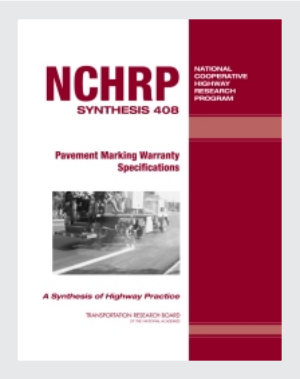

Pavement Marking Warranty Specifications

DETAILS

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP SYNTHESIS 408

Pavement Marking Warranty Specifications

A Synthesis of Highway Practice

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SUBSCRIBER CATEGORIES
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Cover figure: Application of pavement markings. *Courtesy:* Texas Transportation Institute (Hawkins et al., *Pavement Marking Effectiveness and the Pavement Marking Handbook*, 2004).

FOREWORD

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

There is information on nearly every subject of concern to highway administrators and engineers. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire highway community, the American Association of State Highway and Transportation Officials—through the mechanism of the National Cooperative Highway Research Program—authorized the Transportation Research Board to undertake a continuing study. This study, NCHRP Project 20-5, "Synthesis of Information Related to Highway Problems," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute an NCHRP report series, *Synthesis of Highway Practice.*

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

PREFACE

By Jon M. Williams
Program Director
Transportation
Research Board

This study updates information on the use of pavement marking warranties by U.S. and Canadian transportation agencies, including agency specifications. European experience is also presented, for comparison. Interest in applying warranties to pavement markings is driven by the importance of markings for traffic mobility and safety, and a desire to have better marking performance and greater cost-effectiveness.

Information was gathered through a literature review, surveys of state and Canadian provincial/territorial transportation agencies, and interviews with pavement marking contractors and materials suppliers.

Michael J. Markow, Teaticket, Massachusetts, collected and synthesized the information and wrote the report. The members of the topic panel are acknowledged on the preceding page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

CONTENTS

APPENDIXES D AND E OF THIS REPORT CAN BE FOUND AT WWW.TRB.ORG, SEARCH ON "NCHRP SYNTHESIS 408."

PAVEMENT MARKING WARRANTY SPECIFICATIONS

SUMMARY

This synthesis study updates information on the use of pavement marking warranties by U.S. state departments of transportation (DOTs) and Canadian provincial/territorial transportation agencies. It also reviews road construction warranty experience in Europe for comparison. Pavement markings provide information, guidance, and warnings to road users. Interest in applying warranty specifications to pavement markings is driven by their importance to traffic mobility and safety, and the resulting desire for better pavement marking performance, greater cost-effectiveness, and other potential benefits.

Data for this synthesis were obtained from a literature review, a survey of U.S. and Canadian transportation agencies, and interviews with U.S. and Canadian pavement marking contractors and materials manufacturers. Forty state DOTs and eight Canadian transportation agencies responded to the synthesis survey. Respondents were divided almost equally between those that now use pavement marking warranties (23 agencies, or 48% of the survey population) and those that do not (25 agencies, or 52%). Fifteen of the 23 agencies that now use pavement marking warranties provided one or more examples of current specifications, which are compiled in Appendix D (provided as a web-only portion of the report) and are a rich source of information on the various approaches and specific contract provisions now in use.

The experience and assessments of the 23 agencies that now use pavement marking warranties are the basis of several findings on current North American warranty use:

- **Warranty Structure and Timeline.** Most agencies start the warranty evaluation period after installation or after initial acceptance of the marking application. Typical warranty durations are 1 to 6 years, although some agencies apply warranties of 180 days that are timed to encompass one winter season.
- **Variations in Evaluation Periods.** Other agencies impose additional time periods—referred to respectively as observation periods and performance periods—to evaluate pavement marking performance through a lengthier period before initial acceptance or to serve as a further evaluation after initial acceptance but before onset of a multi-year warranty.
- **Warranty Concepts.** Based on the examples provided by the 15 U.S. and Canadian agencies, pavement marking warranty specifications now in use represent a blend of methods-based and performance-based thinking. Only three agencies are now using true performance specifications, in which contractors are given full latitude to select pavement marking materials and installation techniques to meet agency requirements for pavement marking performance.
- **Pavement Marking Performance.** The performance criteria specified in warranties typically include durability or presence, retroreflectivity, and color retention. The minimum acceptable threshold values of these measures through the warranty performance period differ among agencies.
- **Responsible Party.** Within the warranty sample, two-thirds of the agencies (10 of 15) regard the contractor as the warrantor; that is, the party responsible for fulfilling the requirements of the warranty specification. Other agencies either hold the materials manufacturer responsible or employ a dual or discretionary assignment of responsibility.

- **Cost Impacts.** The impacts of pavement marking warranties on costs (whether initial, annual, or life-cycle) are still not well researched. Most assessments of costs are based on subjective judgments or perceptions by parties engaged in the warranty process, with little supporting quantitative information.
- **Issues in Administration.** Several issues in administering pavement marking warranties were identified by the road agencies and the contractors and materials manufacturers. One topic on which the interests of the two groups converged is the scheduling of partial payments through a multi-year warranty period, with questions of what is a reasonable amount for initial payment and what should be the amounts of subsequent annual payments through the duration of the warranty. Comments by the engaged parties suggested that a balanced approach is needed to ensure that agency expectations of quality and performance are met, while providing contractors and materials manufacturers with fair, timely payment for work accomplished in initial installation of markings. This issue will likely grow in importance as more agencies begin to use pavement marking warranties and as the durations of warranty performance periods increase.

Almost 70% of agencies now using pavement marking warranties expressed satisfaction with their warranty program. About 13% reported mixed results, with concerns primarily about timely response by contractors to concerns about observed performance. One agency that cited a "problematic" experience explained its response as actually a concern with the current state of knowledge of warranty performance and the need for stronger capabilities in pavement marking management systems, rather than an issue with the warranties themselves.

Most agencies that use pavement marking warranties viewed their benefits in terms of improved pavement marking performance and quality, protection against premature failure, reduced lane occupancy for repairs or re-application, and attendant savings in annual (or recurring) costs and life-cycle costs (including road-user cost savings resulting from reduced lane occupancy through the warranty period). Agencies use several mechanisms to promote quality in their warranty specifications; for example, stipulated meetings among all parties; required contractor submittals; materials manufacturer's training, certification, onsite representation during installation, and technical assistance; contractor provision of test stripes or sections; use of qualified products lists; and several other measures. Other benefits that were cited included the potential for greater contractor innovation, warranties as a logical component of comprehensive departmental outsourcing, reduced administrative and staffing burden for the agency, a mechanism for generating performance measurement data for pavement markings (which could also be used for product performance comparisons), and a perceived benefit of risk sharing.

The major impediments or drawbacks to pavement marking warranties as reported by agencies that do not use them were the perceived greater administrative burden, potentially higher bid prices, and possible increases in disputes or litigation with contractors. Agencies also mentioned an internal culture and practice that encouraged closing out construction projects as expeditiously as possible. These agencies currently favored effective enforcement of project specifications in lieu of warranties as the preferred approach to managing performance-related risk. Although they might entertain using pavement marking warranties in the future, they would carefully consider the implications before proceeding further. Other problems that were cited included perceived interactions between pavement marking warranties and federal-aid project requirements, requirements of concurrent warranties on other highway assets, and other bonding commitments.

Interviews with seven U.S. and Canadian pavement marking contractors and two marking materials manufacturers provided private sector perspectives on pavement marking warranties. All interviewed firms believed in providing a quality pavement marking job regardless of whether or not the projects involved a warranty. They believed, however, that warranties helped impose a level playing field for bidding among all participating contractors and provided an understood expectation of quality through the warranty performance-evaluation

period. The firms supported warranties that are structured fairly with strong but reasonable specifications that are enforced effectively, for reasons of both quality of result and fair competition. The materials manufacturers related quality to their ability to exercise appropriate management and control of the several facets of jobs they were involved in, believing that one-source accountability was the best approach to achieve project objectives, avoid finger-pointing, and yield the desired savings in life-cycle costs with benefits to the agency and the public. Notwithstanding their general support for warranties, the firms collectively identified a number of risks that contractors and materials manufacturers face on a project under warranty specifications, and ways to mitigate these risks. The risks are categorized in the report as technical, administrative, financial, and business-reputation risks, although these categories are interconnected and somewhat overlapping. Proposers reviewing the project requirements, including the warranty specifications, must therefore deal with the total project context when deciding whether and how to bid on the job.

This study has reviewed several specific aspects of pavement marking warranty provisions and how they are administered. Agencies with successful warranty programs have often refined their individual practices based on past experience, incorporating lessons learned into longer-term, more ambitious pavement marking contracts. One advantage of this very focused agency engagement of the problem is the identification of pavement marking materials and techniques that work well given local pavements, weather, altitude, traffic, and available construction industry capabilities. A more general result, however, is the overall variability among state DOT and Canadian agency practices. Several examples of this variability include the different approaches to warranty formulation (i.e., the particular mix of methods-based vs. performance-based requirements included), the particular performance measures and ranges of values in minimum acceptable performance thresholds, and varying allocations of risk between agency and contractor. For instance, agencies differ in how they treat winter maintenance damage in their warranties; that is, whether or not they hold contractors responsible for repairing pavement marking damage owing to snowplowing, anti-icing and deicing, studded tires, winter chains, and so forth. Some exclude winter damage from warranty requirements (i.e., the contractor is not responsible for repair), whereas others explicitly include it as a warranty requirement and thus a contractor responsibility. Four reporting agencies—all of which are located in regions subject to snow and ice in the United States or Canada—structure their warranty periods on a calendar basis that explicitly includes a winter season.

The literature review provided comparative information on European warranty experience to complement the U.S. and Canadian findings. Two international scans of European highway agencies that were organized by the FHWA and AASHTO observed a different legal and institutional framework that influenced the success of warranty use. European experience in road construction warranties has a long history: Materials and workmanship warranties of various durations have been used for 30 to 40 years. European countries are continuing to move toward performance warranties and other methods to engage the contractor more fully in assuring the quality of asset performance. Institutional differences between Europe (and to some degree Canada) and the United States include a less litigious relationship between agencies and contractors, and greater European use of bid alternatives, contractor testing, and end-result (or performance-based) specifications rather than method-based (or prescriptive) specifications. Several European countries use best-value rather than low-bid procurement and emphasize its importance to successful warranty implementation, because it promotes trust and confidence among the parties. These findings led to several recommendations for improving U.S. practice, including steps to create stronger teamwork between public and private sector firms, a staged approach leading to greater use of long-term performance warranties, and federal establishment of a warranty resource center for use by federal, state, and local governments. Another recommendation, now under consideration by U.S. industry representatives who are engaged in pavement markings, concerned the possible application of a European-style turntable for accelerated identification, evaluation, approval, acceptance, and specification of new pavement marking products.

The study's findings identified several gaps in current knowledge and state of practice that suggest needs for future research. Among the recommended research topics are the following:

- A broader, more strategic, and more quantitative understanding of the role and value of pavement marking warranties. This research could develop more comprehensive knowledge and strengthened analytic techniques in several topic areas; for example, factors affecting the performance of pavement marking materials, the relationship of pavement marking performance to highway mobility and safety, the appropriate distribution of contractor payments through a multi-year warranty period to ensure quality in pavement marking performance while providing fair and timely reimbursement of contractor costs, the potential use of contract incentives to gain superior pavement marking performance beyond warranty requirements, and better quantification of the relative costs and benefits of warranty use. These research findings could help agencies to formulate a more strategic view of warranties; that is, as one method in a range of options to achieve the desired goals of a longer pavement marking life, improve performance during this life, lower life-cycle costs, and reduce the need for road occupancy to repair or replace deficient markings.
- Only 3 of the 15 agencies that submitted samples of warranty specifications employ true performance specifications. A stronger understanding is needed of the advantages and disadvantages of performance specifications for pavement markings, lessons learned from agencies that have used them, and opportunities for wider use.
- Basic improvements in communication and dispute resolution could be researched and discussed for implementation where they do not now exist; for example, wider use of qualified product lists tailored to local conditions, liaison committees between the highway agency and industry representatives to maintain communication on current issues, and formation of a panel to clarify and resolve disagreements where such mechanisms are not now formalized.
- Several agencies that do not now use pavement marking warranties alluded to interactions between pavement marking warranties and other contractual or bonding commitments, including federal-aid project agreements, that they believed impeded use of the warranties. Although it is not clear whether these concerns represent an actual need for research (other agencies had apparently addressed these types of concerns in their own warranty programs), at least wider communication of acceptable procedures—perhaps through roundtable discussions or peer exchanges—could promote wider and more confident use of warranties if these agency concerns were allayed.

CHAPTER ONE

INTRODUCTION

STUDY OBJECTIVES AND SCOPE

Objectives

The primary objective of this study has been to compile information on the existing and potential use of warranty specifications for pavement markings on U.S. and Canadian highways. Further objectives have been to compare U.S. practice with Canadian experience and with the European approach to pavement marking warranties, and to identify gaps in current knowledge that suggest needs for future research.

Pavement Markings

Pavement markings encompass lane dividers, pavement edge marking, crosswalks, "Stop" bars, symbols (such as directional arrows), cross-hatching, and messages or legends that provide information, guidance, and warnings to motorized and nonmotorized road users. Pavement markings play an important role in reducing congestion and improving safety by guiding traffic flows, providing modal separation, getting the attention of drivers at critical locations, and providing information that promotes safe and smooth vehicular and pedestrian movement. Markings comprise different materials including various types of paints, thermoplastics, preformed thermoplastic, tape, polymer materials, and different categories of discrete physical markers [e.g., raised pavement markers (RPMs), recessed markers, snowplowable markers].

Highway Construction Warranties

Pavement marking warranties are one form of highway construction warranty. Construction warranties transfer the risk inherent in maintaining acceptable asset performance to a private sector firm—a contractor or materials manufacturer—in exchange for a potentially higher bid price. Additional benefits may attend to warranty use, particularly in improved product quality and performance. To date, state department of transportation (DOT) experience with pavement marking warranties varies among agencies, but warranty acceptance, use, and willingness to experiment with longer-duration specifications appear to be increasing. Canadian provincial agencies, materials manufacturers, and contractors that provided information for this study exhibited a strong acceptance of pavement marking warranties and confidence in their ability to achieve their respective objectives under a fair and reasonable warranty arrangement. Successful U.S. and Canadian firms have honed production, procurement, and application practices that enable them to meet performance requirements even when faced with demanding traffic, wintertime, or other road conditions.

Transportation agencies may consider the use of pavement marking warranties to gain one or more benefits—for example, superior performance, reduced need for inspection personnel, reduced life-cycle costs, and potential for contractor innovation. Warranties are attractive particularly if a potentially higher bid price is still cheaper than other options; for example, the cost of more frequent pavement re-marking, the cost to highway users of degraded safety and of increased congestion owing to road occupancy during more frequent re-marking, or the cost of research and development that would be needed by agencies to develop superior marking materials and methods on their own. However, there are also drawbacks to pavement marking warranties that are cited by other agencies that choose not to use them; for example, increased demands on personnel to ensure warranty compliance, greater administrative burdens, delays in closing out highway construction contracts, and adverse impacts to construction contractors. This study has explored these different motivations and opinions that surround warranty specifications.

Value of This Study

Both the public and the private sectors have worthwhile knowledge, experience, and perceptions of pavement marking performance and the application of warranty specifications. However, to date, this information has not been organized within a single source for use by the highway community. In meeting this objective, this synthesis report serves several purposes:

- To inform readers of the status of pavement marking warranty use;
- To illustrate current variations in warranty requirements, duration, and administration;
- To identify factors underlying different warranty provisions and approaches; for example, the type of marking (longitudinal, transverse, legend), the marking material, geographic location and climate, traffic volume, and so forth;

- To present the pros and cons of such warranties as expressed by knowledgeable parties; and
- To provide examples of pavement marking warranty specifications now used by several agencies.

Scope

The scope of this study encompasses several topics that will inform readers of the development, use, and effects of pavement marking warranty specifications:

- Current agency use of pavement marking warranty specifications and their degree of satisfaction to date.
- Impact of state law and departmental policy on agencies' evaluations of whether or not to consider using pavement marking warranty specifications.
- Assessments of the cost impacts of pavement marking warranty specifications; that is, the additional costs to the agency of warranty use and the presumed life-cycle benefits in terms of long-term cost reductions to the agency and to road users.
- The types of warranty specifications used by transportation agencies, and the party (or parties) held responsible for meeting warranty requirements.
- The duration of the warranty period, and how that length varies with marking material and other factors.
- Technical aspects of warranty administration; for example, the types of specifications and data provided to bidders, frequency of pavement marking inspection once the installed markings have been accepted, typical measures used to characterize pavement marking performance, corrective measures specified for the contractor or materials manufacturer to maintain compliance, and effects of external factors (e.g., snow plowing and traffic volume) on warranty requirements and responsibilities of the contractor or materials manufacturer.
- Financial and business aspects of warranty administration; for example, payment schedules (particularly for multi-year warranties); bonding arrangements, if any; and whether discussions with the construction industry have been held before warranty implementation.
- The benefits of pavement marking warranty specifications as perceived by agencies that have successfully implemented them and continue to use them.
- By contrast, the perceived drawbacks of pavement marking warranty specifications that have caused agencies to discontinue their use or dissuaded agencies from considering warranties if they have not yet used them.
- Examples of pavement marking warranty specifications currently in use by state and provincial transportation agencies.

The study has focused on pavement marking warranty specifications associated with conventional contracting approaches to construction projects; that is, design-bid-build (DBB). These projects would involve the application of pavement markings as part of new pavement construction, road resurfacing, or re-marking of an existing surface.

STUDY APPROACH

This synthesis study has gathered relevant information through a review of the domestic and international literature, surveys of U.S. state DOTs and Canadian provincial transportation agencies, and interviews with private sector firms involved in manufacturing materials for or applying pavement markings. The literature review provided an historical perspective on highway construction warranties generally and pavement marking warranties specifically. It also established background information on the domestic use of warranty specifications as compared with Canadian and European experience. The state DOT survey was conducted with the assistance of the AASHTO Highway Subcommittee on Traffic Engineering. The survey of Canadian provincial agencies was facilitated by the Transportation Association of Canada. Interviews with materials manufacturers and U.S. and Canadian pavement marking contractors were conducted by telephone, based on contacts suggested by the Topic Panel.

The initial round of the survey, which included several electronic mailings, yielded 32 responses: 24 from U.S. state DOTs and 8 from Canadian provincial agencies. At a subsequent meeting with the Topic Panel it was agreed that the number of survey responses was not sufficient to represent an accurate picture of current pavement marking warranty use. An additional round of surveys was conducted, first by another electronic mailing and then by telephone, using a streamlined version of the questionnaire. This latest round brought the total number of responses to 48, as tallied in Table 1. In addition to response rate, Table 1 gives the number of agencies that provided current examples of their specifications for pavement marking warranties. Several agencies sent more than one specification, because their warranties cover multiple pavement marking materials or different performance periods. These example specifications are compiled in Appendix D (a web-only portion of the report).

Survey responses were organized further according to agency interest and experience in using pavement marking warranty specifications. The relevant categories are described here, with the breakdown of all responses summarized in Figure 1.

- **Agencies that now use pavement marking warranties.** Twenty-three of the 48 responding agencies (48%) now use pavement marking warranties and are likely to continue to do so. One agency reported a history of warranty use extending more than two decades. Several have applied their experience to expanding the scope of their warranties, and others have already implemented or are considering improvements in their warranty administration. Of the 23 agencies that now use pavement marking warranties, 15 sent examples of their specifications (see Table 1), which provided good cov-

TABLE 1
TALLY OF SURVEY RESPONSES

Agency Category	Population Surveyed	No. of Responses (response rate)	No. Providing Warranty Specifications
U.S. State Departments of Transportation	50	40 (80%)	13
Canadian Provincial and Territorial Transportation Organizations	13	8 (62%)	2
Total for All Agencies Surveyed	63	48 (76%)	15

erage of many details of warranty requirements and administration.

- **Agencies that have discontinued their use of pavement marking warranties.** Three of the 48 responding agencies (6%) reported that they had used pavement marking warranties, but have since discontinued their use.
- **Agencies that do not use and have no plans for future use of pavement marking warranties.** Twelve of the 48 responding agencies (25%) do not now use pavement marking warranties and are unlikely to revise their position in the foreseeable future.
- **Agencies that have not used pavement marking warranties but are potentially interested.** Ten of the 48 responding agencies (21%) do not now use pavement marking warranties, but are willing to consider future use.

The statistical findings of the survey that are presented in chapter three are based primarily on the responses from the 23 U.S. and Canadian agencies that reported current use of pavement marking warranties. In addition to these analytic results, the survey yielded considerable supplementary information through managers' responses to open-ended questions. This additional information supplied reasons for particular responses to questions, pointed out directions toward which the agency's warranty program is now evolving, discussed factors (such as climate and materials quality control) that affect pavement marking performance and ways in which warranties account for those influences, and suggested needs for future research. This supplementary information is likewise discussed in chapter three.

WARRANTY NOMENCLATURE AND PERFORMANCE TIMELINE

A nationally recognized quality assurance glossary presents the following definition:

> **Warranty specifications.** A type of performance specification that guarantees the integrity of a product and assigns responsibility for the repair or replacement of defects to the contractor (*Source: Glossary of Highway . . .* May 2005).

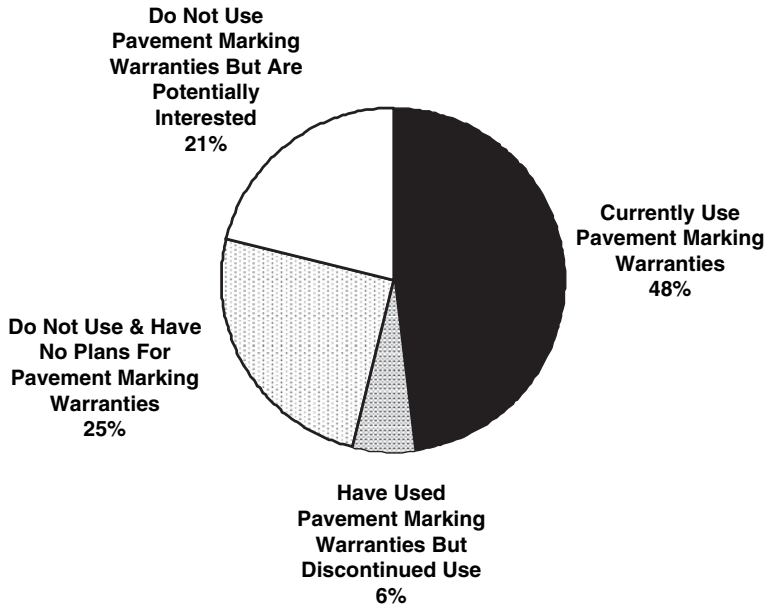


FIGURE 1 Breakdown of survey respondents.

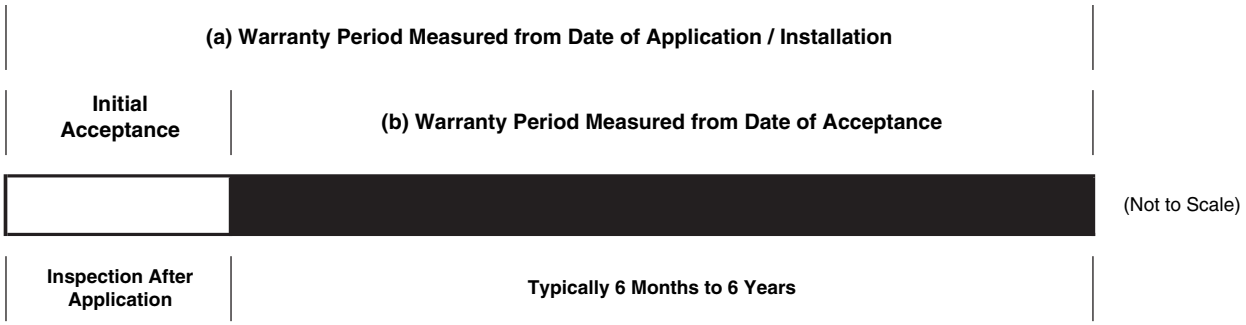


FIGURE 2 Typical pavement marking warranty timeline.

Under this umbrella, two types of warranty specifications are further defined:

> **Materials and workmanship warranties.** Specifications that hold the contractor responsible for correcting defects in work elements within the contractor's control during the warranty period. [Under materials and workmanship warranties [for pavements], the highway agency is responsible for the pavement structural design. The contractor assumes no responsibility for pavement design or those distresses that result from shortcomings in the design. Some responsibility is shifted from the agency to the contractor for materials selection and workmanship.]
>
> **Performance warranties.** Specifications that hold the contractor fully responsible for product performance during the warranty period. [Under performance warranties [for pavements], the contractor guarantees that the pavement will perform at a desirable quality level. The contractor assumes some level of responsibility, depending on the specific project, for the structural pavement or decisions on the mix.]
>
> (*Source: Glossary of Highway . . .* May 2005. Note: The outer set of [square brackets] in each definition above is part of the published definition. The inner set of square brackets [for pavements] has been inserted by the author to clarify that the definitions presume the application of these warranties to pavement projects.)

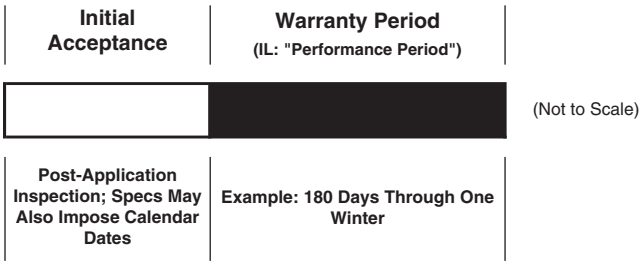
Although these definitions could be adapted from "pavement warranties" to "pavement marking warranties," later findings will show that a more refined explanation of warranty timeline and nomenclature will be useful. It will help in understanding how agencies actually implement warranty specifications with respect to various periods of performance monitoring. Figures 2 through 5 illustrate several options currently in use. Together they illustrate different ways of structuring pavement marking warranties and establish a consistent nomenclature for use in later chapters.

Figure 2 presents the typical sequence of events conducted by most of the 23 agencies that reported using pavement marking warranties.

- After application or installation the pavement markings are inspected to determine that they conform to project construction specifications, in which case they are accepted by the agency in the "initial acceptance" period shown in Figure 2. If deficiencies in the initial application require correction, this repair must be completed before the markings will be accepted. The time allowed for such repair is specified in the construction documents and is considered part of the "initial acceptance" period in Figure 2.
- Figure 2 illustrates two options in how a pavement marking warranty period is described in specifications. Option (a) shows the warranty period measured from marking installation or application. Option (b) shows the warranty period commencing after the pavement markings are initially accepted. Because the time between installation/application and inspection/acceptance can be relatively short (e.g., 30 days or less), the practical difference in the durations of these two options is generally negligible, particularly for multi-year warranties. The duration of current U.S. and Canadian pavement marking warranties varies from 180 days (6 months) to 6 years (72 months), based on information reported by surveyed agencies.

Warranties in force for less than 1 year may be used by agencies that manage roads in harsh climates or that use short-lifetime products such as paint. These warranty periods are structured intentionally to encompass a single winter season. Figure 3 illustrates this subset of the general case described earlier.

The initial acceptance period in Figure 3 includes inspections to verify that pavement markings conform to construc-



Note: IL = Illinois DOT.

FIGURE 3 Pavement marking warranty timeline through one winter period.

FIGURE 4 Pavement marking warranty timeline involving an observation period.

tion specifications, as discussed for Figure 2. However, the actual start of the warranty period may also be affected by calendar dates imposed by contract. For example, specifications may call for the warranty period to start on the *later* of two dates—the date of initial acceptance or a particular date specified in the contract (usually in October or November). This method ensures that the warranty period (i.e., 180 days in Figure 3) carries through the entire winter season. Although one agency refers to the second period in Figure 3 as a "performance period," this report will use the label "warranty period." This practice follows the more widespread usage among other agencies that apply the warranty concept of Figure 3, and reserves the term "performance period" for another interpretation that is explained here.

Some agencies use other configurations of pavement marking warranties:

- Following application, there is an "observation period" in which the pavement markings are observed in service for a specified length of time; for example, 180 days (6 months). This observation period may itself be the basis for initial acceptance, followed by a longer warranty period. This approach is used by Maryland State Highway Administration (SHA), Nebraska, and South Carolina for their durable pavement markings (Figure 4).
- Alternately, initial acceptance may be followed by an additional "performance period," the approach used by Texas for its RPMs and Delaware for its retroreflective preformed patterned tape. The performance period is followed by a longer warranty period, as shown in Figure 5.
- Deficiencies in meeting construction specification requirements that are observed during the initial acceptance period or the performance or observation periods must be corrected before moving to the next performance monitoring stage.
- Following successful completion of the performance or observation period, the warranty period begins, typically extending for 1 to 6 years of additional time. For those surveyed states that use an observation period, the warranty is provided by the manufacturer of a durable pavement marking product.

Figures 2 through 5 reinforce that state and provincial agencies evaluate pavement marking performance in a number of ways through different contractually defined periods. For purposes of this study, the definition of a "pavement marking warranty period" has been based on the following considerations: (1) how individual agencies have characterized their own pavement marking performance periods in their specifications and survey responses; (2) a consensus among surveyed agencies that a warranty of performance follows, and is distinct from, meeting construction specification requirements during marking application/installation; and (3) a consensus among surveyed agencies that successful conclusion of a warranty period relieves the contractor and/or materials manufacturer of further responsibility for pavement marking performance. To recap the nomenclature that will be used in this report:

- **Initial acceptance:** the determination of whether pavement markings meet project construction specifications for initial performance. An inspection to make this determination typically occurs within a short time following application (e.g., 30 days or less), but pavement marking initial acceptance may occur, for example, up to 180 days after application if an observation period is used.

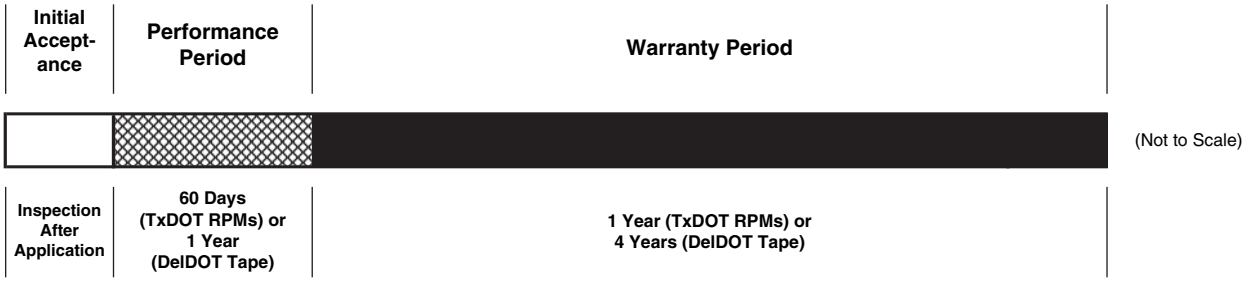


FIGURE 5 Pavement marking warranty timeline involving a performance period. TxDOT = Texas Department of Transportation; RPMs = raised pavement markers; DelDOT = Delaware DOT.

- **Observation period (as used by Maryland, Nebraska, and South Carolina for durable pavement markings):** typically a 180-day period following application to determine whether pavement markings meet project construction specifications for an initial period of performance.
- **Performance period [as used by the Texas DOT (TxDOT) and Delaware DOT]:** a period following initial acceptance to evaluate further the performance of pavement marking materials and installation, but before commencing the provisions of the warranty specification.
- **Warranty period:** a period after construction acceptance during which the provisions of the warranty specifications apply. Warranty periods often extend for 1 to 6 years. Some warranties (e.g., in harsh climates or for paint) may extend for 180 days (6 months) and may encompass a winter period. The successful conclusion of the warranty period relieves the contractor and/or materials manufacturer of any further responsibilities for pavement marking performance.

Multi-year, performance-based warranty specifications are often linked with an alternate method of contracting, design-build (DB). The contracting relationships in DB and the roles and responsibilities of the public and private sector entities involved are different, however, from those in the more conventional DBB projects envisioned in this study. For example, the relationships inherent in work performance and acceptance in Figures 2 through 5 do not apply under DB; moreover, warranty specifications used with DB are subject to a separate set of federal regulations (23 CFR 635.413(e)). To maintain focus and consistency, this study deals with conventional DBB projects and does not address DB contracts.

ORGANIZATION OF SYNTHESIS

Chapter two provides background information drawn from the literature review: a brief history of construction warranty use in the United States, with lessons learned from these early trials; description of the activities of the FHWA related to pavement marking performance and warranty administration; and a summary of measures of the performance of pavement markings that are widely applied in warranty specifications. Chapter three presents the main findings of this study, drawing on statistical tallies of key survey results from U.S. state DOTs and Canadian provincial transportation ministries, as well as interviews with pavement marking contractors and materials manufacturers. This chapter also covers the review of literature related to European pavement markings warranty practices. Chapter four concludes the report. The survey questionnaire, which was developed with the advice and assistance of the Topic Panel, is reproduced in Appendix A. The interview guide that was used in discussions with the contractors and materials manufacturers is included in Appendix B. Agencies and firms that participated in the survey and the interviews, respectively, are listed in Appendix C. Examples of pavement marking warranty specifications that were provided by agencies as part of their survey responses are compiled in Appendix D (which is provided as a web-only portion of this report). Appendix E (also web only) describes comparative road construction–warranty practices of several European nations as identified in previous reports and two international scans conducted by the FHWA and AASHTO.

CHAPTER TWO

BACKGROUND AND CONTEXT

PURPOSE

This chapter provides background and context for the technical findings in chapter three. The chapter is organized as follows:

- An overview of the history of highway construction warranties in the United States, including the roles played by state DOTs and the FHWA in advancing warranty practices generally and those with respect to pavement markings specifically.
- Reference to a warranty framework that was based on cumulative U.S. road construction experience to 1999. This framework synthesized categories of information believed to be useful when developing road construction warranties. Current examples of actual state DOT warranties for pavement markings that are discussed in chapter three and Appendix D generally conform to this framework, but illustrate the variety of specific approaches that agencies have used in implementing their respective warranty specifications.
- A discussion of performance characteristics related to pavement markings, which helps in understanding technical provisions of pavement marking warranties discussed in chapter three and Appendix D, as well as current shifts toward more performance-based approaches when developing warranty specifications.

Pavement markings were the first highway-related asset to be addressed through warranty specifications in recent U.S. road history. The historical review that follows shows that early experience with pavement marking as well as other types of road construction warranties provided useful experience on how to avoid obvious problems and prompted thinking about what information and requirements could be included in warranty specifications.

HISTORICAL REVIEW

Archived Sources

The 1980s and 1990s saw the introduction and growth of trial use of road construction warranties in the United States. Warranties during this period were used for road construction and maintenance on several types of highway assets including pavements, bridges, intelligent transportation system components and buildings, landscaping, pavement markings, sign sheeting, and roofing. Warranty durations ranged from 1 to 10 years across all types of work; for pavement markings, the warranties extended from 2 to 6 years. An FHWA website summarizes the experiences of 27 states in terms of highlights, warranty duration, performance indicators, and bonding and payment provisions ("Briefing: Warranty Clauses . . ." 2000). A subset of these projects in 14 states was accomplished with FHWA assistance through the innovative contracting component of its Special Experimental Projects 14 (SEP-14) program. Following the passage of the Intermodal Surface Transportation Efficiency Act (ISTEA, P.L. 102-240, Dec. 18, 1991), the FHWA subsequently engaged in a rulemaking process to allow the use of warranties on National Highway System (NHS) as well as non-NHS federal-aid projects. This rulemaking was completed successfully and went into force in 1996.

Copies of many documents related to this early warranty research, as well as administrative changes during this period (e.g., *Federal Register* announcements as part of FHWA rulemaking), are available on the technology transfer website for innovative contracting that is operated by Utah State University ("Innovative Contracting" n.d.). Brief histories, discussions, or analyses of these research studies, their successes and failures, and the administrative actions during this period are available in several sources in addition to the FHWA website cited earlier. Among these are compilations of the status and use of road construction warranties in the United States and Europe as presented in *NCHRP Synthesis 195: Use of Warranties in Road Construction* (Hancher 1994) and a paper summarizing U.S. warranty experience by Russell et al. (1999). A study to develop performance-based warranties for the Virginia DOT also reviewed work during this period as well as the concepts underlying warranty specifications (Ozbek 2004). A study conducted in 2001–2003 to update information on U.S. road construction warranties likewise briefly reviewed the warranty use experiments by state DOTs during the 1980s and 1990s (Bayraktar et al. 2004, 2006).

Lessons Learned from Early U.S. Highway Warranty Use

Overview Through 1999

An overview of U.S. warranty contracting for highway construction was developed by Russell et al. (1999). The first experiment with a highway warranty was for pavement markings by the North Carolina DOT (NCDOT), beginning in 1987.

Only a handful of projects were completed through the early 1990s, but warranted work increased substantially in the late 1990s, spurred by passage of ISTEA and subsequent changes in federal regulation that allowed warranty use on federal-aid projects both on and off the NHS. From 1987 through 1997, 240 projects involving warranties were completed by 21 states, and Florida and Utah were planning to begin warranty use in 1998. The count of 240 projects was a conservative number, because DOTs were not able to provide an accurate tally of all the traffic marking, landscaping, and irrigation projects. Warranty specifications in this initial 10-year period covered work on asphalt pavement, chip sealing, microsurfacing, patches on portland cement concrete pavement, bridge painting, bridge components, landscaping and irrigation systems, pavement markings, and roofs (Russell et al. 1999).

For pavement marking specifically, agencies promoted quality of work by focusing on contractor qualifications and quality of materials and methods of application and installation. Specific requirements by DOTs included some or all of the following: personnel resumes, lists of materials and equipment to be used, test reports or manufacturer's data on materials, annual performance reports, and manufacturer's warranty of materials performance and, in some cases, of workmanship. The latter requirement typically included training of contractor's personnel who applied or installed the markings and onsite presence of a manufacturer's representative during application. Other requirements might also include a traffic control plan, a striping plan giving the timing and area of each stage of work, a spill recovery plan, and a placement, procurement, and handling plan (Russell et al. 1999).

Two project examples from this period provide additional insight into the outcomes of these early efforts. The first is the NCDOT project that warranted pavement markings; the second is a pavement (roadway surface) warranty initiative by the Wisconsin DOT (WisDOT).

NCDOT: Pavement Marking Warranty

In 1987, epoxy pavement marking materials were installed on a section of I-85 in central North Carolina, with the objectives of (1) monitoring the condition and performance of the markings through a 4-year performance period, and (2) assessing the use of a performance-based warranty specification that could be applied on future NCDOT pavement marking projects (Stanley 1989, 1990). The warranty specification required that the markings meet or exceed criteria governing physical durability and reflectance during the 4-year performance period.

As the trial progressed, the basic mechanisms of the warranty specification appeared to work as planned. Most of the markings performed satisfactorily through the first two years. Sections of the yellow edge line that had incurred physical damage after one year of service were replaced promptly by the contractor. No other deficiencies attributable to the contractor were observed after that. However, in the third year of the trial, the condition and performance of the markings were unexpectedly degraded by premature failures of the asphalt pavement surface. These problems required maintenance and resurfacing, which first reduced the effectiveness of the markings and then obliterated them. The trial evaluation was halted after three years (Stanley 1990, 1991).

While the logistical and administrative feasibility of pavement marking warranties was demonstrated, the results also showed the sensitivity of pavement marking performance to road maintenance work (Stanley 1991).

- The pavement markings cracked as a result of reflection cracking and spalling of the underlying pavement surface. This cracking caused both a reduced presence (durability) and reduced retroreflectance.
- The reflectance of the pavement markings suffered further from road maintenance and repair as evidenced through asphalt spotting and tracking from nearby crack sealing, short overlays, and pothole filling. Even small amounts of asphalt on the surface of pavement markings reduced their measured reflectance.

