through 14 of the survey questionnaire are described next.

Options for answering question 2, does your agency use RPMs in work zones, were yes or no. Figure 4.1 graphically shows the responses (coded as: Yes =1 and No = 0) for each of the responding DOT. Of the responding DOTs, 79% indicated usage of RPMs in work zones.

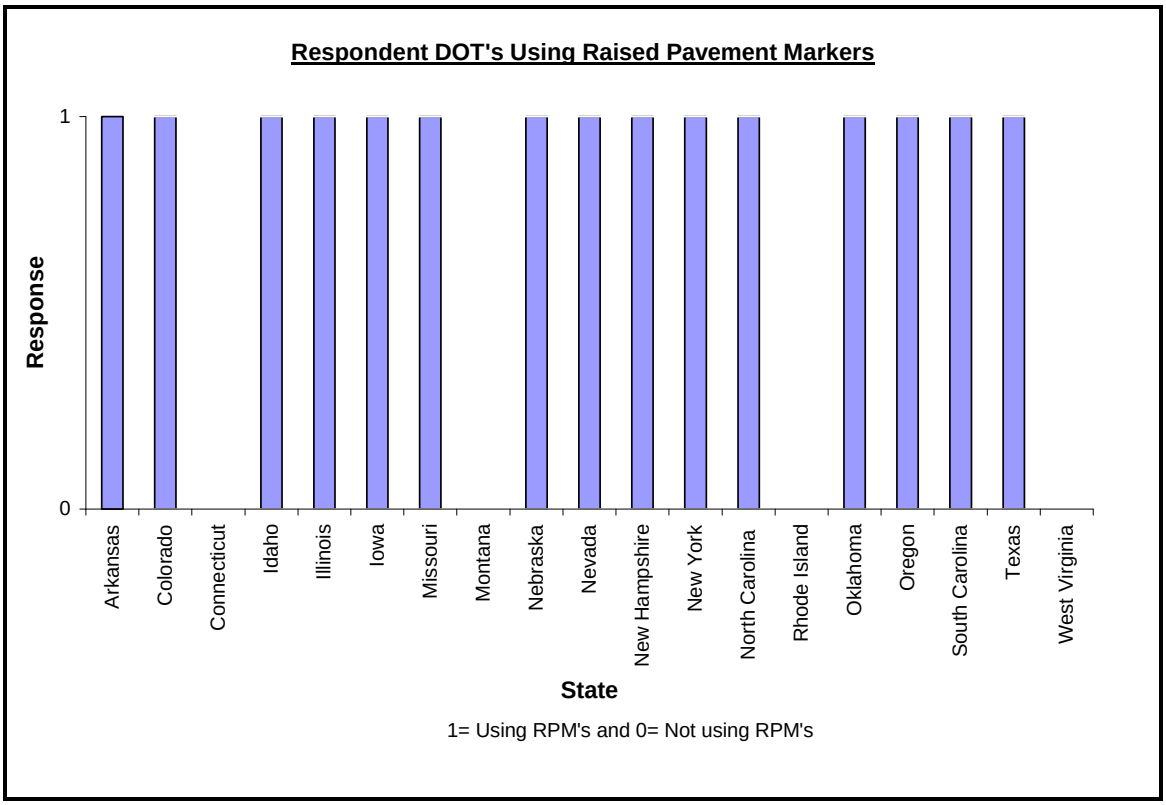

Figure 4.1. Respondent DOTs Using RPMs

DOTs that answered no to question 2 were asked if they intended to use RPMs in the future (question 3). Montana, Rhode Island, and West Virginia DOTs indicated interest in using RPMs but the respondents did not provide information on when or where RPMs would be used and which vendors they might contact for supply of RPMs. The remaining questions in the survey were asked of those that answered yes to question 2. Question 4 explored information on how a decision on implementing the use of RPMs in work zones within each state was reached. Figure 4.2 presents a summary of the responses to question 4. While field evaluations, review of technical literature and success in other agencies were reasons for some to use RPMs, most of the DOTs using RPMS in work zones indicated the decision being influenced by other elements such as, Federal Highway Administration (FHWA) or MUTCD requirements.

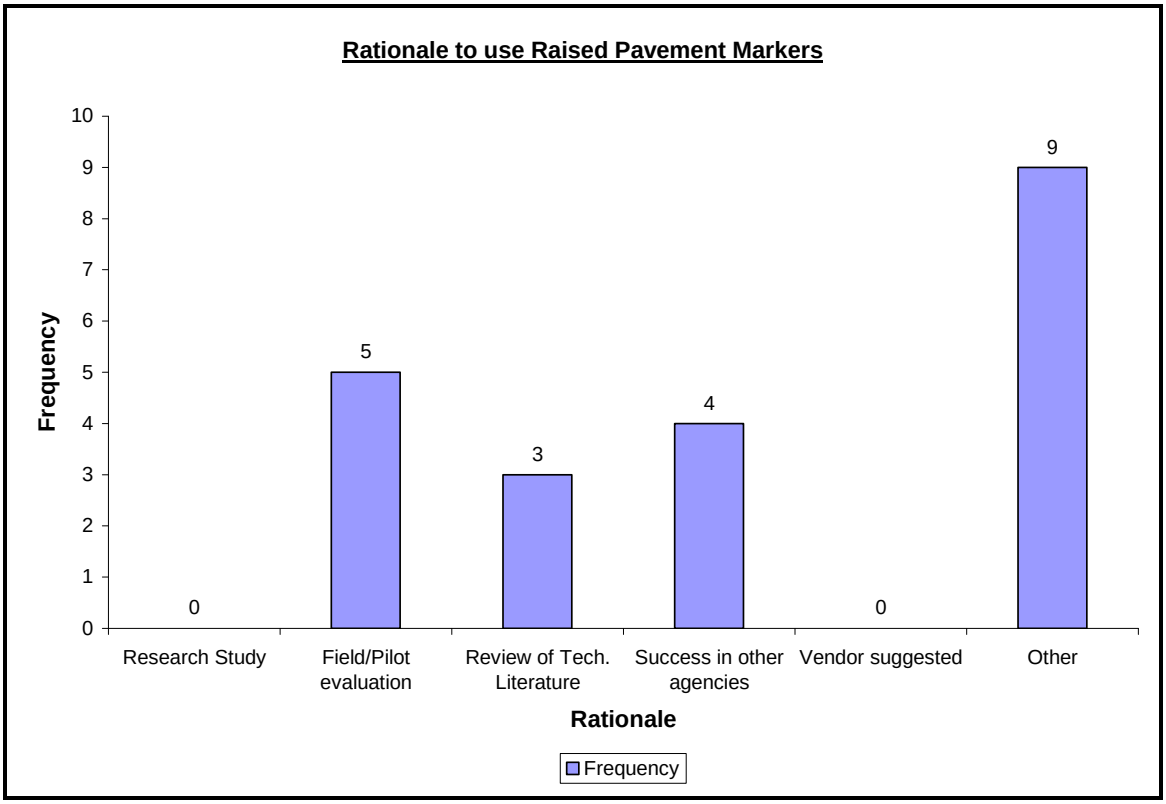

Figure 4.2. Rationale used to implement use of RPMs

In response to what kind of RPMs were being used by each DOT (question 5), 73% indicated using raised reflective markers, 7% used flexible raised pavement markers, and 20% used a combination of raised reflective markers and flexible raised pavement markers or raised reflective markers and traffic buttons. None of the DOTs indicated using rumble strips as RPMs in work zones. Figure 4.3 shows the responses in graphical from.

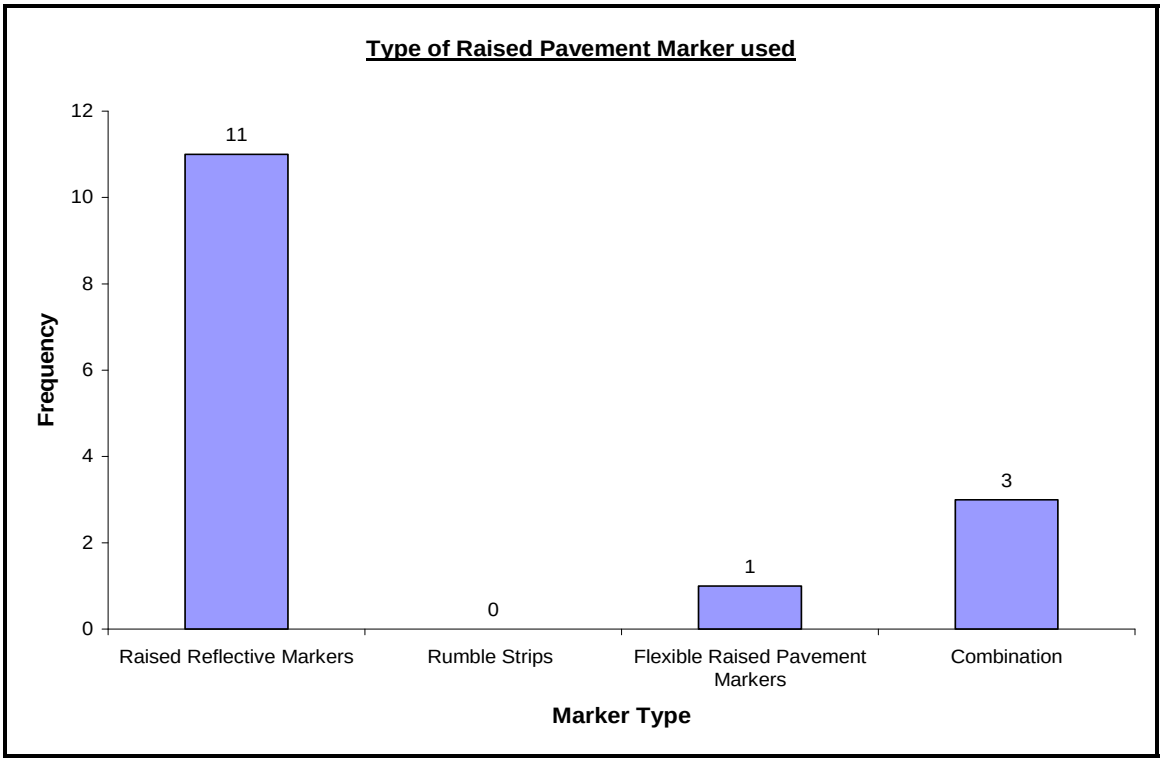

Figure 4.3. Type of RPM used

Question 6 in the survey explored the benefits that each DOT expected from implementing RPMs in work zones. Responses to this question are summarized in Figure 4.4. Most DOTs (60%) expected better delineation while 20% expected nighttime visibility improvements.

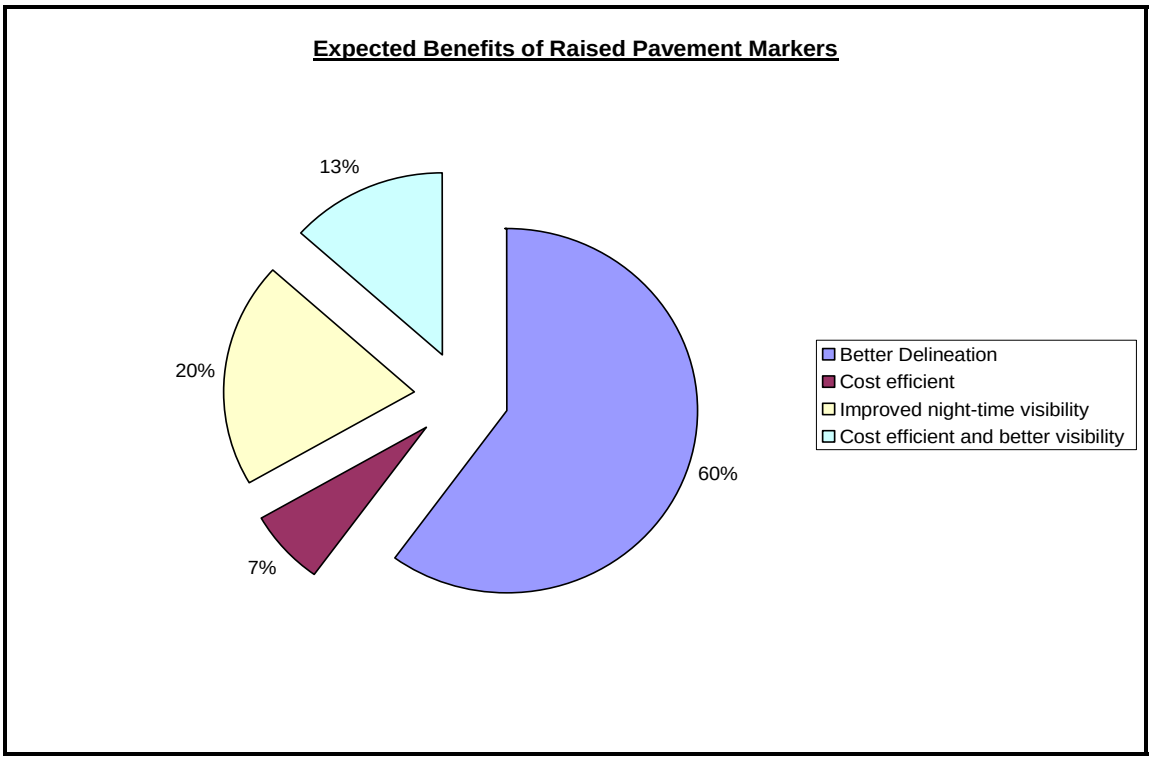

Figure 4.4. Expected benefits of using RPMs

DOTs were asked to describe differences between the expected and actual results of implementing RPMs in work zones (question 7). Figure 4.5 shows that the majority (27%) obtained results in accord with their expectations, while 20% observed RPMs more durable than their expectations, 13% observed RPMs to give better visibility, and 7% observed RPMs to perform better than lane striping.