WisDOT: Asphalt Pavement Warranties

Useful lessons on how to structure and administer warranties also came from demonstration projects involving paved road surfaces. WisDOT engaged in trial use of asphalt pavement warranty specifications with assistance from the FHWA through SEP-14. This effort was an outgrowth of a WisDOT quality control/quality assurance program to give contractors a stronger role and greater responsibility in undertaking pavement work in the state. By 1994 almost all asphalt pavement being placed on the state trunk highway system came under this quality control/quality assurance program, and a warranty specification for asphalt concrete pavement construction was seen as the next logical step. The result indicated that warranty specifications could be developed and used successfully in connection with low-bid project procurements. Warranties added 5% to 10% to the cost of pavement projects over their 5-year duration, but reduced WisDOT's construction engineering costs, gave contractors greater flexibility and control in managing their project work, and provided a quality pavement. Salient characteristics of this warranty program were as follows (Shober et al. 1996):

- **Purpose.** WisDOT identified several purposes of this warranty program; for example, to move from method-based specifications to performance-based specifications; to reduce departmental costs of testing, supervision, and construction; to encourage contractor innovation; to orient highway construction toward a performance-based process; to strengthen customer-oriented results in safety, ride quality, and asset longevity; to gain administrative and management experience in warranty-related matters

such as bonding; and to leverage the WisDOT pavement management system in helping define acceptable performance targets.
- **Duration.** WisDOT considered warranty durations of from 3 to 5 years. A 5-year warranty was selected because it provided sufficient time to assess pavement performance without placing an undue burden on the contractor.
- **Performance indicators.** Developing customer-oriented performance indicators for the warranty likewise involved balancing desired qualities with realistic warranty-based issues. Of eight measures considered initially, three were selected: rutting, friction, and longevity. These customer-oriented indicators were then related to technical categories of pavement distress that are managed using WisDOT's pavement management system.
- **Pavement management system contribution.** Data from WisDOT's pavement management system proved valuable in several tasks: (1) establishing realistic warranty performance thresholds based on historical data; (2) providing well-documented, proven methods of conducting distress surveys to establish pavement performance; (3) through its store of data, giving contractors and surety companies the confidence that what was being asked for in the warranty specifications was entirely achievable; and (4) giving the surety companies proven data on which to base a bond.
- **Conflict resolution.** A conflict resolution team was established for each pavement project and empowered to resolve disputes between WisDOT and the contractor.
- **Agency and contractor practices.** Both WisDOT and the contracting community applied practices that continue to be reflected in warranted road construction. For example, WisDOT adhered to the principle that contractors would not be held responsible for distresses caused by factors beyond their control—an important perspective when considering the multifaceted causes of pavement distresses such as alligator cracking and rutting. Contractors developed a reliable approach based on established construction technology, avoidance of unreasonable risk, and a focus on quality.
- **Sense of opportunity.** Contractors taking a long view of their business opportunities welcomed the use of warranties. Warranties gave the contractors a better understanding of how pavements performed in service, and put long-term performance in their business interest. The greater latitude and responsibility they were given during construction enabled contractors to be more nimble and creative in solving problems.
- **WisDOT recommendations.** Based on this experience, Shober et al. (1996) recommended that WisDOT expand the warranty approach to other types of pavements, reevaluate and adjust performance thresholds as needed, and consider incentives for exceptionally well-performing pavements. If, for example, a pavement exhibited exceptional performance at the end of 3 years, the contractor could be relieved of future warranty work on that project. Such incentives were believed to be beneficial to all parties: the contractor would save on bonding and maintenance costs and WisDOT and the motoring public would have a superior performing pavement.

More Recent Study of U.S. Construction Warranty Experience

An updated picture of the use of road construction warranties in the United States was obtained through a study conducted in 2001–2003 (Bayraktar et al. 2004, 2006). Data were obtained through a literature review, survey questionnaire, and interviews with personnel among selected transportation agencies, contractors, and surety companies. The survey questionnaire was cast broadly among 158 organizations in the United States. Sixty-three responses were received from 40 state DOTs, 16 contractors, and 7 bonding companies. These responses were culled to retain only the subset from agencies and firms that had solid experience with road construction warranties. Questionnaire responses were qualified in this way for 13 state DOTs, 16 contractors, and 6 surety companies. The survey was followed up with interviews of key individuals in transportation agencies to clarify responses where needed and gain additional information on perceived benefits of warranties, perceived barriers to implementation, preferred warranty duration for different types of work, typical bidders' profiles, and possible alternatives to then current warranty provisions. Contractors and bonding companies were likewise interviewed on topics relevant to their experience and perspectives. Key results of the Bayraktar et al. study that relate to findings of this synthesis project are discussed in chapter three.

FHWA Activities

Following the passage of ISTEA in 1991 and final rulemaking in 1996, which together allowed use of construction warranties on federal-aid projects, the FHWA has maintained active support of warranty clauses. The information on the FHWA website regarding the historical development of construction warranties and state usage was discussed earlier. The FHWA has also sponsored international scans on European warranty use, which are discussed in chapter three. In addition, the FHWA is conducting the following activities relevant to the subject of this synthesis:

- The FHWA is sponsoring research by Utah State University to study best practices in innovative contracting and to compile relevant sources on the Innovative Contracting website discussed at the beginning of this chapter ("Briefing: Warranty Clauses . . ." 2000; "Innovative Contracting" n.d.). It has also developed materials that provide an overview and explanations of warranty practices ("A New Look . . ." 2007; "Background for Pavement Warranties" n.d. draft).
- The FHWA is meeting a Congressional mandate to develop minimum acceptable retroreflectivity thresholds

for pavement markings. Background information on this mandate and its importance is discussed in *NCHRP Synthesis 371* (Markow 2007). Accomplishments to date are compiled on an FHWA Safety Program website ("Pavement Markings Visibility" n.d.) and an FHWA research website ("Establishing Criteria for Minimum . . ." n.d.). Technical and economic research contributing to this effort has been performed (Debaillon et al. 2007, 2008; Hawkins et al. 2008). Two workshops were conducted in Summer 2007 to solicit input from state and local transportation agency representatives regarding how the minimum retroreflectivity levels could be incorporated into the *Manual on Uniform Traffic Control Devices* (*MUTCD*) (Falk and Carlson 2008). Work is proceeding on this effort.

- The FHWA is conducting pavement marking demonstration projects in Alaska and Tennessee that are required by Section 1907 of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU, P.L. 109-59, Aug. 10, 2005). The purpose, features, and funding of these demonstration projects are described in an FHWA Fact Sheet ("Pavement Marking Demonstration Projects" 2006), with additional detail on a contractor website ("FHWA Project 475980-00001 . . ." n.d.). Because the legislation specified a number of requirements, the FHWA is conducting research in four major topic areas ("FHWA Project 475980-00001 . . ." n.d.):
  1. **Durability study:** to investigate the cost-effectiveness of different pavement marking systems, including advanced acrylic waterborne markings.
  2. **Safety study:** to evaluate the impacts and effectiveness of increasing the width of pavement marking edge lines from 4 in. to 6 in.
  3. **Environmental study:** to evaluate the potential environmental impacts of the different pavement marking systems that are included in the demonstration projects.
  4. **State bidding and procurement processes study:** to review the effects of state bidding and procurement processes on the quality of pavement marking materials that are employed in state highway projects.

This website includes status reports describing progress and plans within each active topic area. Work is proceeding on these projects.

WARRANTY FRAMEWORK DEVELOPED FROM HISTORICAL EXPERIENCE

Based on a review of state highway warranty specifications covering various types of work through 1998, Russell et al. (1999) compiled a road construction warranty framework comprising 11 key categories of information that were typically included:

- A **description** of the warranty scope and work required.
- The **duration** of the warranty period.
- **Bonding requirements** including bond value, acceptable bond rating, and other administrative and procedural requirements.
- **Maintenance responsibilities** and work approvals.
- Method of **conflict resolution** including requirement for a conflict resolution team, its composition, criteria for invoking the team's involvement, and the resolution process.
- **Contractor responsibilities** regarding the warranty including threshold performance values that trigger the need for remedial work, provisions governing materials and construction methods as applicable, the specified end product, elective or preventive maintenance actions, and insurance requirements.
- **Department (agency) responsibilities** including bond and insurance approvals, inspection, approvals of work plans, reports, and work performed, and criteria and requirements to meet emergency situations.
- **Performance indicators** that will be used to guide work needed under the warranty and criteria to determine whether defects are beyond the contractor's control.
- **Requirements for corrective actions** including any agency approvals needed, the types of activities and allowable time period for remedial actions, and procedures that void the need for corrective action by the contractor (e.g., utility relocation or destructive testing by the department).
- **Method of measurement** of the warranted end product.
- **Basis of payment;** for example, amount, limits, and payment schedule.

Some details have advanced since 1998; for example, the introduction of contractor or third-party inspection in lieu of agency inspection during the warranty period and improved understanding of pavement marking performance. However, the basic structure of this framework, interpreted broadly, can provide a guide in formulating current warranty provisions. The examples of current pavement marking specifications included in Appendix D (included as a web-only document), with key aspects discussed in chapter three, illustrate different ways in which these basic elements have been incorporated within contemporary warranty specifications.

PERFORMANCE ISSUES RELATED TO PAVEMENT MARKINGS

Research and field experience with updated pavement marking materials and practices has accompanied the increasing use of warranty specifications for these markings. These concurrent advances have enabled DOTs to include more refined installation and performance requirements, as well as provisions for items such as multi-year performance measures/criteria and staged payment schedules. The following subsection describes general categories of pavement marking performance typically included in warranty specifications. Specific examples,

with threshold criteria and measurement procedures for various marking materials, are given in Appendix D (web only). Later subsections summarize the current status of research on prediction models for pavement marking performance and impacts of pavement marking quality on road mobility and safety. Past experience with asphalt pavement warranties has shown these topics to be important issues in developing effective warranty specifications. They continue to be important subjects of investigation and the focus of ongoing DOT interest regarding pavement marking performance and related benefits.

Measures of Performance

Pavement marking performance is commonly specified in warranties using the following measures. (These measures relate to the warranty period as defined in chapter one. Other measures may also be included in specifications, relating to initial acceptance or observation or performance periods that precede the warranty period.)

- **Retroreflectivity, visibility:** The visibility of pavement markings is critical to safety and the orderly movements and interactions among motor vehicles, bicyclists, and pedestrians. Retroreflectivity is the ability of marking materials to reflect light back to its source and can be measured quantitatively by instruments. Warranties typically specify minimum retroreflectivity requirements (under dry, wet, or rainy conditions) through the warranty period, but may also allow for visual inspections in daytime or nighttime. Allowable minimum retroreflectivity levels are usually specified separately for white and yellow markings and, depending on individual agency practice, may or may not vary during the warranty period. Technical discussions of retroreflectivity are contained, for example, in the FHWA *Delineation Handbook* (Migletz et al. 1994) and the synthesis of pavement markings research performed for the Iowa DOT (Thomas and Schloz 2001). The issue of the minimum level of reflectivity needed for safe and effective traffic movements has been a subject of continuing research and agencies have adopted different approaches and threshold values.
- **Durability:** Durability, also referred to as presence, refers to the resistance of a pavement marking to physical damage; for example, cracking, chipping, breaking, spalling, flaking, blistering, crazing, delamination, shrinkage, loss of adhesion to the pavement surface, or other damage that causes the marking to appear worn out or unsightly. The durability of a pavement marking depends not only on the marking material, but also on traffic (average annual daily traffic), weather and resulting maintenance activity (e.g., winter maintenance), the quality of materials, preparation, installation, and the type and condition of the pavement surface. An issue in assessing durability is defining when a marking has degraded to the threshold that requires replacement. Agencies have adopted different approaches and threshold values for evaluating durability.
- **Color:** Color retention or stability may be specified with reference to standardized color chips and color tolerance charts and, depending on agency practice, by providing chromaticity coordinate limits for use with a colorimeter. The warranty specifications may refer to test methods or standards of the International Commission on Illumination [CIE (English acronym) or ICE (French)], ASTM International (originally the American Society for Testing and Materials), AASHTO, or other organizations. In addition to these color-related requirements, specifications may also call for minimum daytime reflectance values for white and yellow markings, respectively.

Examples of the use of these measures are provided in each of the specifications included in Appendix D (web only).

Agencies also specify a number of administrative steps to promote quality, including meetings before and during the job; contractor submittal of work plans, spill plans, and progress status reports; and required testing by agencies noted previously or the National Transportation Product Evaluation Program (NTPEP). Readers who would like additional information on the types of pavement marking materials in use today and measures of their performance can refer to a number of recent documents; for example, *NCHRP Synthesis 306: Long-Term Pavement Marking Practices* (Migletz and Graham 2002), *Pavement Marking Handbook* (Texas) (2004), "ODOT's Pavement Marking Program" (Oregon) (2008), and the chapter on pavement marking materials, with cited references, in *NCHRP Synthesis 371* (Markow 2007).

Predicting Pavement Marking Performance

The compilation of good historical data on pavement marking performance and the ability to predict performance reliably would assist both public and private sector organizations to address warranty requirements more dependably and efficiently. This idea is suggested by experience to date in the pavement arena.

- The earlier discussion of WisDOT's pavement warranty experience shows the importance of good historical data on performance. Contractors and sureties have both gained confidence from these data in (1) the proven track record of existing WisDOT pavements, which provided realistic estimates of life expectancies; and (2) the likelihood that warranty requirements were achievable by the contractor.
- Pavement management systems, with predictive models based on periodic inspections and accumulated historical data, enable agencies to forecast trends in condition and the need for corrective work. The timing of maintenance and rehabilitation treatments can thus be optimized to provide satisfactory performance at the lowest long-term cost.
- With an available model to predict performance (in the WisDOT pavement case, the AASHTO pavement design

model) researchers have formulated a method of risk-cost analysis that can be used by agencies and contractors to analyze short-term, warranty-based specifications for pavement projects (Zhang and Damnjanovic 2006).
- Researchers have shown how a pavement management system can be used to track the performance of both warranted and nonwarranted pavement projects, and have demonstrated this approach in five states: Florida, Indiana, Michigan, Ohio, and Wisconsin (Wang et al. 2005).

Work has already been undertaken to develop pavement marking management systems in Minnesota (*Pavement Marking Management System . . .* 1999), Missouri (Weinkein et al. 2002), and Iowa (Hawkins et al. 2006). Work is proceeding on predictive models that can help analyze the factors affecting pavement marking performance and assist in making decisions on when corrective work might be needed; for example, Parker and Meja (2003) and Sathyanarayanan et al. (2008). This work tends to be performed for a single agency or at a single site. Indications from a survey of practice nationwide in the management of pavement markings suggests however that considerable variability will exist in comparing results from different agencies until models better account for a greater number of influencing variables, including road characteristics and driver behavior (Markow 2007).

Impacts of Pavement Marking Performance

The impacts of pavement marking performance in terms of effects on crash rates, for example, are likewise subject to variability, including sometimes apparently counterintuitive effects. At the heart of this issue is the relationship between retroreflectivity and crash rates, or retroreflectivity and drivers' ratings of pavement marking acceptability. Although there is a broad relationship between the two variables in each of these pairs, it is confounded by details of the road site, traffic characteristics, and driver characteristics and behavior. This issue has been addressed in a number of sources and is reviewed, for example, in *NCHRP Synthesis 306* (Migletz and Graham 2002) and *NCHRP Synthesis 371* (Markow 2007). Although the literature on other types of warranties (particularly those for pavement projects) suggests no direct linkage between performance impacts and an agency's ability to administer warranties, there would be a direct relationship between the impacts of asset performance and the presumed benefits or value-added owing to the warranty. For example, with respect to pavement markings specifically, further studies may be needed to determine whether pavement marking warranties contribute to safety by:

- Maintaining a brighter line through the warranty period (because higher retroreflectivity leads to higher driver ratings of visibility and/or lower crash rates), or
- Contributing to a longer life of the warranted marking, implying that the greater safety is being achieved through additional safety benefits accumulated through the longer useful life, but not necessarily to greater brightness during the warranty period.

Current research is ambiguous on this point (e.g., Bahar et al. 2006, in addition to references cited previously). A study in New Jersey suggests that there may be a "threshold effect" in which increases in retroreflectivity above this threshold value do not significantly affect drivers' ratings of visibility (Parker and Meja 2003). Again, these issues relate to the justifications for warranty use and the potential benefits to be achieved, and not to the management or administrative aspects of warranty use. A somewhat analogous issue has been raised by Bayraktar et al., who noted that based on current warranty use in the United States, the practical outcome appears to be protection against premature failures rather than, say, promotion of contractor innovation or reduced life-cycle costs. This does not mean that such benefits cannot be achieved; rather, given the way in which warranties are now used, a main result is essentially that of an "insurance policy" (Bayraktar et al. 2006, pp. 4–6).

Implications for Study Findings

This evolving research in pavement marking performance and its impacts for road users is reflected in the variety of current state DOT practices documented in chapter three and Appendix D (web only). For example, agencies differ in the conceptual approach they take to warranty development. Only a few apply true performance-based concepts in which the specifications deal solely with required outcomes, leaving to the contractor the decisions on specific materials and methods of installation to achieve these requirements. The great majority of state DOTs that responded to the project survey employs rather a combination of prescriptive, methods-based materials and installation provisions, plus performance-based provisions covering the service life of pavement markings. Technical standards for satisfactory performance likewise vary across agencies in the measures of performance used as well as the numerical threshold values that define acceptable performance over time. Further distinctions are also found in particular aspects of warranty coverage; for example, the degree to which winter-related damage is regarded as the contractor's or materials manufacturer's responsibility, as opposed to exclusion of these factors from warranty requirements. Although broad-based comparisons are highlighted in chapter three, the details of specific provisions are purposely left for the reader to investigate in Appendix D. The reason is that it was believed important for the reader to understand the full context of each warranty specification when assessing specific technical requirements.

CHAPTER THREE

CURRENT PERSPECTIVES ON PAVEMENT MARKING WARRANTIES

CHARACTERISTICS OF PAVEMENT MARKING WARRANTIES

Basis for Reporting Survey Results

The descriptions of pavement marking warranty specifications throughout this section are based primarily on questionnaire responses from the 23 U.S. and Canadian agencies that now use these warranties (refer to Table 1 and Figure 1). The example warranty specifications from 15 of these 23 agencies (web-only Appendix D) were obtained as adjuncts to the project survey. Information from these specifications likewise informs the discussion that follows. For a number of survey questions, agencies were allowed to include more than one type of warranty in their responses. The reason is that agencies may manage several pavement marking warranty specifications, each with different terms and requirements that reflect differences among highway classifications, types of markings, marking materials, and the duration of warranty periods; percentage responses to certain questions may therefore sum to more than 100%.

Types of Specifications

As an introduction to the scope, terms, and variability among U.S. and Canadian pavement marking warranties, Table 2 summarizes the characteristics of the example warranties from 15 transportation agencies that are included in Appendix D. The table compiles information on the duration of the warranty period, warranty type or coverage [expressed either by the warranted pavement marking material(s) or by a characterization as a "performance" warranty, with no specific material specified], and the types of markings to which the warranty applies (e.g., longitudinal or transverse markings, symbols, legends, etc.).

- The variability of current practice is evident in terms of the range of warranted materials in Table 2, ways of structuring warranties around different performance periods (referring to the examples in Figures 2 through 5), and the types of pavement markings encompassed by the warranties. Warranty durations generally follow the materials categories, with relatively short periods (1 year or less) corresponding to paint and raised pavement markings, moderate-range durations (e.g., 1 to 4 years) corresponding to thermoplastic and methyl methacrylate among other materials, and 4 to 6 years for durable materials such as high-performance tape, in several cases backed by a manufacturer's warranty.
- Other factors also affect the duration of the warranty period. For example, for a given material warranty periods may be shorter for transverse markings than for longitudinal markings (e.g., refer to Arizona, Delaware, and Oregon in Table 2). Review of the specific technical requirements in each warranty in Appendix D shows other construction or performance distinctions between longitudinal and other markings; for example, different depths of grooving for inlaid markings and different minimum acceptable retroreflectivity levels. Further comparisons among these example warranties are given in subsequent sections. Additional information is also presented in the cover sheets in Appendix D that precede each agency's set of specifications.
- The warranty samples in Appendix D represent a blend of methods-based and performance-based thinking. It is therefore not unexpected that the survey conducted for this synthesis study yielded the responses shown in Figure 6. These results demonstrate a strong identification by agency respondents with both methods-based (i.e., Materials and Workmanship) and performance-based concepts. Table 2 points out that three agencies—Idaho Transportation Department, Missouri DOT, and West Virginia DOT—use warranties based solely on performance and do not call for any particular pavement marking material. These "pure performance" specifications describe required performance levels through the length of the warranty period and leave it to the contractor to select materials and installation techniques that satisfy these criteria. The pavement marking materials that are listed for Idaho in Table 2 are those that have already been used by contractors working under these performance specifications—they are not proposed or required in the specifications themselves. The Indiana DOT, which now applies a Materials and Workmanship warranty to pavement markings, reported that they are considering a performance specification.

Additional comments by agencies reporting survey results included the following:

- **Agencies discern specific responsibilities in their warranties.** Several states refer to manufacturer's recommendations within their own specifications and require a manufacturer's representative to be on site

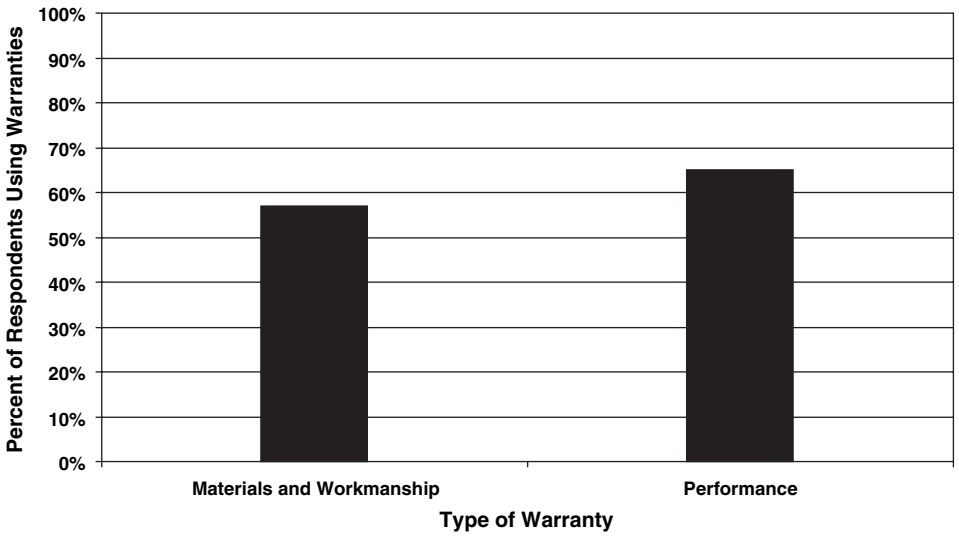


FIGURE 6 Claimed characteristics of warranties.

TABLE 2
CHARACTERISTICS OF EXAMPLE WARRANTIES IN APPENDIX D

State, Province, Territory	Materials or Performance Covered	Warranty Period	Examples of Types of Markings Covered
Alaska	Methyl methacrylate pavement markings (MMA)	2 years	Longitudinal and transverse markings, symbols, markings at roundabouts and gores
Arizona	3M 380 Tape	4 years	Longitudinal markings
		2 years	Symbols and legends
	Retroreflective raised pavement markers (RRPM)	1 year	Longitudinal markings*
Arkansas	Option 1: Inverted profile thermoplastic	4 years	Longitudinal markings only
	Option 2: High-performance marking tape (or, for center and skip lines on portland cement concrete pavements, high-performance contrast marking tape)	4 years	
British Columbia	Paint with glass beads	Calendar-based following application	Longitudinal markings only
Delaware	Retroreflective preformed patterned pavement marking	1-year performance period + 4-year warranty	Longitudinal markings
		1-year performance period + 2-year warranty	Symbols and legends
Idaho	Performance of recessed durable pavement markings	2 years	Longitudinal markings only, including curves and tapers, edge lines, skip lines, centerlines, interchange gore lines, intersection channeling, and bicycle lane lines
	Materials submitted to date under the 2-year performance specification include polyurea, epoxy, and Hi-Build Waterborne paint		
	Performance of recessed durable pavement markings	4 years	Same as above
	Materials submitted to date under the 4-year performance specification include inlaid high-performance tape and MMA		

(*continued on next page*)

TABLE 2
(*continued*)

State, Province, Territory	Materials or Performance Covered	Warranty Period	Examples of Types of Markings Covered
Illinois	Thermoplastic, paint, preformed plastic, epoxy, preformed thermoplastic, and compatible glass beads	180 days through a winter	Longitudinal and transverse markings, words, and symbols
Indiana	Durable pavement marking materials: Thermoplastic, preformed plastic, and epoxy	180 days through a winter	Longitudinal, transverse, and intersection markings
Maryland	Inlaid pavement striping tape	180-day observation period + 5-yr warranty period	Longitudinal markings only
Missouri	Retroreflective pavement marking tape	4 years	Longitudinal markings only
	Performance of durable permanent pavement markings	4 years	Mainline and ramp markings, mainline turn lanes, and crossovers and signalized intersections on the mainline (i.e., all long-line markings within and approaching an intersection, but excluding any markings on the side street approaches, and excluding intersection markings such as stop bars, turn arrows, and hash marks)
Nevada	General warranty requirement covering specified materials	2 years	General—for pavement markings specified in a project
Northwest Territories	Paint with reflecting beads	1 year	Longitudinal single and double lines, solid and broken directional dividing lines, edge lines, lane lines, continuity lines, arrows, gore areas, stop lines, crosswalk areas, railroad crossings, and lines and legends at ferry approaches
Oregon	Durable marking materials:		Long lines
	Surface-mounted thermoplastic	3 years	
	Other materials and methods including various types and applications of thermoplastic, MMA, and pavement marking tape (refer to Appendix D for greater detail)	4 years	
	High-performance marking materials:	1 year	Long lines
	Modified urethane, sprayed (25 mils) or protected inlaid		
	Durable marking materials:	18 months	Legends, stop bars, and crosswalk bars
	Liquid, hot-laid thermoplastic; preformed, fused thermoplastic film; cold-applied plastic film (tape); and MMA		
Texas	Longitudinal prefabricated pavement markings	6 years	Longitudinal markings only
	Multipolymer pavement markings	3 years	Longitudinal markings only
	Raised pavement markers	1 year	Longitudinal markings*
West Virginia	Performance of medium-life pavement marking system	1 year	Longitudinal markings only

*Specifications do not explicitly mention a particular type of pavement marking, but longitudinal markings are a reasonable presumption and likely the dominant if not the only use.
Note: Table is intended as a summary comparison only. Refer to specifications in Appendix D for actual wording and details of warranty requirements.

during pavement marking application. The Delaware DOT noted that the materials supplier will usually cover the cost of replacing defective materials. The DOT would be responsible if the deficiency was the result of inadequate design or materials specifications. The Maryland SHA reports that the contractor takes responsibility for materials and workmanship for the first six months (the Observation Period as defined in Figure 4), after which the materials manufacturer warrants performance for 5 additional years. In addition to materials properties, manufacturer's recommendations are cited with respect to installation method; for example, advisability of a grooved installation and recommended depth of groove.

- **Delivery mechanisms vary.** For example, Indiana uses state forces to apply paint, but contracts for durable markings under its warranty provisions. A contractor may apply pavement markings on its own or employ subcontractors to do this work. Some states impose participation requirements on a general contractor. A materials manufacturer is allowed to serve as a general contractor so long as it meets a state's participation requirements. Materials manufacturers may themselves impose requirements on a contractor installing their products in terms of training, certification, and onsite presence by the manufacturer's representative during installation.
- **Initial quality control is important in reducing risk under a performance-based warranty.** Crediting a very capable inspection staff at work during application of pavement markings, the Delaware DOT noted a history of very few failures.

The parties held responsible for ensuring warranty compliance and correcting deficiencies differ among agencies as shown in Table 3. An agency's practices may be influenced by events in its history with warranties. For example, an experience where one party (either a materials vendor or a contractor) has defaulted on a previous warranty requirement may influence the agency to change its policy and hold the other party responsible in future warranties. Also note that responsibilities of individual parties may be limited to particular performance periods. In the example shown for Texas, the warranty specification is written to hold the materials manufacturer responsible for posting a warranty bond; however, the contractor may assume those responsibilities by posting a bond that satisfies all the requirements of the specification.

Duration of Warranty

Responding agencies reported warranty durations as shown in Figure 7. The "Less Than One Year" category encompasses warranty specifications for either nondurable markings, such as paint, or markings in harsh climates (conforming to Figure 3). Every attempt has been made to exclude unintended survey responses that may have referred to observation or performance periods (refer to Figures 4 and 5) rather than a true warranty period. Warranties of longer duration cover more durable materials, and in selected cases also reflect use on Interstate and other major highway classifications. The prominence of the "Up to 6 Years" selection is the result of warranties on durable markings such as high-performance tape. Such warranties may be backed by the materials manufacturer, who may serve as a general contractor as well. These warranties typically extend for 4, 5, or 6 years. No pavement marking warranty specifications that were reported in this study exceeded a six-year performance period.

These synthesis survey findings are consistent with results of the earlier study by Bayraktar et al. (2004, 2006). The Bayraktar et al. study found that average warranty periods for different categories of construction work ranged from 2 to 7 years (as determined from its own survey results) and 1 to 8 years (as identified in its literature review). The duration of pavement marking warranties specifically ranged from 0.5 to 5 years (based on its interviews) and 2 to 6 years (from its literature review).

The durations of pavement marking warranties are in flux as agencies transition from experimental to operational warranty specifications:

- Idaho has experimented with performance warranties that leave material selection to the contractor and has recently instituted 2-year and 4-year pavement marking warranties.
- Alaska has been using 2-year warranties and is now considering specifications with a 5-year duration.
- Kansas has been using 180-day warranties, but is transitioning to a 1-year warranty and is considering a 5-year warranty period.

Cost Impacts of Warranties

As part of the synthesis survey, agencies were also asked about their perceptions of the effect of warranties on initial and life-cycle cost. The general finding is that warranty effects on pavement marking costs are still uncertain, with most agencies responding in ambiguous and sometimes contradictory ways. Some ventured a perception or supposition, but with little supporting data; for example, a higher initial cost but "reduced," "optimal," or "increased" life-cycle cost. Other agencies admitted that no formal analysis of this question had been performed or that the answer was unknown. Yet others did not respond to the question or indicated "not applicable." The one instance where actual experience informed the response involved a case where longer-term performance of tape was warranted by the manufacturer: the Maryland SHA reported that the warranty had "no effect so far" on initial cost.

By comparison, an earlier study of general highway construction warranties also found varying opinions regarding warranty effects on initial and life-cycle costs (Bayraktar et al. 2004, 2006). Regarding initial costs, agencies and contractors differed somewhat in their assessments of cost increases owing to warranties. Of 10 responding agencies, four

TABLE 3
PARTY RESPONSIBLE FOR MEETING WARRANTY REQUIREMENTS

State, Province, Territory	Contractor	Materials Manufacturer	Remarks
Alaska	●		
Arizona	●	○	Manufacturer warranty is for tape only. Contractor warrants other applicable pavement marking materials.
Arkansas		●	
British Columbia	●		
Delaware	●		
Idaho	●		
Illinois	●		
Indiana	●		
Maryland	○ Observation period only	● Warranty period only	180-day observation period and 5-year warranty period apply to inlaid pavement striping tape only.
Missouri		●	Contracts provided by Missouri DOT are written with materials manufacturer acting as the general contractor (applies to both of the specifications in Appendix D).
Nevada	●		
Northwest Territories	●		
Oregon		●	Oregon specifications require warranties only for durable or high performance materials. These are all manufacturers warranties.
Texas	○	●	Specifications call for a manufacturer's warranty bond, but allow substitution of a contractor-provided warranty bond that meets all requirements.
West Virginia	●		

Notes: *Source*: Appendix D. Table is intended as a summary comparison only. Refer to specifications in Appendix D for actual wording and details of warranty requirements.
● = Primary or predominant responsibility.
○ = Partial, contingent, or secondary responsibility.

estimated a cost increase of less than 5%; four agencies, a 5% to 10% increase; one agency, 10% to 20%; and one agency, 20% to 50%. By contrast, 65% of contractors estimated an increase in bid price of 5% to 15%; 20%, less than 5% bid-price increase; and 15%, 15% to 20% bid price increase. No contractors estimated a bid price increase greater than 20%. Regarding life-cycle costs, 23% of responding agencies believed that there was no effect of warranties on life-cycle costs. Another 23% reported little savings, and 8% substantial savings. Forty-six percent perceived a small increase in life-cycle costs. Again, these outside survey data applied to road construction warranties generally, not necessarily to pavement marking projects.

Pavement Marking Performance Criteria

Agencies reported a number of criteria of acceptability for pavement marking performance under warranty. A summary of usage of each type of technical criterion is given in Figure 8. These data refer to warranty specifications, not to initial acceptance following construction.

Warranty period performance is judged by most responding agencies on the basis of durability and retroreflectivity, and almost half specify a requirement for maintaining proper color; for example, through comparisons with color chips. Less than 10% of responding agencies reported more specific

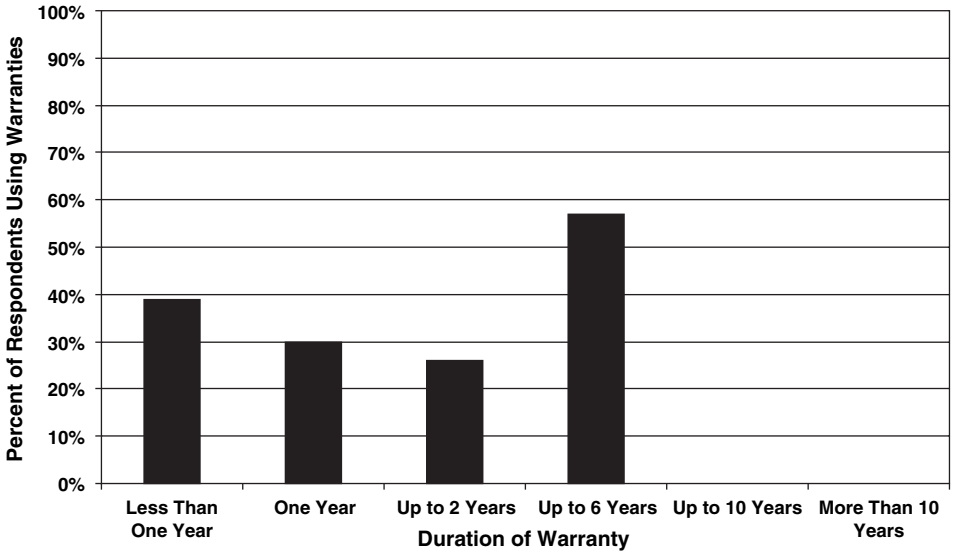


FIGURE 7 Pavement marking warranty duration.

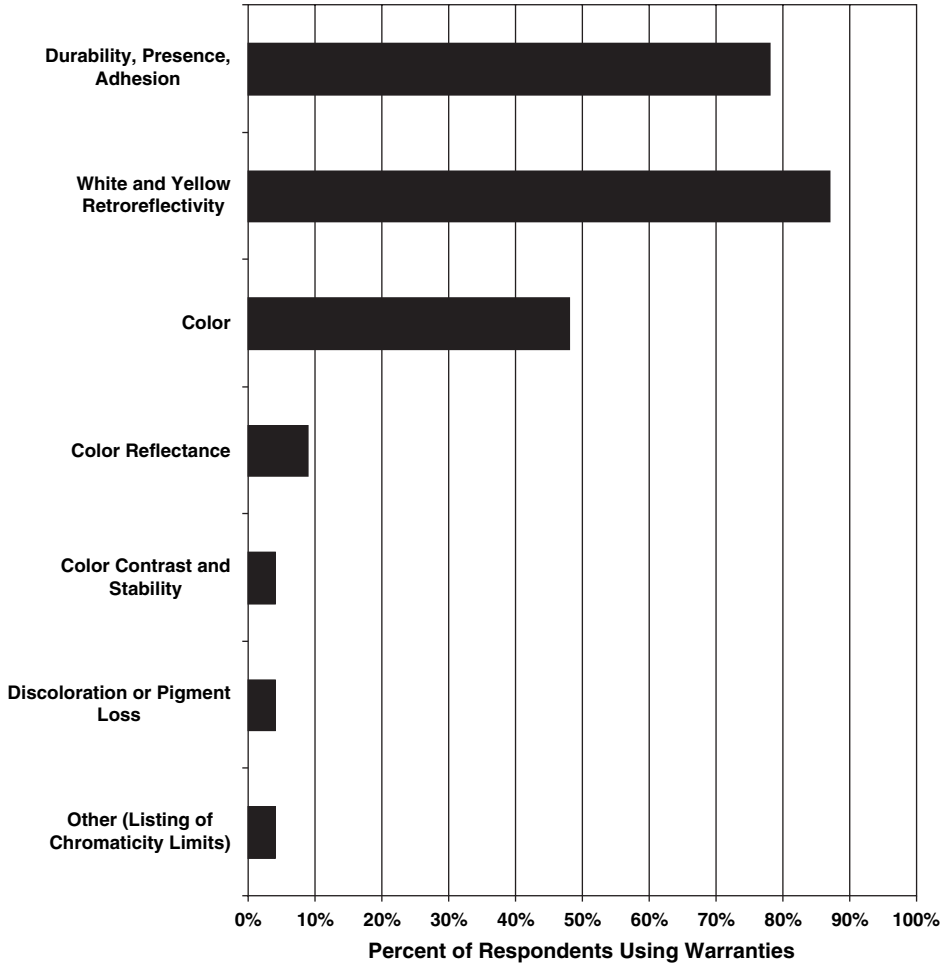


FIGURE 8 Warranty criteria for technical acceptability of pavement markings.

color-related criteria such as measures dealing with color reflectance, color contrast and stability, and chromaticity.

These survey findings are consistent with the example specifications in Appendix D (web only). Most of the Appendix D examples include provisions governing durability and retroreflectivity, often calling for a combination of visual inspection with supporting quantitative measurement if needed. Color retention, or avoidance of discoloration, is evaluated in several ways in the Appendix D specifications, including visual comparison to color chips and color tolerance charts, daytime reflectivity, and chromaticity limits (four agencies).

Corrective Actions

Actions to correct deficient performance under warranty specifications are identified from survey responses in Figure 9. All reporting agencies require repair or replacement of defective markings. Some agencies also assess monetary charges of the various types shown. "Other" potential actions indicated in Figure 9 include relinquishing the bond covering the work, assessing damages if work deficiencies exceed a certain threshold (e.g., Kansas specifies damages if more than 2% of the project must be replaced), and reimbursing the department if repair or replacement must be done by agency forces or another contractor. Minnesota noted that problems are discussed with the contractor to identify a course of action depending on the observed condition of the line markings.

Responsibility for Inspections

The responsibility for inspecting pavement markings to determine whether they are meeting warranty performance criteria is summarized in Figure 10. Most reporting agencies inspect pavement markings using their own forces. A smaller percentage of agencies engage the contractor or a third party. A few agencies responded with more than one method, explaining that different parties might be involved at different points during the life of the pavement markings.

There is little unanimity among agencies in the frequency of performance inspections for warranties. The frequencies of

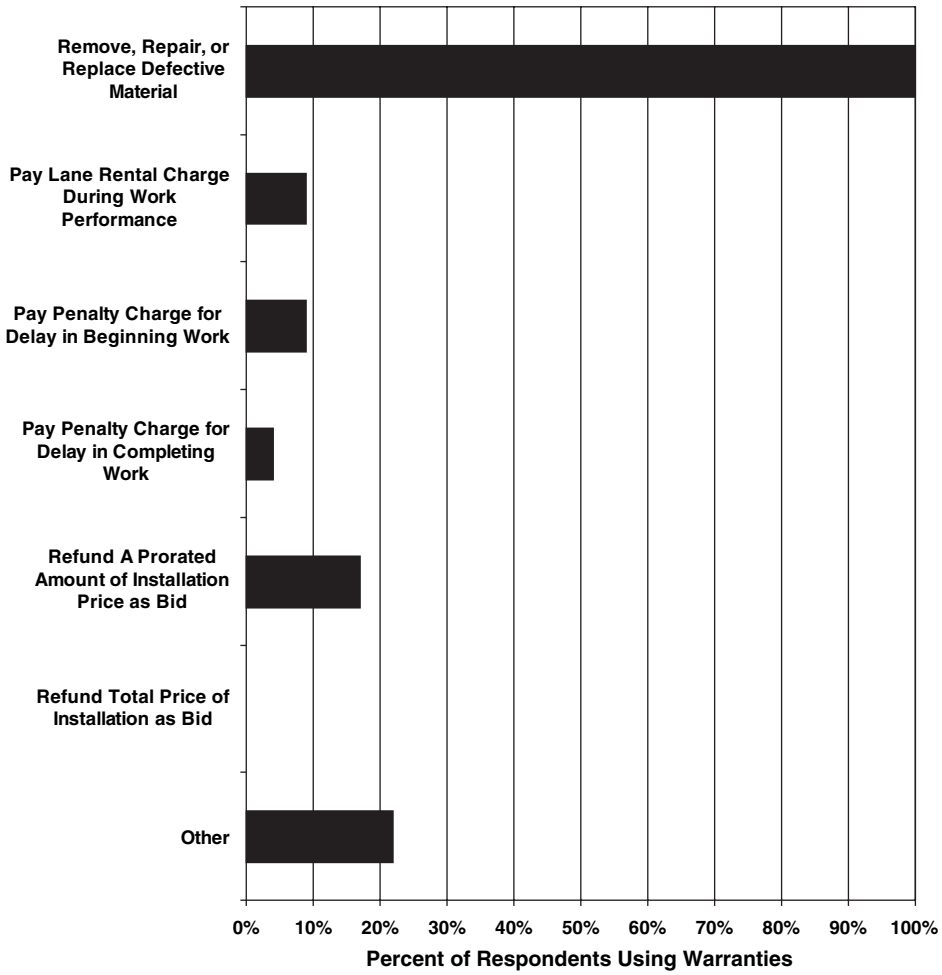


FIGURE 9 Corrective actions.

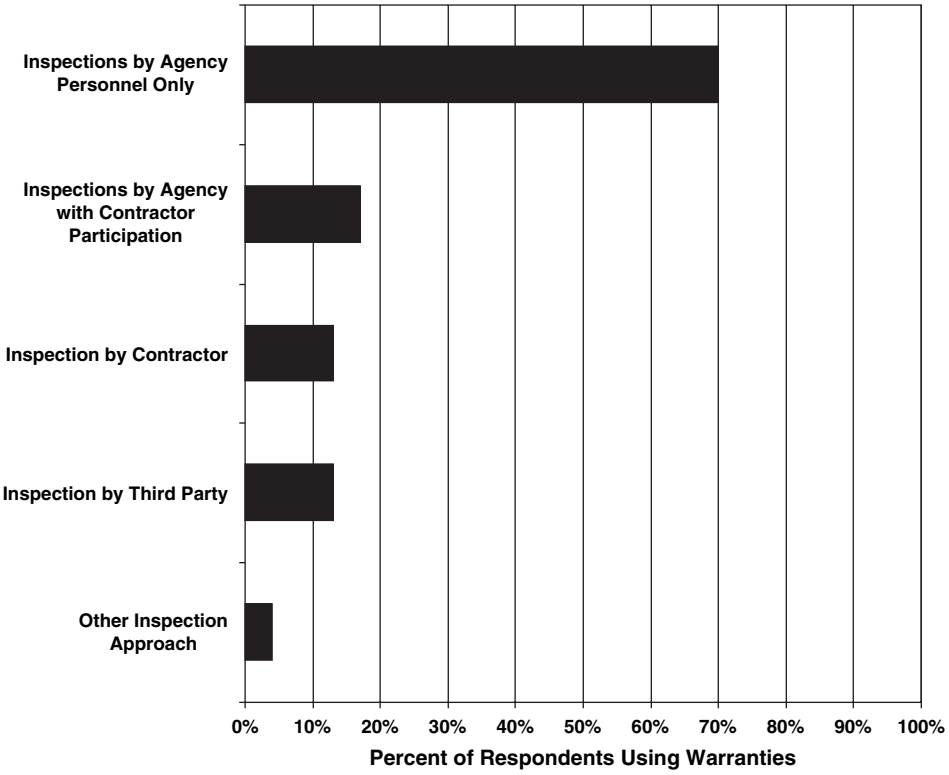


FIGURE 10 Responsibility for inspection of pavement markings under warranty.

scheduled inspections ranged from monthly to quarterly and annually. A sampling of other agencies' comments follows:

- There is no set schedule—nothing is done unless a failure is very noticeable. A variant of this type of response was: As needed, based on concerns or complaints by agency personnel or the public.
- Visual inspections [are conducted] at any time during the warranty period. Variation 1: The Highway Maintenance Supervisor inspects road conditions daily and reports on all aspects of the highway. Variation 2: Only one inspection is done, at the end of the warranty period. Variation 3: There are now not enough inspections and the agency is working to improve this.
- All districts have retroreflectometers and can test markings at any time. A variation: Inspections are performed by state forces following application and at any time within the 4-year warranty period (typically it might occur at 36 to 42 months).

Effects of Climate and Winter Maintenance

Seventy percent of the responding agencies that use pavement marking warranties reported that winter maintenance does not affect their warranty (with a number of other respondents leaving the answer blank). A tabulation of how the example warranties in Appendix D treat winter maintenance is given in Table 4. Very few agencies explicitly exclude winter maintenance from the provisions of the warranty, meaning that contractors are nominally responsible for replacing markings with winter-related damage. With reference to Table 4, several of the specifications in Appendix D are silent on the issue. Of those that discuss winter maintenance explicitly, Arizona excludes high-altitude regions that are subject to snowfall from its warranties, and Texas gives the TxDOT project engineer the authority to determine winter maintenance as an "outside cause" that is excluded from its warranty replacement requirements. Other agencies listed in Table 4 either include winter damage as part of "normal wear and tear" that is subject to replacement under their warranty (Delaware, Missouri performance spec, and West Virginia), or employ a calendar-based warranty that includes a winter season in its period of performance (British Columbia, Illinois, Indiana, and Northwest Territories). Additional points of note:

- Table 4 is compiled from the as-written provisions of the warranty specifications. Interviews with three agencies that do not exclude winter maintenance damage from their warranty requirements revealed that they may exercise discretion in how winter-related damage is treated. For example, in the case of an unusually severe winter, an agency may not hold the contractor responsible for replacing damaged markings. Another agency, which has a 180-day warranty period through the winter season, indicated that it may consider, on a case-by-base basis, a contractor's request to apply temporary markings in the Fall, following up with the specified markings in the Spring.

TABLE 4
TREATMENT OF WINTER MAINTENANCE IN EXAMPLE WARRANTIES

State, Province, Territory	Is Winter-related Damage Excluded from Warranty Provisions?		
	Yes	No	Warranty Period = Calendar Interval That Includes Winter Season
Alaska	—	—	—
Arizona	○	●	
Arkansas	—	—	—
British Columbia			●
Delaware		●	
Idaho	—	—	—
Illinois			●
Indiana			●
Maryland	—	—	—
Missouri			
(Tape)	—	—	—
(Perf. Spec.)		●	
Nevada	—	—	—
Northwest Territory			●
Oregon	—	—	—
Texas	●		
West Virginia		●	

Notes: Data from Appendix D.
"—" = winter conditions are not explicitly addressed in warranty specifications.
○ = partial exclusion in mountainous, heavy-snow regions at altitudes greater than 5,000 ft. Winter damage is not excluded from warranty requirements in other regions.
"Perf. Spec." = performance specification.

- In their standard product warranties, materials manufacturers may exclude damage resulting from winter maintenance equipment.
- The contractors and materials manufacturers who were interviewed—most of whom were used to dealing with winter weather—did not focus solely on winter maintenance damage in their discussions. Their comments encompassed weather effects more broadly; for example, regarding conditions at high altitudes, coastal humidity, weather-imposed restrictions on the working season, and temperature effects on asphalt, in addition to winter-related damage.
- In one instance, problems with winter maintenance damage affected the continuation of a state's pavement marking warranty program. The North Dakota DOT used a warranty specification for epoxy paint pavement markings from 2002 to 2005. This performance specification required the contractor to achieve specified minimum retroreflectivity levels initially (following construction) and after one winter. The DOT experienced a number of warranty administration issues related primarily to reduced retroreflectivity after one winter. Factors such as mechanical damage (snow plow damage, deicing materials, sand abrasion, etc.) affected retroreflectivity levels and were considered outside the contractor's control. These subjective factors made it too difficult to administer the warranty objectively. A second round of warranty testing was therefore discontinued, and the North Dakota DOT no longer uses pavement marking warranties.

Mechanisms to Assure Quality

Survey respondents identified a number of mechanisms they employ to help assure quality in pavement marking work performance, in addition to the warranty itself. The following examples were obtained from agency questionnaire responses and the example specifications that agencies provided (Appendix D).

- Procedural and administrative mechanisms that agencies build into their pavement marking process to promote quality include the following:
  - A pre-placement (pre-operational, pre-construction) meeting among agency, contractor, and materials manufacturer's representative before the start of work.
  - Contractor submittal of a Work Plan before the start of work, with periodic updates of progress during construction and of markings performance through the warranty period.

  - Contractor submittal of a Spill Recovery Plan.
  - Manufacturer's certification of installation/application (sub)contractors and materials to be used, onsite observation by the manufacturer's representative of markings installation/application, and approval of equipment to be used in installation/application.
  - Reliance on standards and test protocols of industry-recognized authorities [e.g., ASTM, AASHTO, NTPEP, *Manual of Uniform Traffic Control Devices* (*MUTCD*), federal or state versions], and standardized state/provincial materials testing procedures.
  - Contractor provision of test grinding strips if inlaid markings are to be used, and test stripes for pavement markings.
  - Daily or weekly reporting of work accomplished and data from specified measurements.
  - Periodic inspection according to stated procedures and criteria by agency personnel, contractor, or independent third party.
- Several agencies use lists of prior-approved materials; for example, Alaska, British Columbia, Florida, Maryland, Minnesota, Northwest Territories, Oregon, Texas, and West Virginia. These lists are referred to by different names across agencies; for example, Qualified Products List, Recognized Products List, Approved Paint Materials, Material Producers List, and Approved Product Listing.
- Among the 15 agencies with example specifications in Appendix D, Illinois and Indiana employ a list of Approved Contractors for pavement marking projects. Kansas also prequalifies contractors.
- A materials manufacturer may fulfill multiple roles on a pavement marking project: (1) to provide a product that meets or exceeds specifications; (2) to back product performance with a warranty that conforms to client requirements; (3) to provide technical services to clients and their contractors; for example, recommendation of the proper method of application/installation, technical advice on correction of problems, and contractor training and certification; (4) through product sheets, manufacturer recommendations, and other technical data, to support and supplement client specifications; and (5) to serve as a general contractor where allowed and appropriate on pavement marking projects. In several states the manufacturer's responsibilities are formalized explicitly within the warranty specifications. Additional manufacturer responsibilities that are stated in specifications include approving equipment used in marking application/installation and approving related materials to be used by the contractor; for example, adhesives for pavement markers.
- Payments and monetary penalties to contractors can reinforce the objective of quality work. The Missouri DOT performance specification illustrates payment adjustments based on the performance of individual 1.0-mile segments covered by the contract. If more than 10% of pavement markings are failed in any one evaluation period, the contractor is regarded as in default and required to submit for Missouri DOT approval a remedial plan to correct these failures. The specification of the West Virginia DOT provides an example of liquidated damages applied to pavement marking projects.
- The matter of how to structure a payment schedule for multi-year warranties will likely grow in importance as more states undertake warranty work and as the length of warranty periods increases. Such a payment schedule ideally would encourage satisfactory long-term pavement marking performance while providing fair and timely payment to contractors. Among the example specifications in Appendix D, most agencies today specify payment following initial acceptance or at successful completion of a performance period or observation period. Three agencies—the Idaho Transportation Department, Missouri DOT in its performance specification, and Texas DOT—include a multi-year schedule of payments in connection with their pavement marking warranties. The Kansas DOT also uses a warranty payment schedule, which was described in its survey response, and Alaska is considering step payments through the duration of a planned 5-year warranty. In the examples that follow, all percentages are based on total contract price:
  - Idaho's 2-year warranty: Initial payment, 60%; end of year 1, 5%; end of year 2, 35%. (Lane rental charges are also employed; refer to Appendix D.)
  - Idaho's 4-year warranty: Initial payment, 60%; payments at end of years 1, 2, and 3, 5% respectively; end of year 4, 25%. (Lane rental charges are also employed; refer to Appendix D.)
  - Missouri's 4-year performance specification was originally advertised with the following payment schedule: Initial payment, 12%; payments in each of years 1 through 4 of the warranty period, maximum of 22% annually subject to adjustment for noncomplying 1.0-mile highway segments. A revised payment schedule was submitted and accepted as part of the successful contractor's value engineering proposal, as follows: Initial payment, 60%; payments in each of years 1 through 4 of the warranty period, maximum 10% annually.
  - Texas' 1-year warranty for RPMs: Initial payment, 80% following written acceptance; at end of performance period including satisfactory replacement of deficient markers, 20%.
  - Kansas' 180-day warranty: Initial payment, 90% following initial acceptance; 10% at successful completion of the warranty period.
  - Kansas was scheduled in 2009 to increase the duration of its warranty period to 1 year, and is now working on a 5-year warranty. It is considering step payments through the 5-year duration, with specific yearly percentages yet to be decided.
  - Alaska is now using 2-year warranties, but is considering a 5-year warranty period with step payments.

Further discussion of multi-year payment schedules is given in the Contractor Perspectives section in the discussion of Financial Risk and Risk Mitigation.

- Bonding is specified by agencies in the following ways:
  - Warranty bonds are required in the amount of 100% of the contract price for the duration of the warranty (Delaware, Idaho, Missouri performance specification, Nevada, West Virginia).
  - (Illinois): At its option, the pavement marking contractor may request a third-party performance bond from the installation (sub)contractor at the completion of pavement marking work, but before final inspection and acceptance following the warranty performance period. This bond, which names the DOT as obligee for the full amount of the pavement marking price, avoids delay in paying the pavement marking contractor.
  - (Texas): A warranty bond is required of the materials manufacturer for the duration of the warranty period. At its option, the contractor may provide a warranty bond that meets all requirements, in which case the contractor becomes the warrantor.

Working with Industry

When asked whether discussions were held with industry representatives (contractors and materials manufacturers) before instituting warranties, agencies that have used such warranties replied as shown in Figure 11. Examples of items discussed at these meetings are as follows:

- Arkansas noted that every item in the specification was thoroughly discussed over a long period of time. Some agencies focused explicitly on technical requirements; for example, the mil thickness and pounds of glass beads per gallon of paint (Delaware), and issues of retroreflectivity, durability, and color (Virginia).
- Missouri and Alberta noted that the main items discussed at their meetings were agency expectations for pavement markings and their reasonableness.
- The Associated General Contractors and manufacturers have been involved in the development of all Oregon DOT construction specifications (primarily to review and provide comments), including the warranty specifications for pavement markings. Texas also noted that its proposed specifications are routed through their local Associated General Contractors office before they can be approved and used.

The benefits of these industry interactions focus on keeping industry informed of agency intentions and expectations, and obtaining industry reactions to pending change in agency policy and project requirements. Examples of public–private interactions within a different institutional setting are given later in the section on European warranty practice. The role of industry in those examples—in which transportation agencies and private sector contractors collaborate within a framework favoring performance, quality, and innovation—extend more widely and systematically into activities such as:

- Participation in specification development;
- New product identification, development, certification, and use;
- Negotiation of warranty periods for new, potentially riskier products; and
- Training and certification of installation contractors.

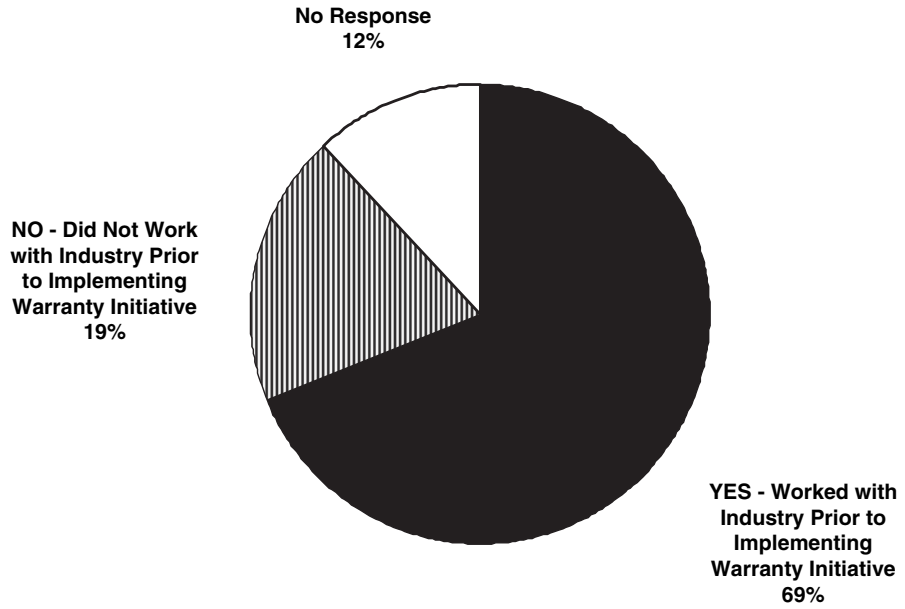


FIGURE 11 Agency experience in meeting with industry on warranties. Results based on responses from a reduced sample of 16 agencies.

Warranty Interactions with Other Requirements

Possible interactions between pavement marking warranties and other state and federal commitments were cited by some agencies as factors discouraging warranty use. These interactions could occur with other existing warranties or bonds (e.g., for pavement construction), or with administrative requirements and closeout procedures of federal-aid projects. Although these issues need to be resolved with knowledge of the details of each case, it appeared that other agencies had been able to circumvent these issues by taking appropriate administrative steps. Examples drawn from the survey findings of this synthesis study are listed here; additional research could organize a more comprehensive identification of questions, answers, and example solutions.

- **Issue:** use of sole-source procurements in connection with warranties on federal-aid projects.
  Example solution: Arizona DOT was able to justify use of a single proprietary product on specific highway segments by submitting a finding in the public interest for FHWA approval.
- **Issue:** Maintaining a multi-year warranty in force on an otherwise completed federal-aid construction project.
  Example solution: The Idaho Transportation Department has reached an agreement with the FHWA on handling multi-year warranties on federal-aid projects. The solution has been to organize the contractor's warranty effort as an active work program, with annual contractor payments as the federal-aid project remains open.
- **Issue:** Potential interactions between a new 5-year pavement marking warranty with bond and an existing asphalt pavement performance bond, also for 5 years. Problems may include contractor bonding capacity and conflicts between respective warranty requirements for pavements versus pavement markings.
  Discussion: These issues were not discussed by other agencies or contractors and may require further research to target the specific conflicts and recommended ways to resolve them. The earlier study by Bayraktar et al. (2004) reported that in its survey of contractors (who had experience in highway construction warranties generally, not focused on pavement markings), three-quarters of these contractors claimed that they were not constrained by their bonding capacity in bidding and performing warranted work; 25% reported that they were.

Agency Satisfaction with Pavement Marking Warranties

The 23 responding agencies that currently use pavement marking warranties were asked to rate their overall degree of satisfaction on the following scale: Very Satisfied, Generally Satisfied, Mixed Results, Problematic, and Very Dissatisfied. Results of this self-rating are shown in Figure 12. Almost three-quarters of the responding agencies now using warranty specifications expressed satisfaction with them. Three agencies reported Mixed Results, whereas one characterized them as Problematic. None said that they were Very Dissatisfied with the experience.

- One agency that is Generally Satisfied noted that there had been communication issues regarding agency expec-

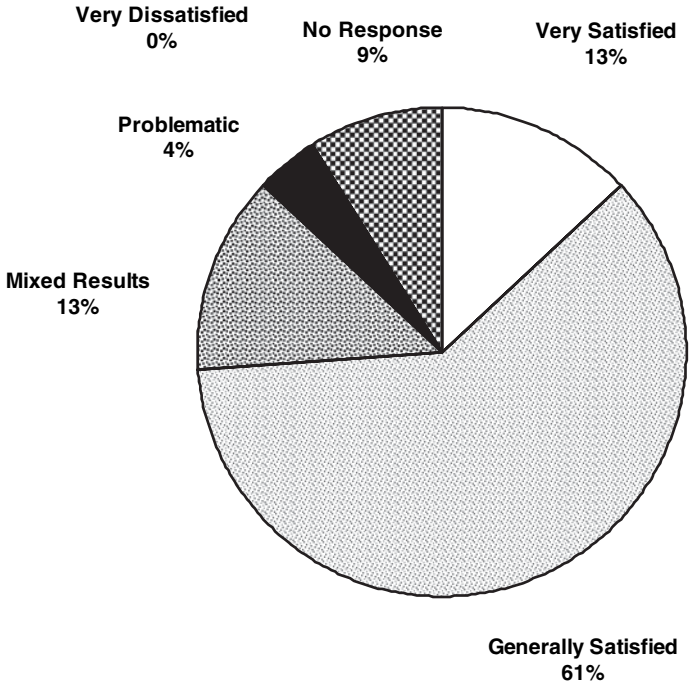


FIGURE 12 Degree of satisfaction with pavement marking warranties.

tations under its warranty, but that these had been worked out and pavement marking performance is better today than it was 4 years ago. Another Generally Satisfied agency also observed that sometimes "they had to argue with the contractor" to get them to comply. A third agency that recorded Mixed Results with warranties also cited problems in getting timely responses by the contractor to perform needed repair work.
- Only one of the responding agencies characterized its experience with pavement marking warranties as Problematic. Further inquiry revealed that this response was not a characterization of agency experience per se. Rather, it was rooted in the philosophical belief of the responding individual that before agencies engage in such warranties they would first establish a pavement marking management system. Such a system could track marking performance as well as the effectiveness of the warranties in a systematic and consistent way, based on periodic field inspections and measurements. (An application used by the Iowa DOT was cited as an example of such a management system; this responding state was not Iowa.) Once such a management system is established and applied effectively by an agency, warranty specifications become more meaningful. The Problematic rating was intended to communicate this perspective.

Although Figure 12 illustrates a degree of satisfaction only among those 23 reporting agencies that are now using warranties, all surveyed agencies were asked to judge what they believed were the advantages or disadvantages of pavement marking warranties according to the following procedure:

- Those agencies that have had a positive experience were asked to identify their primary motivations for using pavement marking warranties and the benefits of their use.
- Those agencies that have not used pavement marking warranties, have had a negative experience when they tried them, or are predisposed not to consider them in the future were asked to identify what they see as impediments, risks, or drawbacks in their use.
- Those agencies that characterized their experience with pavement marking warranties as having "Mixed Results" were asked to identify both the perceived motivations/benefits and the perceived impediments/risks/drawbacks of warranty use.
- Those agencies that have not used pavement marking warranties but are potentially interested in their application were asked to identify what types of information would be most helpful in their future consideration. It turns out that this question was also answered by three agencies that have already had positive experience with warranties (particularly those backed by materials manufacturers) plus two agencies that had a negative stance toward them.

The overall responses to these three "perception" questions—to identify motivations and benefits; to identify impediments, risks, and drawbacks; and to identify useful information—are summarized in Figures 13 through 15 respectively in terms of number of responses received.

Perceived Motivations and Benefits

The perceived motivations for, and benefits of, pavement marking warranties are shown in Figure 13. The main drivers for these warranties are expectations of improved performance and quality, and avoidance of premature failure, with attendant benefits in reduced lane occupancy for repairs or re-application. An additional important benefit is anticipated cost savings in both maintenance and life-cycle costs (including road-user cost savings resulting from reduced lane occupancy through the warranty period). Most of the other benefits options each received 1 to 5 responses. No agency cited a legislative mandate as a reason for using warranties. The "Other" benefits that were suggested were consistent with the themes of improved performance and reduced cost. Specific benefits identified in these responses included: (1) the generation of performance measurement data associated with enforcing the warranty, which can also be used for product performance comparisons; and (2) the encouragement given to contractors to install quality products correctly, thus enhancing performance and reducing the need for road occupancy to do annual restriping.

By comparison, the Bayraktar et al. study found that a majority of agencies saw the benefits of warranties in several areas; for example, improved quality, reduced need for site inspection, and less record keeping, although these perceptions were not unanimous. A relatively small percentage of respondents offered counter-perceptions for certain benefits; that is, 8% believed inspection requirements had increased, and 15% perceived greater record keeping (Bayraktar et al. 2004, 2006).

Perceived Impediments, Risks, and Drawbacks

The perceived downsides of using pavement marking warranties are indicated in Figure 14. The most frequent responses focused on the administrative burden, potentially higher bid prices, and possible increases in disputes or litigation with contractors as the main reasons for not using pavement marking warranties. Three agencies also cited departmental policy or guidelines as discouraging warranty use (more on this point follows later in this section). The "Other" problems that were cited included: (1) administrative difficulties associated with using U.S. federal-aid funding if sole sourcing pavement marking work, (2) keeping contracts open on federal-aid projects while the warranty remains in force, and (3) the perception that an agency's management philosophy and culture discourage greater use of warranties. Some of these items will be discussed further here.

Calls to the three agencies that had checked the questionnaire response, "Warranties are prohibited or discouraged by

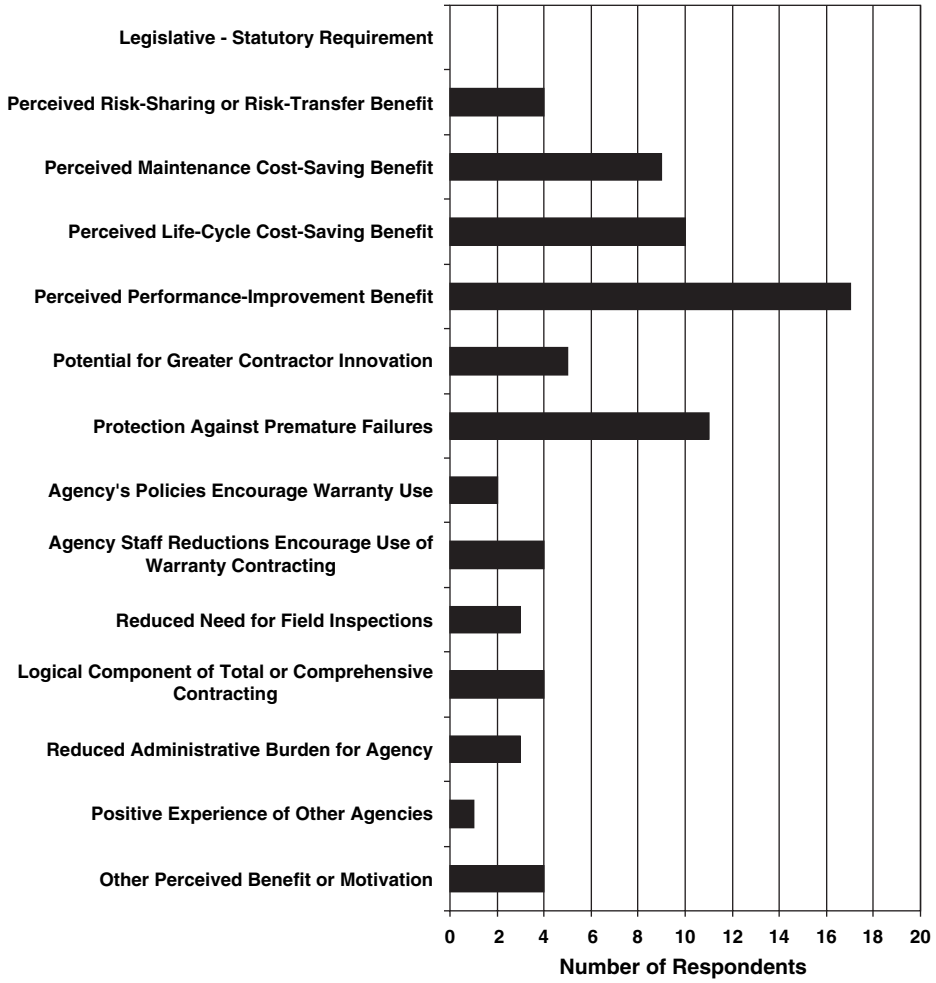


FIGURE 13 Perceived motivations and benefits of warranty use.

agency administrative policy or bidding and procurement guidelines," provided a further elaboration of what was meant by this answer. The agencies' comments all reflected more a tendency rooted in organizational experience, culture, and practice rather than an explicit policy. The net effect was to seek other methods of assuring quality in project delivery, bypassing the issue of pavement marking warranties.

- One agency reported that its prior experience with warranties on other highway items had encountered problems in monitoring, tracking, and resolving performance issues with the contractor or the materials vendor. This situation was aggravated by a shortage of construction office personnel. A preferred approach evolved: to develop the best construction specifications possible and then enforce them. Because its geographical location did not require winter maintenance, the agency could use durable markings. The agency also noted that a warranty might reduce competition if it allowed proprietary materials and processes. The agency did allow for possible use of warranties in the case of RPMs. There have been some issues with marker performance; agency staff believed that a warranty might help identify replacement needs and ensure completion of needed work.
- Another agency reported that it was moving toward performance-based specifications and had considered warranties, even trying them in one case. However, agency field personnel had had significant experience in applying pavement markings themselves. They would therefore want to consider warranties carefully and understand them better before moving ahead—they did not want to go too far too fast. They also had questions about who should be the warrantor—the contractor or the materials vendor.
- A third agency reported that, as a matter of practice, their construction personnel preferred to close out construction contracts expeditiously and not have any remaining work obligations.

Desired Additional Information

The additional information on pavement marking warranties that is desired by survey respondents is identified in Figure 15. Several agencies identified "All Listed Categories" of infor-

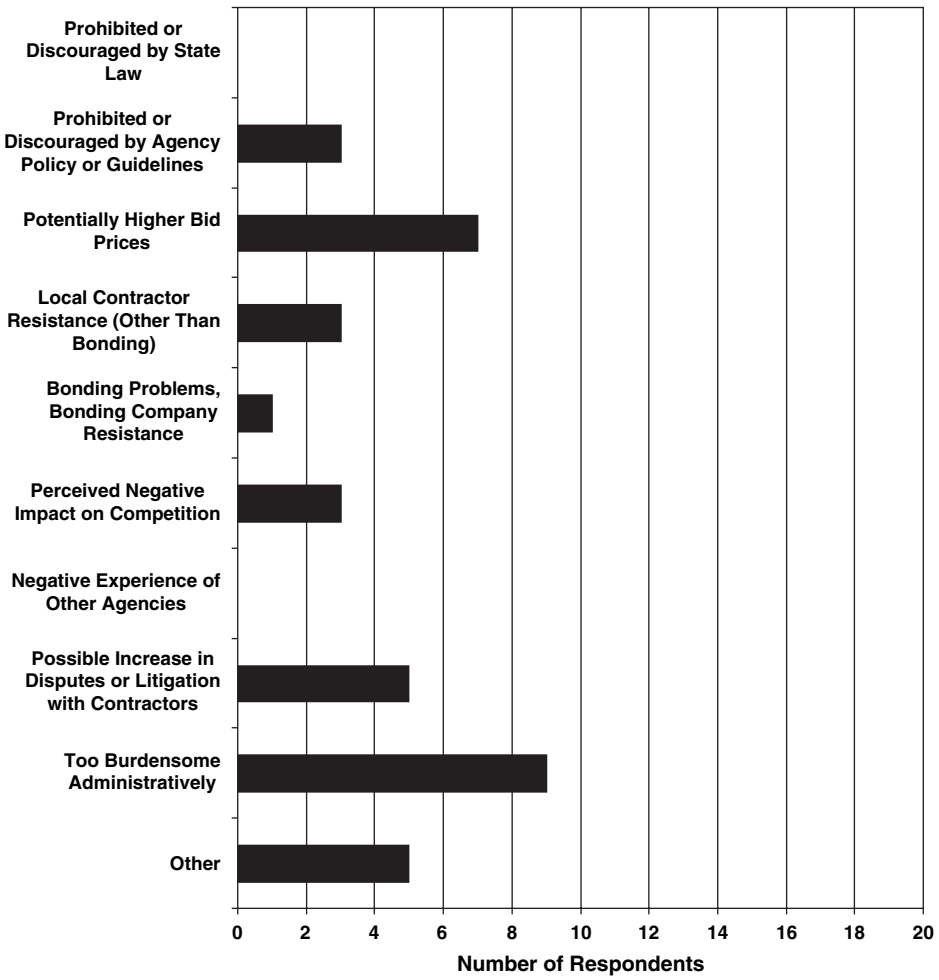


FIGURE 14 Perceived impediments, risks, and drawbacks of warranty use.

mation as helpful; these responses are incorporated within each affected item in Figure 15.

Among "Other" information of interest were the following topics:

- Conflicts with existing pavement or other warranties or bonds,
- How to deal with multi-year warranties in the context of desired closeout of federal-aid projects, and
- How to allocate responsibility between contractor and manufacturer.

PERSPECTIVES OF PRIVATE INDUSTRY

Overview

Telephone interviews were held with seven pavement marking contractors and two marking materials manufacturers to obtain private sector perspectives on pavement marking warranties. These entities are identified in Appendix C. To keep this discussion focused on the issues at hand, general designations such as "Contractor A" and manufacturer "Company M1" are used. Characteristics of the interviewed firms are noted in Table 5. Most of these firms have been engaged in work involving warranties; all are familiar with performance-based specifications and speak from experience. Although the contractors work in different geographic regions and deal with a range of pavement marking materials, their willing participation in the project interviews may reflect a self-selected sample. Attempts to identify a wider range of views from firms of different characteristics (e.g., small-sized firms or firms not as familiar with performance-based specifications) were not successful. Supplementary findings from other studies are cited to fill this gap.

The interviews, together with the responsibilities called for in the specifications in Appendix D (web only), demonstrate that pavement marking materials manufacturers potentially can fulfill several roles in serving state DOTs and other clients and their contractors: (1) to provide a product that meets or exceeds specifications; (2) to back product performance with a warranty that conforms to client requirements; (3) to provide technical services to clients and their contractors; for example, recommendation of proper method of application/installation, technical advice on correction of problems, and contractor

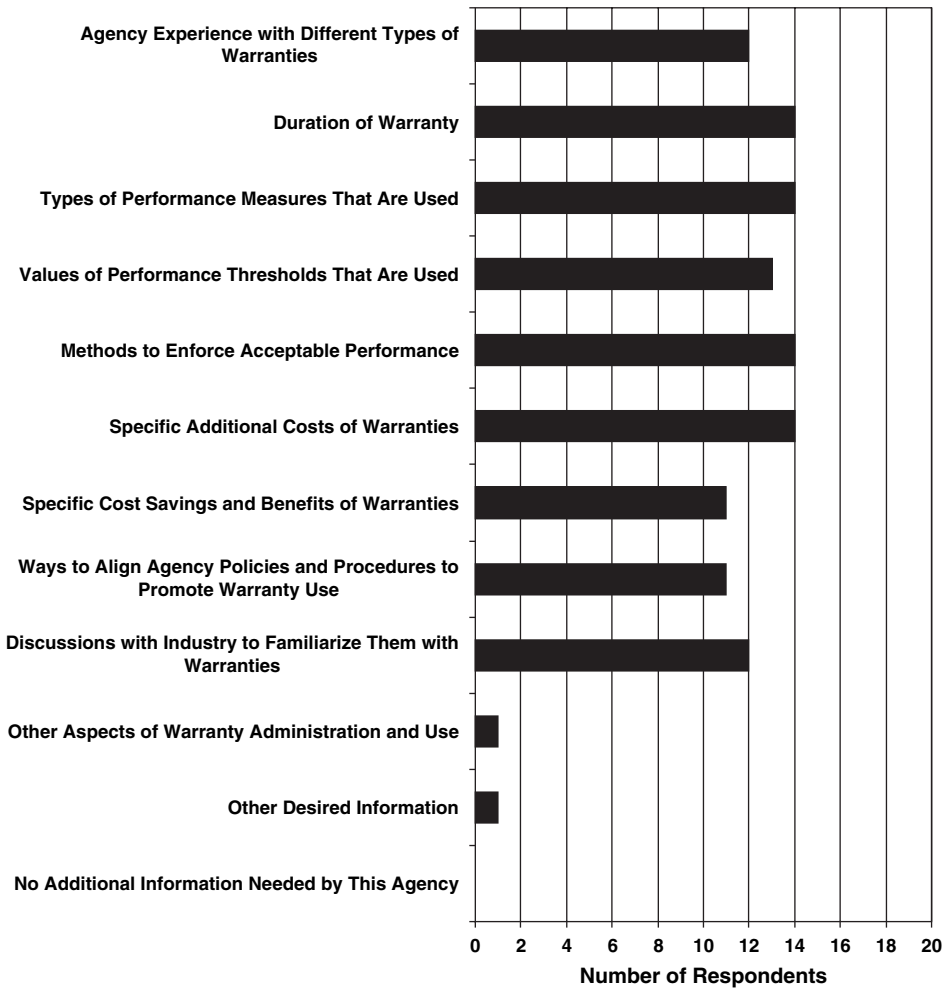


FIGURE 15 Additional information desired.

training and certification; (4) through product sheets, manufacturer recommendations, and other technical data to support and supplement client specifications; and (5) to serve as a general contractor where allowed and appropriate on pavement marking projects.

General Positions on Warranties

All interviewed firms believed in providing a quality pavement marking job, and their comments supported the notion that quality-oriented firms perform their projects to the same high standards and levels of commitment regardless of whether or not the projects involve a warranty. One contractor pointed out that although two-thirds of pavement marking job cost is for materials, using better (i.e., longer life) materials will yield life-cycle cost savings with attendant benefits to all parties: the agency, motoring public, and the contractor itself. The firms supported warranties that are *structured fairly* and *enforced.* This approach promotes use of quality products and proper installation procedures that yield brighter, more durable, more consistently performing markings with attendant benefits to the highway agency and the motoring public. The manufacturers related quality to their ability to manage the several aspects of jobs they are involved in. One-source accountability avoids finger-pointing and yields savings in life-cycle costs with benefits to agency and the public. Several firms saw warranties as a wave of the future and believed strongly in their value and benefit, notwithstanding risks and drawbacks that are discussed here.

Another contractor likewise saw a role for warranties, but spoke about them more in terms of one approach among several options to provide quality performance cost-effectively. In this view, warranties were one way of achieving a guaranteed level of performance at a price or additional cost. The additional cost will be borne either by the agency in paying a higher bid price or by the contractor if the cost of additional work to maintain the specified performance was not included in the bid. However, agencies need not rely solely on warranties if high-quality materials, strong and effective (but reasonable and achievable, not onerous) specifications, and correct installation methods are called for and provided. Good techniques and products that are available today can readily achieve longer, higher-performance service lives; for

TABLE 5
PRIVATE SECTOR FIRMS INTERVIEWED FOR THIS STUDY

Designation in Report	U.S. or Canadian	Description and Remarks
Contractor A	U.S.	Works with primarily waterborne paint under a warranty in several states.
Contractor B	U.S.	Works with various materials (e.g., paint, thermoplastic, polyurea, and tape) in a state under delayed acceptance warranties (i.e., after one winter); no multi-year warranties.
Contractor C	U.S.	Works in a single state applying waterborne paint, tape, thermoplastic, and RPMs. Jobs are with state agency (for new highway construction) and cities and counties (for maintenance). One year is longest warranty period the firm has undertaken.
Contractor D	U.S.	Works worldwide applying waterborne paint for airfield markings. Has worked to produce handbook on airfield pavement markings, but warranties are not yet used in aviation practice.
Contractor E	Canadian	Works in three provinces on highway line painting, and thermoplastic and MMA markings in urban areas. Manufactures own durable marking materials (not epoxy), primarily for urban areas. Performance-based specifications at provincial level are calendar or seasonally based, with duration typically 1 year or less. Warranties for municipal governments are 2 to 5 years for durable materials; more a materials and workmanship warranty.
Contractor F	Canadian	Works for provincial and municipal governments applying paint and thermoplastic. Performance-based specifications are calendar or seasonally based, with duration typically 1 year or less for provincial work.
Contractor G	Canadian	Applies paint and thermoplastic pavement markings and inlaid markers for several provincial, territorial, and local governments. Performance-based specifications are calendar or seasonally based, with maximum duration of 1 year for provincial work.
Manufacturer: Company M1	U.S.	Products include durable preformed tape, wet-reflective paint, RPMs, and wet reflective thermoplastic. A standard warranty is provided on the high-performance tape, but the manufacturer will work with agencies and contractors on individual project arrangements and warranties of other products.
Manufacturer: Company M2	U.S.	Products include durable pavement marking materials: epoxy, polyurea, urethane, and—for warranty work—a specialized multi-polymer based on premium raw materials.

RPM = raised pavement markers, MMA = methyl methacrylate.

example, use of recessed markings in Northern climates; high-quality, durable marking materials; correct placement and application of materials (e.g., glass beads in paint); and increased specification and measurement of wet retroreflectivity. A strong relationship between materials supplier and contractor is very helpful toward these ends. All of these methods can help to avoid, where appropriate, the need to occupy the road annually to redo pavement markings.

Beyond this positive stance toward pavement marking warranties the interviewed firms presented a range of views regarding the use of warranties and their role in future highway construction, risks and risk mitigation, and suggestions for ways to get greater value added from warranty projects. Within the geographic areas in which the interviewed firms work, highway agencies vary in their level of experience and sophistication regarding pavement marking warranties. The comments here therefore represent a blend of very basic concerns and suggestions, combined with observations and proposals for improvement at a more advanced level.

These findings generally agree with earlier findings in a contractor survey and interviews by Bayraktar et al. regarding warranties generally, not just for pavement markings. Although there were some indications of contractor innovation owing to warranties (e.g., use of better equipment, new materials, and innovative technologies and methods), only 2 or 3 of 16 responding contractors identified with these types of innovations. Most contractors (10 of 16) noted, rather, a greater consciousness of quality in construction, and 5 of 16 reported applying better workmanship and the opportunity to provide greater design input (Bayraktar et al. 2004, 2006).