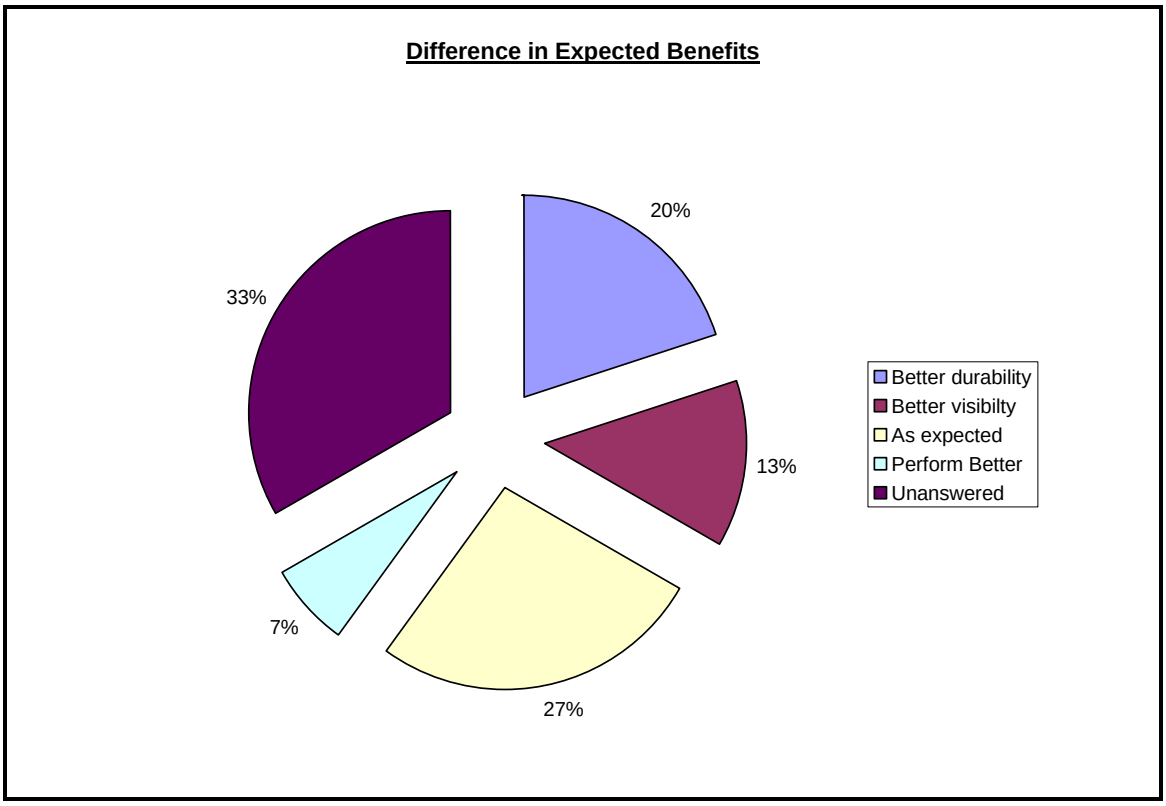

Figure 4.5. Differences in expected benefits

Question 8 asked respondents if safety changed as a result of using RPMs in work zones. Sixty percent of the respondents who had used RPMs in work zones indicated improvements in safety while 20% did not indicate safety improvements and 20% could not tell any difference. Question 9 asked how the change in safety assessed was. Figure 4.6 summarizes the responses to question 9. While 47% relied on personal observation, only 7% conducted a safety study and 13% used word of mouth.

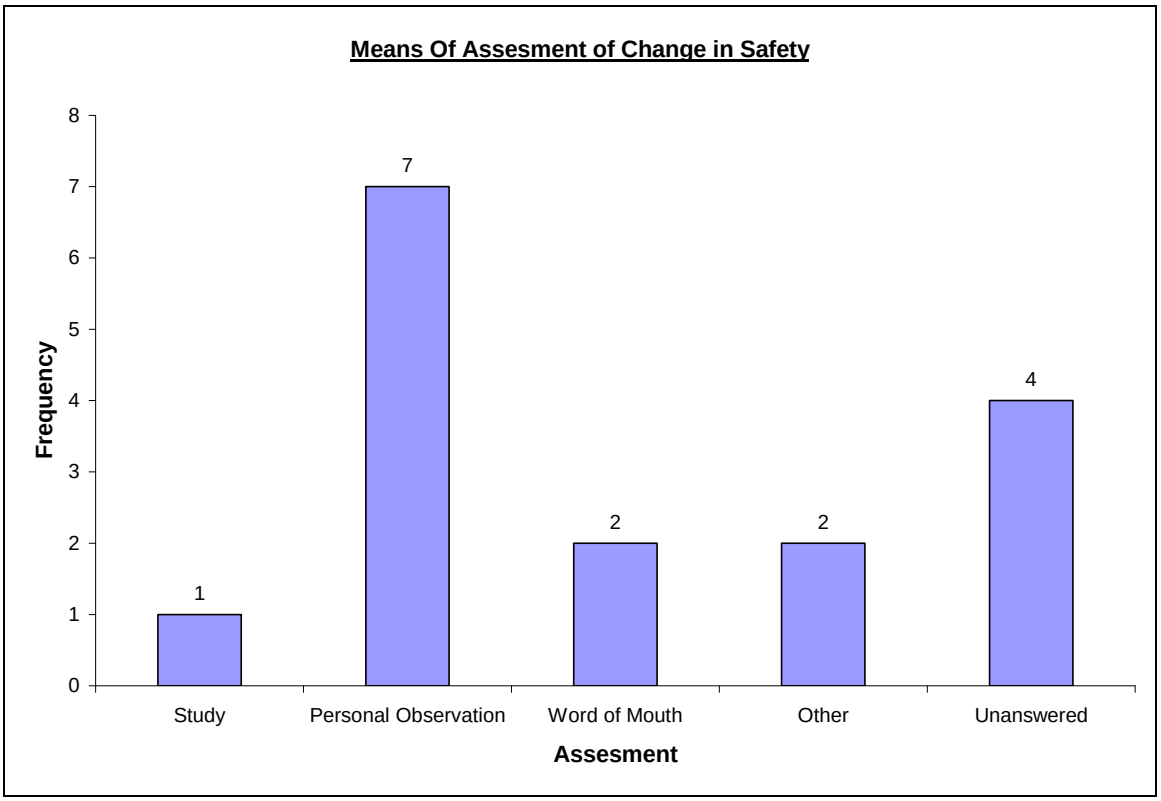

Figure 4.6. Assessment of safety improvement

Question 10 asked what advantages were found by using RPMs in work zones. Figure 4.7 summarizes the responses – better delineation and improved visibility in wet weather being quoted by the majority (87%) of respondents. However, the respondents also acknowledged some disadvantages associated with RPMs by answering question 11 (Figure 4.8). These included maintenance and installation headaches and increased costs. The maintenance and installation headaches acknowledged by seven DOTs included scratched RPMs, premature extrication by snowplows, difficulties in keeping the markers on the pavement, and short life span requiring unanticipated replacement. The increased costs disadvantage acknowledged by four (27%) DOTs included increased labor and longer duration of lane closures during installation.

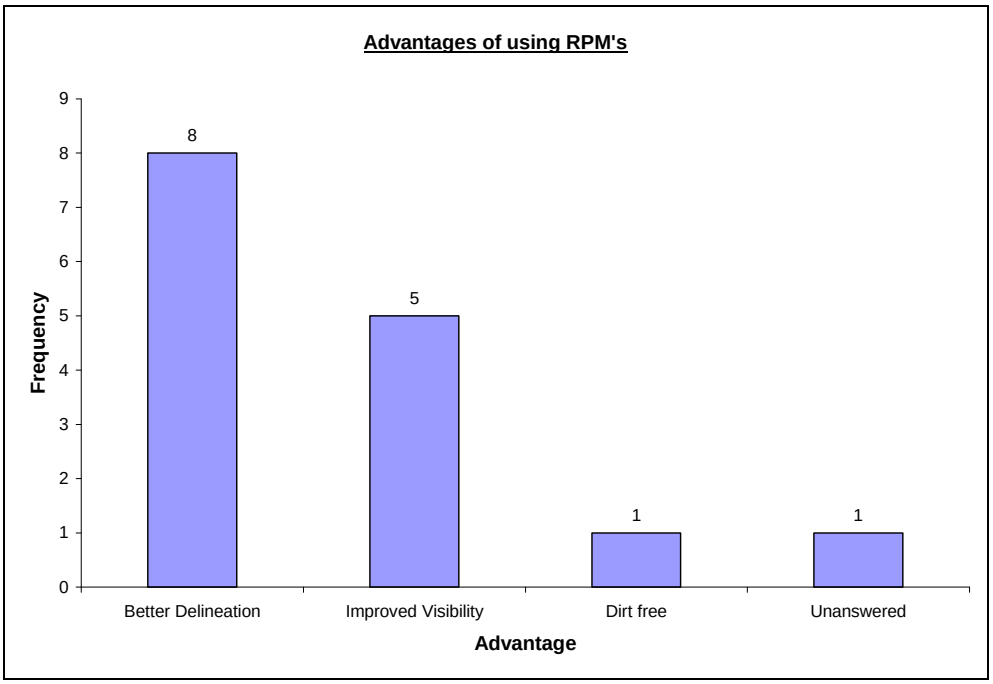

Figure 4.7. Advantages of using RPMs

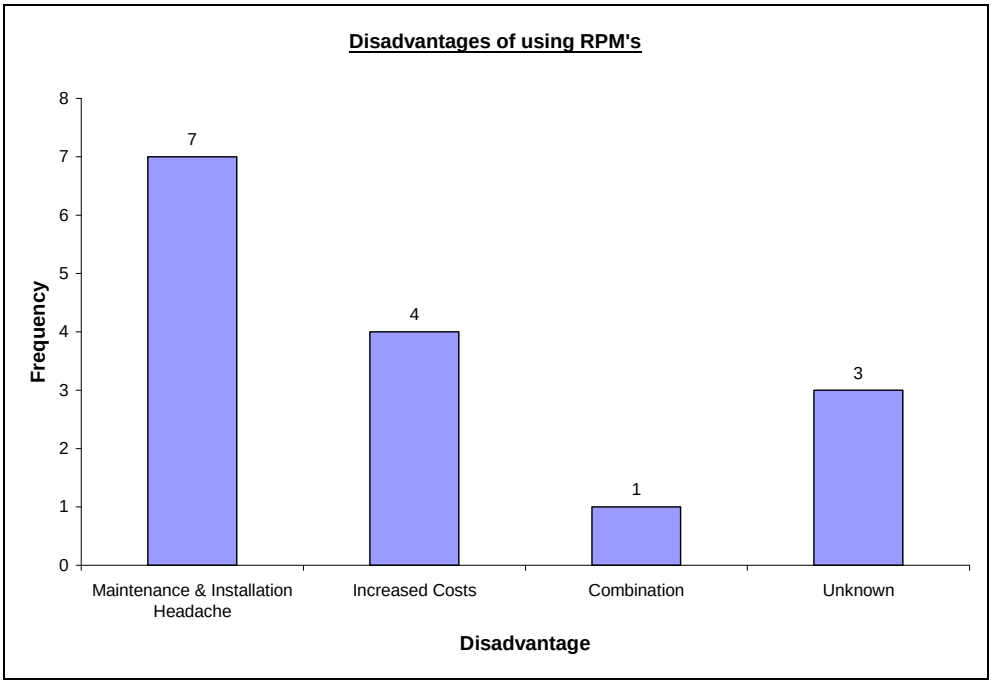

Figure 4.8. Disadvantages of using RPMs

Question 12 asked respondents for placement/installation specifications followed with the use of RPMs in work zones. These varied amongst the responding DOTs; while 40% of the respondents used specifications from the MUTCD, the remaining 60% used other specifications. The MUTCD specifications were described in Chapter 2 of this report. Table 4.1 presents a summary of the specifications used by the respondents. Specification details for the 60% of the respondents that use their own specifications are available in Appendix D.

Table 4.1. Summary of RPM installation specifications

Item	DOT	Specifications for RPMs
1	Arkansas	- Placed at locations shown on plans using epoxy adhesives. Three markers shall be installed equally spaced in the place of 4 foot striping. Markers shall be retro-reflective in the direction facing traffic.
2	Colorado	- MUTCD specifications.
3	Idaho	- Staggered spacing required with normal tubular markers when used on TWTL projects on divided highways.
4	Illinois	- If used to replace a line then RPMs are placed at 5-foot centers and at 25-foot centers to supplement pavement markings.
5	Iowa	- Ten foot center to center spacing along edge lines through transitions and merge line areas on interstate projects and MUTCD specifications.
6	Missouri	- Reflective faces shall be oriented to face traffic, shall be installed according to manufacturer's recommendations, and placed at approximately 40-foot intervals.
7	Nebraska	- MUTCD specifications.
8	Nevada	- For broken lines, place groups of 3 markers longitudinally 2-foot apart at 40-foot intervals. For double yellow lines and centerlines in one-way passing zones, place 2 markers side by side with a 4-inch separation between markers at 20-foot intervals. For edge lines, place markers at 20-foot intervals. Epoxy adhesives or removable adhesive pads.
9	New Hampshire	- MUTCD specifications.
10	New York	- MUTCD specifications.
11	North Carolina	- MUTCD specifications.
12	Oklahoma	- For thick lines, markers are placed at 5-foot centers whereas for double lines, place markers 4-inches apart longitudinally at 5-foot centers. For broken lines place

		5 markers at 3-inches on centers.
13	Oregon	- MUTCD specifications.
14	South Carolina	- On two-lane two-way roadways, supplement yellow center line markings with RPMs at 80-foot intervals; on primary and secondary multi-lane routes and on roadways where turn lanes etc. are present, supplement with RPMs at 40-foot intervals, on multilane highways including interstate supplement broken white lane line markings by installing RPMs at 80-foot intervals.
15	Texas	- MUTCD specifications.

The survey asked for costs and maintenance of RPMs (question 13). On average, most DOTs that responded paid between $2.00 and $4.00 per RPM for installation and maintenance. Table 4.2 provides a summary of the actual installation and maintenance costs reported by each DOT. Finally, respondents were asked who supplies their RPMs used in work zones (question 14). The more popular vendors included Avery Denison, 3M Company, Stimsonite, Hallen Products, Ray-O-Lite Industries and Pac-Tech Inc.

Table 4.2. Summary of RPM Costs

DOT	Unit Cost of RPM
Arkansas	$ 5.70
Colorado	$ 2.50
Idaho	$ 3.50 - $ 6.00
Iowa	$ 2.90
Missouri	Tabs - $ 1.74 Domes - $ 2.23
Nebraska	$ 4.00 - $ 5.00
Nevada	Permanent - $ 1.00 - $ 1.50 Temporary - $ 0.50
North Carolina	$ 3.00 to $ 4.00
Oklahoma	$ 0.50
Oregon	$ 4.00

CHAPTER 5 – CONCLUSIONS AND RECOMMENDATIONS

This relatively brief chapter presents the conclusions and research team's recommendations that are based on the findings reported in Chapter 4. The survey results indicated that 40% of the responding DOT's relied on RPM specifications from the MUTCD while the remaining 60% used other specifications. However, there appears to be significant differences in the specifications of those 60% DOT's that have developed more specific guidelines for installation of RPMs (Table 4.1). These differences are most likely the result of the unique needs of each agency and differences in RPM costs. As such, it is difficult to recommend a uniform set of specifications that can be used by DOTs. However, the availability of a base-line set of specifications that DOTs without agency-specific RPM usage guidelines can utilize to bring about some uniformity in the use of RPMs will be beneficial.

The research team is of the opinion that the MUTCD specifications on the use of RPMs in workzones provide a base-line and recommends that DOTs not having their own more specific guidance can follow the MUTCD specifications for RPM usage in workzones. This will bring about a level of uniformity in the usage of RPMs across different DOTs. Further, many DOTs will likely want to develop more specific guidelines that take into account the agencies' unique needs and RPM costs. Such guidelines can be developed, for which the information contained in this report can serve as a starting point, and on considerations of agency needs, RPM cost and maintenance required, and more research, if needed.

Another aspect to consider in RPM specifications is that of manufacturer recommendations. Since these may differ from manufacturer to manufacturer and may even differ amongst products from the same manufacturer, one would have to deal with this issue on a

case by case basis. The research team recommends that agencies compare manufacturers' recommendations to MUTCD specifications and follow the more stringent of the two sets.

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Appendix A – The Survey Questionnaire

Survey of Raised Pavement Markings in Work Zones

The objective of this Nebraska Department of Roads sponsored survey is to collect information on the use of raised pavement markings in work zones. The results of this survey will be used to develop a report that provides information on the different applications of raised pavement markings in work zones across the U.S. If you have any questions regarding this survey, please call Dr. Aemal Khattak at (402) 472-8126 or Bhaven Naik at (402) 472-1102. Please mail the completed survey to: Dr Aemal Khattak, W348 Nebraska Hall, University of Nebraska-Lincoln, Lincoln, NE 68588-0531. Thank you.

1. Please provide your contact information to enable us to communicate with you in the future.

   Name: _____

   Job Title: _____

   Agency: _____

   Phone Number: (____)_____

   Email Address: _____

2. Does your agency use raised pavement markings in work zones?

   ☐ Yes, (Please go to question 4).

   ☐ No, (Please go to the next question).

3. Does your agency intend to use raised pavement markings in the future?

   ☐ Yes, Can you share some information on:

   When _____,

   Where _____,

   Which vendors does your agency intend to contact _____

   ☐ No

Thank you for participating in the survey. Your assistance is greatly appreciated.

4. How did your agency go about making a decision to implement raised pavement markings in work zones?

☐ Research study

☐ Field/pilot evaluation

☐ Review of the technical literature

☐ Success in other agencies

☐ Vendor suggested

☐ Other, Please comment _____

5. What kind of raised pavement markings does your agency use in work zones?

☐ Raised reflective pavement markings,

☐ Rumble strips,

☐ Other, Please comment _____

6. What benefits did your agency expect from implementing raised pavement markings in work zones?

_____

_____

7. Please describe any differences between the expected and the actual results of implementing raised pavement markings in work zones?

_____

_____

8. Has safety changed as a result of using raised pavement markings in work zones?

_____

_____

9. How was the change in safety assessed?

☐ Study

☐ Personal observation

☐ Word of Mouth

☐ Other, Please comment _____

10. What advantages has your agency found with the use of raised pavement markings in work zones?

_____

_____

11. What disadvantages has your agency found with the use of raised pavement markings in work zones?

_____

_____

12. What placement/installation specifications does your agency follow with the use of raised pavement markings in work zones?

_____

(If available in a document format, can you please share a copy)

13. Can you please share any information on the costs and maintenance of the raised pavement markings?

_____

_____

14. Who supplies your agency with the raised pavement markings used in work zones?

_____

_____

Thank you for participating in the survey. Your assistance is greatly appreciated.

Appendix B – DOT Contact Information and Contact Log

Note: Names of individuals contacted in each DOT have been withheld for privacy reasons

Table B.1. Log of efforts to solicit survey response from non-responding agencies

	State DOT	Total contact attempts	Dates of E-mail and number of E-mails sent					Phone call date and number of calls made			
			9/8/2004	9/10/2004	9/15/2004	9/22/2004	Sub-total	9/15/2004	10/5/2004	10/15/2004	Sub-total
1	Alabama	2	1	1			2				0
2	Alaska	3	1	1			2		1		1
3	Arizona	3	1				1	1	1		2
4	California	3						1	1	1	3
5	Delaware	3			1	1	2	1			1
6	District of Columbia	3						1	1	1	3
7	Florida	5	1	1			2	1	1	1	3
8	Georgia	4	1		1	1	3			1	1
9	Hawaii	3						1	1	1	3
10	Indiana	3			1	1	2	1			1
11	Kansas	5			2	1	3	1		1	2
12	Kentucky	2						1		1	2
13	Louisiana	3	1				1		1	1	2
14	Maine	3	1				1	1	1		2
15	Maryland	4	1			1	2		1	1	2
16	Massachusetts	2						1	1		2
17	Michigan	4	1	1		1	3			1	1
18	Minnesota	3	1				1	1	1		2
19	New Jersey	3	1			1	2			1	1
20	New Mexico	3	1				1		1	1	2
21	Ohio	3	1				1		1	1	2
22	Pennsylvania	3			1		1	1	1		2
23	South Dakota	3	1	1			2		1		1
24	Utah	4				2	2	1	1		2
25	Vermont	2	1				1			1	1
26	Virginia	2	1				1			1	1
27	Washington	3			1	1	2	1			1
28	Wisconsin	2	1				1			1	1
29	Wyoming	2	1				1			1	1

Note: Agencies that responded to the survey have been omitted from the above log.

Table B. 2. State DOTs that responded to the survey questionnaire

State DOT	Job title of respondent
Arkansas	Quality assurance engineer
Colorado	Civil engineer 3
Connecticut	Transportation supervising engineer
Idaho	Transportation staff engineering assistant
Illinois	Work zone traffic control engineer
Iowa	Traffic safety/automation engineer
Missouri	Technical support engineer
Montana	Traffic and safety engineer
Nebraska	Traffic control engineer
Nevada	Senior traffic designer
New Hampshire	Civil engineer 3
New York	Civil engineer 3
North Carolina	State work zone traffic engineer
Rhode Island	Traffic control engineer
Oklahoma	CADD specialist 5
Oregon	State traffic control plans engineer
South Carolina	Work zone traffic control coordinator
Texas	Transportation engineer
West Virginia	Staff engineer traffic control

Appendix C – Responses Spread Sheet and Response Frequency

State	Agency	Q2	Q3	Q3a	Q3b	Q3c	Q4	Q5	Q6	Q6 coding	Q7	Q7 coding	Q8	Q8 coding	Q9	Q10
Arkansas	as St.H'way & Trar	1	0				3, 4	1	Fewer night-time accidents, enhanced wet-night visibility of pavement markings	3	Unknown	5	Unknown	2	N/A	Better visibility at night, especially under wet conditions
Colorado	Colorado DOT	1	0				2, 3 and 6 -Necessity	1and 3 -Flexible pavement markers	Improved delineation and less lane drift resulting in fewer crashes	1	Maintenance resistance to the installation of these devices remains a surprise despite obvious benefits.	1	Safety is greatly improved.	1	1 and 2	Improved delineation, less lane drift, improved visibility in light snow covers.
Connecticut	Bureau of Eng. An	0	0													
Idaho	Idaho DOT	1	0				4 and 6 -FHWA requirement	1 -Rigid raised pa\	To provide guidance when tubular markers are displaced by traffic. Expected continued guidance.	1	Improved nightime	2	Not measurably	2	2 -Observation by various Project inspectors	Additional night-time visibility.
Illinois	Illinois DOT	1	0				6 -Allowed by the MUTCD for projects where there is excavation and dirt that can cover normal painted lines.	1	A delineation that is easier to see and stays cleaner than a painted line.	1	They do perform b	4	Cannot tell.	3	N/A	They do not get co
Iowa	OT, Office of Cons	1	0				2 4	1	Better night-time visibility, especially in wet night-time	3	N/A	5	No statistical data to verify, but subjective evaluations feel that there is an improvement.	1	2	Better night-time visibility, especially at night
Missouri	MoDOT	1	0				6 -Unsure but have been using them for over 20+ years.	1 -Type 1(Tabs) &	Low cost marking that could be used by itself or to highlight other markings which could be applied quickly and easily to both AC and PCC pvmts.	2	None	5	Yes	1	4 -No assessment	Better delineation in supplemental routes and additional guidance in work zones.
Montana	Montana DOT	0	1	No idea	No idea	No idea										
Nebraska	NDOR	1	0				6- RPM's have been an option to paint or tape.	1	An alternative to tape and better reflectivity when wet.	3	Some situations the RPM has not stayed attached to surface of roadway.	1	Cannot tell.	3	N/A	-

State	Q10 coding	Q11	Q11 coding	Q12	Q12 coding	Q13	Q14
Arkansas	2	RPM's do not last long and are a maintenance headache.	1	Placed at locations shown on plans using Epoxy adhesives.	1	$3.75 - $13.00 Weighted Av. $ 5.70 each	Avery Dennison/Stimsonite and 3M company
Colorado	1	Snowplows scrape them prematurely. Are a Maintenace headache.	1	MUTCD	2	$2.50 each	Stimsonite
Connecticut							
Idaho	2	Higher contract costs, but advantages outweigh the disadvantages.	2	Required to be at staggered spacing with the normal tubular markers when used on TWTL projects on divided highways.	2	$3.50 - $6.00 each. Maintenance costs are minimal with removal being simple and inexpensive.	Hallen Products, Ltd.
Illinois	3	The ones used are good for the summer only. They are not snowplowable.	1	If used to replace a line then they are placed at 5-ft centers.	2	N/A	Avery Denison, Hallen Products, Ray-O-Lite Night-Line Markers and 3M company
Iowa	2	Slightly increased costs	2	10-ft center to center spacing along edge lines through transitions and merge lines areas on interstate projects	2	$2.90 including maintenance	Avery Dennison.
Missouri	1	Difficult to keep the markings down and also longevity during snow removal operations	1	See attached spec	2	Type 1 (tabs) - $1.74 Type 2 (domes) - $2.23	Stimsonite, Night-Line Markers, Hallen Products, Pac-Tec and 3M company
Montana							
Nebraska	4	-	4	MUTCD	1	Approx. $4 - $5 each installed.	Avery Denison, Hallen Products, Flex-O-Lite, Amerace Corp. Bunzl/Davidson

State	Agency	Q2	Q3	Q3a	Q3b	Q3c	Q4	Q5	Q6	Q6 coding	Q7	Q7 coding	Q8	Q8 coding	Q9	Q10
Nevada	NV DOT	1	0				6 -used for permanent locations in work zones.	1	Long term visibility, especially at night and cost benefits of the long term use outweigh other temporary markings.	2,3	Same as Questior	2	Yes. Locations with temporary markings were hard to see and follow especially where multiple applications were used.Subsequent 'ghosting" effects were easier to follow.	1	2 - Reduction of crashes.	Motorist visibility, especially at night and reduced impacts to traffic for re-applications of other temporary markings.
New Hampshire	NH DOT	1	0				3	1	Better delineation	1	Unknown	5	No known data	3	N/A	Better lane delinea
New York	NYS DOT	1	0				2	1	Improved delineation in wet, nightime conditions	1	-	5	No quantifiable ch	2	3	Improved lane deli
North Carolina	NC DOT	1	0				2	1	Better delineation inside traffic shifts. Used markers on the edge line of reverse curves and on the centreline.	1	When pavement marking tape is used we place markers half on the tape and on the edge to hold tape down.	3	Yes	1	2	Better wet-night delineation and better delineation in traffic shifts.
Rhode Island	RI DOT	0	1	No idea	No idea	No idea										
Oklahoma	ODOT	1	0				6 -Needed to avoid pavement scars and because removable tape would not stay down.	3 -Flexible pavement markers (Flex-tabs)	Improved visibility, easy installation and removal	2,3	Results are as expected	3	Yes	1	2	Better delineation, easy installation and removal allowing quick and easy changes in construction zones.
Oregon	Oregon DOT	1	0				2, 4 and 6 -allowed by the MUTCD	1and 3 -flexible pavement markers	For increased visibility in high speed, high volume, multi-lane, urban environments and inclement weather.	1	Operate as expect	3	Safety has improved. Old method of painting does not provide the same level of reflectivity, visual acuity nor tactile feedback as the striping.	1	3 - Feed back from Const. managers	Improved reflectivity, visual acquity, channelisation especially in multi-lane environments.
South Carolina	SC DOT	1	0				-	1	Better delineation	1	Very little differenc	3	Yes	1	2	Improve delineatio
Texas	TxDOT	1	0				6 -Not sure	1 and 3 -Traffic buttons	Better delineation espescially when doing lane changes	1	Expected the dura	1	Yes	1	4 -No assessment	Better delineation especially in temporary lane change areas
West Virginia	WV DOT	0	1	No idea	No idea	No idea										

State	Q10 coding	Q11	Q11 coding	Q12	Q12 coding	Q13	Q14
Nevada	2	Increased man hours and longer duration of lane closures during installation times.	2	Epoxy adhesives or removable adhesive pads. 10-ft line, 30-ft gap for lane lines.	2	Permanent raised marker $1.00 - $1. 50 each. Temporary "chipseal" marker $0.50 each.	Avery Dennison, Apex Universal and Ray-O-Lite.
New Hampshire	1	Can be used for 2 weeks then break off. Anything more than 2 week period paint is used.	1	MUTCD	1	Under contract they are subsidiary to work.	Avery Dennison and Bunzl Extrusions
New York	1	Markers are easily	1	MUTCD	1	-	Avery Dennison/Stimson ite
North Carolina	1	None	4	refer to www.doh.c	2	Average bid cost $	Pac-Tech Inc, Brite-line technologies, 3M, Apex Universal Inc., Hallen Products, Stimsonite products, and Avery Denison.
Rhode Island							
Oklahoma	1	Short life span requiring replacement that was not anticipated.	1	Simply peel and stick at 5-feet C/L for solid lines	2	Approximate bids are $0.50 each.	Hallen Products, Ltd.
Oregon	2	Maintenance is more involving, short life span, can be expensive espescially when simulating double-solid lines.	1, 2	MUTCD	1	$4.00 each	Stimsonite and Ray-O-Lite
South Carolina	1	Not aware of any	4	Centreline markers are placed at 40-ft intervals on primary routes and 80-ft intervals on Interstate.	2	-	Contractors
Texas	1	Increased cost, maintenance and durability issues	2	MUTCD	1	Variable due to dif	Avery denison, Apex Universal Inc., Pac-Tech Inc., Semex and 3M company
West Virginia							