Risk and Risk Mitigation

Notwithstanding general support for warranties, the firms collectively identified a number of risks that contractors and materials manufacturers may face on a project. Although these risks have been organized into four major categories here for ease in explanation, the risks are interconnected, and bidders and materials vendors must deal with the total situation when deciding whether and how to bid the job. The four major categories are technical, administrative, financial, and business-reputation risk. As an example of interconnectedness, problems in the technical or administrative aspects of a warranty specification may lead to associated risks in the financial and business-related arenas. Risks associated with project bonding requirements and miscellaneous other topics are also covered.

Technical Risks and Risk Mitigation

Technical risks arise with the failure to use the right material and installation method (including preparation) for a given project. Dealing with this risk involves several tasks; for example, understanding road operating conditions, the pavement surface, and geographical and environmental site conditions; knowing the correct installation method and performing it correctly with a trained crew; and maintaining good communication among all parties. Both manufacturers referred to this basic risk, and contractors elaborated with several examples.

- The failure to match materials properties (e.g., correct bead application in paint) to site and environmental conditions is a risk (Contractor A). Contractor C believes that some state specifications are outdated and therefore do not call for the best material. All material used on a job must have a certificate of compliance; where materials options are allowed, all would meet specifications fully. Contractor E interpreted this type of risk as correctly identifying pavement surface and environmental conditions that can affect performance. For example, with respect to asphalt, there are 12 types of surfacing they deal with (e.g., chip seal, hot-mix asphalt resurfacing, rubber-based asphalt, and recycled asphalt). One must understand the implications of each type for adhesion, cracking, compatibility (particularly with chip seals) with respect to bonding and bleeding, and need for proper preparation and cleaning. Contractor F noted that paint is affected by humidity in coastal regions, a factor that has not been addressed by a client agency that has set very tight completion dates for pavement marking work. (An adjacent jurisdiction has not been able to achieve these more restrictive specifications.)
- Lack of good performance data and/or technical specifications on pavement markings are a risk. Not enough research and testing have been done to define performance reliably. Regarding paint, Contractor A believes that test strips do not give a true indication of performance.
- Warranty provisions and administration are potentially risk factors and may need to be evaluated in the bid decision (and if bid and won, dealt with further during project performance). Following are examples of administrative risk related to the technical performance of pavement markings. Other examples of risk related to more general warranty administration are given in a following section.
  - The degree of control allowed the materials supplier and contractor during installation strongly influences perception of risk (Companies M1 and M2). Company M2 referred to the key role of materials providers in managing this type of risk as one-source accountability.
  - Too high a required performance level (i.e., one that might lead to any proposed product to fail and/or require restriping more than once annually) would be a risk.
    - △ Performance requirements need to be looked at in the context of site conditions, as mentioned earlier. The presence of heavy truck traffic, a need for tight turning maneuvers by these heavy vehicles, or other causes of encroachment that would shear the pavement markings all increase risk (Company M1).
    - △ Performance requirements also need to be consistent with reasonable expectations of specified materials. For example, setting minimum retroreflectivity levels too high for paint is unrealistic and will virtually guarantee failed performance (Contractor F).
  - Pavement marking installation is better performed in daytime, but this is not always possible. Contractors must work with agencies to accommodate project requirements and possible nighttime work (Company M2).
- On roadways with high traffic volume, Company M2 will use a specialized subcontractor for traffic control, overseen by a supervisor certified by the American Traffic Safety Services Association (ATSSA), who is familiar with *MUTCD* requirements. This specialized traffic subcontractor, together with the trained and certified installation subcontractor, forms a Quality and Safety "A" Team for the project.
- According to Contractor E, there are still issues with variability of readings on retroreflectivity devices and the need for correct calibration. This contractor believes the best result is obtained by driving at night and observing the visibility of markings by eye. Also, "wet" retroreflectivity pavement marking products are still in their infancy and are now being evaluated by agencies.

Another area of technical risk has to do with disruption of the "level playing field" that is presumed to exist among competing bidders on a project. Well-specified warranties promote higher quality workmanship and materials. The interviewed firms believe that in the absence of warranties some competitors may attempt to cheat on quality requirements, particularly if the highway agency lacks sufficient

resources to conduct proper inspection and jobsite monitoring. There is also a question as to who will monitor in-place markings and how deficient materials and lengths will be determined (e.g., the particular inspection or test method) to identify the degree of repair or replacement needed.

Contractor D is involved in airfield pavement markings, and has developed a handbook on the subject for the Innovative Pavement Research Foundation (IPRF) (*Airfield Marking Handbook* 2008). Much of the technical information that informs airfield practice comes from the highway industry and, in some areas, airfield practice is not as advanced as that for highways. Examples of areas where airfield pavement marking specifications could be strengthened include contractor training and certification, greater use of enforceable criteria within civilian and military specifications, and institution of more regular, formalized, and comprehensive inspection programs (operations personnel do observe the pavement markings, but may miss a gradual degradation in visibility and retroreflectivity). Comments based on the contractor's experience in developing the airfield pavement markings handbook echoed opinions of highway practitioners; for example, the importance of minimum retroreflectivity values at installation and during the expected service life, a belief that good specifications with enforceable requirements leads to a better pavement marking product, and the desirability of moving toward performance specifications and certification programs. It is important that airport design consultants understand the characteristics of both pavements and paints (e.g., to specify materials that resist the staining of white paint).

Administrative Risks and Risk Mitigation: Specifications

The interviewees supported clear, strong, effective specifications and proper, ongoing agency inspection and enforcement of work requirements. In reviewing the comments by different contractors here, it is important to recognize that their client agencies represent varying levels of experience and degree of comfort with warranties and performance-based contracting generally. Some comments thus may refer to agencies that are relatively new to warranties and performance-based specifications, whereas other comments reflect experience with agencies that have more mature warranty programs and well-developed performance specifications.

- The contractors did not favor projects with "easy" or "cookbook" specifications, particularly those that were not sufficiently performance-based; that is, specifications that did not clearly identify required technical performance levels for measures such as retroreflectivity, nor other performance criteria that would define failure.
- Contractors noted that slack specifications could also lead to unrealistically low bid pricing, which could drive a lower installed quality of pavement markings. Contractors seeking to maintain proper quality might sense a competitive disadvantage and not bid the job.
- At the other extreme, it is important that specifications not be too stringent for the specified pavement marking material; for example, minimum retroreflectivity levels that are set too high in a paint specification so as to be unrealistic.
- Performance requirements, scheduling of the work season, and priorities should accommodate differences in climate, geography, and altitude.
- One contractor reported projects where safety-related provisions were included contractually but not able to be fully enforced because of DOT personnel reductions. The contractor preferred that all bidding competitors realize that safety provisions will be enforced. Other contractors observed that safety and traffic control, as well as inspections for quality control, were tasks that they or third parties could perform on behalf of the agency.

Administrative Risks and Risk Mitigation: Project Bonding

The issue of performance bonds for pavement marking work drew several different comments. One company was able to obtain bonding for a 5-year period with no issues, although it admitted that smaller, nonspecific contractors (i.e., those that do not work regularly on particular categories of pavement markings such as longitudinal striping) might have a problem. Another company found it difficult to get warranty bonding for more than a 2-year period. A third firm mentioned that it generally does not need a warranty bond, although it has had a few jobs that required one, and there were no problems in obtaining one. A fourth firm had considered a job with a 5-year warranty. The bonding company would not grant a bond and the contractor did not bid on the job. The bonding company would have granted one for 2 years, and would have considered a 3-year bond, but not one of 5-year duration. The contractor's relative inexperience with long-line work may have been a factor in the bonding decision.

The earlier study by Bayraktar et al. provided further insights into the impact of bonding requirements. These findings related to highway warranty projects in general, not necessarily pavement marking projects. Surety companies that responded to the Bayraktar et al. survey were unanimous in their perception that small firms would likely be eliminated on warranty projects. Although the risk evaluation methods used on warranty projects are the same as those used on nonwarranty projects, the risk assessments are not adequate to deal with the longer-term obligations that warranties entail. Lacking appropriate risk evaluation methods, the surety companies prefer to deal with larger contractors, which tend to have larger amounts of working capital. Responding to contractor difficulties in obtaining bonds, the Florida DOT has implemented another assurance approach based on the prequalification of contractors as a condition of bidding, and has eliminated warranty requirements. Failure to correct problems after project completion in accordance with the contract can result in a contractor being removed from the prequalification list. Most of

the state DOTs reported that the warranty bond is required when the contract is signed (surety companies would prefer to issue the bond after the completion of project work), and all DOTs noted that the face value of the bond is not reduced. Three-quarters of the contractors claimed that they are not constrained by their bonding capacity in bidding and performing work; 25% reported that they are (Bayraktar et al. 2004, 2006).

Administrative Risks and Risk Mitigation: Other Topics

Contractors raised other topics in warranty administration. Calendar-based performance periods (refer to Figure 3) are potentially a problem where geography and climate may reduce the available work time. For example, a mid-May start of the work season may not be realistic at high altitudes, where mountain passes are still subject to snow. It is important that the timing of the working season be coordinated between agency and contractors. Another contractor believed that a performance evaluation period from April through November was too stringent. For materials such as thermoplastic, durability requirements actually were more a materials warranty than a performance warranty.

Contractors differed somewhat in their reactions to varying methods and styles of warranty contract administration among agency districts. Some believed that more uniform and consistent practices would be desirable. Another observed, however, that administrative differences do not affect their work performance. This company recognized that agencies are facing a paradigm shift, and the company tries to be open in helping them deal with the transition to warranties.

An agency's approach to administering a warranty contract was seen by several firms as a potential opportunity for a win-win result. The materials manufacturers both voiced the opinion that the degree of control of a job is an important determinant of quality. Company M2 described its role as providing one-source accountability in fulfilling warranty specifications. One-source accountability avoids finger-pointing by recognizing and dealing with risks in several areas. Good planning, work execution, and keeping on top of things help ensure that the pavement marking product performs well. Both vendors manufacture premium pavement marking materials having standard 4-year warranties, with variations possible case-by-case. The firms prefer to be involved in inspections—they perform their own inspections and are also on site when the agency performs its inspection. Company M2 voiced the belief that inspections at 1-year intervals are sufficient for warranty enforcement, but more frequent inspections—for example, 2 to 3 times per year—are preferred for internal quality control. A contractor favored longer-term contracts as a way of promoting a good relationship with the owner and achieving greater client satisfaction.

Prequalification of contractors and materials was believed to be a good idea, as is a scorecard or evaluation process on job performance. Repetitive violations on projects might be cause for a contractor to "sit it out" for a period on future work. Contractors reported that some agencies have provisions for contractor evaluation, but do not apply them, and not every agency prequalifies contractors. The interviewees expressed frustration when other contractors won a "warranty" project strictly on the basis of a low bid and then took advantage of the situation.

Financial Risks and Risk Mitigation

The interviewed firms discussed two types of financial risk: (1) having insufficient reserves to fund warranty repairs, and (2) having a situation where agency payments to contractors through the warranty period are not in step with the pace at which project costs are incurred.

With regard to the first type of financial risk, interviewed contractors and materials manufacturers plan for a certain amount of repair work and maintain the funding to accomplish that target if needed. It was believed that some agencies use warranties as a scare tactic, which stresses the relationship with the contractor. A balance is needed in relating time to money through liquidated damages. An incentive program is preferred, in which the contractor is awarded additional money for premium performance—that is, performance exceeding warranty requirements. Combining incentives with measured penalties would keep contractors honest and instill the appropriate negative consequences for those contractors thinking of not fully complying with the performance warranty.

With regard to the second category of financial risk, different approaches that agencies use to pay contractors for work under warranty—and staged payments or step payments in particular—were presented earlier in the section on agency perspectives. Company M2 mentioned that it has discussed the subject of financial modeling with agencies—that is, how should payments for a project under multi-year warranty be distributed through the term of the warranty:

- What is the rationale in scheduling partial payments in the out-years as opposed to paying the contractor fully in year 1? Conversely, what are the financial and other implications of paying 100% up front in year 1 as opposed to lesser amounts (e.g., 60%, 40%, or 30%)?
- What is the limit in first-year payment that an agency would be willing to pay given demonstrated performance on the part of the contractor?
- How could payments be staged to be fair to both agency and contractor? (Contractor A cited an example of a multi-year warranty in which payments extended to out-years, even though most of the contractor's costs occurred in Year 1. The contractor decided not to bid the job.)

This matter of staged payments (or step payments) is an emerging issue that will likely take on increasing significance and attract greater industry awareness as more states begin to use pavement marking warranties and as the durations of warranty periods lengthen.

Business-Reputation Risk and Risk Mitigation

Business-reputation risk concerns damage to a firm's reputation if a pavement marking project does not turn out well. Contractors and materials manufacturers agreed: business reputation is important for maintaining good standing among current and future clients. Although some firms cited specific examples of mishaps that could lead to damaged reputations (e.g., asphalt-related problems discussed under technical risks), it is reasonable to generalize that any of the sources of risk discussed earlier can have negative impacts on business reputation. The way to avoid harm to reputation is therefore to manage the various categories of risk.

Suggestions for Enhancing Benefits

The interviewed firms offered several suggestions for improving the value and benefit of warranties:

- Consider the wider use of incentives tied to superior pavement marking performance above the warranted level. This approach would provide an additional payment of a certain percent if actual retroreflectivity in a given year is at a level higher than that specified as the minimum acceptable in the warranty. An incentive would encourage even better visibility and longer life than that envisioned by the warranty. It is a "do more, get more" proposition in terms of lower life-cycle costs (Contractor A). (Incentive provisions are much preferred to disincentives or penalties.) Contractor E believed in incentives to select the correct material and apply it correctly. Company M2 believed in incentives to promote good performance beyond the warranty period (which saves dollars, for example, in years 5 to 6 of a 4-year warranty).
- View warranties as one method in a range of options to achieve the desired goals of a longer pavement marking life, improved performance during this life, lower life-cycle costs, and reduced need for road occupancy to repair or replace deficient markings (Contractor B, Company M2).
- Company M2: the ideal situation is to have complete control of the project—ultimately a warranty is about *performance,* not *materials.* Tailored materials that they are able to produce are able to provide required performance at a very competitive price. They are open to broader warranty provisions, but the response would likely differ by state when climate, traffic volume and composition, customer expectations, and geography are factored in (e.g., mountainous terrain versus the plains). Company M2 envisioned itself becoming more flexible and innovative to deal with these opportunities.
- Engage contractors more in the pavement marking program; for example, consider their potential to perform the data collection needed to monitor the warranty. If desired, the data could also be posted on an agency's web system for network-level review and assessment, becoming a part of an agency's overall asset management (Company M1, Contractor A).
- The firms made several suggestions for basic improvements in communication and dispute resolution where they do not exist now. For example, in one state a liaison committee has been established between the local chapter of ATSSA and the state agency to maintain communication on current issues. Formation of a panel to clarify and resolve disagreements was also proposed where such mechanisms are not now formalized. (The supporting rationale was that a relatively small infraction would not disqualify a contractor from future work.)
- The concept of qualified product lists (or their equivalents) was widely supported, together with the idea of matching recognized materials to local weather, geography, and paving materials and practices.
- The firms recognized the implications of a changing population, the need for wider and brighter markings, and the greater use of contrast markings where helpful.

EUROPEAN WARRANTY EXPERIENCE

European experience in road construction warranties has a long history. This experience has been addressed in several studies and international scans by U.S. agencies. Although many of these fact-finding missions are not focused on pavement marking warranties specifically, they do establish differences in legal and institutional approaches between European and U.S. practice that likely influence the success of warranty use. Following is a summary of relevant European practices; a more detailed description is provided in Appendix E (web only).

An international scan team organized through the FHWA and AASHTO in November 2002 visited five European nations—Denmark, Germany, Spain, Sweden, and the United Kingdom—to review short- and long-term warranties for asphalt paving projects (D'Angelo et al. 2003). A number of topics were investigated, including a general review of current and proposed approaches to road construction contracts with warranties, risk assessment for agencies and contractors, and administration of warranty contracts. Findings and recommendations of the scan team's report addressed material and workmanship warranties, performance warranties, best-value procurement, and alternative contracting methods. A summary of the scan team's assessments and recommendations follows (D'Angelo et al. 2003):

- Materials and workmanship warranties of various durations have been used for 30 to 40 years. The five countries are continuing to move toward pavement performance warranties and other methods to engage the contractor more fully in assuring the quality of pavement performance through its full life cycle.
- Among these quality-oriented practices are the development of partnership relationships among agencies and industry participants, the use of best-value procurement techniques, and the application of alternative contract methods to conventional DBB.

- All of the countries visited use materials and workmanship warranties of up to 4 years on their traditional road construction projects. Denmark and Sweden use 5-year performance warranties in their traditional contracts, while the United Kingdom employs 5-year performance warranties in DB contracts, which have become its preferred method of pavement construction contracting.
- All five countries visited use best-value rather than low-bid procurement. Among the factors considered in best-value contractor selection are safety, innovation, environmental impact, the additional years of warranty protection proposed by the contractor, and contractor prequalification. All countries reinforced the importance of a best-value approach to the warranty approach, because it promotes trust and confidence among the parties.
- Much longer warranty periods (e.g., up to 35 years) are being explored in alternative types of contracts such as Design-Build-Finance-Operate and Pavement Performance Contracts, which have warranty periods of 11 to 20 years among the host countries. These longer warranty periods reflect the concept that contractors have responsibility for pavement design, construction, and maintenance according to performance criteria established by the owner agency. These alternative arrangements are developed in collaboration with industry.

The scan report recommended actions at the federal, state, and local governmental levels in the United States to promote greater use of warranties, including short-term (e.g., up to 5 years) materials and workmanship warranties that are intended to lead to long-term performance warranties in the future. Legislation enabling wider use of best-value procurement processes and contractor prequalification would be sought where needed. The report also recommended that the federal government take the lead in establishing a warranty resource center for use by the federal, state, and local governments. It is important that state and local governments take practical steps toward developing and implementing materials and workmanship warranties and, when it is appropriate to engage contractors in design, short-term performance warranties. Best-value and contractor-prequalification processes could also be implemented. The report recommended roles for industry in education, participation in roundtable discussions and pilot projects, and strengthening of its knowledge and capabilities regarding construction and maintenance methods and products to support warranty use.

A second international scan team on Superior Materials, Advanced Test Methods, and Specifications toured four European countries—the United Kingdom, Denmark, Germany, and the Netherlands—in July 2003 to learn about European practices in the subject topics. A particular focus concerned ways to accelerate identification, evaluation, approval, and acceptance of new products, and to incorporate the products within project specifications. The investigation also included processes that yielded superior materials—that is, materials that could improve facility performance significantly, cost-effectively, with improved safety or reduced construction time.

A recommendation by the scan team that is relevant to this synthesis concerns procedures for accelerated testing of new pavement marking materials and for product acceptance. Germany has built a laboratory turntable on which to conduct accelerated performance tests of selected pavement markings: tape, temporary paint, and permanent paint. Spain has a similar facility, although it was not visited during this scan tour. The scan team believed that this turntable concept could be considered for application in the United States by AASHTO's NTPEP.

In response to this latter recommendation, the ATSSA prepared a white paper regarding consideration of a U.S. pavement marking test facility. The paper considered the implications of an accelerated testing turntable for pavement markings, raising the following issues ("Pavement Marking Material . . ." n.d.):

- The need to validate laboratory test data versus actual conditions and performance in the field.
- The ability of the turntable to represent climatic and topographic variability throughout the United States.
- The need to better define the goals of the laboratory facility and proposed use of the test results.
- The need to address four areas of technical concern in which the paper's authors believed that a laboratory turntable would not yield valid results:
  - Lack of exposure to ultraviolet light;
  - Laboratory preparation of pavement marking samples that did not mimic actual installation or application methods in the field;
  - Standardized, constant laboratory environmental conditions that reflect neither the full degree of variability in conditions throughout the United States nor the short-term cycles of fluctuation that stress highways in the field; and
  - Differences between the substrate material on the turntable plates that are used to simulate the pavement surface versus the actual pavement substrate properties in the field, including variability in materials (e.g., asphalt vs. concrete) and variations in these material properties among states.
- The much different institutional framework and construction industry and culture in the United States as compared with those in Europe, which raises questions as to whether the effective use of test results from the turntable can be successfully transferred to the U.S. legal and business environment.

These issues remain under discussion. Further information on European warranty practices and ATSSA's response to the 2003 international scan report is given in web-only Appendix E.

CHAPTER FOUR

CONCLUSIONS

OVERVIEW OF FINDINGS

This synthesis study has compiled information on pavement marking warranty specifications used by U.S. state departments of transportation (DOTs) and Canadian provincial/territorial road agencies, with further comparisons to European practice. Pavement markings play an important role in reducing congestion and improving safety by providing information, guidance, and warnings to road users, whether drivers of motorized vehicles, bicyclists, or pedestrians. Transportation agencies typically consider using pavement marking warranties to gain one or more benefits; for example, superior pavement marking performance, reduced need for inspection personnel, greater cost-effectiveness, reduced risk of premature failure, and potential for contractor innovation.

Information on pavement marking warranties has been obtained through a survey of U.S. state DOTs and Canadian provincial transportation agencies, interviews with U.S. and Canadian pavement marking contractors and materials manufacturers, and a literature review. Forty state DOTs and eight Canadian transportation agencies responded to the synthesis survey. Reporting agencies were divided almost equally between those that now use pavement marking warranties (23 agencies) and those that do not (25 agencies). Fifteen of the responding agencies that now use pavement marking warranties submitted one or more examples of their specifications, which are compiled in Appendix D (web-only portion of the report). These examples contributed important information to the study regarding the technical requirements, performance criteria, and administrative provisions that are now used in U.S. and Canadian pavement marking warranties, and how these details vary among agencies. Interviews with seven U.S. and Canadian contractors and two materials manufacturers, who also serve as prime contractors on jobs, provided further information on the benefits of pavement warranties, the risks inherent in their use, and ways to potentially improve their administration as well as their achievement of intended benefits. These findings are elaborated on here.

CURRENT WARRANTIES AND PERCEIVED BENEFITS

The 23 U.S. and Canadian transportation agencies that now use pavement marking warranties illustrate current state of practice and the different ways in which agencies structure and administer warranty specifications:

- **Warranty Structure and Timeline.** Most agencies have the pavement marking warranty begin after marking application or after initial acceptance thereof. Typical durations of the warranty performance evaluation period are 1 to 6 years, with several agencies now considering lengthening their warranty periods. Some agencies that operate roads in harsh climates or that use paint, which has a relatively short expected life, apply warranty periods of 180 days that are timed to encompass one winter season.
- **Variations in Evaluation Periods.** Other agencies impose additional time periods—referred to respectively as observation periods and performance periods—to evaluate pavement marking performance through a lengthier period before initial acceptance or to allow further evaluation after initial acceptance but before onset of a multi-year warranty.
- **Warranty Concepts.** Based on the examples provided by the 15 agencies, pavement marking warranty specifications represent a blend of methods-based and performance-based thinking. A number of these specifications are essentially Materials and Workmanship warranties, but with performance criteria governing minimum acceptable marking characteristics through the warranty evaluation period. Three of the state DOTs, however, employ specifications that are "pure" performance warranties, in which only the required performance from initial application through the end of the warranty performance evaluation period is specified, with choice of material and application method left to the contractor.
- **Pavement Marking Performance.** The performance criteria specified in warranties typically include durability or presence, retroreflectivity, and color retention. Some agencies specify acceptable threshold values of these measures that are constant through the warranty period; others vary the acceptability criteria over time. Agencies also differ in how they assess pavement marking performance and at what intervals. A combination of visual and mechanical sensing is used in inspections, most often conducted by agency personnel. In some cases, however, agencies call upon the contractor to perform inspections, work jointly with the contractor in conducting inspections, or assign an independent third party to assume inspection responsibility.
- **Responsible Party.** Within the warranty sample, the majority of agencies (10 of 15) regard the contractor as

the warrantor—that is, the party responsible for fulfilling the requirements of the warranty specification. Three of 15 agencies give this responsibility to the materials manufacturer, whereas two agencies specify a dual or discretionary assignment of responsibility. In these latter two cases, one agency holds the contractor responsible during an observation period; the materials manufacturer, during the warranty period. In the other instance, the agency calls for a manufacturer's warranty bond, but—at the contractor's discretion—allows the substitution of a contractor's warranty bond and the contractor's assumption of all warrantor responsibilities.

- **Methods of Delivery.** Agencies and contractors employ several mechanisms to apply or install pavement markings under warranty. For example, an agency may contract for durable markings under its warranty provisions, but also continue to use nondurable materials that are applied by its own employees. A contractor may apply pavement markings on its own or employ subcontractors to do this work. Some states impose participation requirements on a general contractor. A materials manufacturer is typically allowed to serve as a general contractor so long as it meets a state's participation requirements. Materials manufacturers may themselves impose requirements on a contractor installing their products in terms of training, certification, and onsite presence by the manufacturer's representative during installation. Manufacturer's product recommendations, participation at meetings, and provision of technical assistance to contractor and agency may be incorporated by an agency explicitly or by reference into its own warranty specifications.
- **Corrective Actions.** All agencies require the repair or replacement of pavement markings that are found to be deficient according to warranty specifications. A few agencies also impose additional terms on the prime contractor; for example, paying cash penalties or lane rental charges, relinquishing the bond covering the work, paying damages if work deficiencies exceed a certain threshold, and reimbursing the department if repair or replacement must be done by agency forces or another contractor.
- **Steps to Enhance Quality.** Agencies use several mechanisms to promote quality in their warranty specifications; for example, use of qualified products lists, prequalification of contractors, stipulated meetings among all parties, Work Plan and other submittals by the contractor, materials manufacturer's training and certification of installation contractors, onsite representation by a manufacturer's representative, incorporation of manufacturer's product information and installation recommendations within agency specifications (if appropriate to the project), reliance upon standards and test procedures of several nationally and internationally recognized organizations, contractor provision of test stripes or sections, frequent contractor reporting of project status, periodic inspections, imposition of penalties for deficient contractor performance, and warranty bond requirements.
- **Other Variations in Warranty Approaches and Provisions.** Several examples of the variability in pavement marking warranty specifications among agencies were described earlier. Others were covered in chapter three (e.g., differences among agencies in whether contractors are held responsible for winter maintenance damage), and yet others are evident in reviewing the example specifications in Appendix D (web-only document) (e.g., different threshold values for minimum acceptable performance of pavement markings through the warranty period).
- **Other Issues in Administration.** Several other issues in administering pavement marking warranties have been identified by the road agencies and the contractors and materials manufacturers. One topic on which the interests of the two groups converge is the scheduling of partial payments through a multi-year warranty period. The issues concern what is a reasonable amount for initial payment and what should be the amounts of subsequent annual payments through the warranty performance period. Comments by the affected parties suggest that a balanced approach is needed to ensure that agency expectations of quality and performance are met, while providing contractors and materials manufacturers with fair, timely payment for work accomplished in the initial installation of markings. This issue will likely grow in importance as more agencies begin to use pavement marking warranties, and as the durations of warranty performance periods increase.
- **Cost Impacts.** The impacts of pavement marking warranties on costs (whether initial, annual, or life-cycle) are still not well researched. Most assessments of costs are based on subjective judgments or perceptions by parties engaged in the warranty process, with little supporting quantitative information. The subjective assessments that have been made exhibit considerable variation; for example, zero to 50% increase in bid price from agency sources, and zero to 20% increase from contractors, according to an earlier study of highway construction warranties in general (i.e., not limited to pavement markings).

Among those responding agencies now using pavement marking warranties, almost 70% expressed satisfaction with their warranty program. About 13% reported mixed results, with concerns primarily about timely response by contractors to correct performance deficiencies. One agency that cited a "problematic" experience explained its response as really a concern with the current state of knowledge of warranty performance and the need for stronger capabilities in pavement marking management systems, rather than an issue with the warranties themselves.

Most of these agencies categorized the benefits of warranties in terms of improved pavement marking performance and quality, protection against premature failure, reduced lane occupancy for repairs or re-application, and attendant

savings in maintenance costs and life-cycle costs (including road-user cost savings resulting from to reduced lane occupancy through the warranty period). Other benefits cited by individual agencies included the potential for greater contractor innovation, the regarding of warranties as a logical component of comprehensive departmental outsourcing, a reduced administrative and staffing burden for the agency, an opportunity to generate pavement marking performance data (which could also be used for product performance comparisons), and a perceived positive effect of risk sharing.

REASONS FOR NOT USING WARRANTIES

Among the 25 agencies that do not now use warranties, 15 indicated no plans to implement such warranties in the foreseeable future. The major impediments to pavement marking warranty use reported by these agencies were the greater administrative burden in monitoring contractor compliance with specifications, potentially higher bid prices, and possible increases in disputes or litigation with contractors. Other drawbacks that were cited included administrative difficulties associated with using U.S. federal-aid funding on projects if sole-sourcing pavement marking work and keeping contracts open on federal-aid projects while the warranty remains in force. Three agencies cited an agency culture and practice that encouraged closing out construction projects as quickly as possible, rather than an opposition to warranties *per se.* These agencies favored effective enforcement of project specifications in lieu of warranties as the currently preferred approach to managing pavement marking performance and the risk of premature failure. Any inclination by these agencies to consider pavement marking warranties in the future would be addressed, but with care and deliberation.

Ten of the agencies that do not now use warranties expressed an open mind toward possible future use and welcomed additional information to help in their decision. These respondents believed that all of the categories of information listed in the survey questionnaire would be useful in their assessments (refer to Figure 15 in chapter three).

VIEWS OF PRIVATE SECTOR FIRMS

Private sector perspectives were obtained through interviews with seven U.S. and Canadian pavement marking contractors and two marking materials manufacturers. Most of these firms had performed work involving warranties; all were familiar with performance-based specifications and spoke from experience. Although the contractors worked in different geographic regions and dealt with a range of pavement marking materials, their willing participation in the project interviews may have represented a self-selected sample. Attempts to obtain a wider range of views from firms of different characteristics, or those less inclined toward warranties, were not successful. Supplementary findings from other studies were gathered to fill this gap.

All interviewed firms believed in providing a quality pavement marking job, and their comments supported the notion that quality-oriented firms perform their projects to the same high standards and levels of commitment regardless of whether or not the projects involve a warranty. Nonetheless, they believed that warranties helped impose a level playing field for bidding among all participating contractors. The firms supported warranties with strong but reasonable specifications that are dependably enforced for reasons of both quality of result and fair competition. This approach was believed to promote use of quality products and proper installation procedures that yielded brighter, more durable, more consistently performing markings, with attendant benefits to the highway agency and the traveling public. Materials manufacturers interpreted project quality in terms of their own ability to exercise appropriate management and control of the several facets of jobs they were involved in. They believed that one-source accountability was the best approach to achieve project objectives, avoid finger-pointing, and yield the desired savings in life-cycle costs with benefits to agency and public. Several firms saw warranties as a wave of the future and believed strongly in their value and benefit, even though they entail risks that will be discussed here.

One firm had a somewhat different, but still supportive, view of warranties as but one approach among several options to provide quality performance cost-effectively. Although this firm had nothing against warranties *per se,* it believed that agencies need not rely solely on warranties if high-quality materials, strong but reasonable and achievable (not onerous) specifications, and correct installation methods were called for and provided. Good techniques and products that are available today can readily achieve longer, higher-performance service lives; for example, use of recessed markings in Northern climates; high-quality, durable marking materials; correct placement and application of materials (e.g., glass beads in paint); and increased specification and measurement of wet retroreflectivity. A strong relationship between materials supplier and contractor is very helpful toward these ends, in the view of this contractor.

Notwithstanding their general support for warranties, the interviewed firms collectively identified a number of risks that contractors and materials manufacturers may face on a warranted project, and ways to mitigate them. The risks are categorized here for ease in explanation, but are actually interconnected and somewhat overlapping, and one type of risk can lead to another. Contractors and materials suppliers must deal with the total situation when deciding whether and how to bid the job. The types of risk are as follows:

- **Technical risks** typically caused by a failure to use the right material or application method for the job, resulting in a pavement marking that fails to perform as intended. Technical risks may arise because of deficiencies in contractor knowledge and preparation, subpar execution at the jobsite, faults in the specifications themselves or with

agency enforcement of contract requirements, and failure to maintain proper communications among all parties. For these reasons, the interviewed firms all supported effective, realistic specifications that are properly enforced. Such an approach, they believed, maintains a level playing field among competing contractors during the bid process and a uniform expectation of quality during the construction and the warranty period.

- **Administrative risks** relate to problems with either the warranty specifications themselves or their administration by the agency. These problems make it difficult to complete a job properly and create stresses in the relationships among agency, contractor, and materials manufacturer. Technical risks resulting from unrealistic specifications and ineffective enforcement of technical requirements have been discussed previously. Other administrative issues that might create risks include project bond requirements, ineffective enforcement of safety requirements, lack of uniformity in agency administration of warranty provisions across multiple jobs, and lack of a competent evaluation of contractors' qualifications and suitability for future work.
- **Financial risks** comprise two types of risks identified by interviewed firms: (1) having insufficient reserves to fund warranted repairs, and (2) having an imbalanced cash flow in which agency payments to contractors are not in step with the pace at which project costs are incurred. The interviewed firms regarded mitigation of the first risk as requiring good technical knowledge of likely pavement marking performance (including the factors affecting that performance) through the warranty evaluation period. This understanding helps guide the firms in maintaining sufficient reserves to fund repairs that might be needed. The second risk points to the need for a shared understanding between agency and contractor on a fair and reasonable financial structure for a multi-year warranty project. Such a structure could protect the interests of agency and contractor alike in providing a proper incentive for satisfactory pavement marking performance, while reimbursing contractors for costs incurred on a fair and timely payment schedule. This issue will likely grow in importance as more agencies begin using warranty specifications and as warranty performance evaluation periods grow longer.
- **Risks to business reputation** concern damage to a firm's reputation if a pavement marking project does not turn out well. Contractors and materials manufacturers agreed: business reputation is important for maintaining good standing among current and future clients. Because any of the risks discussed earlier can have negative impacts on business reputation, mitigating this risk becomes a matter of managing the spectrum of risks identified previously.

In addition to the risk-mitigation steps mentioned earlier, the interviewed firms suggested several ideas that they believed could enhance the benefits of using warranties on pavement marking projects. These suggestions included the wider use of incentives for superior-performing pavement markings, with a balanced administrative approach that combined realistic incentives and penalties; considering warranties as one of a range of available options to achieve improved performance and cost-effectiveness; having materials manufacturers and contractors engaged to a greater degree in all aspects of project performance; improved communication and dispute resolution procedures; and greater use of quality control mechanisms such as approved product lists.

FHWA CONTRIBUTIONS

An important role in the development and promotion of pavement marking warranties has been played in the United States by the FHWA. The FHWA helped sponsor the early trials of pavement marking and other highway construction warranties through its Special Experimental Projects 14 (SEP-14) program. The FHWA promotes the use of road construction warranties on U.S. federal-aid highway projects and supports dissemination of web-based information on such warranties. The FHWA is meeting a Congressional mandate to develop minimum acceptable retroreflectivity thresholds for pavement markings. It is also conducting pavement marking demonstration projects in Alaska and Tennessee to improve pavement marking durability, resulting highway safety, environmental protection, and related agency procurement processes.

EUROPEAN WARRANTY EXPERIENCE

The review of European warranty practice was based on recent international scans of highway agencies that were sponsored by the FHWA and AASHTO, and a review of other literature. The European warranties that were addressed applied primarily to pavements and thus represented general findings rather than those for pavement markings specifically. Nevertheless, these findings established differences in legal and institutional approaches between European and U.S. practice that influence the success of warranty use.

European experience in road construction warranties has a long history. Materials and workmanship warranties of various durations have been used for 30 to 40 years. European countries are continuing to move toward performance warranties and other methods to engage the contractor more fully into assuring the quality of asset performance through its full life cycle. Institutional differences between Europe (and to some degree Canada) and the United States include a less litigious relationship between agencies and contractors in Europe, and greater European use of bid alternatives, contractor testing, and end-result (or performance-based) specifications rather than method-based (or prescriptive) specifications. Several European countries use best-value rather than low-bid procurement. European agencies reinforced the importance of a best-value approach to the implementation of warranties, because it promotes trust and confidence among the parties.

Recommendations of the international scan teams to improve U.S. practice included the following:

- To create a greater sense of teamwork between public and private sector groups. Several themes emerged in this recommendation—for example, early contractor involvement in the project development process, integration of the contractor's role within a partnering approach to meet a customer's goals, a recognized contractor role in promoting quality during the project life cycle, and a willingness to consider alternative processes and methods—all of which can apply to innovative approaches to warranties.
- To take actions at the federal, state, and local governmental levels in the United States to promote greater use of warranties, including short-term (e.g., up to 5 years) materials and workmanship warranties leading to long-term performance warranties in the future. Legislation enabling wider use of best-value procurement processes and contractor prequalification could be sought where needed. Best-value and contractor-prequalification processes could also be implemented.
- To provide roles for industry in education, participation in roundtable discussions and pilot projects, and to strengthen industry knowledge and capabilities regarding construction and maintenance methods and products that can support warranty use.
- To consider ways to accelerate identification, evaluation, approval, and acceptance of new products, and to incorporate these products within project specifications. The example of a European turntable for accelerated testing of pavement marking materials was the focus of one such recommendation. This recommendation is now under discussion among U.S. industry representatives involved in pavement markings.

RESEARCH NEEDS

The discussions in chapter three identified several gaps in current knowledge, including questions raised by agencies in their survey responses that suggest needs for future research.

- A broader, more strategic, and more quantitative understanding of the role and value of pavement marking warranties is needed. Such a research objective would tie together several loose strands in current knowledge; for example, the need for better systematic models of pavement marking performance and how materials properties and initial installation techniques affect this performance, the impacts of pavement marking performance on road-user mobility and safety, the need for an equitable mechanism of contractor payment, and the lack of reliable information on the relative costs of pavement marking warranties—whether initial cost, annual (or recurring) cost, and life-cycle cost. Several research topics can be identified and addressed comprehensively or individually:
  - A recommended framework for managing quality, which could be adapted to developing a better understanding of pavement marking performance, has been proposed by Hughes ("Managing Quality" 2000). This framework emphasizes better knowledge of performance relationships, performance-related specifications, a rational basis for pay schedules, optimal levels of inspection and testing, knowing the cost-effectiveness of quality assurance procedures, and methods of quantitative analysis related to these issues.
  - The appropriate distribution of staged payments through the performance-evaluation period of a multi-year pavement marking warranty was raised by one of the interviewed private sector firms, and agencies now contemplating multi-year warranties are dealing with this question. This issue will likely gain increased attention as more agencies begin to use warranties and as warranty periods grow longer. Research is needed to look at financial modeling from both an agency and a private sector perspective, to provide guidance on a fair distribution of payments over time, to relate the pace of payments to accrual of costs, and to provide sufficient incentive for successful completion of warranted services.
  - Consideration could also be given to the wider use of incentives tied to superior pavement marking performance above the warranted level. This approach would provide, for example, an additional payment if actual retroreflectivity at some point were higher than the minimum acceptable level specified in the warranty. An incentive would encourage even better visibility and longer life than that envisioned by the warranty, a "do more, get more" proposition in terms of lower life-cycle costs.
  - Quantitative research on relative costs and benefits of pavement marking warranties would clarify existing uncertainty on the value of warranties and establish a firmer basis for determining where warranty use might be economically most efficient.
  - Better information on these topics could help agencies formulate a more strategic view of warranties; that is, as one method in a range of options to achieve the desired goals of a longer pavement marking life, improved performance during this life, lower life-cycle costs, and reduced need for road occupancy to repair or replace deficient markings.
- Although all current warranty specifications contain some performance-based provisions, only three agencies' example warranties in Appendix D are pure performance specifications that allow contractors to select materials and methods. Further research could assist agencies in understanding the advantages and disadvantages of performance specifications, lessons learned from agencies that have used them, and opportunities for wider use.