Frequency of Responses

Question 2	Frequency
Use RPM's	15
Do Not Use RPM's	4
No Response	30

Question 4	Frequency
Research Study	0
Field/Pilot evaluation	5
Review of Tech. Literature	3
Success in other agencies	4
Vendor suggested	0
Other	9

Question 5	Frequency
Raised Reflective Markers	11
Rumble Strips	0
Flexible Raised Pavement Markers	1
Combination	3

Question 6	Frequency
Better Delineation	9
Cost efficient	1
Improved night-time visibility	3
Cost efficient and better visibil	2

Question 7	Frequency
Better durability	3
Better visibilty	2
As expected	4
Perform Better	1
Unanswered	5

Question 8	Frequency
Yes	9
No	3
Cannot Tell	3

Question 9	Frequency
Study	1
Personal Observation	7
Word of Mouth	2
Other	2
Unanswered	4

Question 10	Frequency
Better Delineation	8
Improved Visibility	5
Dirt free	1
Unanswered	1

Question 11	Frequency
Maintenance & Installation Headache	7
Increased Costs	4
Combination	1
Unknown	3

Question 12	Frequency
MUTCD	6
Other	9

Question 14	Frequency
Contractors	6
Vendors	8

Appendix D – DOT RPM Use Specifications

RAISED PAVEMENT MARKERS, EPOXY ADHESIVES, AND BITUMINOUS ADHESIVES FOR RAISED PAVEMENT MARKERS

Raised Pavement Markers

Product	Manufacturer
Model 911 Model 948	Avery Dennison / Stimsonite 6565 West Howard Street Niles, IL 60714 1-800-327-5917
Model 290 Series	3M Company Traffic Control Materials Division 3M Center St. Paul, Mn. 55144-1000 (612) 733-1110

Raised Pavement Marker Epoxy
Type II, Standard Set

Product	Manufacturer
E-Bond 1240/1241	E-Bond Epoxies P.O. Box 23069 501 Northeast 33rd Street Ft. Lauderdale, FL 33307 (305)566-6555
Thermoset/Stimsonite RPM Epoxy EP 308 Resin EP 308 Hardener	Avery Dennison / Stimsonite 6565 West Howard Street Niles, IL 60714 1-800-327-5917

Raised Pavement Marker Bituminous Adhesive

Product	Manufacturer
Crafco Standard Marker Adhesive Part No. 34269	Crafco, Inc. 6975 Crafco Way Chandler, Arizona 85226 (800) 528-8242
BT-69	3M Company Traffic Control Materials Division 3M Center St. Paul, Mn. 55144-1000 (612) 733-1110

Raised Pavement Marker Bituminous Adhesive(continued)

Eagle Asphalt Bituminous Adhesive	Texas Fuel & Asphalt P.O. Box 9605 Corpus Christi, Texas 78469 (512) 289-7800
EverGrip	Gulf States Asphalt Co. P.O. Box 508 300 Christy Place South Houston, Tx 77587
Gulf States Bitumen	Avery Dennison / Stimsonite 6565 West Howard Street Niles, IL 60714 1-800-327-5917

Method of Documentation of Acceptance: By brand and manufacturer.

The following procedure must be followed in acquiring approval of materials to be added to the above Qualified Products List:

1. Permanent Raised Pavement Markers, Bituminous Adhesives, Flexible Bituminous Adhesives, Non-Bituminous Hot-Melt Adhesives, and Epoxy Adhesives for the Permanent Raised Pavement Markers must be evaluated by the National Transportation Product Evaluation Program (NTPEP) as a Raised Pavement Marker, or as an Epoxy Adhesive, or Bituminous Adhesive for raised pavement markers. Permanent Raised Pavement Markers, Bituminous Adhesives, Flexible Bituminous Adhesives, Non-Bituminous Hot-Melt Adhesives, and Epoxy Adhesives for the Permanent Raised Pavement Markers upon completion of NTPEP evaluation, final results must be furnished to the Department. At the end of the NTPEP testing, the performance of the Permanent Raised Pavement Markers, Bituminous Adhesives, Flexible Bituminous Adhesives, Non-Bituminous Hot-Melt Adhesives, and Epoxy Adhesives will be evaluated and final approval will based on its NTPEP performance. All reports shall include the manufacturer's name, address, and product name of the Permanent Raised Pavement Markers, Bituminous Adhesives, Flexible Bituminous Adhesives, Non-Bituminous Hot-Melt Adhesives, and Epoxy Adhesives.
2. The manufacturer shall submit samples and product information, including printed instructions for application.
3. If the Permanent Raised Pavement Markers, Bituminous Adhesives, Flexible Bituminous Adhesives, Non-Bituminous Hot-Melt Adhesives, and Epoxy Adhesives meet the performance criteria, a letter and unsigned certification agreement will be sent to the manufacturer. The product will be placed on the QPL upon receipt of the signed certification agreement.
4. Destination samples will be taken as deemed necessary by the Materials Engineer to assure compliance with specifications.
5. Failure of these samples either in the laboratory or in field applications is sufficient reason to reconsider acceptance of the material. Suspension of further use and/or removal from the QPL may occur until the Materials Engineer determines that the product is in compliance with applicable specifications and requirements.

Permanent Pavement Marking Tape (Arrows)(Type___)	Each
Permanent Pavement Marking Tape (Railroad Emblems)(Type___)	Each

SECTION 721
RAISED PAVEMENT MARKER

721.01 Description. This item shall consist of furnishing and installing raised pavement markers according to these specifications and at the locations shown on the plans or as directed.

721.02 Materials. The markers shall conform to the shape and dimensions shown on the plans.

Pavement markers shall be of the type and color shown on the plans or as specified herein.

(a) Type of Markers. Pavement markers shall be one of the following types:

Type I - One-Way (Color) Reflective Markers
Type II - Two-Way (Color/Color) Reflective Markers

(b) Packaging and Storage. Pavement markers shall comply with the following packaging and storage requirements.

(1) Packaging. Each package shall be clearly marked as to the name of the manufacturer, type, color, quantity enclosed, lot number, and date of manufacture.

(2) Storage. Markers shall be stored indoors and shall be protected from any source of moisture both during shipment to the project site and at the project site. The markers shall be maintained at a temperature high enough to preclude moisture condensation, and, at the time of placement, both the markers and their containers shall be dry.

(c) Reflective Pavement Markers. Reflective pavement markers shall be one of the following types:

- Prismatic reflector type, consisting of methyl methacrylate (MM) or suitable compounded acrylonitrile butadiene styrene (ABS) shell filled with a mixture of an inert thermosetting compound and filler material. The exterior surface of the shell shall be smooth and contain one or two methyl methacrylate prismatic reflector faces with thin, untempered glass bonded to the faces to provide an extremely hard and durable abrasion-resistant surface. The glass is not required on the red faces of two-way (Clear/Red) reflective markers. The infrared curves of the compounded MM or ABS shells shall match approved curves on file in the Materials Division.

- High performance microprismatic lens type, consisting of a polycarbonate lens with independent lens cells and a ceramer lens coating. The marker shall consist of hermetically sealed components in a fiber reinforced polycarbonate body with finger grip indentations for ease of handling.

The base of the marker shall be flat (the deviation from a flat surface shall not exceed 0.05" [1.3 mm]), rough textured, and free from gloss or substances that may reduce its bond to the adhesive.

Raised pavement markers shall meet the following requirements when tested according to ASTM D 4280 by the National Transportation Product Evaluation Program (NTPEP):

1. Adhesive Bond Strength. Flat bottomed markers shall withstand adhesive bond strengths of not less than 200 psi (3.4 MPa).

2. Coefficient of Luminous Intensity (Specific Intensity). The specific intensity of each clear (white) reflecting surface at 0.2° observation angle shall not be less than the following :

Horizontal Entrance Angle	Specific Intensity (cd/fc) Initial	Specific Intensity (cd/fc) (12 months)
0°	3.0	0.301
20°	1.2	0.129

For yellow reflectors, the specific intensity shall be 60% of the value for the clear. For red reflectors, the specific intensity shall be 25% of the value for clear.

3. Flexural Strength (as applicable). The marker shall withstand 2000 lbs. (900 kg) without breakage or significant deformation.

4. Compressive Strength (as applicable). The marker shall support a load of 6000 lbs. (2727 kg) without breakage or significant deformation.

5. Color. The color of the marker shall meet the requirements of ASTM D 4280.

6. Temperature Cycling. There shall be no cracking or delamination of the marker when subjected to temperature cycling.

(d) Adhesives.

(1) Epoxy Adhesives. The epoxy adhesives shall comply with all the requirements of either Type I, Rapid Setting, High Viscosity Epoxy Adhesive or Type II, Standard Setting, High Viscosity Epoxy Adhesive as specified in AASHTO M 237.

(2) Bituminous Adhesive for Pavement Markers. Bituminous adhesive shall be an asphalt material with a homogeneously mixed filler formulated primarily for use in bonding pavement markers to portland cement concrete and asphalt concrete. The adhesive must be heated to a liquid state for application.

The epoxy adhesive and/or the bituminous adhesive shall be listed on the QPL.

721.03 Construction Requirements. Existing raised pavement markers shall be removed prior to the placement of any overlay or seal course. On pavements that are not to be overlaid or sealed, existing raised pavement markers which are damaged or which conflict with the new markers shall be removed as directed by the Engineer. Removal of existing pavement markings will not be paid for separately but will be considered subsidiary to other items of the work.

The surface to which the marker is to be bonded shall be free of dirt, curing compound, grease, oil, moisture, paint, and any other material that would adversely affect the bond of the adhesive. The adhesive shall be placed uniformly on the surface or on the bottom of the marker in a quantity sufficient to result in complete coverage of the area of contact of the marker with no voids present and with a slight excess after the marker has been pressed into place. Markers utilizing epoxy shall be placed in position and pressure applied until firm contact is made with the pavement. Markers with bituminous adhesive shall have a minimum adhesive pad thickness of 3/32" (2.4 mm) after installation. Viscosity of the bituminous material shall be such that flow about the periphery of the marker does not exceed 1½" (38 mm). Excess epoxy adhesive around the edge of the marker, excess adhesive on the pavement, and adhesive on the exposed surfaces of the markers shall be immediately removed using a solvent and procedure recommended by the manufacturer of the markers. No other solvent shall be used. The marker shall be protected against impact until the adhesive has sufficiently set to resist movement.

Epoxy adhesive requires that the mixing operation and placing of the markers be performed rapidly. Just before use, components A and B shall be mixed in a 1:1 ratio by volume. When automatic proportioning and mixing machines are used, the temperature of the components shall be maintained by indirect heating or cooling, if required, for the adhesive to meter, mix, and extrude properly. The maximum temperature shall be such that after proper mixing, there shall be no excess flow of adhesive from under the marker other than that previously specified.

When hand mixing the Standard Set Type adhesive, not more than 1 quart (1 liter) shall be mixed at one time, and the markers shall be aligned and pressed into place within 5 minutes after mixing operations are started. Any mixed batch that becomes so viscous that the adhesive cannot be readily extruded from under the marker on application of slight pressure shall not be used.

Rapid Set Type adhesive shall not be mixed by hand. This adhesive shall be mixed by a 2 component type automatic mixing and extrusion apparatus.

When machine mixing the Standard Set Type adhesive or the Rapid Set Type adhesive, the markers shall be placed within 60

seconds after the adhesive has been mixed and extruded and no further movement of the marker will be allowed. In addition, no more than 90 seconds shall be permitted between the time the adhesive is pumped into the mixing head and the time this adhesive is in place on the roadway and not subject to further movement. The mixed adhesive shall not remain in the mixing head for more than 45 seconds. Adhesive remaining in the mixing head longer than this period shall be wasted before resuming the operation.

Automatic mixing equipment for the epoxy adhesive shall use positive displacement pumps and shall properly meter the 2 components in the specified ratio, ± 5% by volume of either component. At the beginning of each day, and at any other time ordered by the Engineer, the ratio shall be checked by the Contractor in the presence of the Engineer. This check shall be made by disconnecting the mixing heads, or using suitable bypass valves, and filling 2 suitable containers with the unmixed components. The mixing head shall properly mix the 2 components so that there is no trace of black or white streaks in the mixed material.

The Standard Set Type adhesive shall not be used when either the pavement or the air temperature is less than 50° F (10° C). The Rapid Set Type adhesive shall not be used when either the pavement or air temperature is less than 30° F (-1° C). No markers shall be installed if the relative humidity of the air is greater than 80% or if the pavement surface is not dry.

Voids in a cured, undisturbed sample of the mixed adhesive obtained from the extrusion nozzle shall not exceed 4%.

The Bituminous Type adhesive shall require the use of a melting apparatus. The melting apparatus shall incorporate a means of mixing the material before and during installation to assure homogeneity. Diffuse heat distortion (diffuse plate) shall be used to prevent overheating the material. A dispensing nozzle shall be utilized that has an independent way of heating the material to provide regulated control over output. The working temperature shall be from 400° F to 450° F (204° C to 232° C). The Bituminous adhesive shall not be used when either the pavement or air temperature is less than 32° F (0° C). The pavement markers can only be installed on a dry pavement surface.

Reflective markers shall be placed in such manner that the reflective face of the marker is perpendicular to a line parallel to the roadway centerline.

No pavement markers shall be placed over longitudinal or transverse joints of the pavement surface or over pavement cracks.

721.04 Method of Measurement. Raised Pavement Markers will be measured by the unit complete in place.

721.05 Basis of Payment. Work completed and accepted and measured as provided above will be paid for at the contract unit price bid each for Raised Pavement Markers of the type specified, which price shall be full compensation for furnishing and installing Raised Pavement Markers; and for all materials, labor, equipment, tools, and incidentals necessary to complete the work.

Payment will be made under:

Pay Item	**Pay Unit**
Raised Pavement Markers (Type___)	Each

SECTION 722
PLOWABLE PAVEMENT MARKER

722.01 Description. This item consists of furnishing and installing plowable pavement markers on Portland cement concrete and/or asphalt concrete pavement according to these specifications at the locations shown on the plans or as directed by the Engineer.

722.02 Materials. The plowable pavement marker shall consist of an iron casting to which is attached a replaceable prismatic retroreflector for reflecting light. Both ends of the casting shall be shaped to deflect a snowplow blade. The bottom of the casting shall incorporate two parallel keels and an accurately shaped web designed to fit into a grooved surface. The markers shall conform to the shape and dimensions shown on the plans.

A Type I marker shall reflect light in one direction. A Type II marker shall reflect light in opposite directions.

Used By Idaho DOT

Specs used by Idaho DOT

HALLEN PRODUCTS LIMITED

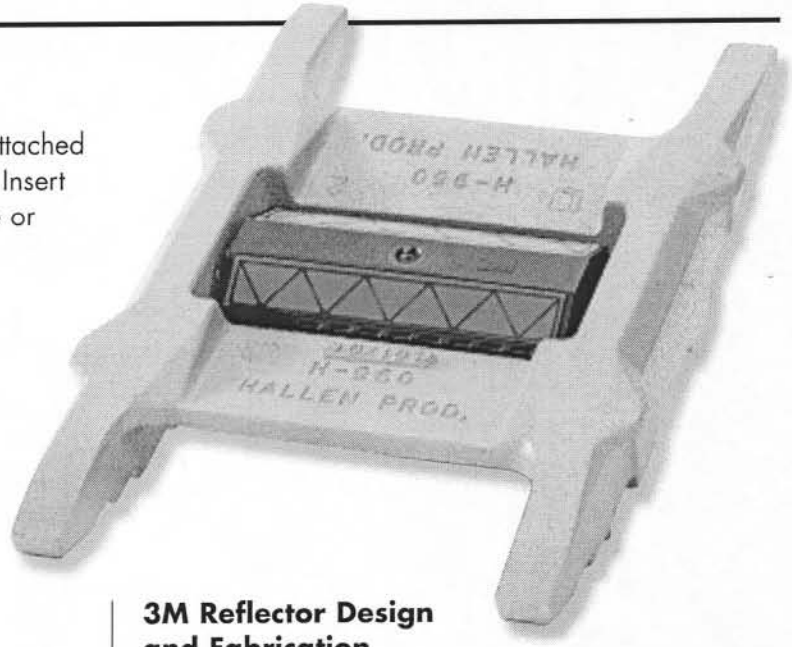
Specifications

Model H960 Low Profile

Two Way, All Weather, Snowplowable, Raised Reflective Pavement Marker

Hallen Products, Ltd.
4090 Ryan Road, Suite A
Gurnee, Illinois 60031 USA

Phone: 847/662-6868
Fax: 847/662-7129
email: hallen@ais.net



Description

Marker consists of Iron casting to which is attached a replaceable 3M™ Snowplowable Marker Insert (Series 190) for reflecting light from a single or opposite directions. Reflector features:

- Polycarbonate prismatic optics,
- Abrasion resistant lens hardcoat,
- Impact resistant polycarbonate body.

All aspects of reflector installation are factory controlled to insure proper adhesion to casting.

Dimensional Details

Overall Dimensions are approximately:

- 9.3 inches long
- 5.86 inches wide
- 1.7 inches high
- Installed Height is approximately .250 inches above road surface

Material

Nodular Iron, conforming to Specification ASTM A536-84 Hardened to 52-54 Rockwell "C".

Surface

Surfaces of casting shall be free of scale, dirt, rust, oil, grease or any other contaminant which may reduce its bond to the installation adhesive.

Weight

Approximately 5.2 pounds each

Identification

Casting is marked with manufacturer's name and model number of marker.

3M Reflector Design and Fabrication

Construction Details:

- Polycarbonate body and lens
- Dimensions are approximately 3.95 inches long (100 mm) by 1.9 inches wide (48 mm) and 0.4 inches high (10 mm)
- Face Angle: 30 Degrees
- Area of Reflecting Surface: 1.84 in^2 (11.9 cm^2)
- Pad Thickness: .04 inches (1.0 mm)

3M Optical Performance

(0.2) observation angle; (measured in cd/ftcd)

Entrance Angle	0°	20°
White	3.0	1.2
Yellow	1.8	.72
Red	.75	.30

Note

3M Snowplowable Marker Series 190 are provided in new Hallen Products castings and can also be applied as replacement markers in Hallen Products castings. The 190 series markers are manufactured with an adhesive layer and peel-away liner and can be installed in existing castings using Liquid Nails LN-602 adhesive. Please follow the detailed instructions in the Information Folder 190, *Application Procedures for 3M Snowplowable Marker*, available from 3M by calling technical service at 1-800-553-1380.

For yellow reflectors, the specific intensity shall be 60% of the value for the clear. For red reflectors, the specific intensity shall be 25% of the value for clear.

3. Flexural Strength (as applicable). The marker shall withstand 2000 lbs. (900 kg) without breakage or significant deformation.

4. Compressive Strength (as applicable). The marker shall support a load of 6000 lbs. (2727 kg) without breakage or significant deformation.

5. Color. The color of the marker shall meet the requirements of ASTM D 4280.

6. Temperature Cycling. There shall be no cracking or delamination of the marker when subjected to temperature cycling.

(d) Adhesives.

(1) Epoxy Adhesives. The epoxy adhesives shall comply with all the requirements of either Type I, Rapid Setting, High Viscosity Epoxy Adhesive or Type II, Standard Setting, High Viscosity Epoxy Adhesive as specified in AASHTO M 237.

(2) Bituminous Adhesive for Pavement Markers. Bituminous adhesive shall be an asphalt material with a homogeneously mixed filler formulated primarily for use in bonding pavement markers to portland cement concrete and asphalt concrete. The adhesive must be heated to a liquid state for application.

The epoxy adhesive and/or the bituminous adhesive shall be listed on the QPL.

721.03 Construction Requirements. Existing raised pavement markers shall be removed prior to the placement of any overlay or seal course. On pavements that are not to be overlaid or sealed, existing raised pavement markers which are damaged or which conflict with the new markers shall be removed as directed by the Engineer. Removal of existing pavement markings will not be paid for separately but will be considered subsidiary to other items of the work.

Raised Pavement Marker Bituminous Adhesive(continued)

Eagle Asphalt Bituminous Adhesive	Texas Fuel & Asphalt P.O. Box 9605 Corpus Christi, Texas 78469 (512) 289-7800
EverGrip	Gulf States Asphalt Co. P.O. Box 508 300 Christy Place South Houston, Tx 77587
Gulf States Bitumen	Avery Dennison / Stimsonite 6565 West Howard Street Niles, IL 60714 1-800-327-5917

Method of Documentation of Acceptance: By brand and manufacturer.

The following procedure must be followed in acquiring approval of materials to be added to the above Qualified Products List:

1. Permanent Raised Pavement Markers, Bituminous Adhesives, Flexible Bituminous Adhesives, Non-Bituminous Hot-Melt Adhesives, and Epoxy Adhesives for the Permanent Raised Pavement Markers must be evaluated by the National Transportation Product Evaluation Program (NTPEP) as a Raised Pavement Marker, or as an Epoxy Adhesive, or Bituminous Adhesive for raised pavement markers. Permanent Raised Pavement Markers, Bituminous Adhesives, Flexible Bituminous Adhesives, Non-Bituminous Hot-Melt Adhesives, and Epoxy Adhesives for the Permanent Raised Pavement Markers upon completion of NTPEP evaluation, final results must be furnished to the Department. At the end of the NTPEP testing, the performance of the Permanent Raised Pavement Markers, Bituminous Adhesives, Flexible Bituminous Adhesives, Non-Bituminous Hot-Melt Adhesives, and Epoxy Adhesives will be evaluated and final approval will based on its NTPEP performance. All reports shall include the manufacturer's name, address, and product name of the Permanent Raised Pavement Markers, Bituminous Adhesives, Flexible Bituminous Adhesives, Non-Bituminous Hot-Melt Adhesives, and Epoxy Adhesives.
2. The manufacturer shall submit samples and product information, including printed instructions for application.
3. If the Permanent Raised Pavement Markers, Bituminous Adhesives, Flexible Bituminous Adhesives, Non-Bituminous Hot-Melt Adhesives, and Epoxy Adhesives meet the performance criteria, a letter and unsigned certification agreement will be sent to the manufacturer. The product will be placed on the QPL upon receipt of the signed certification agreement.
4. Destination samples will be taken as deemed necessary by the Materials Engineer to assure compliance with specifications.
5. Failure of these samples either in the laboratory or in field applications is sufficient reason to reconsider acceptance of the material. Suspension of further use and/or removal from the QPL may occur until the Materials Engineer determines that the product is in compliance with applicable specifications and requirements.

Illinois Department of Transportation
Bureau of Materials and Physical Research
(Maintained by Bureau of Operations)

APPROVED LIST OF SNOWPLOWABLE RAISED PAVEMENT MARKERS
March 1, 2004

Standard Specifications for Road and Bridge Construction Article 1096.01 **Raised Reflective Pavement Markers** (Adopted January 1, 2002)
and
Raised Reflective Pavement Markers (Bridge) (BDE Special Provision) effective August 1, 2003.
Material Code No. 70801

Ray-O-Lite
Division of Pac-Tec, Inc
1870 James Parkway
Heath, Ohio 43056

RAISED REFLECTIVE PAVEMENT MARKER
Snow-Lite Model 200 - Conditionally approved - As new products, these markers meet the specifications for raised reflective pavement markers but are being monitored for performance. Notify the contact indicated on the Index if these markers are to be installed.

REPLACEMENT REFLECTOR
Model 2004

3M Center
Building 225-5S-08
St. Paul, MN 55144-1380
Phone: 1-800-553-1380 prompt # 1.

REPLACEMENT REFLECTOR
Model RPM-190

Specs for Illinois DOT

Standard 701416.

Reflective solid edge lines and double yellow centerline shall be used when the closure time exceeds four days or when the normal posted speed outside the area of operations exceeds 80 km/h (50 mph). Reflectorized pavement marking tape shall be used for marking the edge lines and centerline on existing pavement. Either tape or reflectorized Art. 701.06 Work Zone Traffic Control pavement marking paint may be used for markings on the paved crossovers. Raised reflective pavement markers at 8 m (25 ft) centers shall also be installed under good weather conditions, for additional delineation. When Standard 701416 is specified, the impact attenuator shall be positioned so as not to encroach onto the outer lane. Vertical panels may be attached to the concrete barriers where available space prohibits the use of drums. When Standard 701416 is specified, vertical panels may be attached to concrete barriers where available space prohibits the use of drums.

(h) Standard 701431.

Reflective solid edge lines and a double yellow centerline shall be used when the closure time exceeds four days or when the normal posted speed outside the area of operations exceeds 50 mph. Reflectorized pavement marking tape shall be used for marking the centerline and edge lines on the existing pavement. Raised reflective pavement markers at 8 m (25 ft) centers shall be installed under good weather conditions to supplement the pavement marking tape. All existing pavement markings which conflict with the revised traffic pattern shall be removed.

Avery Dennison Corporation
Highway Safety Division
6565 West Howard
Niles, Illinois 60714
Phone: 847-647-7717

RAISED REFLECTIVE PAVEMENT MARKER
Model 96LP
Model 101LP

REPLACEMENT REFLECTOR
Model 944
Model C40

RAISED REFLECTIVE PAVEMENT MARKER (BRIDGE)
Model 96LPS
Model 101LPS

Hallen Products, Ltd
4090 Ryan Road, Suite A
Gurnee, Illinois 60031
Phone: 847-662-6868

RAISED REFLECTIVE PAVEMENT MARKER
IronStar Model 664
Model H-960
Model H-1010

RAISED REFLECTIVE PAVEMENT MARKER (BRIDGE)
Model H-960B
IronStar Model 664

Nightline Markers, Inc.
1030 Seaview Court
Schaumburg, Illinois 60193
Phone: 847-301-7560

RAISED REFLECTIVE PAVEMENT MARKER
Model A-250
Model B-250

deductions will be made for gaps in the removal. Measurement will not be made for removal of pavement marking within the limits of a bypass roadway or other roadway to be obliterated at the completion of the project.

620.60.4 Basis of Payment. The accepted quantity of pavement marking removal will be paid for at the contract unit price for each of the pay items included in the contract.

SECTION 620.70 TEMPORARY RAISED PAVEMENT MARKERS

620.70.1 Description. This work shall consist of installing, maintaining and removing reflectorized temporary raised pavement markers (RPM's) on roadway lane lines, centerlines or edge lines as shown on the plans or as directed by the engineer.

620.70.2 Material. All material shall be in accordance with Division 1000, Material Details, and specifically as follows:

Item	Section
Temporary Raised Pavement Markers	1048.60

620.70.3 Construction Requirements.

620.70.3.1 Temporary RPM's shall be of the colors shown on the plans unless otherwise directed by the engineer. Reflective faces shall be oriented to face traffic. Temporary RPM's shall be installed according to the manufacturer's recommendations and placed at approximately 40-foot (12 m) intervals.

620.70.3.1.1 Type 1 Temporary RPM's shall be used for surface treatment projects when temporary RPM's are specified.

620.70.3.1.2 Type 2 Temporary RPM's shall be used on all projects other than surface treatment projects when temporary RPM's are specified.

620.70.3.2 On resurfacing projects, temporary RPM's shall be removed on intermediate lifts of asphalt before additional lifts are laid above them. Temporary RPM's on final wearing surfaces shall be removed if specified on the plans or as directed by the engineer.

620.70.4 Method of Measurement. Final measurement will not be made, except for authorized changes, during construction or where significant errors are found in the contract quantity. Where required, measurement of temporary raised pavement markers will be made per each. The revision or correction will be computed and added to or deducted from the contract quantity.

620.70.5 Basis of Payment. The accepted quantity of temporary RPM's will be paid for at the contract unit price for each of the pay items included in the contract, except when temporary RPM's are used in accordance with Sec 620.2.5, then no direct payment will be made. No direct payment will be made for the removal of temporary RPM's.

SECTION 620.80 HOT SPRAY THERMOPLASTIC PAVEMENT MARKING

620.80.1 Description. This work shall consist of furnishing and placing thermoplastic pavement marking material applied by the hot spray process at a 45-mil (1.14 mm) thickness as specified on the plans or as directed by the engineer. Hot spray thermoplastic pavement marking shall be used only on bituminous surfaces.

screen, as determined by visual inspection. The remaining sieve fractions shall be determined visually per aspect ratio using microfiche reader to be no less than 75 percent rounds. The tests shall be in accordance with Federal Lands Highway - Test Method T520-93.

1048.50.3.3 Gradation. Type L beads shall meet the following gradation requirements when tested in accordance with ASTM D 1214:

Type L Bead Gradation Requirements	
Sieve Size	**Percent Passing**
No. 12 (1.7 mm)	100
No. 14 (1.4 mm)	95 - 100
No. 16 (1.18 mm)	80 - 98
No. 18 (1.00 mm)	10 - 42
No. 20 (850 µm)	0 - 7
No. 25 (710 µm)	0 - 2

1048.50.4 Intermix Beads. Intermix beads shall be uncoated, and in accordance with AASHTO M 247, Type 1. Intermix beads shall be uniformly mixed throughout the thermoplastic material at the rate of no less than 30 percent, by weight (mass) of the thermoplastic material.