- Research could investigate engaging contractors to a greater degree in the pavement marking program, performing functions such as data collection needed to monitor the warranty, and processing and posting the data for segment- or network-level review and assessment.
- Several agencies that do not now use warranties alluded to interactions between pavement marking warranties and other contractual or bonding commitments, including federal-aid provisions. Some agencies also perceived warranties to conflict with the desire to close out construction contracts expeditiously once construction work was accepted. Although it is not clear whether these concerns represent an actual need for research (other agencies had apparently addressed these types of concerns in their own warranty programs), at least wider communication of acceptable procedures—for example, through roundtable discussions or peer exchanges—would assist agencies and could promote greater use of warranties if their concerns were allayed.
- The interviewed private sector firms suggested basic improvements in communication and dispute resolution where they do not now exist. For example, qualified product lists could be introduced where they are not now used. As another example, a liaison committee has been established between a local chapter of the American Traffic Safety Services Association (ATSSA) and the state agency to maintain communication on current issues. Formation of a panel to clarify and resolve disagreements was also proposed where such mechanisms are not now formalized; for example, to determine whether an infraction is serious enough to disqualify a contractor from future work. Again, this matter might be dealt with through a research study or through industry roundtable discussions and peer exchanges.
- The ATSSA white paper discussed in chapter three and Appendix E (web only) raises several questions on how the United States might proceed in pursuing accelerated testing of pavement marking materials and product approvals, building on European experience with test turntables. Research to address these questions could determine whether an accelerated test facility is needed and is feasible, the role of the National Transportation Product Evaluation Program in relation to such a facility, and a recommended strategy, if warranted, to develop such a facility and an agency-acceptable capability for product approvals.
- A comprehensive handbook on pavement markings has been produced for airfield applications. A corresponding handbook for highways could consolidate information on materials properties, performance histories, correct application methods, and other data for reference by agencies, contractors, materials suppliers, and other interested parties.

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APPENDIX A

Survey Questionnaire

NCHRP TOPIC 39-13 SURVEY QUESTIONNAIRE PAVEMENT MARKING WARRANTY SPECIFICATIONS

FEBRUARY 2008

Warranty contracts for **pavement markings** have been used by several states, but there is little information on comparative experience or on best practices to help other states with implementing this contracting procedure. This questionnaire is part of the effort in NCHRP Synthesis Topic 39-13 to gather information on agency as well as private sector perspectives on warranty specifications for pavement markings. We are interested in the experience and opinions of agencies regardless of whether they have used pavement marking warranties. The questionnaire has only 10 questions, and you will be asked to complete only a subset of these based upon your agency's experience with and perception of pavement marking warranties. A survey pre-test has shown that the questionnaire can be completed in 45 minutes or less.

Navigate the survey form by using the Tab or arrow keys or positioning the cursor with your mouse. Text fields allow great flexibility in responses. Use Comment fields freely to explain responses as you see fit. On multiple-choice questions, enter an "X" in a check box by clicking on it to indicate your selection. (Click on the box once again to clear.) You may select more than one item for most multiple-choice questions. Question 7 is looking for a single choice—use the drop-down list to make your selection.

The following definitions are used in this questionnaire:

- **Warranty:** a guarantee of the integrity of a product and its performance and the maker's (i.e., contractor's or manufacturer's) responsibility to repair or replace defective items. "Warranty" will refer in this survey to a warranty for pavement markings generally, regardless of type or material, including raised or recessed markers.
- **Total or comprehensive maintenance contracting** involves a performance-based maintenance contract that gives a contractor responsibility for many or all maintenance activities within the right-of-way (also known as "fence line to fence line maintenance responsibility" or "total asset management" contracts).

Please return the completed questionnaire via email by Friday, March 14, 2008 to:

Michael J. Markow, P.E.	Email: mjmarkow@comcast.net	Phone (508) 540-5966

If you would prefer filling out a paper copy, please mail the completed form to:

Michael J. Markow
43 Rivers End Road
Teaticket, MA 02536-5858

If you could kindly send me an e-mail mentioning that you have mailed the form that would be greatly appreciated.

Your Agency Information

Please provide the following information for your agency. Your agency will be identified in the report as a survey respondent when the completed questionnaire is returned. NCHRP will e-mail you a link to the online report when it is posted.

Agency:

Address:

City: State: ZIP:

Person Submitting Questionnaire Responses:

Position/Title:

In case of questions and for NCHRP to send you a link to the final report, please provide:

Tel. No. : E-mail:

If your agency **uses or has used** warranties for **pavement markings,** please describe this use in Questions 1–7.

If your agency **has not used** pavement marking warranties and **has no interest** in using them, please go directly to Question 9.

If your agency **has not used** pavement marking warranties but is **willing to consider them,** please go directly to Question 10.

1. What type of warranty does your agency use for pavement markings, and what effect has it had on your initial and life-cycle cost of pavement markings? (If you check more than one type of warranty, please provide a comment indicating where the different warranties are used.)

Type of warranty	Effect on Pavement Marking Costs and Other Comments
☐ **WORKMANSHIP WARRANTY:** Contractor corrects defects arising from poor workmanship.	Effect on initial cost: Effect on life-cycle cost: Other comments (optional):
☐ **MATERIALS AND WORKMANSHIP WARRANTY:** Contractor corrects defects arising either from defective materials or poor workmanship. The owner is responsible for defects due to an inadequate design or materials specification.	Effect on initial cost: Effect on life-cycle cost: Other comments (optional):
☐ **PERFORMANCE WARRANTY:** Contractor selects materials, installs pavement markings, and is responsible for any defects arising during the warranty period.	Effect on initial cost: Effect on life-cycle cost: Other comments (optional):

2. What duration of warranty does your agency use for pavement markings? (If you check more than one item, please provide a comment indicating where the different durations are used.)

   ☐ Less than 1 year

   ☐ 1 year

   ☐ Up to 2 years

   ☐ Up to 5 years

   ☐ Up to 10 years

   ☐ More than 10 years

   Comments (optional):

3. What types of performance criteria govern your warranty? Select all that apply. For each item checked, please indicate critical threshold values (or ranges of values) and units in the right-hand column. If these thresholds are used for warranties of particular types of marking materials (e.g., “Paints,” “Thermoplastics,” “Markers” (raised or recessed), “Preformed tapes,” “Multicomponent” materials, or “Other”), please add that to your response.

Performance Criterion	Threshold Value or Range of Values for Each Criterion	
	Example	*Your numerical value(s) and units*
☐ Initial installation requirements	Initial R_A, thickness, width, etc.	
☐ Durability or Presence or Missing Segments	90% remains within 1000-ft section	
☐ Retroreflectivity (coefficient of, R_A)	150 mcd/m^2/lux for 5 years after installation	
☐ Retroreflectivity, white	150 mcd/m^2/lux after 2 winters	
☐ Retroreflectivity, yellow	120 mcd/m^2/lux after 1 winter	
☐ Color reflectance, R_d	≥ 75	
☐ Red-green reflectance, *a*	[−5] to [+5]	
☐ Yellow-blue reflectance, *b*	[−10] to [+10]	
☐ Color	Color doesn't match federal standard color chips	
☐ Color contrast and stability	For white markings: yellow index >30 by colorimeter	
☐ Discoloration or pigment loss	Judged unacceptable vs. color plates by inspection team	
☐ Other—please describe:		

4. If the contractor or manufacturer fails to meet the above acceptability criteria within the warranty period, what is the corrective action required of the pavement marking contractor or manufacturer? (Check all that apply.)

   ☐ Remove/repair/replace material

   ☐ Pay lane rental charge during work performance

   ☐ Pay penalty charge for delay in beginning work

   ☐ Pay penalty charge for delay in completing work

   ☐ Refund a pro-rated amount of installation price as bid

   ☐ Refund total amount of installation price as bid

   ☐ Other

   Comments (optional):

5. Please describe how your agency administers its pavement marking warranties.

   A. How frequently are payments made for warrantied work that is performed during the warranty period?

   B. How often are performance inspections done for your agency?

   C. Who does the inspections?

      ☐ Agency personnel only

      ☐ Agency with contractor participation

      ☐ Contractor

      ☐ Third party (please describe)

      ☐ Other approach (please describe)

   D. Prior to issuing warranty specifications, did your agency work with the contracting industry to explain requirements and expectations? ☐ YES ☐ NO
   If Yes, please describe the agenda (key discussion items) briefly.

   E. Does winter maintenance affect the warranty? ☐ YES ☐ NO
   If your answer was YES, how do your warranty provisions reflect winter maintenance?

   F. How are disagreements with contractors resolved?

   G. Does your agency require project bonding [YES ☐] or do you use another assurance mechanism (e.g., a guarantee program tied into the prequalification process, as in Florida) [YES ☐]? If the latter, please describe this assurance mechanism:

   H. If bonding is required, when does your agency require the bond to be issued?

      ☐ At contract signing for the road project

      ☐ Following project completion

   I. How is the value of the bond computed?

   J. Is the face value of the bond reduced over time? ☐ YES ☐ NO
   If it is reduced, by what method (e.g., linear, stepwise, other)?

6. Would you be willing to provide a copy of your pavement marking warranty specifications as an example? ☐ YES ☐ NO

   If it is possible to attach it to an e-mail, please do so when you return this questionnaire. Otherwise, please mail it to me at the address given at the front of the questionnaire. Thank you.

7. What is the overall degree of satisfaction with pavement marking warranties? Please select one of the following responses, which are listed in order of decreasing satisfaction that best describes your warranty experience.

   SELECT FROM THIS
   DROP-DOWN LIST:

   (Select One Item From List)

   Comments (optional):

If your experience has been satisfactory (you selected one of the first two responses above), please go to Question 8. If your experience has been unsatisfactory (you selected one of the last two responses above), please go to Question 9. If you have had mixed results (you selected the middle response above), please answer both Questions 8 and 9.

Your agency is generally satisfied with its use of pavement marking warranties.

8. What is/are the primary motivation(s) for your use of warranties?

- ☐ Legislative/statutory requirement
- ☐ Perceived risk-sharing or risk-transfer benefit
- ☐ Perceived maintenance cost-saving benefit
- ☐ Perceived life-cycle cost-saving benefit
- ☐ Perceived performance-improvement benefit
- ☐ Potential for greater contractor innovation
- ☐ Protection against premature failures
- ☐ Agency's policies including bidding, outsourcing, or procurement guidelines encourage warranty use
- ☐ Agency staff reductions encourage use of contracting
- ☐ Reduced need for field inspections
- ☐ Warranties are logical components of agency's "total or comprehensive contracting" initiative
- ☐ Reduced administrative burdens; for example, need for record-keeping
- ☐ Positive experience of other agencies
- ☐ Other

If you have been asked to complete Question 9, please do so now. Otherwise the survey is complete. Thank you for your participation!

Your agency either has no interest in pavement marking warranties or has used them but is dissatisfied with the experience.

9. What are the reasons your agency has no interest in warranties or is dissatisfied with them?

- ☐ Prohibited or discouraged by state law
- ☐ Prohibited or discouraged by agency administrative policy or bidding and procurement guidelines
- ☐ Potentially higher bid prices
- ☐ Local construction contractor resistance (for reasons other than bonding—refer to next item for bonding issues)
- ☐ Bonding company resistance, inability of contractors to obtain long-term bonding
- ☐ Perceived negative impact on competition (i.e., reduced number of bidders, particularly among small contractors)
- ☐ Negative experience of other agencies
- ☐ Possible increase in disputes with contractors and litigation
- ☐ Too burdensome administratively
- ☐ Other

The survey is complete. Thank you for your participation!

Your agency has not used pavement marking warranties but is willing to consider them.

10. What information would be useful to your agency in considering pavement marking warranties? (Check all that apply.)

- ☐ All of the following categories of information would be useful
- ☐ Agency experience with materials & workmanship vs. performance warranties
- ☐ Duration of warranty
- ☐ Types of performance measures used
- ☐ Values of performance thresholds used
- ☐ Methods to enforce acceptable performance
- ☐ Specific additional costs of warranties
- ☐ Specific cost savings (benefits) of warranties
- ☐ Guidelines in reviewing and modifying procurement regulations and policies to allow warranty specifications
- ☐ Prior meetings with pavement marking contractors to familiarize them with warranty specifications and proposed administration
- ☐ Other aspects of pavement marking warranty administration and use:
- ☐ Other desired information:
- ☐ No additional information is needed by this agency

The survey is complete. Thank you for your participation!

APPENDIX B

Interview Guide

INTERVIEW GUIDE

This interview guide is intended for the private sector participants in this study: pavement marking contractors and materials manufacturers or vendors.

1. What has been your involvement, if any, with warranty specifications for pavement markings? [Discuss agencies, type and duration of warranties, role of firm, etc.]

2. What is your company's overall position on warranties?

3. What are the benefits your firm sees in warranties? What are the risks?

4. What changes would reduce the uncertainties or unknowns in these risks? Have agencies given any indication as to whether these changes may possibly be enacted?

5. What are the additional tangible and intangible costs to your company of participating in warranty work, and what factors influence these costs?

6. Under what conditions would your company accept broader warranty provisions or use? What are options to reduce your risk exposure in warranty work?

7. What flexibility do you have in warranty projects to select materials, determine when to repair or replace existing markings, and control methods and procedures of application?

8. If advising on a warranty project, how do you evaluate the performance requirements to determine the best materials and method and timing of application?

9. How do an agency's practices in administering warranties influence your judgment of their favorability?

10. What specific warranty provisions or practices do you tend to support? To oppose?

11. What factors do you see driving future trends in warranty use; for example, technological advances in marking materials? Financial and management trends in the highway community toward PPP and broader maintenance outsourcing? Changing driver and pedestrian demographics? Changing vehicle characteristics? Technological advances in application equipment and testing/inspection devices and procedures?

APPENDIX C

Survey and Interview Participants

U.S. AGENCIES

Alaska Department of Transportation & Public Facilities
Juneau, AK 99811-2500

Arizona Department of Transportation
Phoenix, AZ 85007

Arkansas State Highway and Transportation Department
Little Rock, AR 72203-2261

California Department of Transportation
Sacramento, CA 94273-0001

Colorado Department of Transportation
Denver, CO 80222

Delaware Department of Transportation
Dover, DE 19903-0778

Florida Department of Transportation
Tallahassee, FL 32399-0450

Georgia Department of Transportation
Atlanta, GA 30334-1002

Hawaii Department of Transportation
Honolulu, HI 96813-5097

Idaho Transportation Department
Boise, ID 83707

Illinois Department of Transportation
Springfield, IL 62764

Indiana Department of Transportation
Indianapolis, IN 46204-2249

Iowa Department of Transportation
Ames, IA 50010

Kansas Department of Transportation
Topeka, KS 66603-3754

Kentucky Transportation Cabinet
Frankfort, KY 40622

Louisiana Department of Transportation and Development
Baton Rouge, LA 70804-9245

Maryland State Highway Administration
Hanover, MD 21076

Massachusetts Highway Department
Boston, MA 02116-3973

Michigan Department of Transportation
Lansing, MI 48933

Minnesota Department of Transportation
St. Paul, MN 55155

Mississippi Department of Transportation
Jackson, MS 39215-1850

Missouri Department of Transportation
Jefferson City, MO 65102

Montana Department of Transportation
Helena, MT 59620-1001

Nebraska Department of Roads
Lincoln, NE 68509-4759

Nevada Department of Transportation
Carson City, NV 89712

New Jersey Department of Transportation
Trenton, NJ 08625

North Dakota Department of Transportation
Bismarck, ND 58505-0700

Ohio Department of Transportation
Columbus, OH 43223

Oklahoma Department of Transportation
Oklahoma City, OK 73105

Oregon Department of Transportation
Salem, OR 97301-3871

Pennsylvania Department of Transportation
Harrisburg, PA 17120-0095

Rhode Island Department of Transportation
Providence, RI 02903-1124

South Carolina Department of Transportation
Columbia, SC 29201-3959

Tennessee Department of Transportation
Nashville, TN 37243-0349

Texas Department of Transportation
Austin, TX 78701-2483

Virginia Department of Transportation
Richmond, VA 23219

Washington State Department of Transportation
Olympia, WA 98504-7315

West Virginia Division of Highways
Charleston, WV 25305-0440

Wisconsin Department of Transportation
Madison, WI 53707-7910

Wyoming Department of Transportation
Cheyenne, WY 82009-3340

CANADIAN AGENCIES

Alberta Transportation
Edmonton, AB

British Columbia Ministry of Transportation
Prince George, BC

Manitoba Infrastructure and Transportation
Winnipeg, MB

Newfoundland–Labrador Department of Transportation and Works
St. John's, NL

Nova Scotia Transportation and Infrastructure Renewal
Halifax, NS

Government of Northwest Territories, Department of Transportation, Highways Division
Yellowknife, NT

Ministry of Transportation of Ontario
Toronto, ON

Prince Edward Island Department of Transportation and Public Works
Charlottetown, PE

PRIVATE SECTOR FIRMS

Central Seal Company
Danville, KY

Lafrentz Road Marking
Edmonton, AB

Mainroad Pavement Marking
Langley, BC

PK Contracting
Troy, MI

Poly-Carb, Inc.
Cleveland, OH

Safety Striping Service, Inc.
Goshen, CA 93227

Sightline, LC, Airport Marking Consultants
Culpeper, VA 22701

Yellowhead Pavement Marking, Inc.
Terrace, BC V8G 4M2

3M Corporation
St. Paul, MN 55144-1000

APPENDIX D

Example Warranty Specifications

APPENDIX D1

Agency: Alaska Department of Transportation & Public Facilities

Attached Example(s) of Warranty Specifications:

Pavement Marking	Period	Remarks
Methyl Methacrylate Pavement Markings (MMA)	2 years after initial acceptance	Attached specs are proposed updates (as of 12-10-2008) to existing special provisions. *Warranty provisions are in Section 670-3.07. Specifications are for MMA pavement markings, which represent a combination of methyl methacrylate, glass beads, and anti-skid aggregate. The contractor is responsible for fulfilling the warranty. Application must be by manufacturer-certified installers, with manufacturer's representative observing application. Specifications address longitudinal markings, transverse markings, symbols, and markings in roundabouts and gores. See Section 670-3.07. Quality: Contractor must furnish a manufacturer's certification for materials components (Sect. 712-2.17).

*NOTE: Attached specifications are identified as AK DOT&PF HWY CR updates, 670.712.CR246 as of 12.10.2008, 7 pages.

SECTION 670

TRAFFIC MARKINGS

Special Provisions

670-1.01 DESCRIPTION. Add the following:

Furnish, locate, and install Pavement Markings as shown on the Plans and as directed.

Pavement Marking Type: Methyl Methacrylate (MMA)

670-2.01 MATERIALS. Replace the material reference,

"Methyl Methacrylate Markings	Subsection 712-2.17," with,
Methyl Methacrylate Pavement Markings	Subsection 712-2.17

Methyl Methacrylate Pavement Markings are a combination of methyl methacrylate, glass beads, and anti-skid aggregate.

Replace the last sentence with the following:

Submit a single certification from the manufacturer of the marking material, for each material combination, certifying the combination of marking material, glass beads and anti-skid aggregate, as furnished, provides the durability, retroreflectivity, and skid resistance specified.

670-3.01 CONSTRUCTION REQUIREMENTS. Delete No. 4 and substitute the following:

4. Methyl Methacrylate Pavement Markings (MMA).

a. General. 15 days before starting work meet with the Engineer for a prestriping meeting. At this meeting, do the following:
(1) Furnish a striping schedule showing areas and timing of work, placing materials and the Traffic Control Plans to be used.
(2) Discuss placement of materials, potential problems.
(3) Discuss work plan at off ramps, on ramps and intersections.
(4) Discuss material handling procedures.
(5) Provide copies of the manufacturer's installation instructions and copies of the Material Safety Data Sheets.

b. Manufacturer's Representative. Provide the services of a manufacturer's representative (the "Manufacturer's Representative"). Ensure the Manufacturer's Representative observes the application of the pavement marking materials. Cooperate with the Manufacturer's Representative and the Engineer to ensure that the materials are placed according to these Specifications and the manufacturer's recommended procedures.

c. Manufacturer Certified Installers. Install pavement markings using only striping installers certified by the marking materials manufacturer for the specific striping material and method. Submit these certifications to the Engineer at the Preconstruction Conference.

d. Preparation. Prepare the roadway surface to receive pavement markings according to these Specifications and the manufacturer's recommendations. Clean and dry the roadway surface. Completely remove contaminants such as dirt, loose asphalt, curing agents, surface oils, or existing road marking materials before applying pavement marking material.

e. Equipment.

(1) Grooving Equipment.
Use grooving equipment that produces a dry cut. Use vacuum shrouded equipment or other equally effective containment procedures.
(2) Marking Equipment.
(a) Longitudinal Marking: Use truck mounted application equipment capable of installing a double centerline and a single shoulder line in a single pass. Use automatic bead applicators that place a uniform layer of beads on the lines. Hand units are not permitted.
(b) Other Markings: Use manual or automatic application equipment. Use stencils or extruders to form sharply defined markings.

f. Application. Apply marking material according to these Specifications and the manufacturer's recommendations. Use equipment designed and capable of properly mixing at the place and time of application and approved by the manufacturer for the type of product being installed.

Anti-skid Aggregate. During marking material application, anti-skid aggregate will be evenly distributed and visible throughout the top 20 mils of the marking material mixture, and after the application, in the surface of the cured material.

SURFACE APPLIED **[*Surface markings, 60 mils unless T & S Eng specifically directs otherwise. Delete note.*]**

Marking thickness will be measured from the pavement surface.

(1) Longitudinal Markings. Apply markings for lane lines, edge lines, and centerlines to yield a thickness of 60 mils.

(2) Other Markings.
   (a) Transverse and Symbol Markings:
   Apply marking for symbols, arrows, stop bars, railroad symbols, and cross walks to yield a thickness of 60 mils.
   (b) Gore Markings:
   Apply diagonal gore markings to yield a thickness of 60 mils.

INLAID **[*Consult the T & S Eng for inlay depth, 60-500 mils. Insert 4 places. Delete note.*]**

Groove the area(s) designated in the Plans. Install markings in the same work shift as the grooving operation. Markings will be measured flush with the pavement surface.

(1) Longitudinal Markings. Groove the pavement to a depth of ___ mils. Apply markings for lane lines, edge lines, and centerlines to yield a thickness of __ mils.
(2) Other Markings.
   (a) Transverse and Symbol Markings:
   Groove the area for inlaid markings to a depth of __ mils. Apply marking for symbols, arrows, stop bars, railroad symbols, and cross walks to yield a thickness of __ mils.
   (b) Roundabouts:
   As designated on the plans, groove the area for inlaid markings in roundabouts to a depth of 500 mils. Apply markings to yield a thickness of 500 mils.
   (c) Gore Markings:
   Diagonal gore markings will not be inlaid unless shown in the Plans.

g. Disposal of Waste. Waste material(s) are the Contractor's property. This includes grindings and removed marking material. Do not dispose of or store waste material(s) on State property. Dispose of waste material(s) according to applicable Federal, State, and local regulations.

h. Sampling. On the form provided by the Engineer, record the following readings and locations where they were taken using project stationing, and submit them to the Engineer with 24 hours for evaluation. Thickness of material and depth of slot are measured from the surface of the pavement.

SURFACE APPLIED

(1) For surface applied longitudinal applications, measure the thickness of the lines (above the pavement surface) at the time of application, every 500 feet.
(2) For surface applied other markings measure the thickness in three locations for each marking.

INLAID

(1) For inlay longitudinal applications, record the depth of the slot every 500 feet during the grinding operation.
(2) For inlay other markings measure the thickness in three locations for each marking.

Inspect the markings initially, and again two weeks after placement, to ensure the material has cured properly. Remove soft spots or abnormally darkened areas and replace with material meeting specifications.

The Engineer may elect to use the Contractor's readings or perform additional sampling.

Add the following:

Refer to the Survey Field Books identifying the no passing zones (see Subsection 642-3.01)

670-3.04 PAVEMENT MARKING REMOVAL. Add the following:

Coordinate removal work with construction activity. Remove pavement markings the same day permanent markings are applied, unless otherwise directed. Use vacuum shrouded equipment or other equally effective containment procedures.

Add the following Subsection:

670-3.06 TOLERANCE FOR LANE STRIPING.

1. Length of Stripe. ±2 inches.
2. Width of Stripe. ±1/8 inch.
3. Lane Width. ±4 inches from the width shown on the Plans.
4. Stripes on Tangent. Do not vary more than 1 inch laterally within a distance of 100 feet when using the edge of the stripe as a reference.
5. Stripes on Curves. Uniform in alignment with no apparent deviations from the true curvature.
6. All Stripes. Keep the center of the stripe within planned alignment.
7. Double Stripes. ±1/4 inch.
8. Thickness of Surface Applied. Minimum specified to a maximum of + 30 mils.
9. Depth of Inlay Slot. Minimum specified to a maximum of + 40 mils.
10. Thickness of Inlaid Marking Material. Fill inlay area completely from the bottom of the inlay to the surface of the pavement.

If it is determined that the material is being placed too thin, the beads are not properly placed, the anti-skid aggregate is not visible, or otherwise not to specification, make immediate adjustments to correct the problem.

Pavement markings applied by any method will be unacceptable if:

1. Marking is not straight or wide enough.
2. Thickness of line is not uniform.
3. Thickness of line is less than specified.
4. Material is uncured.
5. Material blackens or is inconsistent in color.
6. Inlay slot is not the specified depth.
7. Inlay slot is not filled to the specified depth.
8. Edge of the markings is not clear cut and free of overspray.
9. Reflective elements are not properly embedded.
10. Retroreflectivity of the markings is less than specified.
11. Anti-skid aggregate is not visible in the marking material during application and the dried surface.
12. Markings exhibit poor adhesion.
13. Color is not as specified.

Perform repairs using equipment similar to the equipment initially used to place the materials. Do not perform repairs in a “patch work” manner. If more than one repair is required in a single 500 foot section, grind and repair the entire section.

Add the following Subsection:

670-3.07 CONTRACTOR'S WARRANTY. Provide a warranty, for the Methyl Methacrylate Pavement Markings, as specified herein.

The period of warranty is 2 years. The warranty period will start on the date the Engineer accepts the work and authorizes payment.

Pavement markings that do not satisfy the specified performance requirements will be repaired and or replaced by the Contractor. The Department will determine if the failed markings will be repaired or replaced. The Contractor will be notified, in writing, of the marking failure(s) and the corrective measures required including repairs and or replacement.

The Contractor will have 6 months to complete repairs. The Contractor will coordinate the repair start and end dates with the Department.

The warranty period, for all project MMA pavement markings, will stop until corrective work is approved complete by the Department.

Performance Requirements.

1. Retroreflectivity. If retroreflectivity becomes a concern during the warranty period, the Engineer will measure the retroreflectivity of the area in question. The roadway surface will not be cleaned in preparation for taking readings, but areas of obvious contamination or debris will be avoided.

   a. Longitudinal sample areas will be a minimum length of 500 feet and have at least three samples taken.
   b. Transverse, symbols and gore samples will be three per transverse line or symbol.

Table 670-1
PAVEMENT MARKING MINIMUM RETROREFLECTIVITY REQUIREMENTS

Marking Color	Retroreflectivity, Minimum Levels		
	Initial Retroreflectivity[a]	6 Months[b]	2 Years[b]
Yellow, White	200 mcd/m^2-lux	150 mcd/m^2-lux	40 mcd/m^2-lux

Footnotes:
a. The initial retroreflectivity readings will be completed after the MMA has cured and no more than 7 days prior to the Engineer accepting the work.
b. The 6 month and 2 year readings will be measured from the date of the initial retroreflectivity readings.

2. Color Stability. The pavement markings shall retain color throughout the warranty period. Yellow striping will be compared to the PR-1 chart, and shall meet 33538 Federal Yellow. White striping shall have a minimum daylight reflectance of 84 throughout the Warranty period.
3. Adhesion. For the purpose of the warranty a cumulative 5% or greater loss of longitudinal line of any 500 foot segment of marking and 5% or greater loss of each transverse line, gore stripe and symbol, due to nonadhesion, shall constitute failure of the material in that segment.

Repair. Repair pavement markings as specified by the Department.

Replacement. Replace pavement markings as specified in Section 670-3.01 Construction Requirements 4.f. Application and as specified by the Department.

670-4.01 METHOD OF MEASUREMENT. Add the following:

Thickness will be measure from the top of the marking to the top of the pavement surface. Marking material placed in a depression left by pavement line removal will not be included in measuring the thickness of the line.

Delete No. 2.

Delete No. 3 and replace with the following:

3. Each. Pavement markings using letters, numbers, and arrows will be measured on a unit basis with each separate word or symbol constituting a unit. Railroad Markings will be measured by the complete unit shown for each lane of travel.

Add the following No. 4:

4. Foot Basis. Longitudinal pavement markings, transverse, and gore markings, surface applied or inlaid will be measured by the linear foot of 4 inch wide line. Wider striping will be measured in multiples of 4 inches.

670-5.01 BASIS OF PAYMENT. Add the following:

Payment for Methyl Methacrylate (MMA) Pavement Markings includes furnishing the Warranty. Payment for the installation of the pavement markings will be limited to 80% of the amount due until the Department has received a signed Warranty.

For all phases of construction: There will be no separate payment for:

- Over-runs of material caused by the variation of the gradation of the asphalt
- Additional material required to achieve the thickness specified on open graded pavement

All work and materials associated with pavement markings are subsidiary to 670 items, including but not limited to:

- Milling for installation of the inlaid pavement markings including the removal of millings
- Temporary pavement markings and removal of conflicting markings, including repair of the roadway surface, milled surface or otherwise
- Traffic Control required for the installation of permanent and temporary pavement markings, removal of conflicting markings, and repairs

Replace Item 670(10) with the following:

Payment will be made under:

Pay Item No.	Pay Item	Pay Unit
670(10)	MMA Pavement Markings	Lump Sum
670(10A)	MMA Pavement Markings, Longitudinal Surface Applied	Linear Foot
670(10B)	MMA Pavement Markings, Symbols and Arrow(s) Surface Applied	Each
670(10C)	MMA Pavement Markings, Transverse and Gore Surface Applied	Linear Foot
670(10D)	MMA Pavement Markings, Longitudinal Inlaid	Linear Foot
670(10E)	MMA Pavement Markings, Symbols and Arrow(s) Inlaid	Each
670(10F)	MMA Pavement Markings, Transverse and Gore Inlaid	Linear Foot

Delete Items 670(11) and 670(12).

CR246.12.10.08

SECTION 712

MISCELLANEOUS

Special Provisions

712-2.17 METHYL METHACRYLATE PAVEMENT MARKINGS. Replace No. 1. Quality Requirements: with the following:

1. Quality Requirements: Use a marking material formulated for the application type specified. Use a marking material manufactured from new materials and free from dirt and other foreign material. Use a methyl methacrylate based resin system for part "A." Use benzoyl peroxide system for part "B."

   Extruded or stenciled application: Material formulated for extruded or direct stenciled application with factory intermix beads, and anti skid aggregate and the application of additional surface applied beads.

   Submit a manufacturer certification for the methyl methacrylate material, glass beads, and anti-skid aggregate to ensure that the materials furnished conform to these Specifications.

2. Performance Properties: Add the following:

   I. Color: Yellow, PR-1 Chart, 33538 Federal Yellow. White, minimum daylight reflectance of 84.

712-2.18 GLASS BEADS FOR METHYL METHACRYLATE PAVEMENT MARKINGS. Replace the bead table with the following:

Use the type and quantity of beads specified in writing by the marking material manufacturer required to satisfy the specified performance requirements. The written certification will note the bead coating is compatible with the marking material binder.

1. Bead Manufacturer and Type.

   a. Swarco, Megalux-Beads or
   b. Approved equal beads

   Approved Equal Beads. Equal beads will demonstrate:

   (1) Bead coatings compatible with marking materials. Marking Material Manufacturer will certify compatibility.
   (2) Lasting retroreflectivity. For the two year specified Warranty Period and retroreflectivity levels, Subsection 670-3.07. The Engineer will determine the test location.

CR246.12.10.08

APPENDIX D2

Agency: Arizona Department of Transportation

Attached Example(s) of Warranty Specifications:

Pavement Marking Specification	Period	Remarks
ADOT General Warranty Requirements for Pavement Markings	Periods below begin following installation	Document comprises excerpts from three contracts and provides general requirements across a range of marking materials. The term of the warranty for a particular material is assumed to be the expected pavement marking lifetime. The warranty period is measured from the date of installation. The contractor warrants that workmanship and materials will perform satisfactorily during the expected pavement marking lifetime. Pavement markings shall not deteriorate due to natural causes under normal road wear during this period. Anticipated lives and warranty periods are listed by material type and by type of marking; for example, all waterborne paint markings are specified as 6 months; thermoplastic and epoxy long-line markings are specified as 2 years, while thermoplastic and epoxy legend and symbol markings are specified as 1 year minimum or manufacturer's warranty period if longer. Ref: excerpt from Section 3.0, Special Terms and Conditions.

Pavement Marking Specification	Period	Remarks
3M 380 Tape	4 years	Original warranty period for longitudinal markings. Special extension to 6 years for longitudinal markings was later issued by 3M.
	2 years	Warranty period for symbols and legends. Warranty does not address transverse line markings.
		FHWA has approved a finding in the public interest that 3M 380 tape shall be used exclusively on urban freeway to freeway interchanges and for lane-line skip stripes on other urban mainline projects.
		A full replacement warranty is provided by the contractor and 3M. 3M's warranty covers only design and manufacturing defects in the tape. 3M's warranty does not cover material damaged by snow removal equipment. The warranty does not apply in "mountainous, heavy snowfall areas above 5,000 feet."
Retroreflective Raised Pavement Markers (RRPM)	1 year	Warranty period for RRPM.
		Contractor must replace all markers that are subject to defective materials or work deficiencies. For ADOT-supplied materials, the contractor's warranty extends only to the installation of the marker and the performance of the adhesive.

Note: "---" = not applicable.

ARIZONA DOT WARRANTY REQUIREMENTS FOR PAVEMENT MARKINGS

The following is an excerpt of the warranty requirements for pavement markings from the Arizona Department of Transportation maintenance contract which was bid in August of 2003 per Solicitation Number T04-11-00001.

Contracts were awarded in June 29, 2004. There are three contract holders: Road Markings Inc (RMI) T0411A0042, United Rentals Highway Technologies T0411B0042 (now just Highway Technologies) and Pavement Markings Inc. (PMI) T0411C0042. The contracts for these three vendors have been renewed through thru June 28, 2008. The term of the contract expires in June 28, 2009. The contract specifications address various types of pavement marking materials including paint, thermoplastic, epoxy, and preformed tape markings. It should be noted that these contracts apply only to maintenance and not to new construction or re-construction projects.

The contract specifications include a section on Warranty Requirements. The contract states that the warranty term is also assumed to be the expected pavement marking lifetime.

The contract specifications also include a section on Satisfactory Performance Life Requirements. This section states that satisfactory performance life is achieved if the markings do not deteriorate due to natural causes and normal road wear within the specified marking expected lifetime. The contract specification calls out minimum initial retroreflectivity performance criteria.

The requirements of this contract imply that materials that are found defective shall be replaced. The actual sentence in the warranty subsection of the Special Terms and Conditions states: "The Contractor agrees they will, at their own expense, provide all materials, equipment, labor and traffic control required to repair and/or replace any such defective workmanship and/or materials which become or are found to be defective during the terms of the warranty." This statement implies the warranty is a full replacement warranty.

From Section 1.0 Specification (page 20–21):

4.2.14 Retroreflectance

The white and yellow pavement markings shall have the following minimum retroreflectance values as measured by a 30 meter Mirolux 30 or equivalent portable retroreflectometer initially, and/or forty-five (45) days after application to the roadway surface:

Product	Retroreflectance (Millicandelas)
White	175
Yellow	125

The sample rate to determine if the applied markings meet this requirement will be based on a minimum of four randomly selected points taken approximately at quarter points throughout the entire length of the project. Readings taken at each point shall be for each type of marking that is represented at that location. Such as edge lines, lane lines, legends, symbols, stop bars and cross walks. Three readings will be taken and then averaged with the compliance determination based on the average of those three readings. Additional sample points may be taken by the Department.

The Department considers the LTL-2000 and MX-30 to be equivalent portable retroreflectometers for determining the requirements stated herein.

If approved by the Department, the Contractor may elect to increase bead application rates to ensure conformance within these requirements."

From Section 1.0 Specification (page 22–23):

4.3.3 Satisfactory Performance Life

All materials shall be applied per the manufacturer's recommendations and per the applicable requirements of the specifications. Satisfactory performance life shall be considered to be achieved if the actual life of the applied markings do not deteriorate due to natural causes and normal road wear within the specified expected pavement marking life times. The minimum expected pavement marking lifetimes are detailed in Special Terms and Conditions, paragraph 17, **WARRANTY**. The contractor shall correct any unsatisfactory performance conditions within that time frame without

cost to the Department. Consistent unsatisfactory performance may be grounds for parcel or total cancellation of a contract.

Unsatisfactory performance conditions include, but are not limited to, the display of the following:

Any shrinkage that is more than 1/4 inch.

Any delamination of any layer.

Significant discoloration to the point that the marking fails to conform to specified color.

Significant cracking, crazing, blistering, flaking, or chipping that causes the markings to look unsightly and worn out.

The markings were not placed properly per the requirements of the specifications.

Loss of adhesion due to underlying dirt that should have been cleaned off before the markings were placed.

Subjective and/or objective measures as based on this specification and other nationally accepted standards and practices will be used by the Department to judge unsatisfactory performance. The contractor shall warranty all applied materials specified expected pavement marking life times.

From Section 3.0 Special Terms and Conditions (pages 77–78):

17. WARRANTY FOR THE PAVEMENT MARKING PORTION OF THIS CONTRACT

The Contractor warrants:

That all services performed hereunder shall conform to the requirements of this contract and shall be performed by qualified personnel in accordance with the highest professional standards.

That all items furnished hereunder shall conform to the requirements of this contract and shall be free from defects in design materials and workmanship.

The warranty period on pavement marking materials and workmanship from the date that they were installed shall be as follows:

- All Waterborne Paint Markings—Six (6) Months
- Thermoplastic, Profile Thermoplastic, and Epoxy Long Line Markings—Two (2) Years
- Thermoplastic and Epoxy Legend and Symbol Markings—a minimum of one year or the manufacturers warranty period, whichever is longer.
- Profile Pavement Markings—Two (2) Years
- Preformed Short Line Tape—Two (2) Years
- Preformed Tape Long Line Markings—A minimum of four (4) years or the manufacturers warranty period, whichever is longer.

These time periods will be termed, for the purpose of this contract, as the **expected pavement marking life times**.

If there is any failure that can be attributable to failure of the materials and/or application as herein defined, the contractor, at no additional cost to the Department, shall correct the problems through the removal and/or replacement of the faulty pavement markings.

The warranty shall cover that the pavement marking materials as applied in the field by the contractor shall perform, as intended for this period of time, without degradation that is directly related to unsatisfactory performance of those materials and/or the installation of those materials. The specifications sections of this document contain additional definitions regarding unsatisfactory performance.

The Contractor agrees that they will, at their own expense, provide all materials, equipment, labor and traffic control required to repair and/or replace any such defective workmanship and/or materials which become or are found to be defective during the terms of their warranty. The contractor shall guarantee the services to be supplied, comply with the requirements of the specifications.

ARIZONA WARRANTY REQUIREMENTS FOR 3M 380 TAPE FOR LANE LINES AND FREEWAY TO FREEWAY RAMP EDGE LINES

The Department (or ADOT) submitted a request for finding in the public interest to Federal Highway Administration (FHWA) Arizona Office regarding 3M 380 tape. The letter, dated March 25, 2003, was addressed to Robert Hollis at FHWA's Arizona office and signed by ADOT Director Victor Mendez. Specifically, the Department requested to use 3M 380 tape exclusively on urban freeway to freeway interchanges and for lane line skip stripes on other urban main line projects.

The Department justified its request based on the following:

- an installation of 380 tape in "the tunnel and on the I-10 Westbound to I-17 Southbound Ramp" that "lasted for over nine years"
- a two-year old installation of tape that "continues to be brighter at night than brand new thermoplastic"
- 380 tape is "much more retroreflective than any other tape product on the market"
- despite its high cost, "10% more than conventional preformed tape… and about four times more than 90 mil thermoplastic," 380 tape has "unique features and performance characteristics that should help mitigate the frequent maintenance of existing striping in areas with high traffic volumes"
- quantitative analysis that demonstrates 380 tape has "special visibility enhancing features that should enable drivers to see better at night"
- high durability with a 4-year warranty
- high retroreflectivity levels initially and throughout the life of the product

FHWA responded to the Department's request by approving the finding in the public interest. An approval letter, dated May 27, 2003, was sent to ADOT Director Victor Mendez and signed by FHWA Division Administrator Robert Hollis. The approval letter states that ADOT can use 3M 380 tape on "Federal-aid projects for a five-year period" effective from the date of the letter. The approval is for use on "freeway to freeway interchanges and freeway skip lines in the five urbanized areas of Phoenix, Tucson, Yuma, Flagstaff, and Prescott."

The reasons for the finding are:

- 380 tape offers visibility and maintainability unequaled by any other similar product
- less frequent traffic exposure due to less frequent maintenance increases worker safety
- less frequent maintenance requires fewer lane and ramp closures and minimizes inconvenience to the motoring public

The five-year approval period for this finding in the public interest will expire on May 27, 2008. A new finding in the public interest has been recently submitted by the Department to FHWA. As of May 12, 2008 the status of this new finding is still pending.