1048.50.5 Type P Drop-On Glass Beads. Type P beads shall be manufactured from glass of a composition that is highly resistant to traffic wear and to the effects of weathering. If coating is required to meet the performance requirements for the specific marking material used, the beads shall be coated to ensure satisfactory embedment and adhesion. Glass beads shall have a minimum of 95 mass percent passing a No. 18 (1 mm) sieve and a maximum of 5 mass percent passing a No. 100 (150 µm) sieve.

SECTION 1048.60 TEMPORARY RAISED PAVEMENT MARKERS

1048.60.1 General. The brand name and manufacturer shall be stamped or indelibly printed on each container.

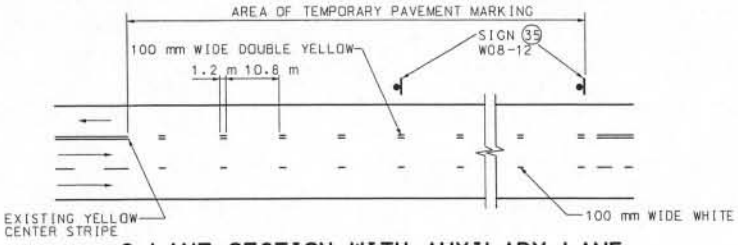
1048.60.2 Type 1 Temporary Raised Pavement Markers. Markers shall consist of an L-shaped or T-shaped flexible polymer body with prismatic reflective tape on both faces of the vertical section. The prismatic reflective faces shall be a minimum of 0.38 square inches (0.0002 m^2) for each face. The marker base shall have affixed a pressure-sensitive adhesive, protected by a release paper, for application to the pavement surface. A protective sleeve that prevents contamination of the reflective faces during pavement surface treatment operations shall be affixed to each marker. The protective sleeve shall be easily removable after the work is complete.

1048.60.3 Type 2 Temporary Raised Pavement Markers. Markers shall consist of a plastic shell with prismatic reflective faces with a minimum of 0.38 square inches (0.0002 m^2) of reflective surface for each face. If reflective faces are specified on both sides, the faces shall be 180 degrees opposed. The marker shall be fitted with a pressure-sensitive adhesive for application to a primed surface or may be applied to the pavement surface with a bituminous adhesive material.

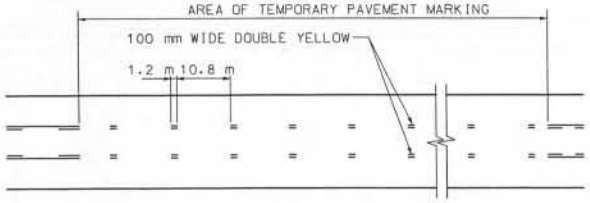
SECTION 1048.70 HOT SPRAY THERMOPLASTIC PAVEMENT MARKING

1048.70.1 Thermoplastic Compound.

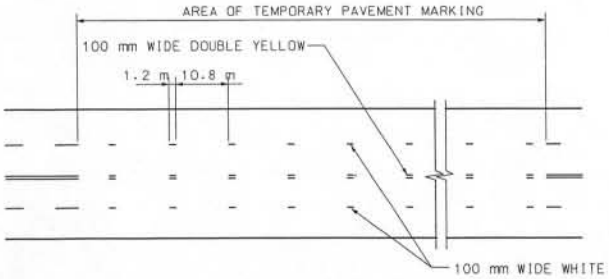
1048.70.1.1 Except where otherwise specified, tests shall be performed in accordance with AASHTO T 250.



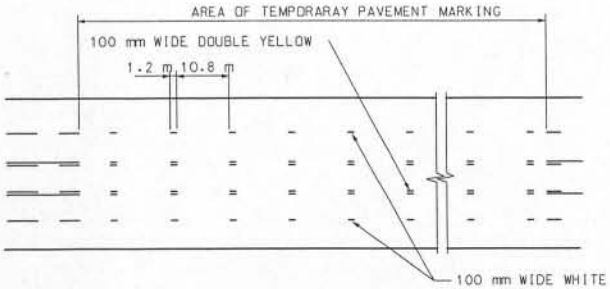
2-LANE SECTION WITH AUXILARY LANE



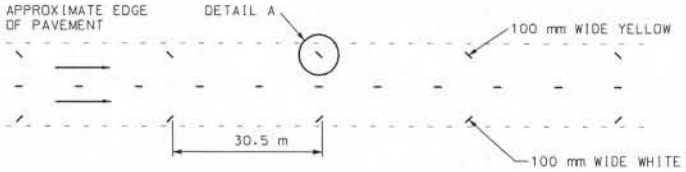
3-LANE SECTION



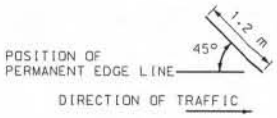
4-LANE SECTION



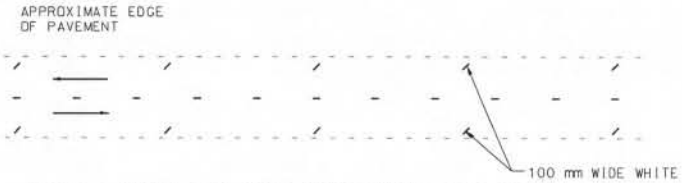
5-LANE SECTION



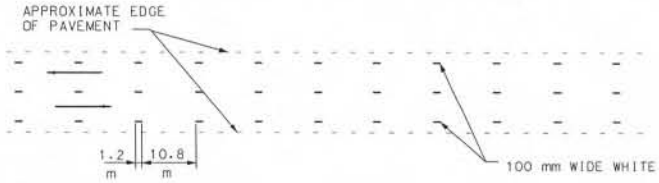
EDGE LINES ON MULTILANE DIVIDED SECTIONS



DETAIL A



EDGE LINES ON TWO-WAY SECTIONS WITH PAVED SHOULDERS GREATER THAN 1.2 m WIDE



EDGE LINES ON SECTIONS WITH AGGREGATE OR PAVED SHOULDERS 1.2 m OR LESS

SIGN 35
W-08-12

GENERAL NOTES:

ALL DIMENSIONS SHOWN ARE IN mm UNLESS OTHERWISE NOTED.

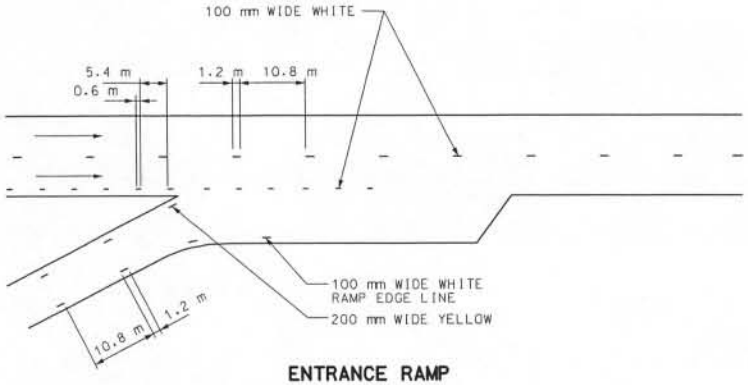
SIGN 35 SHALL BE POST MOUNTED.

SIGN 35 IS PLACED AT APPROXIMATELY 0.8 km INTERVALS AND AT SIDE ROADS. WHEN INSTALLED AT A SIDE ROAD, ANY OTHER SIGN 35 LOCATED WITHIN 200 m FROM THE SIDE ROAD MAY BE DELETED.

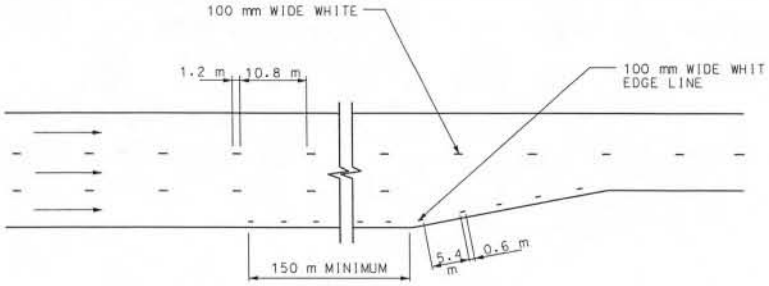
MISSOURI HIGHWAYS AND TRANSPORTATION COMMISSION

TEMPORARY PAVEMENT MARKING
TYPICAL HIGHWAY SECTIONS

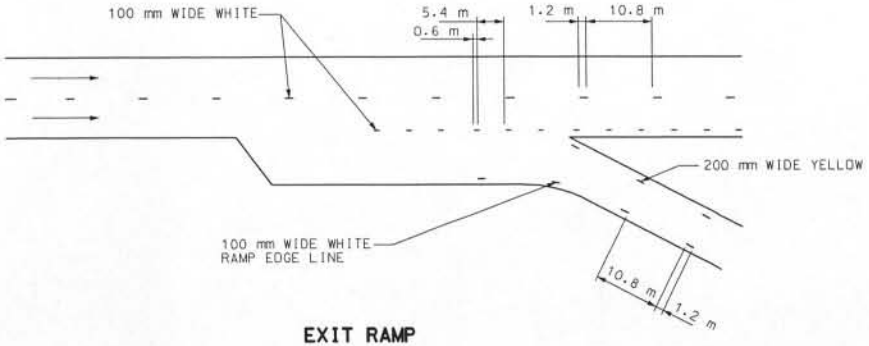
DATE:_____ | EFFECTIVE: 07-01-2004 | M620.10 | 1/4



ENTRANCE RAMP



LANE TRANSITION



EXIT RAMP

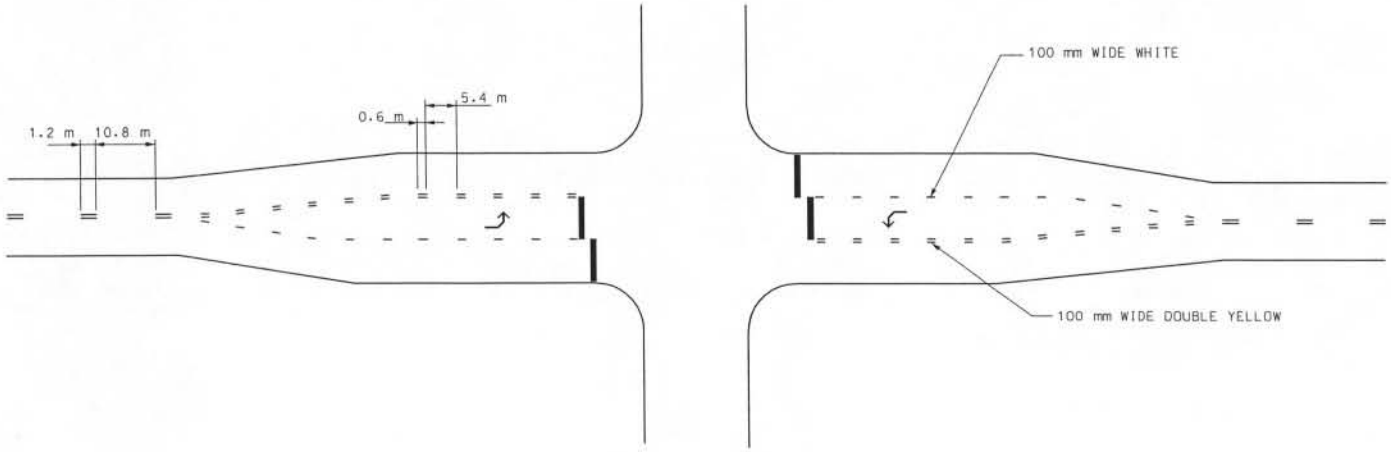
GENERAL NOTES:

ALL DIMENSIONS SHOWN ARE IN mm UNLESS OTHERWISE NOTED.

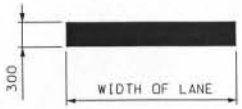
TEMPORARY PAVEMENT MARKING IN INTERSECTIONS, RAMPS GORES AND OTHER TRANSITION AREAS USE AN INTERMITTENT MARKING OF 0.6 m LONG AT A CYCLE OF 6 m.

LIMITS OF TEMPORARY GORE MARKING ARE THE SAME AS THE EXISTING GORE LINES.

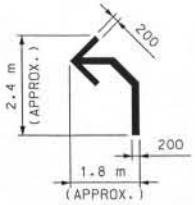
MISSOURI HIGHWAYS AND TRANSPORTATION COMMISSION			
	TEMPORARY PAVEMENT MARKING LANE TRANSITION AND RAMP AREAS		
DATE:_____	EFFECTIVE: 07-01-2004	**M620.10**	2/4



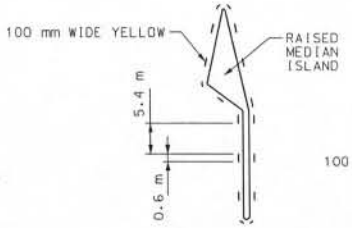
PLAN VIEW



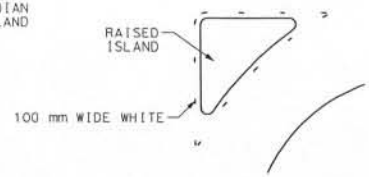
TEMPORARY STOP BAR DETAIL (WHITE)



TEMPORARY ARROW DETAIL (WHITE)



RAISED DIVISIONAL ISLAND



RAISED CHANNELIZING ISLAND

GENERAL NOTES:

ALL DIMENSIONS SHOWN ARE IN mm UNLESS OTHERWISE NOTED.

TEMPORARY ARROWS AND STOP BARS ARE REQUIRED WHEN GOEMETRIC MODIFICATIONS DURING CONSTRUCTION CREATE LANE CONFIGURATIONS DIFFERENT THAN EXISTING, OR THE EXISTING PAVEMENT MARKING INCLUDES THEM.

YELLOW AND WHITE TEMPORARY MARKING AROUND ISLANDS ONLY REQUIRED WHEN THE ISLAND CURB IS NOT PAINTED.

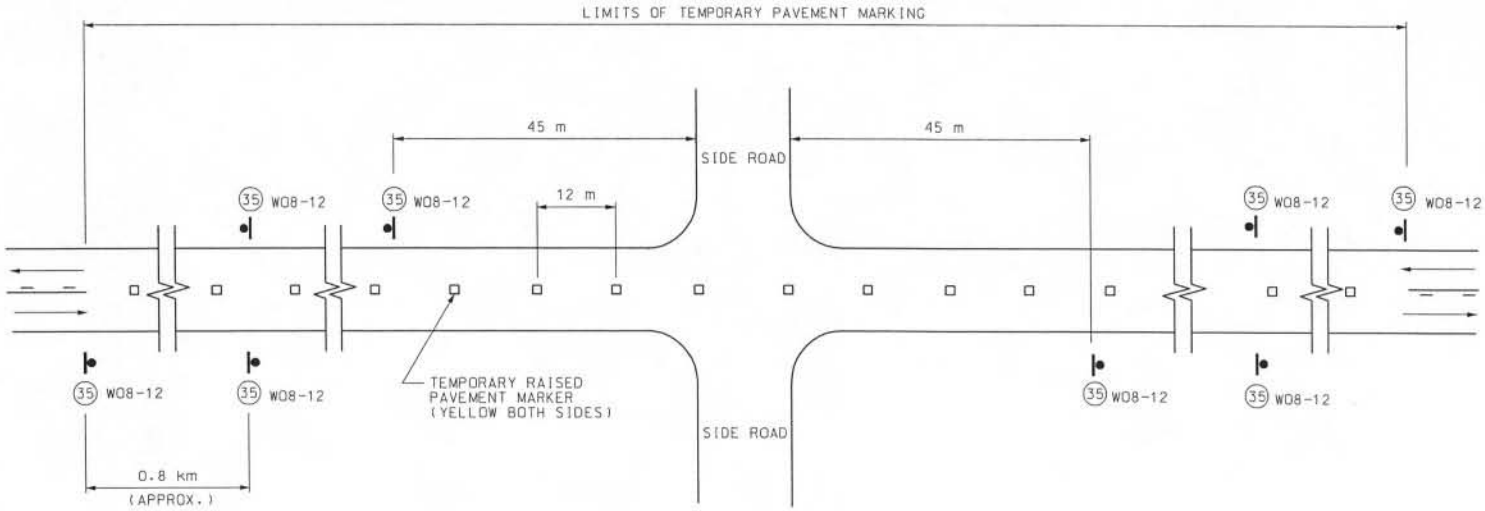
TEMPORARY PAVEMENT MARKING IN INTERSECTIONS, RAMP GORES AND OTHER TRANSITION AREAS USE AN INTERMITTENT MARKING 0.6 m LONG AT A CYCLE OF 6 m.

MISSOURI HIGHWAYS AND TRANSPORTATION COMMISSION

TEMPORARY PAVEMENT MARKING

INTERSECTIONS

DATE:_____ EFFECTIVE: 07-01-2004 M620.10 3/4



GENERAL NOTES:

ALL DIMENSIONS SHOWN ARE IN mm UNLESS OTHERWISE NOTED.

SIGN 35 AND TEMPORARY PAVEMENT MARKING INSTALLED WHERE CENTERLINE STRIPING HAS BEEN COVERED OR REMOVED. SIGNS ARE TO REMAIN IN PLACE UNTIL THE PERMANENT CENTERLINE PAVEMENT MARKINGS ARE IN PLACE. SIGNS SHALL BE COVERED OR REMOVED WHEN PAVEMENT CENTERLINE MARKING HAS BEEN INSTALLED.

SIGN 35 IS PLACED AT APPROXIMATELY 0.8 km INTERVALS AND AT SIDE ROADS. WHEN SIGN 35 IS INSTALLED AT A SIDE ROAD, ANY OTHER SIGN 35 LOCATED WITHIN 200 m FROM THE SIDE ROAD MAY BE DELETED.

SIGN 35 IS POST MOUNTED IN ACCORDANCE WITH STANDARD PLAN M616.10 AND M903.03.

MISSOURI HIGHWAYS AND TRANSPORTATION COMMISSION			
	TEMPORARY PAVEMENT MARKING TWO-LANE TWO-WAY HIGHWAY		
DATE:_____	EFFECTIVE: 07-01-2004	M620.10	4/4

PAVEMENT MARKING
FIELD SECTION 620 TABLE 2
QUALIFIED (PERMANENT) SNOWPLOWABLE RAISED PAVEMENT MARKERS
(620PMPRSPCR, 620PMPRSPRD, 620PMPRSPAM)

Brand Name	Manufacturer
Castings	
96 LP 96LPS Lifelite 101 LP	Stimsonite 7542 North Natchez Ave. Niles, IL 60648
A-250 B-250	Nightline Markers, Inc. 1030 Seaview Court Schaumburg, IL 60193
H-960	Hallen Products, LTD. 475 Keller Drive Park City, 60085
Snowlite 300 (3/03)	PacTec Inc. 1870 James Parkway Heath, OH 43056
Reflectors	
944	Stimsonite Corp. 7542 N. Natchez Niles, IL 60714
Ray-0-Lite 2004	Pac-Tec, Inc 1870 James Parkway Heath, OH 43056
RPM-190	3M Traffic Control 7827 N.W. Roanridge Road # I Kansas City, MO 64151

Note: These materials are approved by RDT.

Nevada DOT Specs

SECTION 633

PAVEMENT MARKERS

DESCRIPTION

633.01.01 General. This work consists of furnishing and placing pavement markers. Use pavement markers of an approved color. Off-color markers shall constitute grounds for rejection.

This work also consists of furnishing and placing temporary reflective lane line markers.

MATERIALS

633.02.01 Non-Reflective Pavement Markers. Non-reflective pavement markers shall consist of a heat-fired, vitreous, ceramic base and a heat-fired, opaque, glazed surface. Produce the markers from any suitable combination of intimately mixed clays, shales, tales, flints, feldspars, or other inorganic material. Thoroughly and evenly mature and free the markers from defects which effect appearance or serviceability.

The top surface of the non-reflective marker shall be convex and the radius of curvature shall be between 88 mm (3.5 in.) and 150 mm (6 in.), except that the radius of the 12.5 mm (0.5 in.) nearest the edge may be less. Any change in curvature shall be gradual. The top and sides shall be smooth and free of mold marks, pits, indentation, air bubbles, or other objectionable marks or discolorations.

The bottom of the ceramic markers shall be free from gloss or glaze and shall have areas of integrally formed protrusions projecting from the surface which will increase the effective bonding surface area of adhesive. The faces of the protrusions shall not deviate more than 1 mm (0.04 in.) from a flat surface. The areas of protrusion shall have faces parallel to the bottom of the marker and shall project approximately 1 mm (0.04 in.) from the bottom. The area of protrusions shall constitute a minimum of 30% of the area of the bottom of the marker and shall increase the bonding surface area by a minimum of 24%. To facilitate forming and mold release, the sides of the protruded area may be tapered. This taper shall not exceed 15 degrees from the perpendicular to the marker bottom.

The non-reflective ceramic type markers shall conform to the following tests:

(a) Adhesive Bond Strength (to bottom surface of the marker) ..... 4.8 MPa (700 psi) min.
(b) Glaze Thickness ..... 130 μm (5 mil) min.
(c) Moh Hardness ..... 6 min.
(d) Directional Reflectance (white markers only)
  1. Glazed Surface ..... 7 min.
  2. Body of Marker ..... 65 min.
(e) Yellowness Index (white markers only)
  1. Glazed Surface ..... 7 max.
  2. Body of Marker ..... 16 max.
(f) Color (yellow markers only)
  1. Purity ..... 76% to 96%
  2. Dominant Wave Length ..... 579 to 585 nm
  3. Total Luminous Reflectance (Y value x 100) ..... 41 min.
(g) Autoclave Reflectance ..... Glaze shall not spall, crack or peel
(h) Strength ..... 6,670 N (1,500 lb) min.
(i) Water Absorption ..... 2.0% max.

Plastic Non-Reflective Pavement Markers. Plastic type markers may be used in lieu of the ceramic type markers specified above. The plastic type markers shall be either polyester or acrylonitrile butadiene styrene (ABS) plastic type.

Polyester markers shall consist of polyester resin binder, inert organic filler material and colorant pigments and shall conform to the test requirements for ceramic type markers except the requirement for adhesive bond strength in Test (a) shall be 3.3 MPa (480 psi) minimum and Tests (b), (c), (g), and (i) shall not apply.

ABS markers shall consist of ABS plastic conforming to ASTM D4673, Designation ABS0122, and shall conform to the test requirements for ceramic type markers except Tests (a), (b), (c), (g), and (i) shall not apply. The bottom of ABS plastic markers shall be configured to produce a structural bond with the pavement.

Use non-reflective pavement markers listed in the QPL.

633.02.02 Reflective Pavement Markers. Reflective pavement markers shall be of the prismatic reflector type consisting of a methyl methacrylate or suitably compounded acrylonitrile butadiene styrene (ABS) shell filled with a mixture of an inert thermosetting compound and filler material. The exterior surface of the shell shall be smooth and contain one or two methyl methacrylate prismatic reflector faces of the color specified.

The reflective lens shall not contain any voids of airspace and the back lens shall be metallized. Fabricate the shell with a mechanical interlock between the thermosetting compound and the shell. Bond the thermosetting compound directly to the backside of the metallized lens surface.

The base of the marker shall be flat [the deviation from a flat surface shall not exceed 1 mm (0.04 in.)], rough textured and free from gloss or substances which may reduce its bond to the adhesive.

The color of the reflector when illuminated by an automobile headlight shall be an approved color. Off-color reflection shall constitute grounds for rejection. The daylight color of the marker body shall be an approved color, compatible with the color of the primary lens.

Note that the 100 mm (4 in.) x 100 mm (4 in.) x 10 mm (0.4 in.) size of the reflective pavement marker shown on Standard Plan Sheet T-37.1.1 is only a common size and other sizes of markers may be accepted.

The reflective type markers shall conform to the following tests:

(a) Adhesive Bond Strength (to bottom surface of the markers) .....3.4 MPa (500 psi) min.
(b) Reflectance .....Specific Intensity

	Clear	Yellow	Red
0 degree Incidence Angle, min.	3.0	1.5	0.75
20 degrees Incidence Angle, min	1.2	0.60	0.30

(c) Strength .....8,900 N (2,000 lb) min.
(d) Water Soak Resistance .....No delamination of the body or lens system of the marker nor loss of reflectance

Failure of the markers body or filler material before reaching 3.4 MPa (500 psi) in the bond strength test, test (a) above, shall also constitute a failing bond strength test.

Deformation of the marker of more than 3 mm (0.125 in.) at a load of less than 8,900 N (2,000 lb) or delamination of the shell and the filler material of more than 3 mm (0.125 in.) regardless of the load required to break the marker shall be cause for rejection of the marker.

Use reflective pavement markers listed in the QPL.

633.02.03 Recessed Reflective Pavement Markers. Reflective pavement markers to be placed in pavement recesses shall conform to Subsection 633.02.02 with the following exceptions. The pavement markers need not conform to the strength requirements, and the specific intensity requirements shall apply after abrading the lens surface by the following "Steel Wool Abrasion Procedure".

Steel Wool Abrasion Procedure—Form a 25 mm (1 in.) diameter flat pad using No. 3 coarse steel wool conforming to FSS FF-W-1825. Place the steel wool pad on the reflector lens. Apply a load of 23 kg (50 lb) and rub the entire lens surface 100 times.

Use recessed reflective pavement markers listed in the QPL.

633.02.04 Adhesive for Pavement Markers. Use adhesives for pavement markers listed in the QPL.

633.02.05 Temporary Reflective Lane Line Markers. Use temporary reflective lane line markers listed in the QPL.

The temporary lane line markers used for centerlines shall have yellow bodies and yellow reflective sheeting on both sides.

The temporary lane line markers used for lane lines or edge lines shall have the same body and reflector color as required for the permanent striping and the reflective sheeting shall be only required on the side that faces oncoming traffic.

633.02.06 Certificates. Furnish certificates of compliance executed by the manufacturers of the markers and adhesives attesting that they conform to these specifications.

CONSTRUCTION

633.03.01 Pavement Marker Installation. Remove dirt, curing compound, grease, oil, moisture, loose or unsound layers, paint and any other deleterious material from the surface to be marked. Clean Portland cement concrete by blast cleaning. Uniformly place the adhesive on the cleaned pavement surface or on the bottom of the marker in a quantity sufficient to result in complete coverage of the area of the contact of the marker with no voids present and with a slight excess after the marker has been pressed in place. Place the marker in position and apply pressure until firm contact is made with the pavement. Immediately remove excess adhesive around the edge of the marker, on the pavement, and on the exposed surfaces of the markers. Remove adhesive from exposed faces of pavement markers with soft rags moistened with mineral spirits conforming to FSS TT-T-291 or with kerosene.

Prepare and apply the adhesive according to the manufacturer's requirements. Protect the markers against impact until the adhesive has sufficiently hardened to keep traffic from dislodging the markers.

Install markers to the line established by the Engineer. Install reflective markers so that the reflective face of the marker is at right angles to a line parallel to the roadway centerline.

Do not install pavement markers over longitudinal or transverse joints of the pavement surface.

633.03.02 Pavement Recesses. Locate pavement recesses along the line of new or existing stripes. Select method to construct recesses. Use power-operated equipment capable of removing the pavement to the dimensions shown on the plans. Remove residue from the roadbed with vacuum equipment and dispose according to Subsection 107.14.

633.03.03 Temporary Lane Line Marker Installation. Install temporary lane line markers according to the manufacturer's recommendations. Maintain the markers by replacing lost or damaged markers daily.

Use temporary lane line markers specified in Subsection 633.02.05.

The patterns and spacings for the temporary pavement markers shall be as follows:

For broken lines, place groups of 3 markers spaced longitudinally 600 mm (24 in.) apart at 12 m (40 ft) intervals.

For double yellow lines, place 2 markers side by side with a 100 mm (4 in.) separation between markers at 6 m (20 ft) intervals.

For the centerline in a one way passing zones, place 2 markers side by side with a 100 mm (4 in.) separation between markers at 6 m (20 ft) intervals.

Place temporary lane line markers on edge lines at 6 m (20 ft) intervals.

(a) Installation of Temporary Markers on Open-Graded Surface. Temporary markers may be required to be placed on the new plantmix bituminous open-graded surface. See Subsection 632.03.04 for limitations on the application of the epoxy pavement striping and optional placement of temporary markers.

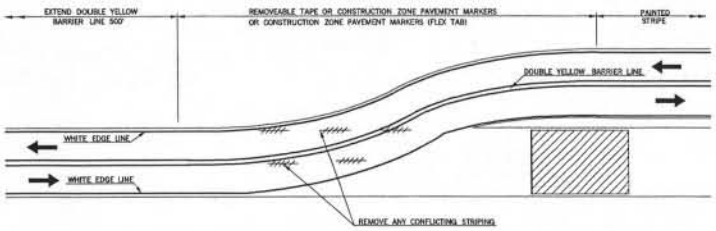
The adhesive used with the temporary lane line markers shall not damage the pavement surface when they are removed. Remove the markers placed on the new plantmix bituminous open-graded surface just before the application of the permanent striping.