From ADOT Specifications:

The following is a summary of the typical special provision requirements that typically have been used for the 3M 380 tape that has been installed as a part of freeway construction projects. It should be noted that since ADOT is using 3M 380 exclusively for this particular use, then 3M's own 380 warranty becomes:

AzDOT Warranty Provisions:

"A full replacement warranty (removal, materials and installation) for this tape installation shall be provided by the contractor and 3M. The terms of the warranty shall be that the tape shall remain effective, show no appreciable presences loss, discoloration, fading, lifting, shrinkage, chipping, cracking or tearing, as a ten foot lane line for this application under normal traffic conditions for a period of four years. The contractor and 3M shall assist the Department in period inspections of the tape throughout its warranty period. The contractor and 3M upon completion of this project shall provide a certification of this warranty to the Engineer. This notarized certification shall identify the responsible parties (name, addresses, and phone numbers) verify that the tape was properly installed and the dates on which it was installed."

Related 3M 380 Warranty Provisions:

3M states that its 380 permanent marking tape will "remain effective for its intended use under normal traffic conditions and meet the minimum retroreflection value of 100 mc/fc/ft^2" (or mcd) subject to the following provisions.

Warranty Period The warranty period is 4 years for longitudinal markings and 2 years for symbols and legends. The warranty does not address transverse line markings. **ADOT received a special extension of the warranty period for 380 tape to 6 years when used as longitudinal markings in a letter from 3M dated August 8, 2005.**

Exclusions The warranty does not apply to use in "mountainous, heavy snowfall areas above 5,000 feet."
Covered Failures
The warranty covers tape that is applied in accordance with all 3M's application procedures as documented in:

- product bulletins
- information folders
- technical memos

3M does not specifically list the documents that must be complied with. The warranty document describes the relevant documents in general terms, exactly as listed above.

3M will cover product that fails to maintain minimum retroreflectivity values, fails to adhere to the pavement, or fails due to complete wear through.

In the case of an eligible failure, 3M will provide replacement pavement marking materials. 3M will determine the type of replacement markings and the method of installation. The warranty on replacement markings is the balance of the warranty for the material that it replaces.

Excluded Failures 3M will only cover material that fails as a result of design or manufacturing defects. 3M will not cover material that fails due to any other reason including failure of the pavement surface and improper installation.

3M will not cover any material that is damaged due to snow removal equipment.

Reporting Protocol 3M will only warranty material if the customer "has maintained accurate record of the dates of material installation." Further, 3M must be notified of a failure with "a reasonable time."

Identifying a Failure If a failure is suspected, a 3M representative and a customer representative must make a visual night inspection of the areas where it is suspected that the retroreflectivity performance fall below warranty levels. Each area that is suspected to be below warranty levels is identified as a "zone of measurement." Only zones that are at least 360 feet in length are eligible for material replacement. The 360 feet total length must include *either* edge lines, center lines, or lanes lines but not a combination of different line types. A single word or symbol marking also qualifies as a zone of measurement.

Retroreflectivity Measurement Protocol For each zone of measurement, retroreflectivity measurements must be taken at specific "checkpoint areas." There are three different measurement protocols depending on the length of the zone of measurement.

When the zone of measurement measures between 360 feet and 1,080 feet, measurements must be made at 20-foot intervals throughout the zone for continuous lines. For skip lines, two measurements must be taken at random locations on each skip line. This protocol requires from 18 (9 lines @ two measurements per line or one measurement every 20 feet on an edge line) to 54 (27 lines @ two measurements or one measurement every 20 feet on the edge line) measurements per suspect line, depending on the zone length.

When the zone of measurement measures between 1080 feet and 6 miles in length, then three "checkpoints" are identified within the zone. The first checkpoint includes the first 360 feet of the zone, the second checkpoint includes the middle 360 feet of the zone, and the third checkpoint includes the end 360 feet of the zone. For continuous lines, measurements must be made every 20 feet within the zone. For skip lines, two measurements must be taken at random locations on each skip line. This protocol requires 18 measurements per checkpoint per suspect line.
When the zone of measurement measures greater than 6 miles in length, then checkpoints must be established at the start and end of the zone and every 3 miles within the zone. Each checkpoint must be 360 feet in length. For continuous lines, measurements must be made every 20 feet within the zone. For skip lines, two measurements must be taken at random locations on each skip line. This protocol requires 18 measurements per checkpoint per suspect line.

For each zone, the *average* of all of the measurements within the zone is compared to the warranty retroreflectivity levels to determine if failure has occurred.

All measurements for warranty consideration must be made on a clean, dry surface with a temperature of at least 40°F. The measurement device must use an Entrance Angle of 88.76° and an Observation Angle of 1.05°. This is the measurement geometry of LTL-X and other commonly available hand held pavement marking retroreflectometers.

ARIZONA WARRANTY REQUIREMENTS FOR RETROREFLECTIVE RAISED PAVEMENT MARKERS (RRPM)

The following is an excerpt of the warranty requirements for retroreflective raised pavement markers (RRPM) from the Arizona Department of Transportation maintenance contract which was bid in January of 2006 per Solicitation Number T06-11-00035.

From Section 1.0 Specification (page 20):

Satisfactory Performance Life

All materials shall be applied per the manufacturer's recommendations and per the applicable requirements of the specifications. Satisfactory performance life shall be considered to be achieved if the actual life of the applied markers does not deteriorate due to natural causes and normal road wear within the specified expected pavement marker life times. **The minimum expected pavement marker lifetimes are detailed in the Special Terms and Conditions, "Warranty."** The contractor shall correct any unsatisfactory performance conditions within that time frame without cost to the Department. Consistent unsatisfactory performance may be grounds for partial or total cancellation of a contract.

Unsatisfactory Performance Conditions: include, but are not limited to, the display of the following:

1. Any cracks and/or breaks in any portion of the applied markers that may cause a loss of adhesion or unsightliness that is clearly visible to passing motorists.
2. Any loss of position or alignment which causes the marker to be ineffective as a pavement marker.
3. Any delamination of any layer (marker to marker, adhesive to marker, and adhesive to pavement).
4. Product discoloration to the point that the marker fails to meet the color specification.
5. Significant cracking, crazing, blistering, flaking or chipping that causes the marker to look unsightly and worn out.
6. Loss of nighttime reflectivity.
7. Initial retroreflectance that is below the required minimums.
8. The markings were not placed properly and per the requirements of the specifications.

Subjective and/or objective measures as based on this specification and other nationally accepted standards and practices will be used by the Department to judge unsatisfactory performance. The contractor shall warranty all applied materials specified expected marker life times.

From Section 3.0 Special Terms and Conditions (pages 64–65):

17. WARRANTY

The bidder warrants:

1. That all services performed hereunder shall conform to the requirements of this contract and shall be performed by qualified personnel in accordance with the highest professional standards.
2. That all items furnished hereunder shall conform to the requirements of this contract and shall be free from defects in design materials and workmanship.
3. The warranty period on pavement markers and workmanship shall be one year and will commence from the date of installation.

The warranty length for the purpose of this contract is defined as the **pavement marker life expectancy**.

During the warranty period, the contractor shall correct all defective materials and/or workmanship deficiencies, including but not limited to: Reflector delamination, breakage, or loss of reflectivity. Unsatisfactory performance is further defined in the Specifications section of this contract.

The contractor shall not be responsible for events that cause marker failure that is beyond their control. Such events include, but may not be limited to: Pavement failure, unusual physical damage caused by passing vehicles (e.g., vehicles driving on tire rims) and Force Majeure.

All warranty work shall be performed at no cost to the Department. The cost of all warranty work shall be borne by the contractor. These costs may include, but are not limited to: Materials, equipment, labor, and traffic control.

For Department-supplied materials, the contractor shall only be responsible for a warranty for the installation of the marker and the performance of the adhesive. The warranty for the actual performance of the marker shall be the responsibility of the manufacturer.

All bidders shall indicate on a separate written sheet that is submitted with their bid the exact conditions, limitations and duration of their warranty. As a minimum the warranty provided shall conform to the requirements stated herein.

APPENDIX D3

Agency: Arkansas State Highway and Transportation Department

Attached Example(s) of Warranty Specifications:

Pavement Marking Specification	Period	Remarks
HIGH-PERFORMANCE PAVEMENT MARKING—two options:		
Option 1: Inverted profile thermoplastic	4 years from installation	Specified for center lines, edge lines, and skip lines. Specifications include required physical and materials characteristics of pavement markings, application methods, and weather conditions during placement. Manufacturer provides written warranty for retaining required minimum retroreflectivity. See para. (b), (g)(3), and (j) for warranty provisions. Warranty covers "normal roadway conditions… regardless of average daily traffic." The 48-month warranty performance requirement is evaluated against both dry and wet criteria.
Option 2: High-performance marking tape (or, for center and skip lines on portland cement concrete pavements, high-performance contrast marking tape)	4 years from installation	Specified for center lines, edge lines, and skip lines. Specifications include required physical and materials characteristics of pavement markings, application methods, and weather conditions during placement. Manufacturer provides written warranty for retaining required minimum retroreflectivity. See para. (b) and (d) for warranty provisions. Warranty covers "normal roadway conditions… regardless of average daily traffic." The 48-month warranty performance requirements are evaluated against both dry and wet criteria.

ARKANSAS STATE HIGHWAY AND TRANSPORTATION DEPARTMENT
SPECIAL PROVISION
JOB _____
HIGH PERFORMANCE PAVEMENT MARKING

This special provision shall cover the work of furnishing all materials and placing High Performance Pavement Markings in accordance with this special provision and the Standard Specifications for Highway Construction, Arkansas State Highway and Transportation Department, Edition of 2003, Section 719. High Performance Pavement Markings shall be either Inverted Profile Thermoplastic Pavement Markings (Option 1) or High Performance Marking Tape (Option 2) as specified herewith. These markings shall be placed in conformity with the types, dimensions, and lines shown on the plans or as directed by the Engineer. This special provision supersedes items in the Standard Specifications for Highway Construction.

The Contractor shall assume all costs and other responsibilities resulting from the use of patented materials, equipment, devices or processes used on, or incorporated in the work. Unsatisfactory pavement marking performed by the contractor must be removed and replaced in compliance with these specifications. No payment will be made for removal or replacement of the Contractor's unsatisfactory marking.

All High Performance Permanent Pavement Markings as shown on the plans must consist of one of the options below.

OPTION 1, INVERTED PROFILE THERMOPLASTIC PAVEMENT MARKINGS:

(a) Description. This option consists of the material requirements and application of inverted profile thermoplastic striping material for 1) Center lines, 2) Edge lines, and 3) Skip lines.

The inverted profile thermoplastic is hot applied to the pavement surface and shall be formed during application with an inverted profile that will rapidly drain water from the highway surface. This rapid draining shall allow the traffic stripe to be highly reflective in heavy rain. This Inverted Profile Thermoplastic Pavement Marking for edge lines shall be composed of three (3) items: a thermoplastic marking compound, a double drop glass bead system, and special equipment capable of producing the inverted profile pavement marking. For use on center and skip lines on portland cement concrete pavements, the Inverted Profile Thermoplastic Pavement Marking will also require a black contrasting edge surrounding the stripe. This type of pavement marking shall be designated as Inverted Profile Thermoplastic Contrast Pavement Marking.

(b) Warranty. The manufacturer shall supply a written warranty for retaining minimum retroreflectivity values as specified herein. This written warranty will indicate the terms of the requirements in accordance with these specifications.

(c) Sampling and Testing. Sampling and testing shall be in accordance with the Arkansas State Highway and Transportation Department's sampling and testing procedures.

(d) Materials.

(1) Description. This section covers machine applied alkyd/maleic or hydrocarbon thermoplastic pavement marking material with both intermixed and drop-on glass beads for use in the inverted profile pavement marking.

(2) Thermoplastic Material. The thermoplastic material used for hot alkyd/maleic or hydrocarbon applications shall consist of homogeneously mixed pigments, fillers, resins and glass beads and shall be available in both white and yellow.

The thermoplastic material shall be free of contaminates and shall be dry blended from 100% virgin stock, using no reprocessed materials. The thermoplastic material, while on the roadway surface, and at any natural ambient temperature, shall exist in a hard solid state with cold ductility that permits normal movement with the road surface without chipping and/or cracking.

The material shall meet the minimum requirements specified herein including, but not limited to, composition, physical characteristics, etc. The physical and chemical properties contained in this specification shall apply regardless of the type of formulation used. The pigment, beads and fillers shall be free from all skins, dirt and foreign objects.

The thermoplastic material upon heating shall not exude fumes which are toxic, or injurious to persons or property.

The thermoplastic material shall not deteriorate or discolor when held at the application temperature for periods of time up to four (4) hours, or upon reheating to the application temperature for a period of time not to exceed four (4) hours.

The thermoplastic material shall be readily applicable at temperatures between 400 and 430°F (200 and 225°C) from the approved equipment, to produce pavement markings of the required type and thickness above the pavement surface as described elsewhere in this specification.

(e) Composition. The pigment, beads, resin and fillers shall be a uniform blend. The material shall be free from all skins, dirt, and foreign objects and shall comply with requirements according to Table 1.

Table 1: Composition

Component	Composition by Weight	
	White	Yellow
Binder	19% Min.	19% Min.
Glass Beads (Intermixed)	40% Min.	40% Min.
Titanium Dioxide (For White Material Only)	10% Min.	N/A
Yellow Pigment (For Yellow Material Only)	N/A	5% Min.
Calcium Carbonate & Inert Filler	31% Max	41% Max

NOTE "A": The amount of calcium carbonate and inert fillers shall be at the option of the manufacturer, providing all other requirements of the specifications are met.

Other Ingredients. Titanium Dioxide shall meet ASTM D 476–Type II, (Rutile grade—92% Min. Titanium content).

(f) Glass Beads. The glass beads used in formulating the thermoplastic compound or dropped on the thermoplastic shall be smooth, clear and free from any air inclusions and scratches that might affect their function as retro-reflective media, and shall have the characteristics listed as follows.

When an adhesion promoting coating is required, it shall conform to the specific test requirements contained in Subsection 718.02 (g) (2) of the Standard Specifications for Highway Construction, Arkansas State Highway and Transportation Department, Edition of 2003.

(1) Intermix Glass Beads. The intermix glass beads shall make up a minimum of 40% of the thermoplastic compound, by weight. These beads shall meet all requirements of ASTM D 1155 with 70% true spheres; the +20 sieve shall be tested visually. These beads shall also be coated with an adhesion promoting coating.

Size Distribution. The gradation of Class B glass beads shall have the size distribution shown in Table 2.

Table 2: Bead Size Distribution

US Standard Sieve Size (mm)	% Passing
16 (1.18)	99–100
20 (0.850)	75–100
30 (0.600)	55–95
50 (0.300)	10–35
100 (0.150)	0–5

(2) Drop-On Glass Beads. Drop-on glass beads shall be separated into the two following classes:

Class A drop-on glass beads shall be used in the first bead coat and shall be coated with a silane adhesion coating. Class A drop-on beads shall exhibit the following characteristics:

- Color and Clarity. The glass beads shall be colorless and clear and shall be free of carbon residues.
- Index of Refraction. The index of refraction shall be 1.50 or higher.
- Roundness. The glass beads shall have a minimum of eighty (80)% rounds per screen for the two highest sieve quantities (determined visually) and no more than three (3)% angular particles per screen (visual). The remaining sieve fractions shall be no less than 75% rounds (determined visually, per aspect ratio using microfiche reader). (Angulars are defined as particles with sharp edges.)
- Air Inclusions. The glass beads may contain a maximum of ten (10)% air inclusions.
- Specific Gravity. The specific gravity of the glass beads shall be a minimum of 2.50.
- Gradation. The gradation of Class A glass beads shall be as shown in Table 3.

Table 3: Class A Bead Gradation

US Standard Sieve Size (mm)	% Passing
12 (1.70)	100
14 (1.40)	95–100
16 (1.18)	80–95
18 (1.00)	10–40
20 (0.850)	0–5
25 (0.710)	0–2

Class B drop-on glass beads shall be used in the second bead coat and shall comply with ASTM D 1155; the +20 portion shall be tested visually and shall have an adhesion promoting coating which shall also provide moisture resistance as tested by AASHTO M 247. Not more than thirty (30)% of the glass spheres shall be irregular or fused spheroids. At least seventy (70)% of the beads shall be true spheres. (ASTM D 1155, Procedure B).

- Gradation. The gradation of Class B glass beads shall be as shown in Table 4.

Table 4: Class B Bead Gradation

US Standard Sieve Size (mm)	% Passing
16 (1.18)	99–100
20 (0.850)	75–100
30 (0.600)	55–95
50 (0.300)	10–35
100 (0.150)	0–5

(g) Physical Characteristics.

(1) Color. The thermoplastic pavement marking material shall meet the following requirements for daylight reflectance and color when tested using a standard color difference meter (0°–45°) ICE, Illuminate C and a magnesium oxide standard or an approved secondary standard. (ASTM E 1347 and I.T.E. spec. section 4.3.1)

White—Daylight reflectance at 45°–0° of 75% minimum and match federal test standard number 595b, (Color 17886).

Yellow—Daylight reflectance at 45°–0° of 45% minimum and match federal test standard number 595b, (Color 13538), which shall fall within the limits of FHWA highway color tolerance chart, PR color #1.

Chromaticity. Coordinates *x* and *y* shall fall in an area bordered by these coordinates:

x	0.470	0.510	0.490	0.537
y	0.455	0.489	0.432	0.462

(2) Initial Retroreflectivity. The initial retroreflectivity for the in-place marking shall have the minimum retroreflectivity readings shown here, as obtained with a retroreflectometer using 30-meter geometry, as per ASTM E 1710:

Dry:	White—450 mcd/m²/lux	Yellow—300 mcd/m²/lux
Wet:	White—150 mcd/m²/lux	Yellow—100 mcd/m²/lux

Wet Test Procedure: Mark or delineate a 3 foot (1 m) long section of pavement marking to be tested. Follow the procedure in ASTM E 2177 to determine retroreflectivity.

(3) Retained Retroreflectivity. The thermoplastic pavement marking material shall retain the minimum retroreflectivity value of 150 mcd/m² /lux under dry night conditions and 75 mcd/m² /lux under wet conditions for at least 48 months after placement. This value will be required for both white and yellow markings. Failure to meet this requirement shall require the manufacturer to replace the portion of the material shown to be below these minimums. The manufacturer shall supply a written warranty indicating the terms of this requirement.

(4) Yellowness Index. The white thermoplastic material shall not exceed a yellowness index of 0.15. (AASHTO T-250)

(5) Cracking Resistance at Low Temperature. The thermoplastic pavement marking material shall be 100% passing. (AASHTO T-250)

(6) Impact Resistance. The impact resistance of the thermoplastic pavement marking material shall be a minimum of 10-inch pounds [1.13 joule (j)]. (AASHTO T-250)

(7) Softening Point. The thermoplastic material shall have a softening point of 215° ± 15° F (102.5° ± 9.5° C). (ASTM D 36)

(8) Drying Time. When applied at a temperature of 412° ± 12.5° F (211° ± 7° C) and at a thickness of 0.140 in. (4 mm), the thermoplastic material shall set to bear traffic in not more than 2 minutes when the air temperature is 50° F (11° C) and not more than 10 minutes when the air temperature is 90° F (32° C).

(9) Profilability. The thermoplastic pavement marking material shall be formulated so that when applied at a temperature of between 400° F and 430° F (200° C and 225° C), the individual profiles shall be a minimum of 0.140 in. (4 mm) when measured at the highest point of the profile and shall not excessively run back together.

(10) Flashpoint. The thermoplastic material shall have a flashpoint not less than 475° F (246° C). (AASHTO T-250)

(11) Indention Resistance. After 15 seconds with the sample panels and Shore Durometer (Ty-A2) reading 90° F (32° C), and applying a 5 lb (2 kg) load, the reading shall not be less than 45. (ASTM D 2240)

(12) Flowability. After heating the thermoplastic material for 4 hours ± 5 minutes at 425° ± 3° F (218° ± 2° C) and testing for flowability, the white thermoplastic shall have a maximum percent residue of 22 and the yellow thermoplastic shall have a maximum residue of 24%. (AASHTO T-250)

(13) Extended Heating. The thermoplastic shall have a maximum residue of 28%. (AASHTO T-250)

(14) Storage Life. The thermoplastic material shall meet the requirements of this specification for a period of 1 year. The thermoplastic must also melt uniformly with no evidence of skins or unmelted particles for the 1 year period. Any material not meeting the above requirements shall be replaced by the manufacturer.

(15) Packaging and Marking. The thermoplastic material shall be packaged in suitable containers to which it will not adhere during shipment and storage. The bags of thermoplastic material shall be approximately 22 in. x 14 in. x 4 in (560 mm x 350 mm x 100 mm) and shall weigh approximately 50 pounds (23 kg). Each container label shall designate the color, manufacturer's name, batch number, and date of manufacture. Each batch manufactured shall have its own separate number. The label shall warn the user that the material shall be heated to 400° F to 430° F (200° C to 225° C) during application.

(h) Construction Methods.

(1) Equipment. The application equipment shall be specially designed for placing hot thermoplastic material in a hot molten state on the pavement surface utilizing a pressure type application method. The hot thermoplastic inverted profile pavement marking shall be formed by a thermoplastic die that is allowed to travel along in proximity with the road surface. The die is pulled forward by a special linkage that will allow it to automatically level itself as to float and remain parallel with the road surface. The top of the die shall be enclosed and provide entry means for the hot molten thermoplastic to enter the die cavity. The bottom of the die shall contain a moveable door that is remote controlled so as to start or stop the flow of thermoplastic on to the pavement surface. When the moveable door is open, thermoplastic can flow through the die and will apply a thermoplastic line that will be formed rearward of the advancing die. The road surface shall be at the bottom of the die enclosure. Thermoplastic shall be fed to the die under pressure through flexible oil-jacketed stainless steel hoses. The thermoplastic die shall be formed from a single solid block of steel that is oil-jacketed on four (4) sides in order to keep the die hot at all times.

The thermoplastic die shall incorporate within the same housing a special curtain coater, low pressure drop-on type glass bead gun, (Bead Coat #1). The pressure die and curtain coat bead gun shall be a single unit that is oil-jacketed on 4 sides and is formed from a single solid block of steel. This glass bead gun shall dispense glass beads onto the hot thermoplastic line from a height of approximately 1 inch (25 mm) above the road surface. The point at which the glass beads strike the surface of the pavement marking shall be approximately 3 inches (75 mm) behind the strike point of the thermoplastic itself. This reflective bead coat #1 shall utilize Class A glass beads as specified in the Subsection (f)(2) above and shall provide a surface coating of 50% of the thermoplastic pavement marking surface. Of this 50% surface coverage, at least 50% of the beads will be embedded to a depth of 60% of their diameter.

A second curtain coater, low pressure drop-on type glass bead gun capable of applying a continuous sheet or ribbon of glass beads shall follow at an interval of approximately 10 inches (250 mm) behind the first bead gun. This second glass bead gun shall apply bead coat #2 which will form a continuous drop-on coat of Class B glass beads, meeting the requirements of Subsection (f)(2) above, immediately in front of the pavement marking profiling device. This second curtain coat of glass beads shall have a low impact speed so that they are not forced into the pavement marking under pressure.

A special rotatable wheel pavement marking profiling device shall be located approximately 8 inches (200 mm) behind bead gun #2. This rotatable wheel device shall be approximately 7 inches (175 mm) in diameter and shall have a plurality of spaced projections located around its circumference. The pavement marking profiling device shall be wider than the pavement marking being applied in order that the pavement marking shall be adequately covered. The projections on the profiling device shall have an angular pavement marking profiling surface set at an angle to the pavement surface. The rotatable pavement marking profile device shall be mounted with an automatic leveling device to the same carriage assembly as the thermoplastic gun. Using rollers to place grooves in the traffic marking utilizing a separate vehicle or grooves that are not pressed within 1 second of thermoplastic material application will not be allowed under this specification. To insure that no hot thermoplastic adheres to the wheel as it rotates and profiles the marking, a small air atomized water jet shall apply a thin mist of water to the rotatable profile wheel. No water puddles greater than 1/4 inch (6 mm) in diameter shall be allowed to accumulate on the pavement surface in proximity to the freshly placed pavement marking.

All parts of the thermoplastic holding tank including manifolds, hoses, pipes, dies, etc., shall be oil-jacketed to insure accurate temperature control. The thermoplastic material shall be preheated in kettles designed specifically for that purpose. Each kettle of preheated thermoplastic material shall be properly mixed and heated to the correct application temperature. The preheated material shall then be fed to the thermoplastic gun for application.

The striper unit shall be truck mounted with kettle capacity to hold 2,000 lb (907 kg), of thermoplastic and shall have the capacity to contain enough glass beads and water to apply one full kettle of thermoplastic.

(2) Surface Preparation. All new asphalt surfaces shall have a minimum cure period of 14 days prior to installing the inverted profile pavement marking, unless otherwise approved by the engineer. If the roadway is to be opened to traffic during the 14 day curing period, the Contractor shall place painted markings according to Section 718 of the Standard Specifications. These painted markings will be measured and paid for under Section 604 of the Standard Specifications. In this case, the Contractor shall maintain the painted markings at no additional cost to the Department until the permanent markings are installed.

All pavement areas to be marked shall be thoroughly cleaned using equipment capable of cleaning without damaging the surface. This will include, but not be limited to all vegetation, loose soil, oils, and other debris. Installation of the inverted profiled pavement marking shall follow as closely as practical after the surface has been cleaned.

Where so shown on the plans or as directed by the engineer, the existing pavement marking shall be removed by grinding.

When placing Inverted Profile Thermoplastic Pavement Marking on asphalt pavement that has more than one existing coat of striping material, the existing marking shall be removed to the point that 80% of the pavement surface is visible.

When placing Inverted Profile Thermoplastic Pavement Marking or Inverted Profile Thermoplastic Contrast Pavement Marking on portland cement concrete, no existing pavement marking or curing compound shall be marked over, with the exception of placement of white or yellow inverted profile thermoplastic over the black contrast material. Concrete surfaces shall be ground to the point that 80% of the pavement surface is visible prior to placing the material. The contrast material shall match federal test standard number 595b, (Color x7038 series).

When installing Inverted Profile Thermoplastic Pavement Marking or Inverted Profile Thermoplastic Contrast Pavement Marking over old oxidized asphalt, or on portland cement concrete surfaces, a two component epoxy primer sealer shall be used and installed as recommended in writing by the thermoplastic material supplier. The epoxy primer sealer shall be EX255/EX256 as manufactured by Crown Paint Company of Oklahoma City, OK, or approved alternate.

If an alternate epoxy primer sealer to the Crown Paint EX255/EX256 is chosen, the Contractor shall supply a formulation analysis and proof of adequate performance of the alternate when used with thermoplastic inverted profile pavement markings.

Removal of existing pavement marking will be measured and paid for under the appropriate items under Section 604 of the Standard Specifications.

(3) Weather Conditions/Limitations. When placing Inverted Profile Thermoplastic Pavement Marking or Inverted Profile Thermoplastic Contrast Pavement Marking, no striping shall be permitted when the surface temperature is less than 60° F (16° C)**.** A non-contact infrared pyrometer shall be supplied by the contractor for use by the Engineer for temperature verification. To prevent the rapid cooling of the freshly placed marking, no striping shall be performed when there is moisture on the pavement surface or when winds exceed 12 mph (19 km/hr). After hard rains, even though no moisture is visible, Portland Cement Concrete and asphalt surfaces can hold water. When unseen moisture is suspected to be present, a moisture test shall be performed. The test shall be as follows:

- Place a piece of paper, minimum 60 pound bond, such as Kraft paper, on the pavement surface.
- Pour 1/2 gallon (2 L) of thermoplastic onto the paper.
- After 2 minutes, lift the paper and inspect to see if moisture has been drawn from the pavement.
- If moisture is present, do not proceed with the Inverted Profile Thermoplastic Pavement Marking or Inverted Profile Thermoplastic Contrast Pavement Marking until the surface is moisture free.

Documentation of weather and pavement conditions shall be maintained by the Contractor and supplied to the Engineer on a form approved by the Department.

On all roadways opened to traffic, when temperature limitations prohibit placement of the marking within the three (3) or fourteen (14) day limit specified in Section 604, the Contractor shall place painted markings according to Section 718 of the Standard Specifications. Painted markings required due to temperature limitations will be measured and paid for under Section 604 of the Standard Specifications. In this case, the Contractor shall maintain the painted markings at no additional cost to the Department until the permanent markings are installed.

(4) Placement. The thermoplastic material shall be preheated and thoroughly mixed at an application of between 400° F (204°C) minimum and 430° F (221°C) maximum. A digital thermometer, complete with a 24 inch probe, shall be supplied to the Engineer by the Contractor for temperature verification.

When measured at the highest point of the profile, the cold thickness of the in place thermoplastic pavement marking shall be a minimum of 0.140 inch (4 mm) for inverted profile markings. The thickness of the thermoplastic in the bottom of the profiles shall range from 0.025 inch–0.050 inch (0.6 mm–1.2 mm). The individual profiles shall be located transversely across the pavement marking at interval of approximately 1 inch (25 mm). The bottoms of these intervals shall be between 3/32 inch and 5/16 inch (2 mm and 8 mm) wide. In order to drain water and to reflect light, it is normal for the top surface of the inverted profiles to be irregular. The rate of thermoplastic application for Inverted Profile thermoplastic pavement marking shall be approximately 2,500 lbs/mile (705 kg/km) for a 4 inch (100 mm) solid pavement marking and there shall be appropriate adjustments for skip markings or various line widths.

The glass bead application rate for Class A glass beads (bead coat #1) shall be approximately 500 lbs/mile (141 kg/km) of 4 inch (100 mm) solid pavement marking. There shall be appropriate adjustments for skip markings or various line widths.

The glass bead application rate for Class B glass beads (bead coat #2) shall be approximately 500 lbs/mile (141 kg/km) of 4 inch (100 mm) solid pavement marking. There shall be appropriate adjustments for skip markings or various line widths.

The thickness of the pavement marking materials shall be verified periodically [at least every 1/4 mile (400m)] and any thickness more than 5% under the designated thickness shall be reworked. A consistent, un-corrected underrun will not be allowed and the Contractor will be required to install the specified minimum thickness of 0.140 inch (4 mm). A wet film thickness gauge, such as a GulfLine Model 140W, shall be provided to the Engineer.

For Center and Skip line applications on Portland Cement Concrete pavements, a contrasting edge must be in place prior to laying the Inverted Profile Thermoplastic Pavement Marking. The contrasting edge will consist of a black thermoplastic material with a minimum thickness of 0.140 inch (4 mm) and a minimum stripe width of 7 inches (175 mm) so that there will be a minimum edge of 1 ½ inches (38 mm) on each side of the Inverted Profile Thermoplastic Pavement Marking.

The contrast material must be dry to the touch, yet clean and non-oxidized, prior to placing the Inverted Profile Thermoplastic Pavement Marking. There must be no bleed-through of the contrast material after the inverted profile has been placed.

(i) Inspection Procedure for In-Place Inverted Profile Thermoplastic Pavement.

(1) Purpose. To provide supervising Department personnel with a procedure for insuring compliance with various items in the performance specifications for in-place inverted profile thermoplastic pavement marking. A supplier's representative must be present at the time of the application of the markings to

ensure that the markings are placed in accordance with this specification and the manufacturer's recommended procedures.

(2) Apparatus.

- Measuring tape or ruler
- A 30-meter retroreflectometer complying with ASTM E 1710
- Magnifying glass
- Cold Thickness Gauge
- Wet Thickness Gauge
- Non-Contact Infrared Pyrometer
- Digital Thermometer with 24 inch (600 mm) Probe
- Electronic Digital Wind Speed Indicator

(3) Procedure—Line Selection. 3 foot (1 m) test sections shall be selected by the Engineer throughout the project. Measurements of the pavement marking cool thickness, width, retroreflectivity, beads and bonding shall be taken. In a given 3 foot (1 m) section, several retroreflectivity readings will be taken and averaged to yield a net reading for that section. (See Section j, Warranty)

(4) Procedure—Thickness. After the striper unit has passed a given point by a distance of 40 ft (12m), use a wet thickness gauge to test the pavement marking thickness. Place the gauge over the pavement marking so that the ends rest on the road surface on either side of the marking. Slide the gauge forward along the pavement marking for about a 6 in (150 mm) distance. All wet thickness measurements shall be reported to the Engineer.

After the pavement marking is allowed to completely cool, the marking thickness can be accurately measured by placing the cold thickness gauge over the marking in the same manner as the wet test. Rest the gauge pad that is connected to the dial indicator on the highest point of the pavement marking. From time to time test the calibration of the gauge by placing it on a flat surface. The dial indicator can be rotated so as to set a 0 reading on a flat surface.

Note: The minimum required in-place thickness of the inverted profile pavement marking shall be 0.140 inch (4 mm) as measured at the highest point of the marking.

(5) Procedure—Width. Measure the pavement marking width across the marking at the bottom of the inverted profile. The line width should be $3\ ^{7}/_{8}$ inches to $4\ ^{3}/_{8}$ inches (98 mm–110 mm).

(6) Procedure—Retroreflectivity. Use the 30-meter retroreflectometer to measure the retroreflectivity at random locations. See Section (g)(2). Also, see the operation manual distributed with this device for detailed instructions on usage. Initial readings shall be taken within 7 days of application.

(7) Procedure—Beads. 50% of the glass beads should be embedded to approximately 60% of their diameter to insure proper adherence to the thermoplastic marking material and provide maximum initial retroreflectivity. Shallow embedment allows the beads to debond and deep embedment reduces retroreflectivity. Use a magnifying glass to view bead embedment.

(8) Procedure—Bonding. The thermoplastic inverted profile pavement marking shall be properly bonded to the pavement surface. When completely cured, it should be almost impossible to get a knife or screwdriver blade between the marking and the roadway.

(j) Warranty. Longitudinal markings, designated as Inverted Profile Thermoplastic Pavement Marking or Inverted Profile Thermoplastic Contrast Pavement Marking, shall meet the minimum performance level of 150 mcd/m² /lux under dry pavement conditions and 75 mcd/m² /lux under wet pavement conditions in accordance with ASTM E 2177 (white or yellow) for a period of 48 months from the date of installation when exposed to normal roadway conditions and regardless of average daily traffic. Failure to meet this requirement shall result in the total replacement of the portion of the material shown to be below these minimums.

Adequacy will be determined by an average brightness reading over a zone minimum marking length of 300 linear feet (90 m) using the 30-meter retroreflectometer. The zone of measurement referred to includes: 1) Center lines, 2) Edge lines, and 3) Skip lines.

The measurement procedure for this warranty will entail a visual night inspection by a supplier's representative and a Department representative to identify areas of the installation which appear to be below the specified minimum warranted reflectance value. All reflectance measurements should be made on a clean dry surface at a minimum temperature of 40° F (4° C).

Measurement intervals for installations with areas less than, or equal to, 3 miles (5 km) that appear to be below the minimum specifications, should be made at a minimum of 3 check points for each zone. These should include the start point, approximate mid-point, and the end point.

Measurements for installations with areas greater than 3 miles (5 km) which appear to be below the minimum specifications should be made at the start point and end point of the areas in questions with additional measurements spaced at 3 mile (5 km) intervals between the start and end points.

The number of measurements at each check point for each zone will be as follows:

- Skip lines: 18 measurements distributed over 6 skip lines, should be made at each check point.
- Center lines and/or edge lines: 18 measurements should be made and the measurements should be distributed over 300 linear feet (90 m) of continuous stripe.
- If the pavement markings are more than 6 in (150 mm) wide, the cross sections should be determined by 1/3 of the measurements on the right edge, 1/3 of the measurements on the axis, and 1/3 of the measurements on the left edge.

In addition, the reflectance values at each check point shall be averaged by zone to determine conformance to the minimum reflective values.

(k) Method of Measurement. Inverted Profile Thermoplastic Pavement Markings and Inverted Profile Thermoplastic Contrast Pavement Markings will be measured by the linear foot (meter) of the color and width specified. Where double stripes are placed, each pavement marking will be measured separately.

(l) Basis of Payment. Work completed and accepted and measured as provided above will be paid for at the contract unit price per linear foot (meter) for Inverted Profile Thermoplastic Pavement Markings and Inverted Profile Thermoplastic Contrast Pavement Markings of the color and width specified, which price shall be full compensation for furnishing and installing markings; for surface preparation; and for all labor, equipment, tools, furnishing thickness gauge, and incidentals necessary to complete the work.

Payment will be made under:

Pay Item	Pay Unit
Inverted Profile Thermoplastic Pavement Marking White (___"/___mm)	Linear Foot (Meter)
Inverted Profile Thermoplastic Pavement Marking Yellow (___"/___mm)	Linear Foot (Meter)
Inverted Profile Thermoplastic Contrast Pavement Marking White (___"/___mm)	Linear Foot (Meter)
Inverted Profile Thermoplastic Contrast Pavement Marking Yellow (___"/___mm)	Linear Foot (Meter)

OPTION 2, HIGH PERFORMANCE MARKING TAPE:

(a) Description. This option consists of the material requirements and application of High Performance Marking Tape for 1) Center lines, 2) Edge lines, and 3) Skip lines.

The high performance marking tape is a durable, conformable and retroreflective marking designed for long-term reflectivity. For use on center and skip lines on portland cement concrete pavements, the High Performance Marking Tape will require a black contrasting edge surrounding the stripe. This type of pavement marking shall be designated as High Performance Contrast Marking Tape.

(b) Warranty. The manufacturer shall supply a written warranty for retaining minimum retroreflectivity values as specified herein. This written warranty will indicate the terms of the requirements in accordance with these specifications.

(c) Materials.

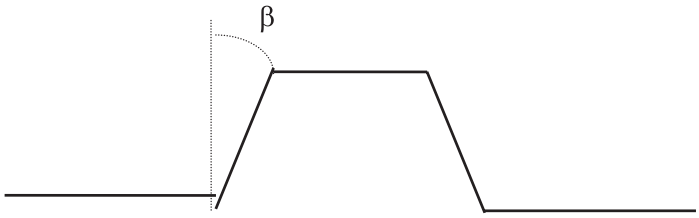
(1) General. The High Performance Marking Tape shall consist of white or yellow films with clear and/or yellow-tinted microcrystalline ceramic beads incorporated to provide immediate and continuing retroreflection. The contrast material for the High Performance Contrast Marking Tape shall also include a black preformed patterned film border, bonded to the edges to form a continuous roll. These films shall be manufactured without the use of lead chromate pigments or other similar, lead-containing chemicals.

The total width of the High Performance Contrast Marking Tape shall be an additional 3 inches (75 mm) wider than the standard width specified. This additional 3 inch (75 mm) width shall be a black non-reflective film with 1½ inches (37.5 mm) on both sides of the white or yellow film.

The High Performance Marking Tape and the High Performance Contrast Marking Tape shall be capable of being adhered to asphalt cement concrete or portland cement concrete by a pre-coated pressure sensitive adhesive. In accordance with the manufacturer's recommendations, a surface preparation adhesive may be used to precondition the pavement surface. The markings shall conform to pavement contours by the action of traffic. The marking also shall be capable of application on new, dense, and open grade asphalt concrete wearing courses in accordance with the manufacturer's instructions. Following proper surface preparation, application, and tamping, the markings shall be immediately ready

for traffic. The markings shall be suitable for use for at least one year after the date of manufacture, when stored in accordance with the manufacturer's recommendations.

(2) Composition. The High Performance Marking Tape and the High Performance Contrast Marking Tape shall be retroreflective, patterned pliant polymer pavement markings consisting of a mixture of high-quality polymeric materials, pigments and glass beads distributed throughout its base cross-sectional area, with a reflective layer of microcrystalline ceramic beads bonded to a durable polyurethane topcoat surface. The patterned surface shall have approximately 50% ± 15% of the surface area raised and presenting a near vertical face (β angle) to traffic from any direction. (See diagram below.) The channels between the raised areas shall be substantially free of exposed beads or particles.



The High Performance Contrast Marking Tape shall consist of highly durable, retroreflective white or yellow pliant polymer materials with durable matte black, non-reflective pliant polymer borders. This material shall be designed for typical longitudinal pavement marking configurations such as lane lines, edge lines, and gore markings.

(3) Reflectance. The white and yellow tape shall have the following minimum reflectance values as measured with a 30-meter geometry retroreflectometer according to ASTM E 1710. The photometric quantity to be measured shall be coefficient of retroreflected luminance (R_L) and shall be expressed as millicandelas per square meter per lux (mcd/m² /lux).

Dry Initial: White: 450 mcd/m² /lux Yellow: 300 mcd/m² /lux
Wet Initial: White: 150 mcd/m² /lux Yellow: 100 mcd/m² /lux

Wet Test Procedure: Mark or delineate a 3 foot (1 m) long section of pavement marking to be tested. Follow the procedure in ASTM E 2177 to determine retroreflectivity.