There will be no additional compensation for furnishing, installing, maintaining, and removing the temporary lane line markers placed on the new plantmix bituminous open-graded surface before applying the permanent striping.

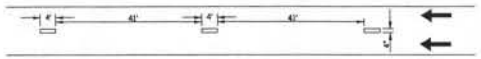
(b) Installation of Temporary Markers with the Application of Screenings. In areas to receive a surface treatment of screenings, apply the temporary lane line markers before application of the bituminous material. After placement of screenings and before allowing public traffic on the roadway surface, remove the clear protective coverings from the temporary lane line marker reflectors.

Equip temporary lane line markers with an additional clear protective covering when a seal coat is to be applied on the screenings. After application of the seal coat and before allowing public traffic on the roadway surface, remove the secondary clear protective coverings from the temporary lane line marker reflectors.

Maintain the markers by replacing lost or damaged markers daily. The markers need not be removed after the application of the permanent striping.



CONSTRUCTION ZONE PAVEMENT MARKINGS THRU SHOO-FLY

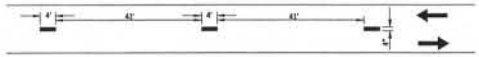


ONE-WAY PAVEMENT MARKING
REMOVEABLE TAPE OR PAINT

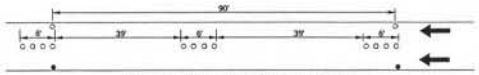
PAVEMENT MARKINGS: REMOVEABLE TAPE OR PAINT

WIDTH OF LINES SHALL BE A MINIMUM OF 4".

SHORT-TIME PAVEMENT MARKINGS ARE THOSE THAT MAY BE USED UNTIL THE EARLIEST DATE WHEN IT IS PRACTICAL AND POSSIBLE TO INSTALL PERMANENT PAVEMENT MARKINGS THAT MEET THE FULL OKLAHOMA DEPARTMENT OF TRANSPORTATION STANDARDS FOR PAVEMENT MARKINGS.



TWO-WAY PAVEMENT MARKING
REMOVEABLE TAPE OR PAINT



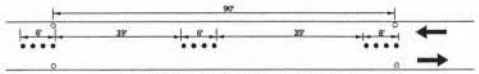
ONE-WAY PAVEMENT MARKING
FLEX TABS

PAVEMENT MARKINGS: FLEX TABS

TYPE I - FLEX TAB MARKERS SHALL HAVE REFLECTORIZED MATERIAL ON BOTH SIDES.

TYPE II - FLEX TAB MARKERS SHALL HAVE REFLECTORIZED MATERIAL ON BOTH SIDES AND SHALL HAVE A CLEAR REMOVEABLE COVER.

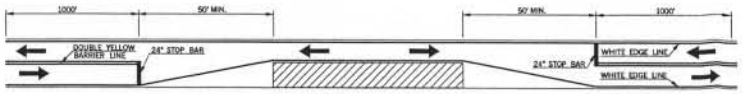
FLEX TABS MAY BE INSTALLED AS SHOWN FOR INTERIM PAVEMENT MARKINGS



TWO-WAY PAVEMENT MARKING
FLEX TABS

SHORT TIME PAVEMENT MARKINGS

DESCRIPTION	REVISIONS	DATE



TYPICAL PAVEMENT MARKINGS FOR ONE LANE CLOSURE ON TWO LANE /TWO WAY ROADWAY
REMOVEABLE TAPE OR CONSTRUCTION ZONE PAVEMENT MARKERS (FLEX TAB)

NOTES:

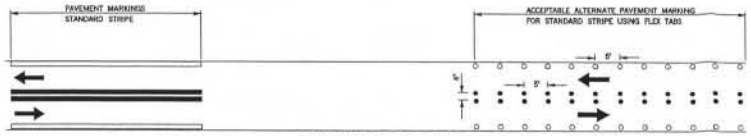
CONSTRUCTION ZONE PAVEMENT MARKINGS SHALL CONSIST OF EITHER PAINT, CONSTRUCTION ZONE PAVEMENT MARKERS (FLEX TABS) OR REMOVABLE MARKING TAPE. THERMO-PLASTIC STRIPE MAY BE USED IN CONJUNCTION WITH PAINT, FLEX TABS OR TAPE WHEN SPECIFIED IN THE PLANS.

ALL PAVEMENT MARKINGS TO BE PLACED ON TEMPORARY SURFACES OR ON SURFACES SCHEDULED TO BE REMOVED SHALL BE DONE WITH PAINT UNLESS OTHERWISE SHOWN IN THE PLANS OR STANDARD DRAWINGS. ALL FINAL OR FINISHED SURFACES SHALL BE MARKED WITH EITHER REMOVABLE PAVEMENT MARKING TAPE OR CONSTRUCTION ZONE PAVEMENT MARKERS (FLEX TABS), UNLESS OTHERWISE NOTED ON THE PLANS.

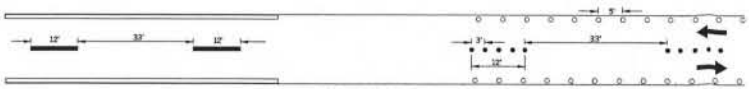
WIDTH OF STRIPED LANE LINES SHALL BE A MINIMUM OF 4".

KEY:

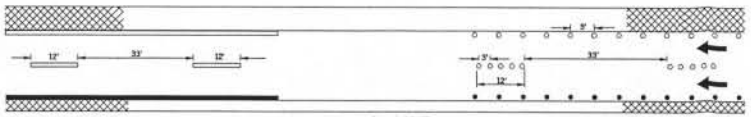
- WORK ZONE
- WHITE LANE LINE (PAINT OR TAPE)
- YELLOW LANE LINE (PAINT OR TAPE)
- WHITE FLEX TAB
- YELLOW FLEX TAB



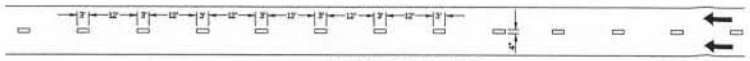
TWO-LANE /TWO-WAY
NO PASSING



TWO-LANE /TWO-WAY
PASSING PERMITTED



4 -LANE
DIVIDED ROADWAY



WHITE DOTTED LINE

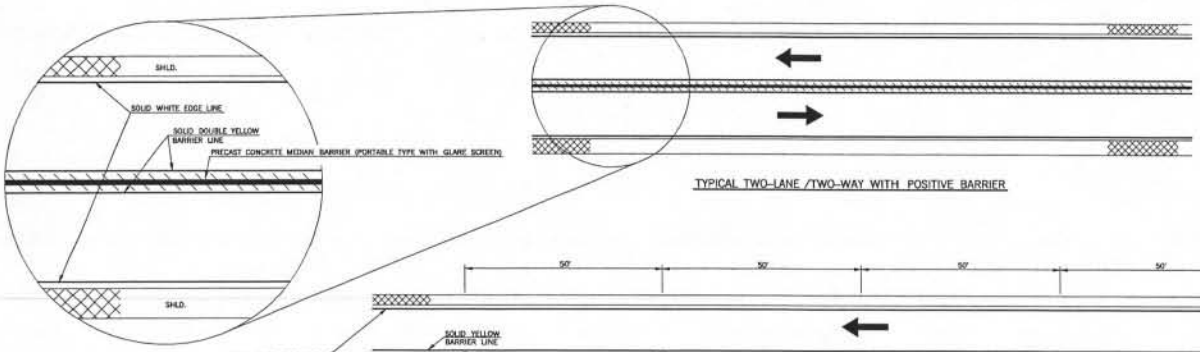
INTERIM PAVEMENT MARKINGS

APPROVED BY TRAFFIC ENGINEER DATE

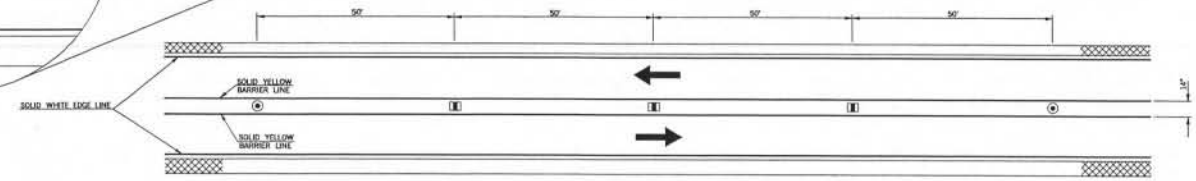
OKLAHOMA DEPT. OF TRANSPORTATION
TRAFFIC STANDARD (ENGLISH)
TRAFFIC CONTROL STANDARD
CONSTRUCTION ZONE PAVEMENT MARKINGS

1999 SPECIFICATIONS	TCS10-1	00E
		T-510E

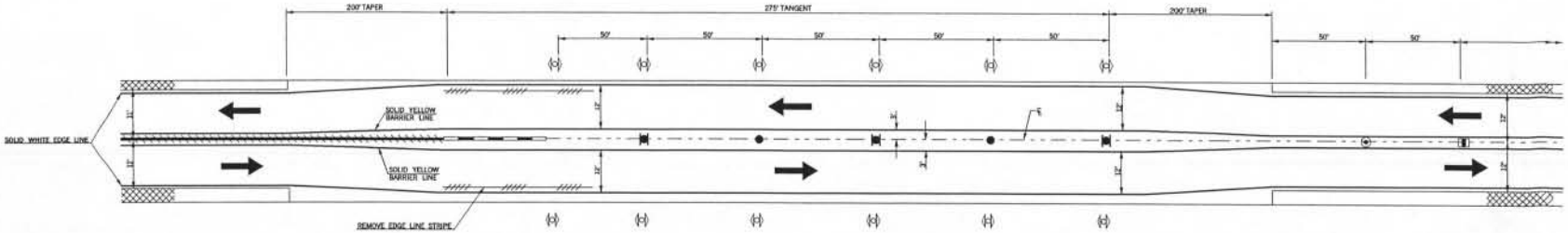
DESCRIPTION	REVISIONS	DATE



TYPICAL TWO-LANE /TWO-WAY WITH POSITIVE BARRIER



TYPICAL TWO-LANE /TWO-WAY WITHOUT POSITIVE BARRIER



TRANSITION INTO NARROW IMPACT ATTENUATOR

CONSTRUCTION ZONE PAVEMENT MARKINGS

KEY:

- VERTICAL PANEL W/TYPE "C" STEADY BURN LIGHT
- CENTERLINE CONST. ZONE PAVEMENT MARKER (YELLOW)
- TUBE CHANNELIZERS
- NARROW CZ IMPACT ATTENUATOR
- PRECAST CONCRETE MEDIAN BARRIER (PORTABLE TYPE WITH GLARE SCREEN)
- EXISTING PAVEMENT MARKINGS TO BE REMOVED
- DRUM
- DRUM WITH SIGNS MOUNTED ON BOTH SIDES

NOTES:

CONSTRUCTION ZONE PAVEMENT MARKINGS SHALL CONSIST OF EITHER PAINT, CONSTRUCTION ZONE PAVEMENT MARKERS (FLEX TAB) OR REMOVABLE PAVEMENT MARKING TAPE. THERMO-PLASTIC STRIPE MAY BE USED IN CONJUNCTION WITH PAINT, MARKERS OR TAPE WHEN SPECIFIED IN THE PLANS.

APPROVED BY TRAFFIC ENGINEER DATE

OKLAHOMA DEPT. OF TRANSPORTATION
TRAFFIC STANDARD (ENGLISH)
TRAFFIC CONTROL STANDARD
CONSTRUCTION ZONE PAVEMENT MARKINGS

1999 SPECIFICATIONS	TCS11-1	00E
		T-511E

South Carolina DOT Specs

Full specs available at: http://www.dot.state.sc.us/doing/

barrier wall. If the Contractor limits the work and reduces the length of barrier wall used, the Contractor will only receive payment for the length of barrier wall actually used. The Department will make no separate payment for moving equipment or miscellaneous hardware. Consider such items incidental to the use of the item.

602.50 Basis of Payment. Payment shall be full compensation for providing, installing, removing, relocating as necessary, and maintaining the temporary concrete barrier wall. Payment shall include applying paint or coating, re-coating or re-painting previously used or discolored barrier wall, and removal and replacement of discolored barrier wall. Payment shall include relocation and reinstallation throughout all stages of construction, repair or replacement of damaged barrier walls, and anchoring barrier walls where necessary. Payment shall also include furnishing materials, labor, hardware, equipment, tools, incidentals, anchors, anchor installations and miscellaneous items necessary to complete the work as directed by the Engineer.

Payment for this item includes all direct and indirect costs and expenses required to complete the work.

Payment will be made under:

Item No.	Pay Item	Pay Unit
6025001	Temporary Concrete Barrier	Linear Foot

TEMPORARY PAVEMENT MARKERS

602.51 Description. This item consists of temporary pavement markers installed during stage construction as a supplement to the pavement markings. Reapply the pavement markers for each traffic control scheme or traffic relocation or each asphalt concrete course application as directed. However, do not install temporary pavement markers on a new asphalt concrete surface course or any other final surface course unless otherwise directed by the plans, the special

provisions, or the Engineer. Provide, install, and maintain the temporary pavement markers as required by **Subsection 605.03** of these standard specifications, the plans, the special provisions, the *SCMUTCD*, and the Engineer. However, these temporary pavement markers will not require an abrasion-resistant face.

On two-lane two-way roadways, supplement the yellow centerline markings by installing the temporary pavement markers at 80-foot intervals. On primary and secondary multilane roadways, supplement the yellow centerline markings by installing the temporary pavement markers at 40 foot intervals. Also, on all multilane roadways including interstate routes, supplement the broken white lane line markings by installing the temporary pavement markers at 80' intervals. On roadways where turn lanes, accel lanes, and decel lanes are present, supplement the broken white auxiliary lane lines by installing the temporary pavement markers at 40-foot intervals.

At the beginning of a project, install temporary pavement markers on the existing pavement if the existing pavement markers are deficient or no pavement markers are present. Install temporary pavement markers upon the application of an asphalt concrete binder course or an intermediate course to any two adjacent travel lanes. Also, reapply the temporary pavement markers each time the traffic control scheme or the traffic patterns change.

During interstate rehabilitation projects, omit installation of temporary pavement markers on an asphalt concrete binder course or an intermediate course if a final asphalt concrete surface course is applied to all adjacent travel lanes within 60 calendar days of beginning the application of the asphalt concrete binder course or the intermediate course.

On jobs with permanent pavement markers, the Department prohibits the time between completion of the asphalt concrete surface course application to all travel lanes and beginning the application of the permanent pavement mark-