(4) Beads—Index of Refraction. All microcrystalline ceramic beads bonded to the polyurethane-coated, patterned surface of the material shall have a minimum index of refraction of 1.70 when tested using the oil immersion method. The glass beads mixed into the pliant polymer shall have a minimum index of refraction of 1.50 when tested by the oil immersion method. The test shall be performed as follows:

- Equipment required**:** Microscope (minimum 100X magnification); light source - preferably sodium light or other monochromatic source, but not absolutely essential; refractive index liquids; microscope slide and slide cover; mortar and pestle.
- Using the mortar and pestle, crush a few representative beads and place a few of these crushed particles on a microscope slide.
- Place a drop of a refractive index liquid, with an index as close to that of the glass as can be estimated, on the particles.
- Cover the slide with a microscope slide cover and view the crushed particles by transmitted light normal to the slide surface (illuminated from the bottom).

- Adjust the microscope mirror to allow a minimum light intensity for viewing. This is particularly important if sodium light is not used.
- Bring a relatively flat and transparent particle into focus.
- By slightly raising and lowering the objective (microscope tube), look for one or both of the following:

  1. Becke Line—This light line will appear to move either into the particle or away from it. In general, if the objective is raised, the line will move toward the material of higher refractive index; if the objective is lowered, the line will move toward the material of lower index.
  2. Variation in Particle Brightness—When raising the object from a sharp focus, the particle will appear to get brighter or darker than the surrounding field. If it becomes brighter, the glass has a higher refractive index than the liquid. If it becomes darker, the glass has a lower refractive index than the liquid. In both cases, the opposite will be true if the object is lowered.

This test can be used to confirm that the beads are above or below a specified index. It can also be used to give an accurate determination of the index (±0.001). This is done by using several refractive index liquids until a match or near match of indices occurs. The index of the glass will equal that of the liquid when no Becke line and no variation in bead brightness can be observed.

The size and quality of the beads shall be such that the material and performance requirements for the retroreflective pliant polymer shall be met.

(5) Acid Resistance. The beads shall show resistance as described herein to corrosion of their surface after exposure to a 1% solution (by weight) of sulfuric acid. The 1% acid solution shall be made by adding 5.7 mL of concentrated acid into 1000 mL of distilled water. CAUTION: Always add the concentrated acid into the water, not the reverse. The test shall be performed as follows:

- Take a 1 inch x 2 inch sample, adhere it to the bottom of a glass tray and place just enough acid solution to completely immerse the sample.
- Cover the tray with a piece of glass to prevent evaporation and allow the sample to be exposed for 24 hours under these conditions.
- Then decant the acid solution (do not rinse, touch or otherwise disturb the bead surfaces) and dry the sample while adhered to the glass tray in a 150° F (66° C) oven for approximately 15 minutes.

Microscopic examination (20X) shall show no more than 15% of the beads having a formation of a very distinct opaque white (corroded) layer on their entire surface.

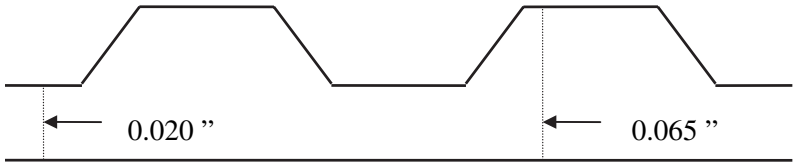
(6) Color. The markings shall consist of white and yellow films with pigments selected and blended to conform to values in the table below and a black preformed patterned film border. White and yellow shall conform to the following table when measured with ASTM E 1349, using 45/0 (0/45) geometry, CIE Standard Illuminant D65 and CIE 2° standard observer.

	Chromaticity Coordinates								Daytime Luminance Factor (*Y*)
	1		2		3		4		
	x	*y*	*x*	*y*	*x*	*y*	*x*	*y*	minimum
White	0.355	0.355	0.305	0.305	0.285	0.325	0.335	0.375	35
Yellow	0.560	0.440	0.490	0.510	0.420	0.440	0.460	0.400	25

(7) Skid Resistance. The patterned surface of the retroreflective pliant polymer shall provide an initial average skid resistance value of 45 BPN (British Pendulum Number) when tested according to AASHTO T 278, except values shall be taken in one direction and then at a 45° angle from that direction. These two values shall then be averaged to find the skid resistance of the patterned surface.

(8) Patchability. Worn areas of the marking material shall be capable of being patched using the same material in accordance with manufacturer's instructions.

(9) Thickness. The patterned material without adhesive shall have a minimum caliper measurement of 0.065 inch (1.65 mm) at the thickest portion of the patterned cross-section and a minimum caliper measurement of 0.02 inch (0.51 mm) at the thinnest portion of the cross-section.



(c) Construction Requirements. The placement of the marking shall comply with the manufacturer's recommendations. The Contractor shall identify proper surface preparation adhesive (where necessary) to be applied at the time of application, all equipment necessary for proper application, and recommendations for application that will assure effective product performance.

The air temperature shall be a minimum of 60° F (16° C) and rising or a minimum road temperature of 70° F (21° C) before installation is allowed.

On all roadways opened to traffic, when temperature limitations prohibit placement of the marking within the three (3) or fourteen (14) day limit specified in Section 604, the Contractor shall place painted markings according to Section 718 of the Standard Specifications. Painted markings required due to temperature limitations will be measured and paid for under Section 604 of the Standard Specifications. In this case, the Contractor shall maintain the painted markings at no additional cost to the Department until the permanent markings are installed.

The roadway surface shall be cleaned by the Contractor with high pressure air or by sweeping. The roadway shall then be marked where the pavement marking is to be applied.

The marking can then be applied by hand or with a manual or mechanical highway tape applicator designed for that purpose. Only butt splices will be allowed with no overlapping.

After application, firmly tamp the tape with a minimum 200 pounds (90 kg) load or by slowly (2-3 mph [3-5 km/h]) driving over the tape with a vehicle tire. Do not twist the tamping device on the tape. The Contractor shall ensure that all edges are firmly adhered.

Spotting of the center line and lane line locations, if required, shall be the responsibility of the Contractor. Establishment of no passing zones, if required, will be done by the Department and will be completed at such time as the Contractor begins work. Edge lines shall not be broken for driveways. The trace of the line shall be uniform.

All conflicting existing markings shall be removed according to Section 604 of the Standard Specifications.

(d) Warranty. Longitudinal markings, designated as High Performance Marking Tape or High Performance Contrast Marking Tape, shall meet the minimum performance level of 150 mcd/m² /lux under dry pavement conditions and 75 mcd/m² /lux under wet pavement conditions in accordance with ASTM E 2177 (white or yellow) for a period of 48 months from the date of installation when exposed to normal roadway conditions and regardless of average daily traffic. Failure to meet this requirement shall result in the total replacement of the portion of the material shown to be below these minimums.

Adequacy will be determined by an average brightness reading over a zone minimum marking length of 300 linear feet (90 m) using the 30-meter retroreflectometer. The zone of measurement referred to includes: 1) Center lines, 2) Edge lines, and 3) Skip lines.

The measurement procedure for this warranty will entail a visual night inspection by a supplier's representative and a Department representative to identify areas of the installation which appear to be below the specified minimum warranted reflectance value. All reflectance measurements should be made on a clean dry surface at a minimum temperature of 40° F (4° C).

Measurement intervals for installations with areas less than, or equal to, 3 miles (5 km) that appear to be below the minimum specifications, should be made at a minimum of 3 check points for each zone. These should include the start point, approximate mid-point, and the end point.

Measurements for installations with areas greater than 3 miles (5 km) that appear to be below the minimum specifications should be made at the start point and end point of the areas in questions with additional measurements spaced at 3 mile (5 km) intervals between the start and end points.

The number of measurements at each check point for each zone will be as follows:

- Skip lines: 18 measurements distributed over 6 skip lines, should be made at each check point.
- Center lines and/or edge lines: 18 measurements should be made and the measurements should be distributed over 300 linear feet (90 m) of continuous stripe.
- If the pavement markings are more than 6 in. (150 mm) wide, the cross sections should be determined by 1/3 of the measurements on the right edge, 1/3 of the measurements on the axis, and 1/3 of the measurements on the left edge.

In addition, the reflectance values at each check point shall be averaged by zone to determine conformance to the minimum reflective values.

(e) Method of Measurement. High Performance Marking Tape and High Performance Contrast Marking Tape will be measured by the linear foot (meter) of the color and width specified. Where double stripes are placed each pavement marking will be measured separately.

Removal of permanent pavement markings will be measured and paid for under Section 604 of the Standard Specifications.

(f) Basis of Payment. Work completed and accepted and measured as provided above will be paid for at the contract unit price bid per linear foot (meter) for High Performance Marking Tape and High Performance Contrast Marking Tape of the color and width specified, which price shall be full compensation for surface preparation (including furnishing and applying any primer required by the manufacturer), furnishing and installing the markings, and for all labor, equipment, tools, and incidentals necessary to complete the work.

Payment will be made under:

Pay Item	Pay Unit
High Performance Marking Tape White (___”/___mm)	Linear Foot (Meter)
High Performance Marking Tape Yellow (___”/___mm)	Linear Foot (Meter)
High Performance Contrast Marking Tape White (___”/___mm)	Linear Foot (Meter)
High Performance Contrast Marking Tape Yellow (___”/___mm)	Linear Foot (Meter)

APPENDIX D4

Agency: British Columbia Ministry of Transportation and Infrastructure

Attached Example(s) of Warranty Specifications:

Pavement Marking Specification	Period	Remarks
Pavement Marking Specifications for Longitudinal Pavement Markings—paint with glass beads	Performance measure-ments to Oct. 15th of year of application and to Jan. 15th of following year.	First part contains general information on definitions, referenced manuals, test methods, etc. This is followed by separate specifications for longitudinal pavement markings and longitudinal pavement markings on new projects. Paint materials must be listed on one or more Recognized Products Lists of British Columbia MOT, Alberta MOT, Washington State DOT, Idaho Transportation Department, or Alaska DOT&PF. Contractor is responsible for fulfilling warranty requirements. Specifications require contractors to conform to dimensional requirements, application methods, test standards and protocols, and performance requirements for retroreflectivity and durability. Measurement of retroreflectivity is taken to Oct. 15th of the year of application. Durability measurement is taken to Jan. 15th of the year following application.

SCHEDULE "1"
PAVEMENT MARKING SPECIFICATIONS

TABLE OF CONTENTS

INTRODUCTION

A. MATERIALS

The Contractor will use, unless otherwise approved in writing by the Province;

(a) traffic paint in accordance with the Recognized Products List (or equivalent) from at least one of the following agencies:

(i) British Columbia Ministry of Transportation and Infrastructure,

(ii) Alberta Ministry of Transportation,

(iii) Washington State Department of Transportation,

(iv) Idaho Transportation Department,

(v) Alaska Department of Transportation and Public Facilities;

(b) white paint that conforms to US Federal specification 595b White 37886;

(c) yellow paint that conforms to US Federal specification 595b Yellow 33538; and

(d) glass beads for traffic paint that conform to AASHTO M 247 Type 1 gradation with a minimum roundness value of 75% true spheres.

B. DEFINITIONS

In this Schedule:

(a) **"Broken Lines"** means any line with fixed longitudinal spacing as referenced in the Manual of Standard Traffic Signs and Pavement Markings, figure 7.1;

(b) **"CHRIS"** means the Ministry's Corporate Highway Resource & Information System;

(c) **"Government Property"** means Highways and all structures and other property appurtenant thereto owned or administered by the Province, including all signs, guardrails, pavement, roadbeds, shoulders, culverts, tunnels, bridges, fences and posts;

(d) **"Layout"** means the process of creating a reference to establish Pavement Markings where there are no visible Pavement Markings or where existing Pavement Markings must be altered;

(e) **"Line"** means any of the lines illustrated in Figure 7.1 of the Manual of Standard Traffic Signs and Pavement Markings;

(f) **"Test Site"** means a site where all six tests described in section "G" of the Introduction to Specifications have been performed at a single location; and

(g) **"Unacceptable Work"** means any work, workmanship, materials, or products produced or supplied by the Contractor or any Subcontractor which, in the opinion of the Ministry, does not conform to the requirements of this Agreement.

C. INTERPRETATION

Whenever more than one Pavement Marking Specification or more than one part of a Pavement Marking Specification applies to a particular Highway location, condition, circumstance or activity, the Contractor will comply with each and every applicable Pavement Marking Specification or part of a Pavement Marking Specification.

D. PAVEMENT MARKING SERVICES COMPLETION

Wherever the time within which work must be performed by the Contractor under these Pavement Marking Specifications exceeds the time remaining in the Term, the Contractor will, notwithstanding any other provision of these Pavement Marking Specifications, perform the work prior to the end of the Term.

E. DAMAGE TO GOVERNMENT PROPERTY

All damages to Government Property caused by the Contractor are to be repaired by the Contractor at its own expense and will not be recoverable.

F. REFERENCED MANUALS

The following sets out a list of manuals that are referenced throughout these Pavement Marking Specifications and are required by the Contractor to perform the Pavement Marking Services. It is the Contractor's obligation to obtain these manuals and maintain them throughout the term of this Agreement.

- Manual of Standard Traffic Signs and Pavement Markings, Ministry of Transportation and Infrastructure, September 2000 Edition, which can be accessed through the following Internet address: http://www.th.gov.bc.ca/publications/eng_publications/electrical/MoST_PM.pdf

- The latest edition of the Recognized Products List, Ministry of Transportation and Infrastructure, which can be accessed through the following Internet address: http://www.th.gov.bc.ca/publications/eng_publications/geotech/rpl.htm

- The latest edition of the Standard Specifications for Highway Construction, Ministry of Transportation and Infrastructure, which can be purchased from the following Internet address: http://www.publications.gov.bc.ca/ or viewed at: http://www.th.gov.bc.ca/publications/const_maint/contract_serv/standardspecs.htm

- The latest edition of the Traffic Control Manual for Work on Roadways, Ministry of Transportation and Infrastructure, which can be accessed through the following Internet address: http://www.th.gov.bc.ca/publications/eng_publications/TCM/Traffic_Control_Manual.htm

- Technical Bulletins, Engineering, Ministry of Transportation and Infrastructure, which can be accessed through the following Internet address:
- http://www.th.gov.bc.ca/publications/eng_publications/TE_Bulletins/TE_bulletins.htm

G. QUALITY ASSURANCE TESTING METHODS

This section defines how the pavement markings will be tested for conformance to the Detailed Performance Specifications.

Once per Operational Day a minimum of two test sites are to be selected for each paint crew. This selection must be representative of the line type accomplishments of that day (e.g., if 90% of the accomplishment of the day was centreline, than the expectation is that the test sites will be on centreline; if 50% of the accomplishment was on centreline and 50% was on lane line, then the expectation would be that there would be a test site on each line type). The following tests must be performed and recorded per site for that day:

1. Colour

1.1 The colour of white pavement markings will comply with U.S. Federal specification 595b White 37886.

1.2 The colour of yellow pavement markings will comply with U.S. Federal specification 595b Yellow 33538.

1.3 Testing for conformance will be made by visual comparison to a standard color card provided by the paint manufacturer that certifies color compliance with the specification.

2. Dimensions

2.1 Longitudinal Pavement Markings will be measured and documented for conformance with the Pavement Marking Specifications.

3. Night Time Retro-reflectivity

3.1 Retro-reflectivity will be measured as per ASTM 6359-99 Standard Specification for Minimum Retro-reflectance of Newly Applied Pavement Markings Using Portable Hand-Operated Instruments and ASTM E1710 Standard Test Method for measurement of Retro-reflective Pavement Marking Materials with CEN-prescribed Geometry Using a Portable Retroreflectometer, notwithstanding the following exceptions contrary to ASTM 6359-99:

(a) contrary to Section 6.2.1.4 and 6.2.2.4 of the ASTM 6359-99 Standard Specification for Minimum Retro-reflectance of Newly Applied Pavement Markings Using Portable Hand-Operated Instruments referenced in paragraph 3.1, measurements will be required for Test Sites;

(b) contrary to Section 6.2.1.4 and 6.2.2.4 of the ASTM 6359-99 Standard Specification for Minimum Retro-reflectance of Newly Applied Pavement Markings Using Portable Hand-Operated Instruments referenced in paragraph 3.1, all measurements made within a single Test Site may be averaged and recorded as an average. Any average of the readings that do not meet the Pavement Marking Specifications will be determined as Unacceptable Work;

(c) contrary to Section 5.1 of the ASTM 6359-99 Standard Specification for Minimum Retro-reflectance of Newly Applied Pavement Markings Using Portable Hand-Operated Instruments referenced in paragraph 3.1, testing for retro-reflectivity will be carried out only when the newly painted surface is clean, dry, free of all excess beads, and after 24 hours of paint being applied.

3.2 Longitudinal Pavement Markings will have a minimum initial coefficient of retro-reflective luminance as indicated in these Pavement Marking Specifications.

3.3 All measurements for night time retro-reflectivity will be made using a Mirolux MX-30, Stripemaster or Stripemaster 2 retroreflectometer or equivalent, as approved in writing by the Ministry. Measurements will be made using the retro-reflectometer manufacturer's instructions for operation and procedures and will be made only by competent staff.

3.4 Sampling will be made using a sample size of 20 measurements at 5 meter intervals on a single line.

3.5 All measurements and related data will be retained by the Contractor in an electronic format approved by the Ministry Representative and will be submitted to the Ministry Representative on request.

3.6 A report will be produced for each Test Site and will include the following information:

(a) test date;
(b) average of the measurements at each Test Site, expressed as millicandelas per square metre per lux (mcd·m−2·lx−1); the average of the measurements will be reported for each traffic direction for centerlines;
(c) geographical location of the Test Site, referenced by offsets from CHRIS landmarks;
(d) identification of the pavement marking material tested: type, color, date painted, and transverse location on road (line type);
(e) identification of the instrument used;
(f) value and date of standardization of the instrument standard panel used;
(g) remarks concerning the overall condition of the line, such as rubber skid marks, carryover of asphalt, snow plow damage, and other factors that may affect the retro-reflection measurement;
(h) ambient temperature; and
(i) operator's name.

4. Thickness and Consistency

4.1 Longitudinal Pavement Markings will have a sufficiently thick cross-section throughout their entire length and width to completely cover the intended area being marked. Pavement markings will be tested as per ASTM D913-03 Standard Test Method for Evaluating Degree of Resistance to Wear of Traffic Paint. Newly applied pavement markings must exceed the photographic reference standard of 97%.

5. Daytime Visibility

5.1 When viewed dry or wet in the daytime, the pavement markings will be readily visible for a forward distance of 150 metres, or as far forward as possible until obstructed by the road geometry if less than 150 metres.

5.2 Daytime visibility will be assessed visually. Where it is not clear that the specification is met, the distance will be measured.

6. Durability

6.1 Longitudinal Pavement Markings will be visually assessed for conformance with the specification using ASTM D913-03 Standard Test Method for Evaluating Degree of Resistance to Wear of Traffic Paint.

7. Test Site and Acceptance or Rejection

7.1 A Test Site is defined as a site where the above six tests have been performed in a single location. If two or more line types are applied per Operational Day, it may be necessary to perform relevant tests for each line type at more than one location.

7.2 A failure of any one of the six above components will constitute a failure for that Test Site, and will be considered Unacceptable Work.

H. QUALITY CONTROL/DIGITAL PAVEMENT MARKING MEASURING INSTRUMENT

8.1 A Digital Pavement Marking Measuring Instrument (herein referred to as a "DPMMI") (for example: LineTech Dataline, Epic Solutions M7, or similar product) must be mounted to the paint application vehicle that will track the following conditions at an interval no greater than every 15 seconds at all times during paint application:

(a) date
(b) time
(c) location
(d) speed of vehicle
(e) paint application thickness (wet mils)
(f) distance painted
(g) glass bead application rate
(h) road temperature
(i) air temperature
(j) paint temperature

8.2 The Contractor is responsible to accurately track the road and exact location on the road that all recorded data applies to. The Contractor is to provide to the Ministry Representative a program capable of transferring the raw digital file produced by the digital measuring instrument into a Microsoft Excel spreadsheet file.

8.3 If, for any reason, the DPMMI becomes inoperable, the Contractor will immediately advise the Ministry Representative. The Contractor will inform the Ministry Representative of the area that has been painted without the DPMMI and a date when the instrument will be back in operation. If the instrument will be out of service for 5 or more days of operation, the Contractor may be required to provide documentation from the manufacturer regarding the problem and the proposed date for the solution.

8.4 The Contractor will provide site specific and/or entire logs of raw data files from the digital measuring instrument to the Ministry Representative as and when requested.

8.5 Detailed records are required to be kept that reference load slips for paint, bead and any other product used in the work. These records will include the quantities and locations the loads were applied to.

8.6 All Quality Control records are to be retained by the Contractor, and made available to the Ministry Representative upon request.

B.C. MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE

PAVEMENT MARKING SPECIFICATION 1

Longitudinal Pavement Markings

1. OBJECTIVE

To facilitate the safe and efficient movement of traffic on Highways through the use of Longitudinal Pavement Markings to delineate, guide and inform travellers.

2. DETAILED PERFORMANCE SPECIFICATIONS

Longitudinal Pavement Markings

The Contractor must:

(a) repaint Longitudinal Pavement Markings to match those in the field, provided that the existing markings conform to the Manual of Standard Traffic Signs and Pavement Markings;

(b) contact the Ministry Representative about any existing Longitudinal Pavement Markings that do not conform to the Manual of Standard Traffic Signs and Pavement Markings prior to proceeding with the repainting;

(c) Layout, with no additional payment, and paint Longitudinal Pavement Markings in areas where the previous markings are not visible in accordance with the Manual of Standard Traffic Signs and Pavement Markings or as instructed by the Ministry Representative;

(d) apply Longitudinal Pavement Markings at a wet thickness of not less than 16 mils;

(e) ensure all Longitudinal Pavement Markings have well defined edges and are free of tire tracking, with no splatter, excessive overspray or other defects;

(f) ensure lateral deviation from any existing Longitudinal Pavement Markings do not exceed 10 mm;

(g) ensure Longitudinal Pavement Markings are straight, or of uniform curvature, and conform with the alignment;

(h) ensure the following dimensional criteria are met:

- **(i)** Longitudinal Pavement Markings do not exceed a dimensional width of 110 mm for specified 100 mm wide line. No tolerance below 100 mm is allowed for the specified 100 mm line;
- **(ii)** Longitudinal Pavement Markings do not exceed a dimensional width of 210 mm for specified 200 mm wide line. No tolerance below 200 mm is allowed for the specified 200 mm line;
- **(iii)** the distances between the lines for double solid and simultaneous solid and Broken do not exceed a dimensional separation of 110 mm. No tolerance below 100mm is allowed;
- **(iv)** Longitudinal Pavement Marking lane lines do not exceed a maximum dimensional length deviation of ±100 mm for the specified length; and
- **(v)** no spaces between Broken Lines exceed a maximum dimensional length deviation of ± 100 mm from the specified length of space;

(i) apply glass beads immediately following the paint application. Glass beads are to be applied on all Longitudinal Pavement Markings at a uniform application rate;

(j) conduct all durability testing as per ASTM D913-03 Standard Test Method for Evaluating Degree of Resistance to Wear of Traffic Paint, and:

(i) the condition of Longitudinal Pavement Markings must meet the minimum of photographic reference standard of No. 8 (Film 97% Intact) Chipping ASTM Method D913-03 from time of application to October 15th of the calendar year in which the line was painted. Longitudinal Pavement Markings that do not meet this criteria must be repainted immediately upon detection or as directed by the Ministry Representative; and

(ii) the condition of Longitudinal Pavement Markings must meet the minimum of photographic reference standard of No. 4 (Film 77% Intact) Chipping ASTM Method D913-03 on January 15th of the subsequent year to which the line was painted.

(k) measure retro-reflectivity properties as per Section G of the Introduction to these Pavement Marking Specifications;

(l) ensure:

(i) retro-reflectivity properties of not less than 200 millicandela$\cdot m^{-2} \cdot lux^{-1}$ for white paint under dry conditions are achieved on all Longitudinal Pavement Markings for at least 30 days from the time of application;

(ii) retro-reflectivity properties of not less than 150 millicandela$\cdot m^{-2} \cdot lux^{-1}$ for yellow paint under dry conditions are achieved on all Longitudinal Pavement Markings for at least 30 days from the time of application;

(iii) retro-reflectivity properties of not less than 150 millicandela$\cdot m^{-2} \cdot lux^{-1}$ for white paint under dry conditions are achieved from time of application to October 15th of the calendar year in which the line was painted; and

(iv) retroreflectivity properties of not less than 100 millicandela$\cdot m^{-2} \cdot lux^{-1}$ for yellow paint under dry conditions are achieved from time of application to October 15th of the calendar year in which the line was painted.

3. MATERIALS

Refer to Section A of the Introduction to these Pavement Marking Specifications.

B.C. MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE

PAVEMENT MARKING SPECIFICATION 2

Longitudinal Pavement Markings on New Projects

1. OBJECTIVE

To facilitate the safe and efficient movement of traffic on Highways through the use of Longitudinal Pavement Markings to delineate, guide and inform travellers on New Projects.

2. DETAILED PERFORMANCE SPECIFICATIONS

Longitudinal Pavement Markings on New Projects

The Contractor must:

(a) Layout, with no additional payment, Longitudinal Pavement Markings on New Projects in accordance with the Manual of Standard Traffic Signs and Pavement Markings or as instructed by the Ministry Representative; and

(b) paint Longitudinal Pavement Markings on New Projects as follows:

(i) apply an initial application of Longitudinal Pavement Markings at a wet thickness of not less than 10 mils;

(ii) apply a second application, with no additional payment, in accordance with the paint manufacturer's suggested application interval;

(iii) apply the second application at a wet thickness of not less than 15 mils regardless of product used; and

(iv) the wet thickness of all Longitudinal Pavement Markings will be applied uniformly.

(c) ensure all Longitudinal Pavement Markings have well defined edges and are free of tire tracking, with no splatter, excessive overspray or other defects;

(d) ensure Longitudinal Pavement Markings are straight, or of uniform curvature, and conform with the alignment;

(e) ensure the following dimensional criteria are met:

(i) Longitudinal Pavement Markings do not exceed a dimensional width of 110 mm for specified 100 mm wide line. No tolerance below 100 mm is allowed for the specified 100 mm line;

(ii) Longitudinal Pavement Markings do not exceed a dimensional width of 210 mm for specified 200 mm wide line. No tolerance below 200mm is allowed for the specified 200 mm line;

(iii) the distance between the lines for double solid and simultaneous solid and broken does not exceed a dimensional separation of 110 mm. No tolerance below 100 mm is allowed;

(iv) Longitudinal Pavement Marking Broken Lines do not exceed a maximum dimensional length deviation of ±100mm for the specified length; and

(v) no spaces between Broken Lines exceed a maximum dimensional length deviation of ± 100 mm from the specified length of space;

(f) apply glass beads immediately following each paint application. Glass beads are to be applied on all Longitudinal Pavement Markings at a uniform application rate;

(g) measure retro-reflectivity properties as per Section G of the Introduction to these Pavement Marking Specifications.

(h) ensure;

(i) retro-reflectivity properties of not less than 200 millicandela·m^{-2}·lux^{-1} for white paint under dry conditions are achieved on all Longitudinal Pavement Markings for at least 30 days from the time of application;

(ii) retro-reflectivity properties of not less than 150 millicandela·m^{-2}·lux^{-1} for yellow paint under dry conditions are achieved on all Longitudinal Pavement Markings for at least 30 days from the time of application, and;

(iii) retro-reflectivity properties of not less than 150 millicandela·m^{-2}·lux^{-1} for white paint under dry conditions are achieved from time of application to October 15th of the calendar year in which the line was painted; and

(iv) retro-reflectivity properties of not less than 100 millicandela·m^{-2}·lux^{-1} for yellow paint under dry conditions are achieved from time of application to October 15th of the calendar year in which the line was painted.

(i) conduct all durability testing as per ASTM D913-03 Standard Test Method for Evaluating Degree of Resistance to Wear of Traffic Paint and;

(i) the condition of Longitudinal Pavement Markings must meet the minimum of photographic reference standard of No. 8 (Film 97% Intact) Chipping ASTM Method D913-03 from time of application to October 15th of the calendar year in which the line was painted. Longitudinal Pavement Markings that do not meet this criteria must be repainted immediately upon detection or as directed by the Ministry Representative; and

(ii) the condition of Longitudinal Pavement Markings must meet the minimum of photographic reference standard of No. 4 (Film 77% Intact) Chipping ASTM Method D913-03 on January 15th of the subsequent year to which the line was painted.

3. MATERIALS

Refer to Section A of the Introduction to these Pavement Marking Specifications.

APPENDIX D5

Agency: Delaware Department of Transportation

Attached Example(s) of Warranty Specifications:

Pavement Marking Specification	Period	Remarks
Retroreflective Preformed Patterned Pavement Marking for Longitudinal Markings	1 year; 4 years after initial acceptance	Specifications describe materials composition and characteristics, methods of placement, allowable weather conditions, and procedures for performance testing. Warranty provisions are in section titled "WARRANTY." Contractor is responsible for meeting warranty requirements. Performance is evaluated 1 year after acceptance, then through an additional warranty period of 4 years for dry retroreflectivity (wet and rainy retroreflectivity is warranted for 2 years). Contractor's team members involved in placing these markings must attend a preplacement meeting with DelDOT and the tape manufacturer's representative. Contractor shall be certified by the manufacturer for installation and approved by DelDOT. Manufacturer's representative shall be onsite for the start of the markings and provide technical assistance as needed. Contractor must post a warranty bond to insure the Department through the warranty period. The bond is in the sum of 100% of the original contract total cost for this item.
Retroreflective Preformed Patterned Pavement Marking for Symbols and Legends	1 year; 2 years after acceptance	All the above remarks apply, but the overall warranty period differs: 2 years for dry retroreflectivity, and 1 year for wet and rainy retroreflectivity.

DELAWARE DEPARTMENT OF TRANSPORTATION

SPECIFICATIONS:

748512—RETROREFLECTIVE PREFORMED PATTERNED MARKINGS, 6-inch width

748513—RETROREFLECTIVE PREFORMED PATTERNED MARKINGS, 12-inch width

748514—RETROREFLECTIVE PREFORMED PATTERNED MARKINGS, 8-inch width

748519—RETROREFLECTIVE PREFORMED PATTERNED MARKING, 4-inch width

748529—RETROREFLECTIVE PREFORMED PATTERNED MARKING, SYMBOL/LEGEND

748547—RETROREFLECTIVE PREFORMED PATTERNED CONTRAST MARKINGS, 9-inch width

Description:

This work shall consist of furnishing and installing retroreflective preformed patterned pavement marking in accordance with this provision and in conformance to the existing pavement markings or as established by the Engineer. The Contractor is required to have all subcontractors involved in the placement of these markings attend the preplacement meeting along with the tape manufacturer representative and Department representatives to coordinate this operation. The subcontractor for pavement markings shall be approved by the Department prior to the preconstruction meeting.

Materials:

General: The preformed patterned markings shall consist of white or yellow films with clear microcrystalline ceramic beads incorporated to provide immediate and continuing retroreflection. The markings shall be suitable for application on new or existing P.C. Concrete or bituminous pavements with a pre-coated pressure sensitive adhesive.

The preformed marking material must be used prior to one year from date of manufacture. When not placed by inlaid method a surface preparation adhesive shall be used. The markings shall be capable of providing retroreflection during both wet and dry conditions.

The markings shall be highly durable retroreflective pliant polymer materials designed for longitudinal and word/symbol markings subjected to high traffic volumes and severe wear conditions such as shear action from crossover or encroachment on typical longitudinal configurations such as edge lines and lane lines. This film shall be manufactured without the use of lead chromate pigments or other similar, lead-containing chemicals.

Composition: The pavement marking shall consist of a mixture of high quality polymeric materials and pigments with glass beads distributed throughout the base cross-sectional area, with a reflective layer of microcrystalline ceramic beads bonded to a durable polyurethane topcoat surface. The patterned surface shall have approximately 50% plus or minus 15% of the surface area raised and presenting a near vertical face, angled from 0 degrees to 60 degrees, to traffic from any direction. The channels between the raised areas shall be substantially free of exposed beads or particles. The marking shall have a precoated pressure sensitive adhesive. The edges of the markings shall be clean cut and true.

Retroreflectance: The white and yellow markings shall have the initial expected retroreflectance values as shown in Table 1 under dry, wet, and rainy conditions. The photometric quantity to be measured shall be coefficient of retroreflected luminance (RL) and shall be expressed as millicandelas per square foot per foot-candle [(mcd· ft^{-2})· fc^{-1}]. The metric equivalent shall be expressed as millicandelas per square meter per lux [(mcd· m^{-2})· lx^{-1}].

Retroreflectance values shall be measured under dry conditions in accordance with the testing procedures of ASTM D4061. Retroreflectance values shall be measured under wet conditions in accordance with ASTM E2176 or ASTM E2177. Wet retroreflectance values measured under a "condition of continuous wetting" (simulated rain) shall be in accordance with ASTM E2176. Wet retroreflectance values measured under a "condition of wetness" shall be in accordance with ASTM E2177.

Table 1 Expected Initial R_L under dry, wet, and rainy conditions

WHITE	DRY	WET & RAINY
Entrance Angle	88.76°	88.76°
Observation Angle	1.05°	1.05°
Retroreflected Luminance R_L [(mcd·m^{-2}) · lx^{-1}]	500	250
YELLOW	**DRY**	**WET & RAINY**
Entrance Angle	88.76°	88.76°
Observation Angle	1.05°	1.05°
Retroreflected Luminance R_L [(mcd·m^{-2}) · lx^{-1}]	300	250

Beads, Index of Refraction: All "dry-performing" microcrystalline ceramic beads bonded to the polyurethane-coated, patterned surface of the material shall have a minimum index of refraction of 1.70 when tested using the liquid oil immersion method. All "wet-performing" microcrystalline ceramic beads bonded to the polyurethane-coated, patterned surface of the material shall have a minimum index of refraction of 2.30 when tested using the liquid oil immersion method. The glass beads mixed into the pliant polymer shall have a minimum index of refraction of 1.5 when tested by the liquid oil immersion method.

Beads, Acid Resistance: The beads shall show resistance to corrosion of their surface after exposure to a 1% solution (by weight) of sulfuric acid. The 1% acid solution shall be made by adding 5.7 cc of concentrated acid into 1000 cc of distilled water.

Color: The markings shall consist of white and/or yellow films with pigments selected and blended to conform to standard highway colors.

Skid Resistance: The patterned surface of the markings shall provide an initial average skid resistance value of 45 BPN when tested according to ASTM E 303.

Patchability: The pavement marking material shall be capable of use for patching worn areas of the same type in accordance with manufacturer's instructions.

Thickness: The patterned material without adhesive shall have a minimum caliper of 0.065 inch (1.651 mm) at the thickest portion of the patterned cross section and a minimum caliper of 0.020 inch (0.508 mm) at the thinnest portion of the cross section.

Tolerance: The Contractor will be responsible for applying these markings in a straight manner not exceeding 1/2O (12 mm) per 40N (12 m). Any markings exceeding the 1/2O (12 mm) tolerance will require the Contractor to make corrective action approved by the Engineer and the tape manufacturer representative at no extra cost to the Department.

Construction Methods:

The Contractor shall be certified, by the manufacturer, in the installation of the pavement marking material prior to the start of the markings. The Contractor shall install the pavement marking material in accordance with the manufacturer's published recommendations.

The manufacturer shall provide technical assistance as required to ensure successful installation of the markings. This shall include a representative on site for the start of the markings, training, product information, problem solving, etc.

Installation of the pavement markings shall be performed in a neat and workmanlike manner. The Contractor shall premark the pavement to ensure correct location of markings and such layout work shall be incidental to the price bid for the pavement marking items. The method for premarking should be as recommended by the manufacturer. A thin layer of paint as a premarking is not recommended.

Particular care shall be taken to ensure that the leading edges of the markings are secured to the pavement.

General application rules:

- The Air and surface temperature shall be a minimum of 40° F.
- The pavement must be clean and dry. 24 hours of dry weather where no rain is expected.
- When not placed by inlaid method a surface preparation adhesive shall be used.
- Do not overlap tape—use butt splice.
- Do not apply tape on longitudinal seams or joints or cracks.
- Do not apply tape on deteriorating pavement surfaces.
- Existing markings must be 80% removed.

After application, the markings shall be immediately ready for use by traffic.

Inlay into Fresh Bituminous Concrete:

When markings are specified in the contract for newly paved asphalt concrete surfaces, they shall be applied before public traffic is allowed on the freshly paved surface - the pavement markings shall be

inlaid in the fresh surface during final rolling of the mat, in accordance with the manufacturer's recommendations unless otherwise directed by Engineer.

The Contractor shall show how the pavement mats will be placed to avoid applying the tape on longitudinal seams or joints or cracks and maintain correct marking location.

The Contractor shall employ a sufficient number of workers to premark the pavement and install the markings such that all markings are inlaid into the hot pavement prior to the finish rolling. No paving shall be permitted unless the striping crew and materials are on the project site.

General procedure for inlay application on fresh asphalt surfaces:

- Tape is applied after the compaction roller and before the finish roller using minimum water, slow speed and no vibration.
- Tape shall be applied using equipment recommended by manufacturer.
- Tamping shall be done by the finish roller and in the same direction the tape was applied. A separate roller of a size approved by the tape manufacturer may be required to meet the manufacturer's requirements.
- Roller shall use minimum speed to prevent wrinkling the tape.
- Asphalt temperatures shall be between 180°F (66°C) and 120°F (49°C) when tape is applied.

NOTE: Even though the tape will stand these high temperatures the contractor is to use caution to assure the asphalt is firm enough to walk on above 140°F (60°C).

Placement on new P.C. Concrete Pavement:

When markings are specified in the contract for new P.C. concrete pavement surfaces they shall be applied after the concrete has adequately cured as determined by the Engineer and prior to opening to traffic.

1. When a membrane curing compound has been applied to the concrete surface, it shall be removed by sandblasting prior to applying the markings. Cost for such sandblasting shall be incidental to the price bid for the pavement marking item. The road shall be cleaned by sweeping and with high pressure air.

2. The manufacturer shall specify a primer/solvent for the pavement surface.

3. The tape shall be applied with an approved applicator.

4. The tape shall be tamped with a roller tamper cart with a minimum 200 lb (90 kg) load or by slowly (2–3 mph [3–5 km/hr]) driving over the tape with a vehicle tire. Do not twist or turn on the tape. A minimum of three passes back and forth over the tape will be required. All edges of the tape shall be thoroughly tamped.

Placement on Existing Pavement:

When markings are specified in the contract for existing pavement, the pavement surface shall be free of any existing markings.

1. The road shall be cleaned by sweeping and with high pressure air.

Steps 2 through 4 are the same as for new P.C. concrete pavement.

Method of Measurement:

This work will be measured for payment by the number of linear feet (meters) of line or square foot (meter) of symbol/legend of Retroreflective Preformed Patterned Markings installed on the pavement and accepted in accordance with the plans.

Basis of Payment:

This work will be paid for at the contract unit price bid per linear foot (meter) of line or square meter of symbol/legend as measured for item “Retroreflective Preformed Patterned Markings” of the type specified. This price shall include cleaning and preparing the pavement surface, furnishing and placing all materials, for all labor, tools, equipment and incidentals necessary to complete the work.

WARRANTY

The Contractor shall warrant to the Department that the installed retroreflective preformed patterned pavement markings are free of defects, as hereafter defined, for one calendar year beginning at the initial acceptance of the marking installation by the Department. The initial acceptance of the marking installation will occur upon the satisfactory correction of all deficiencies noted in the marking installation during the Final Inspection of the project. The markings shall show no fading, lifting, shrinking, tearing, rollback, distortion or chipping due to vehicular traffic or normal maintenance activities including snow plowing. Although some wear is expected, the markings shall remain intact and serviceable (as defined below) for no less than 95% of the total item quantities in the first year of installation.

In addition, the pavement markings shall be warranted to retain a minimum reflective value of 150 millicandelas per square foot (meter) per lux for the first year after initial acceptance.

Reflectance Measurements Procedures during One (1) Year:

1. Within the project limits, reflectance measurements shall be taken at specified checkpoint areas as outlined below:

- Δ Reflectance measurements shall be taken on one skip in every 100 feet (30 linear meters). Two measurements must be taken on each skip that is tested, one measurement at each end of skip (within 6 inches (150 mm) of the end).
- Δ For continuous lines, reflectance measurements shall be taken at approximate 100 foot (30 meter) intervals throughout the project limits.

The Department reserves the right to test additional areas. Each measurement shall meet the minimum reflective value of 150 millicandelas per square foot (meter) per lux or the material shall be replaced.

2. All reflectance measurements shall be made on a clean, dry surface at a minimum temperature of 40°F (4°C).

3. All reflectance measurements shall be made using a “LTL 2000” retroreflectometer.

4. One year from initial installation acceptance all pavement marking material shall meet the minimum retained coefficient of dry retroreflection value of 125 millicandelas per foot squared per foot-candle (in accordance with ASTM E1710), and meet the minimum retained coefficient of wet retroreflection value of 75 millicandelas per foot squared per foot-candle (in accordance with ASTM E2177) for the following Warranty Periods.

Warranty Periods

APPLICATION	Dry Retroreflectivity Warranty Period	Wet Retroreflectivity Warranty Period
Longitudinal Markings	4 years	2 years
Symbols and Legends	2 years	1 year

After initial installation, the Contractor shall submit to the Department a Warranty Bond to insure the State of Delaware during the above Warranty periods. The bond shall be in the sum of 100%% of the original contract total cost bid for this item. The bond secures performance by the Contractor of any corrective work identified by the Department during the first (or subsequent) inspections after initial acceptance of the work. The bond shall be in effect for the entire warranty period (including the time to perform corrective work) listed in the table above. The Engineer will withhold in reserve an amount equal to 50% of the total Contract amount bid for this item until the Warranty Bond has been received.

The Contractor shall repair all defective areas identified by the Department after initial installation or during the Warranty Period. All repairs shall begin immediately following the notice to the Contractor unless weather limitations prevent the corrective work. Should the contractor not commence work within seventy-two hours, weather permitting, and pending severity, the Department reserves the right to remedy the condition and charge the contractor for the work. The contractor will be given the option of reimbursing the state prior to charging this work toward the bond. Any corrective work shall be as recommended by the manufacturer of the marking material and approved by the Department. The Department shall be given notification before the Contractor begins corrective work to allow for inspection of the operation. All costs associated with the repair work shall be the responsible of the contractor. These costs shall include, but are not limited to, removal, material, maintenance of traffic, etc.

12/27/06

APPENDIX D6

Agency: Idaho Transportation Department

Attached Example(s) of Warranty Specifications:

Pavement Marking Warranty	Period	Remarks
Recessed durable pavement markings with a 2-year warranty	2 years after initial acceptance	This is a true performance specification in that the overall requirement for durable markings does not specify any particular material. Materials that have been submitted under this specification include polyurea, epoxy, and hi-build waterborne paint. The specifications cover the following longitudinal lines including curves and tapers, edge lines, skip lines, centerlines, interchange gore lines, intersection channeling, and bicycle lane lines. The warranted performance is backed by the contractor, who must provide a warranty bond equal to total contract value prior to applying the pavement markings. This bond shall be maintained for the life of the contract. Warranty provisions are found in several parts of the "Construction Requirements" section: (1) the subsection titled "Warranted Retroreflective Performance and Monitoring Values," which includes quantitative performance values in Table 1; (2) the subsection titled "Warranted Durability Performance and Monitoring"; and (3) the subsection titled "Contractor's Warranty," followed by the subsection "Warranty Bond." Lane rental fees are assessed during the warranty performance period (but not for initial installation). The specifications include several quality-based mechanisms such as third-party inspection throughout the installation and performance periods, requirements for manufacturer's onsite representation and certification of the installing party, contractor submittal of a Pavement Marking Services Work Plan and other plans, a Pre-Operational meeting and annual meetings during the performance period, and contractor provision of test grinding strips and line stripes prior to actual application. Payment is staged annually over the 2-year performance period.

Pavement Marking Warranty	Period	Remarks
Recessed durable pavement markings with a 4-year warranty	4 years after initial acceptance	The above remarks apply in principle here as well, except that the warranty performance period is 4 years rather than 2 years. Materials that have been submitted under this specification include inlaid high-performance tape and methyl methacrylate (MMA).

IDAHO TRANSPORTATION DEPARTMENT
SPECIAL PROVISIONS: 2-YEAR WARRANTY

S910-05A MONITORING AND REPORTING
S911-05A RECESSED PAVEMENT MARKINGS

Description. This work shall consist of the application of durable pavement markings on the roadway in accordance with these specifications and as shown on the plans or as directed. The work to be done under this contract consists of the following activities and locations:

1. Install all recessed pavement markings in the locations indicated in the plans. Recessed pavement markings shall replace the existing pavement markings unless otherwise directed. The following pavement marking lines shall be replaced with recessed durable pavement markings:

- 4” white edge lines
- 4” white and yellow skip lines
- 4” yellow centerlines
- 8” interchange gore, intersection channelizing, and bicycle lane lines
- All of the above lines that are part of curves and tapers

2. Performance of additional and incidental work as called for by the specifications, including but not limited to brooming and layout work needed where existing pavement markings are not visible.

3. Prepare a Pavement Marking Services Work Plan that consists of proposed materials and methods of work and a schedule for work completion. The Work Plan shall also include provisions for traffic control and emergency responses and demonstrate how the Contractor shall comply with the construction requirements set forth in this specification.

4. Prior to acceptance of the installations, the initial retroreflectivity of the installed durable pavement markings shall be tested for compliance by a third party Independent Monitoring Contractor who is independent from both the Contractor and the durable pavement marking material Manufacturer. This Independent Monitoring Contractor shall monitor the retroreflectivity and report on the performance of all the installed durable pavement markings annually for the duration of the 2-year warranty. [0]The Independent Monitoring Contractor shall also inspect and report on all locations identified by the

Engineer as losing presence on the roadway. These reports will determine locations where the durable pavement markings will be replaced.

Materials. This specification is for performance based durable pavement markings. No material will be specified.

The Contractor shall be responsible for ordering, delivering, storing, handling, transferring, placing, and disposing of all materials used on this project. The State will not be responsible for any costs of sampling, testing, or certifying any materials used by the Contractor, Manufacturer, or supplier to fulfill contract requirements.

The Contractor shall provide and install Manufacturer certified products for durable pavement markings according to the Manufacturer's current guidelines and specifications. The materials shall be consistent with the Manufacturer's requirements and provide a pavement marking that will meet or exceed the warranty section of these specifications.

Color Stability—The Yellow color shall approximately match Federal 595 Color 33538. The products shall be lead and chromate free. The yellow product shall maintain its color for the duration of the warranty. Yellow product that shows a loss of color or appears white when viewed during the day or night shall be unacceptable.

The White color shall approximately match Federal 595 Color 37875. The products shall be lead and chromate free. The white product shall maintain its color for the duration of the warranty.

Construction Requirements. Install the markings according to the Manufacturer's recommendations and instructions. The Manufacturer shall provide a Representative during construction. The Manufacturer's Representative shall observe the application of durable pavement marking materials. The Contractor shall require the Manufacturer's Representative to immediately alert the Contractor of anything that could affect the performance of the product to meet the terms of the Warranty. The Contractor shall cooperate with the Manufacturer's Representative and the Engineer to ensure that the materials are placed in accordance with the Manufacturer's recommended procedures.

Project and Data Management—The Contractor shall provide effective and continuous communication between all vehicles in the operation and with the Engineer. The Contractor shall be responsible for project management throughout the term of the project. This effort shall be considered incidental to the overall S911-05A Recessed Pavement Markings bid.

The Contractor shall report the progress of installation work daily to the Engineer. Third party Independent Monitoring and reporting of performance data shall be reported on the initial installation. Performance data shall include location of work, including milepost, the pavement marking lines monitored, initial retroreflectivity values, initial durability values, and any segments that have been replaced as a result of the initial installation monitoring and testing.

The Contractor shall schedule an annual meeting at the beginning of each calendar year to discuss warranty compliance and evaluation data with the State. At the meeting, the Contractor shall indicate the third party Independent Monitoring inspection schedule. The third party Independent Monitoring and reporting of performance data shall be reported on each calendar year during the contract. Performance data shall include location of work, including milepost, the pavement marking lines monitored, initial and annual retroreflectivity values, initial and annual durability values, and any segments that have been replaced as a result of the annual monitoring and testing. At the meeting, the Contractor shall also present any plan for correction of deficient markings.

Submittals and Pre-Operational Meeting—A minimum of two weeks prior to the Pre-Operational Meeting, the Contractor shall submit all certification and product information for review and approval. The items to be submitted are as follows:

- The Pavement Marking Services Work Plan.
- Certification from the material Manufacturer that the Contractor and their equipment are certified to perform the applicable work.
- Pavement marking material samples shall be taken at the Manufacturer's facility by an approved, independent third party inspector. Samples shall be sent to the Idaho Transportation Department, Materials Laboratory, Chemistry Section, 3293 Jordan Street, Boise, Idaho, 83702. For all samples taken, the approved inspector shall include the following information: inspectors name, name of company, address, phone and fax numbers, project number, project key number, date and time sampled, batch or lot numbers, quantities, the name of the Manufacturer, and product name. A color chip or tape sample, depending on the material used, for each color shall be submitted for approval prior to use. These material samples are for reference only and not for testing or approval.
- An acceptable method of identifying each component of the inspected material from the Manufacturer.
- All durable pavement marking material documentation, certifications, specifications, application instructions, and samples.
- A spill recovery plan, which shall include at a minimum the following items:
  - Name, address, and phone number for the person designated as the Contractor's response coordinator and contact with the DEQ.
  - Name, address, and phone number of persons qualified, capable and on-call to do any cleanup.
- A warranty signed by the Contractor.
- Proof of a warranty bond from the Contractor equal to the total contract value.

Five working days prior to starting work, the Contractor shall meet with the Engineer for the Pre-Operational Meeting. At this meeting, they will discuss and provide the following:

- A pavement marking schedule showing work areas, timing of work, and placing of materials.
- A traffic control plan for review and acceptance.
- Discuss placement of materials and potential problems.
- Discuss the work plan at intersections.
- Discuss material handling procedures and procurement.

Recessed Markings—Placement of the recessed pavement markings shall not proceed without approval of the grinding.

The Contractor shall grind the slot to the correct depth, width, and length as specified by the durable pavement marking material Manufacturer's specifications and recommendations and in proper alignment. All grinding must be given final approval prior to the placement of any marking material. A diamond grinder shall be used to grind a smooth square slot to the depth tolerance specified by the material Manufacturer, to the width of the pavement marking line ±5%, and to the correct skip cycle length ±2 inches. Measurements for the depth and width of the slot and the marking material shall be taken at the centerline of the slot.

The diamond grinder shall have an articulating head so that the slots are installed parallel to the roadway surface on grades and super elevated sections. The ability of the diamond grinder to correctly install slots on grades and super elevated sections shall be demonstrated and approved. Shrouds and a vacuum apparatus shall be included as part of the grinder to pick up the pieces of pavement that are ground out.

Slots that are ground deeper or wider than the specified allowable limits shall be repaired according to the Manufacturers' approved repair procedure at no additional cost to the State. Slots that are ground too shallow or narrow shall be reground to the specification limits at no additional cost to the State. Slots that are ground out of alignment, too deep, or too wide shall be cut out and patched using an approved method and approved materials.

Equipment—All equipment used shall be approved by the pavement marking material Manufacturer and made specifically for the purpose of applying the durable material to a uniform width and thickness on the roadway surface. All equipment used to place double pavement markings shall be designed to place two parallel pavement markings in one pass.

Each grinding operator and each piece of grinding equipment must obtain approval before use. Each operator shall complete ¼ mile of grinding and shall receive approval prior to beginning the grinding operation. Each new operator or piece of equipment must obtain approval.

Prior to starting the grinding process, the Contractor shall place a ¼ mile test grinding in each District to demonstrate the pavement marking application processes. The Contractor shall not grind additional recessed slots on the project without receiving approval of the test performance. The test grinding shall be repeated until it has been demonstrated that the Contractor has suitable controls to grind the recessed slots accurately and properly. Any delay due to this test requirement will be at the Contractor's expense.

Pavement Surface—The Contractor shall prepare the pavement surface as the Manufacturer recommends.

Test Stripe—Prior to starting pavement marking installation, the Contractor shall place a 500 foot test stripe to demonstrate the pavement marking application processes. The Contractor shall not place additional permanent materials without receiving approval of the test performance. The test stripe shall be repeated until it has been demonstrated that the Contractor has suitable controls to place the materials accurately and properly. Any delay due to this test requirement will be at the Contractor's expense.

Application—The pavement markings shall be uniform and free from waving. Pavement markings shall not deviate laterally from the intended alignment by more than 2 in. per 100 feet. Skip pavement markings lengths shall be within ±2-inch tolerance for length and their placement shall be in accordance with Standard Drawing I-21-A except as noted below, or approved. If the existing skip markings have been placed so that they are longer than required or the gaps are less than required, the Contractor shall gradually adjust the spacing of the recessed pavement markings to match the existing markings, or as

directed. A maximum difference of 1.5 feet between the end of the new and the end of the existing skip markings may be allowed on an individual skip line to account for making this adjustment, as approved. All ends shall be square and clean. Dribbling of material beyond the cutoff will require immediate cleanup. Work shall be stopped until corrective measures can be taken if the pavement markings are not applied satisfactorily. The pavement marking widths shall be within a tolerance of ±5%.

If multiple passes of equipment are required to place the durable material to the correct depth, they shall result in the material being placed directly over the top of previous passes. The overlap shall result in a uniform thickness and width of the pavement marking and within the width tolerance of ±5%.

The Contractor shall protect the pavement markings to prevent tracking and to maintain the retroreflectivity of the markings. The new pavement marking material must be installed before the highway work zone is opened to traffic.

Alignment—Place markings on the roadways in proper alignment with existing markings and within the recessed slots. All marking ends shall be square and clean.

Pavement Marking Measurements and Records—The Contractor shall take Quality Control retroreflectivity readings representing the pavement markings installed each day during installation. Readings shall be taken at intervals not exceeding 1,000 feet of line distance per each pavement marking installed. The Contractor shall provide written documentation showing the section of highway the test area will represent, exact sample location, including mileposts, type of line, location on the roadway of the line tested, and the average retroreflectivity readings.

For Quality control retroreflectivity readings, the Contractor shall use a retroreflectometer having 30 meter geometry to determine the retroreflectivity of the pavement markings. Retroreflectivity measurements shall be taken according to ASTM E 1710 following the Manufacturers instructions for calibration and operation of the retroreflectometer.

Pavement markings shall be evaluated according to the requirements of ASTM D 6359 Standard Specification for Minimum Retroreflectance of Newly Applied Markings.

The Contractor shall record the following readings, and the locations where they were taken, for daily Quality Control evaluation:

- Record the depth of the ground slot and the marking material every 500 feet during the grinding and marking application operation.
- Measure the retroreflectivity of each pavement marking placed using a 30 meter geometry retroreflectometer that is compliant to ASTM E 1710 at intervals not exceeding 1,000 feet of line distance. Perform testing daily using handheld units to measure retroreflectivity of installed pavement markings.
- Make results available immediately after they have been recorded.

The Engineer reserves the right to use State handheld units to take independent Quality Assurance measurements of retroreflectivity.

Prior to acceptance of the project, the initial retroreflectivity for each line type shall be tested for compliance by a third party Independent Monitoring Contractor. The initial acceptance monitoring and annual monitoring shall be performed by a third party Independent Monitoring Contractor who is

independent from the Contractor and the Manufacturer. This Independent Monitoring Contractor shall notify the Engineer before performing monitoring. The findings of the durability and retroreflectivity monitoring shall be recorded and shared with the Engineer and Contractor within five business days of the readings be taken.

Warranted Retroreflective Performance and Monitoring Values—Table 1 provides the minimum warranted retroreflective performance values effective for the life of this Contract. The retained retroreflectivity of all pavement markings shall meet the minimum requirements in Table 1. They shall be maintained through the term of this contract and shall be considered the minimum level allowed for compliance and payment.

Table 1. Lane Line Retroreflectivity Performance Values

	Retroreflectivity (30 m geometry) mcd/m^2/lux	
	White	**Yellow**
Initial	250	175
End of 1st Year or Installation	150	125
End of 2nd Year of Installation	150	125

The Independent Monitoring Contractor shall use a mobile highway retroreflectometer system to measure all installed markings for initial acceptance and annual retroreflectivity measurements. The van shall be the Laserlux CEN 30 with the appropriate software from Gamma Scientific or approved equal.

All Independent Monitoring Contractor performed monitoring will be the average of 10 readings per line. Each reading will be the average of a 100 foot interval. The readings will be taken evenly spaced on a running 1,000 foot section. Failing averages will require replacement in kind of the entire 1,000 foot section.

Initial and annual measurement of the durable pavement markings will be conducted by the Independent Monitoring Contractor. If areas of pavement markings are found to be deficient during these annual inspections, the Contractor shall replace the deficient sections. The replaced pavement markings shall meet the performance requirements for the initial evaluation and shall also meet subsequent year evaluation criteria. Failure to meet any subsequent year performance criteria shall result in deficient markings and shall require another replacement to bring pavement markings into compliance.

Warranted Durability Performance and Monitoring—The Independent Monitoring Contractor shall monitor the durable pavement marking material for material retention on the pavement annually. This will be a staged inspection with the Engineer designating locations to inspect for material presence remaining on the pavement. Results from the retroreflectivity monitoring may also be used to identify locations that may be losing material. Once these locations are identified, the Independent Monitoring Contractor shall evaluate each identified location to determine the amount of material remaining on the roadway for each line per standards found in the National Transportation Product Evaluation Program (NTPEP) Project Work Plan for the Field and Laboratory Evaluation of Pavement Marking Materials.

Durability will be rated as a percent of marking material remaining on the pavement based on testing by the Independent Monitoring Contractor. The Independent Monitoring Contractor shall assign a percentage of marking material remaining (non-exposed substrate) on the 1,000-foot segment. Ten (10) percent of this number will be the rating assigned. Thus, a marking with no wear would receive a rating of 10. Three trained evaluators will rate separately and their ratings averaged for a final score. For each marking line, in each 1,000 foot section, the durability will be rated at 100 ft intervals. The average of the ratings per line will be used to rate that 1,000 foot section line. Lines with averages less than 8 will be failing averages and will require replacement of the entire 1,000 foot section under the warranty terms.

Unacceptable Materials and Work—All work that does not conform to the requirements of these specifications will be considered unacceptable. Non-specification materials, tracking marks, spilled material, materials not within allowable placement tolerances, rain damaged, unauthorized work, or markings applied in non-specified areas shall be considered as unacceptable work.

Unacceptable work placed during installation shall be remedied immediately if it causes a safety problem; otherwise, it shall be remedied prior to initial acceptance. Removal of this unacceptable work shall be accomplished by blasting, grinding, or removing the pavement and replacing it back to grade. Blacking out is not an acceptable method of removal. Removal of unacceptable work, collection of removed material, disposal, and remarking the effected area shall be at the Contractor's expense and the Contractor must receive approval before leaving the area.

The Contractor shall take immediate corrective action to correct pavement markings that do not meet the initial minimum retroreflectivity values found in Table 1 after daily Quality Control testing. The Contractor shall make the necessary adjustments to bring the pavement markings into conformance for retroreflectivity. The Contractor shall submit to and pass verification testing by the State on the pavement markings in the unacceptable area. The Contractor shall then apply a compliant pavement marking to the previously unacceptable section at no additional cost to the State.

Work and materials that conform to these Specifications shall replace any unacceptable work.

Durable permanent pavement markings applied by any method will be unacceptable if:

- The thickness of the pavement marking is inconsistent or less than specified.
- The top of the pavement marking is not smooth and uniform.
- Any pavement markings are damaged prior to curing.
- Retroreflectivity is too low.
- The material is uncured.
- The substrate is visible in the striped areas.
- The recessed slot is ground too deep or not ground deep enough.
- The recessed slot is ground too wide or not ground wide enough.
- The recessed slot is not filled to the specified depth.

- Successive spray passes are not aligned over the previous pass.
- The material blackens or is inconsistent in color.
- The marking exhibits poor adhesion.
- The color does not match the approved color chips.
- The top of the pavement marking is cupped.

Removal or Repair of Unacceptable Work—Areas that are unacceptable or fail to meet the specification requirements shall be corrected by the Contractor at no additional cost to the State. Repairs shall not be performed in a "patch-work" manner, meaning repairs shall not be any less than 1,000 feet of one line of material. If one repair is required in a single 1,000 foot section, the entire section shall be removed and replaced. The removed material becomes the property of the Contractor. If traffic control is required for removal of unacceptable material, the Contractor shall provide it at no additional cost to the State.

All materials that fail initial or annual durability and/or retroreflectivity requirements will be completely removed and replaced in kind at no additional expense to the State. The recessed slots will be cleared of all material and reviewed to ensure they are still within specified tolerances for depth and width. Slots not meeting the depth and width requirements shall be filled in or ground out to meet the specified tolerances.

Lane Rental Fees—Lane rental fees shall be assessed to the Contractor whenever traffic is impeded by work at each specific location during the duration of the contract period. There will be no assessment of the lane rental fees for the initial installation during the specified working hours and prior to the start of the performance period. The Engineer may determine that the fee will not be charged for lane closures for additional work not covered in the scope of the project or for any work stoppage or extenuating circumstances.

Work zones shall not exceed three miles in length in any one direction with a minimum of three miles between zones. The Contractor shall provide all necessary traffic control devices to provide adequate guidance and safety to the public at no additional cost to the State. All work will be performed at night between the hours of 10:00 PM and 6:00 AM, unless otherwise approved. All traffic control shall be approved before replacement work begins.

The lane rental fee for all lane closures shall be $750 per hour per mile of lane closed during night work hours. If the lane closure starts prior to 10:00 PM or extends beyond 6:00 AM the lane rental fee shall be $2,000 per hour per mile or portion thereof of lane closed.

The assessed lane rental charge will be deducted from the annual payment due the Contractor after markings are brought into compliance with the performance requirements of the contract. The lane rental charges will be assessed when lane closures are in place rounded up to the next full hour, whether or not work is in progress.

The lane rental assessment rate applies to traffic restrictions in one travel direction. If the Contractor chooses to restrict traffic in both directions at the same time, lane rental assessments will be applied for each direction. The Contractor shall be prohibited from closing two lanes in the same direction on multiple lane roads during any portion of the peak traffic period and shall maintain at least one lane of

traffic in each direction during all operations. The Contractor shall maintain at least one lane for traffic and flagger control when performing work on two-lane, two-way roads.

Work accomplished under moving operation lane closures shall be charged the same lane rental assessment rate.

Contractor's Warranty—The Contractor shall furnish a signed Warranty consisting of the following:

- A Warranty that all markings will stay in place and will maintain the minimum retroreflectivity found in Table 1. Lane Line Retroreflectivity Performance Values, through the 2-year Warranty period which will start on the date the work is accepted and initial payment is authorized.
- Annual monitoring of the durable pavement markings retroreflectivity and durability shall be conducted by a third party Independent Monitoring Contractor to determine if the durable pavement markings are performing within the requirements of this specification.
- The Independent Monitoring Contractor shall notify the Engineer before performing monitoring.
- An annual report, including a CD of the data, will be prepared and submitted summarizing the results of the monitoring and the corrective action required of the Contractor.
- The annual payments will be made once the annual durability and retroreflectivity inspection of the durable pavement markings has been completed, the annual report received, and all unacceptable markings have been replaced and accepted.
- The Warranty will state that the Contractor is required to replace all markings that fail bonding or drop below the required minimum retroreflectivity during the Warranty period. Corrective action shall be made within 30 days of written notice.
- When the Engineer makes a written request to the Contractor for repair or replacement, the Warranty period will suspend until the requested repairs or replacements are made and accepted.
- For the purpose of the Warranty, the average of the retroreflectivity readings of the pavement marking along a 1,000-foot segment not meeting the minimum retroreflective values will be considered a retroreflectivity failure. The monitoring will be the average of 10 readings per line. Each reading will be the average of a 100 foot interval. The readings will be taken evenly spaced on a running 1,000 foot section. Failing averages will require replacement in kind of the entire 1,000 foot section. The Contractor shall replace the entire 1,000-foot segment of pavement marking under the warranty terms.
- For the purpose of the Warranty, less than 80% of the material remaining along a 1,000-foot segment of markings will be considered a durability failure. Durability will be rated as a percent of marking material remaining on the pavement based on testing by the Independent Monitoring Contractor. This will be a staged inspection with the Engineer designating locations to be inspected. Results from the retroreflectivity monitoring may also be used to identify locations that may be losing material. Once these locations are identified the Independent Monitoring Contractor shall evaluate each identified location to determine the amount of material remaining on the roadway for each line per standards found in the National Transportation Product Evaluation Program (NTPEP) Project Work Plan for the Field and Laboratory Evaluation of Pavement Marking Materials. The Independent Monitoring Contractor shall assign a percentage

of marking material remaining (non-exposed substrate) on the 1,000-foot segment. Ten (10)% of this number will be the rating assigned. Thus, a marking with no wear would receive a rating of 10. Three trained evaluators will rate separately and their ratings averaged for a final score. For each marking line, in each 1,000 foot section, the durability will be rated at 100 ft intervals. The average of the ratings per line will be used to rate that 1,000 foot section line. Lines with averages less than 8 will be failing averages and will require replacement in kind of the entire 1,000 foot section. The marking along the entire 1,000-foot segment will be replaced under the warranty terms.

- All materials that fail initial or annual durability and/or retroreflectivity requirements shall be completely removed and replaced in kind at no additional expense to the State. The slots shall be cleared of all material and inspected to ensure they remain within specified tolerances for depth and width. Slots not meeting the depth or width requirements shall be filled or ground out to meet the specified tolerances. The new pavement marking material shall be identical to the original material and shall be placed in a manner similar to the original installation

- The Warranty shall include that the Contractor shall provide traffic control at Contractor's expense to replace all failing segments.

- Perform Warranty work when weather permits after coordinating an accepted schedule with the State. At the discretion of the Engineer, until the Warranty work is complete, temporary pavement markings and traffic control shall be required at the Contractor's expense.

The following practices will not be accepted as meeting the requirements of the warranty:

- Placing new, identical material on top of the original failed material.

- Placing paint or other material that is not identical to the original material over the top of the original failed material.

- Covering the original material with paint or another substance and placing new material, identical or not, over blacked out areas.

Warranty Bond—The Contractor shall be required to supply to the State a warranty bond equal to the total contract value. The entire value of the warranty bond shall be maintained for the life of the contract. The Contractor shall submit proof of bond before placing the material.

Method of Measurement. The Recessed Pavement Markings will be measured by the foot of actual pavement markings placed, exclusive of the gaps between skip stripes. The standard application width is considered to be 4 inches. If wider pavement markings are placed, the length of those pavement markings will be adjusted by converting them to an equivalent length of a 4 inch line on a proportionate area basis.

The Monitoring and Reporting will be measured by the line mile of actual pavement markings monitored.

Basis of Payment. Payment for Monitoring and Reporting will be made annually as the monitoring work for each evaluation period is completed and the report is approved by the State.

Payment for Recessed Pavement Markings accepted work will be made as a percentage of the bid amount as follows:

Initial (%)	End of 1st Year (%)	End of 2nd Year (%)
60	5	35

Initial payment shall be issued after all of the permanent markings included in the pay for performance project have been accepted. The date of this payment shall be the start of the two year performance period. Each annual payment will be made once the annual durability and retroreflectivity inspection of the permanent pavement markings has been completed, the annual report has been received, and all unacceptable markings have been replaced and accepted.

Payment for accepted work will be made as follows:

Pay Item	Pay Unit
S910-05A Monitoring and Reporting	MILE
S911-05A Recessed Pavement Markings	FT

Payment for Monitoring and Reporting will be for furnishing all materials, equipment, labor, and incidentals necessary to complete the work specified, and include annual payment to the Contractor for the following:

- Testing initial and annual retroreflectivity compliance
- Identifying locations that do not meet warranty specifications
- Recording, tabulating, and reporting monitoring and testing to the Engineer and the Contractor

Payment for Recessed Pavement Markings will be for furnishing all materials, equipment, labor, and incidentals, including brooming and material disposal, necessary to complete the work specified, and include payment for the following:

- Laying out the alignment
- Checking dimensional tolerance
- Removing existing pavement markings and other waste materials
- Furnishing a pavement marking schedule
- Placing test strips
- Placing layout guidelines
- Installing recessed pavement markings
- Removing and disposing of unacceptable materials

- Furnishing the Warranty
- Furnishing the Warranty bond

IDAHO TRANSPORTATION DEPARTMENT
SPECIAL PROVISIONS: 4-YEAR WARRANTY

S910-05A MONITORING AND REPORTING
S911-05A RECESSED PAVEMENT MARKINGS

Description. This work shall consist of the application of durable pavement markings on the roadway in accordance with these specifications and as shown on the plans or as directed. The work to be done under this contract consists of the following activities and locations:

1. Install all recessed pavement markings in the locations indicated in the plans. Recessed pavement markings shall replace the existing pavement markings unless otherwise directed. The following pavement marking lines shall be replaced with recessed durable pavement markings:

- 4” white edge lines
- 4” white and yellow skip lines
- 4” yellow centerlines
- 8” interchange gore, intersection channelizing, and bicycle lane lines
- All of the above lines that are part of curves and tapers

2. Performance of additional and incidental work as called for by the specifications, including but not limited to brooming and layout work needed where existing pavement markings are not visible.

3. Prepare a Pavement Marking Services Work Plan that consists of proposed materials and methods of work and a detailed schedule for work completion. The Work Plan shall include a complete initial inventory of all assets to be used in performing the work, a detailed reporting system, and work plans. All work performed shall be documented in a monthly report. The Work Plan shall also include provisions for traffic control and emergency responses and demonstrate how the Contractor shall comply with the construction requirements set forth in this specification.

4. Prior to acceptance of the installations, the initial retroreflectivity of the installed durable pavement markings shall be tested for compliance by a third party Independent Monitoring Contractor who is independent from both the Contractor and the durable pavement marking material Manufacturer. This Independent Monitoring Contractor shall monitor the retroreflectivity and report on the performance of all the installed durable pavement markings annually for the duration of the 4-year warranty. [0]The Independent Monitoring Contractor shall inspect and report on all locations identified by the Engineer as losing presence on the roadway. These reports will determine locations where the durable pavement markings will be replaced.

Materials. This specification is for performance based durable pavement markings. No material will be specified.

The Contractor shall be responsible for ordering, delivering, storing, handling, transferring, placing, and disposing of all materials used on this project. The State will not be responsible for any costs of sampling, testing, or certifying any materials used by the Contractor, Manufacturer, or supplier to fulfill contract requirements.

The Contractor shall provide and install Manufacturer certified products for pavement marking according to the Manufacturer's current guidelines and specifications. The materials shall be consistent with the Manufacturer's requirements and provide a pavement marking that will meet or exceed the warranty section of these specifications.

Color Stability—The Yellow color shall approximately match Federal 595 Color 33538. The products shall be lead and chromate free. The yellow product shall maintain its color for the duration of the warranty. Yellow product that shows a loss of color or appears white when viewed during the day or night shall be unacceptable.

The White color shall approximately match Federal 595 Color 37875. The products shall be lead and chromate free. The white product shall maintain its color for the duration of the warranty.

Construction Requirements. Install the markings according to the Manufacturer's recommendations and instructions. The Manufacturer shall provide a Representative during construction. The Manufacturer's Representative shall observe the application of durable permanent pavement marking materials. The Contractor shall require the Manufacturer's Representative to immediately alert the Contractor of anything that could affect the performance of the product to meet the terms of the Warranty. The Contractor shall cooperate with the Manufacturer's Representative and the Engineer to ensure that the materials are placed in accordance with the Manufacturer's recommended procedures.

Project and Data Management—The Contractor shall provide effective and continuous communication between all vehicles in the operation and with the Engineer. The Contractor shall be responsible for project management throughout the term of the project. This effort shall be considered incidental to the overall S911-05A Recessed Pavement Markings bid.

The Contractor shall report the progress of installation work daily to the Engineer. Monitoring and reporting of performance data shall also be reported on an annual basis during the contract. Performance data shall include location of work, including milepost, the pavement marking lines monitored, initial and annual retroreflectivity values, initial and annual durability values, and any segments that have been replaced as a result of the annual monitoring and testing.

The Contractor shall schedule an annual meeting at the start of each contract year to discuss warranty compliance and evaluation data with the State. At the meeting, the Contractor shall present any plan for correction of deficient markings.

Submittals and Pre-Operational Meeting—A minimum of two weeks prior to the Pre-Operational Meeting, the Contractor shall submit all certification and product information for review and approval. The items to be submitted are as follows:

- The Pavement Marking Services Work Plan.

- Certification from the material Manufacturer that the Contractor and their equipment are certified to perform the applicable work.

- Pavement marking material samples shall be taken at the Manufacturer's facility by an approved, independent third party inspector. Samples shall be sent to the Idaho Transportation Department, Materials Laboratory, Chemistry Section, 3293 Jordan Street, Boise, Idaho, 83702. For all samples taken, the approved inspector shall include the following information: inspectors name, name of company, address, phone and fax numbers, project number, project key number, date and time sampled, batch or lot numbers, quantities, the name of the Manufacturer, and product name. A color chip or tape sample, depending on the material used, for each color shall be submitted for approval prior to use. These material samples are for reference only and not for testing or approval.

- An acceptable method of identifying each component of the inspected material from the Manufacturer.

- All durable pavement marking material documentation, certifications, specifications, application instructions, and samples.

- A spill recovery plan, which shall include at a minimum the following items:

  - Name, address, and phone number for the person designated as the Contractor's response coordinator and contact with the DEQ.
  - Name, address, and phone number of persons qualified, capable and on-call to do any cleanup.

- A warranty signed by the Contractor.

- Proof of a warranty bond from the Contractor equal to the total contract value.

Five working days prior to starting work, the Contractor shall meet with the Engineer for the Pre-Operational Meeting. At this meeting, they will discuss and provide the following:

- A pavement marking schedule showing work areas, timing of work, and placing of materials.

- A traffic control plan for review and acceptance.

- Discuss placement of materials and potential problems.

- Discuss the work plan at intersections.

- Discuss material handling procedures and procurement.

Recessed Markings—Placement of the recessed pavement markings shall not proceed without approval of the grinding.

The Contractor shall grind the slot to the correct depth, width, and length as specified by the durable pavement marking material Manufacturer's specifications and recommendations and in proper alignment. All grinding must be given final approval prior to the placement of any marking material. A diamond grinder shall be used to grind a smooth square slot to the depth tolerance specified by the material

Manufacturer, to the width of the pavement marking line ±5%, and to the correct skip cycle length ±2 inches. Measurements for the depth of the slot and the marking material shall be taken at the centerline of the slot.

The diamond grinder shall have an articulating head so that the slots are installed correctly on grades and super elevated sections. The ability of the diamond grinder to correctly install slots on grades and super elevated sections shall be demonstrated and approved. Shrouds and a vacuum apparatus shall be included as part of the grinder to pick up the pieces of pavement that are ground out.

Slots that are ground deeper or wider than the specified allowable limits shall be repaired according to the Manufacturers' approved repair procedure at no additional cost to the State. Slots that are ground too shallow or narrow shall be reground to the specification limits at no additional cost to the State. Slots that are ground out of alignment shall be cut out and patched using an approved method and approved materials.

Equipment—All equipment used shall be approved by the pavement marking material Manufacturer and made specifically for the purpose of applying the durable material to a uniform width and thickness on the roadway surface. All equipment used to place double pavement markings shall be designed to place two parallel pavement markings in one pass.

Each grinding operator and each piece of grinding equipment must obtain approval. Each operator shall complete ¼ mile of grinding and shall be approved prior to beginning the grinding operation. This approval shall be for the duration of the entire statewide project. Each new operator or piece of equipment must obtain approval.

Prior to starting the grinding process, the Contractor shall place a ¼ mile test grinding in each District to demonstrate the pavement marking application processes. The Contractor shall not grind recessed slots on the project without receiving approval of the test performance. The performance test shall be repeated until it has been demonstrated that the Contractor has suitable controls to grind the recessed slots accurately and properly. Any delay due to this test requirement will be at the Contractor's expense.

Pavement Surface—The Contractor shall prepare the pavement surface as the Manufacturer recommends.

Test Stripe—Prior to starting pavement marking installation, the Contractor shall place a 500 foot test stripe to demonstrate the pavement marking application processes. The Contractor shall not place permanent materials without receiving approval of the test performance. The performance test shall be repeated until it has been demonstrated that the Contractor has suitable controls to place the materials accurately and properly. Any delay due to this test requirement will be at the Contractor's expense.

Application—The pavement markings shall be uniform and free of waves. Pavement markings shall not deviate from the intended alignment by more than 2 in. per 100 ft. Skip pavement marking lengths shall be as currently marked on the roadway and within ±2-inch tolerance for length of placement. If the existing skip markings have been placed incorrectly so that they are longer than required or the gaps are less than required, the Contractor shall install the recessed pavement markings in the correct skip pattern as directed by the Engineer. A 1.5-ft end-to-end overlap on skip markings is allowed during the initial startup but the overlap shall be back to within ±2 inches within three skip cycles. All ends shall be square and clean. Dribbling of material beyond the cutoff will require immediate cleanup. If the pavement markings are not applied satisfactorily, work shall be stopped until corrective measures can be taken to produce satisfactory work. The pavement marking widths shall be within a tolerance of ±5%.

If multiple passes of equipment are required to place the durable material to the correct depth, they shall result in the material being placed directly over the top of previous passes. The overlap shall result in a uniform thickness and width of the pavement marking and within the width tolerance of ±5%.

The Contractor shall protect the pavement markings to prevent tracking and to maintain the retroreflectivity of the markings. The pavement marking material must be installed before the highway work zone is opened to traffic.

Alignment—Place markings on the roadways in proper alignment with existing markings and within the recessed slots. All marking ends shall be square and clean.

Pavement Marking Measurements and Records—The Contractor shall take Quality Control retroreflectivity readings representing the pavement markings installed each day during installation. Readings shall be taken at intervals not exceeding 1,000 feet of line distance per each pavement marking installed. The Contractor shall provide written documentation showing the section of highway the test area will represent, exact sample location, including mileposts, type of line, location on the roadway of the line tested, and the average retroreflectivity readings.

The Contractor shall use a retroreflectometer having 30 meter geometry to determine the retroreflectivity of the pavement markings. Retroreflectivity measurements shall be taken according to ASTM E 1710 following the Manufacturers instructions for calibration and operation of the retroreflectometer. Pavement markings shall be evaluated according to the requirements of ASTM D 6359 Standard Specification for Minimum Retroreflectance of Newly Applied Markings.

The Contractor shall record the following readings, and the locations where they were taken, for daily Quality Control evaluation:

- Record the depth of the ground slot and the marking material every 500 feet during the grinding and marking application operation.
- Measure the retroreflectivity of each pavement marking placed using a 30 meter geometry retroreflectometer that is compliant to ASTM E 1710 at intervals not exceeding 1,000 feet of line distance. Perform testing daily using handheld units to measure retroreflectivity of installed pavement markings.
- Make results available immediately after they have been recorded.

The Engineer reserves the right to use State handheld units to take independent Quality Assurance measurements of retroreflectivity.

Prior to acceptance of the project, the initial retroreflectivity for each line type shall be tested for compliance by a third party Independent Monitoring Contractor. The initial acceptance monitoring and annual monitoring shall be performed by a third party Independent Monitoring Contractor who is independent from the Contractor and the Manufacturer. This Independent Monitoring Contractor shall notify the Engineer before performing monitoring. The findings of the durability and retroreflectivity monitoring shall be recorded and shared with the Engineer and Contractor within five business days of the readings be taken.

Warranted Retroreflective Performance and Monitoring Values—Table 1 provides the minimum warranted retroreflective performance values effective for the life of this Contract. The retained retroreflectivity of all pavement markings shall meet the minimum requirements in Table 1. They shall

be maintained through the term of this contract and shall be considered the minimum level allowed for compliance and payment.

Table 1. Lane Line Retroreflectivity Performance Values

	Retroreflectivity (30 m geometry) mcd/m^2/lux	
	White	**Yellow**
Initial	250	175
End of 1st Year	150	125
End of 2nd Year	150	125
End of 3rd Year	150	125
End of 4th Year	150	125

The Independent Monitoring Contractor shall use a mobile highway retroreflectometer system to measure all installed markings for initial acceptance and annual retroreflectivity measurements. The van shall be the Laserlux CEN 30 with the appropriate software from Gamma Scientific or approved equal.

The monitoring will be the average of 10 readings per line. Each reading will be the average of a 100 foot interval. The readings will be taken evenly spaced on a running 1,000 foot section. Failing averages will require replacement in kind of the entire 1,000 foot section.

Annual measurement of the durable pavement markings will be conducted by the Independent Monitoring Contractor. If areas of pavement markings are found to be deficient during these annual inspections, the Contractor shall replace the deficient sections. The replaced pavement markings shall meet the performance requirements for the initial evaluation and shall also meet subsequent year evaluation criteria. Failure to meet any subsequent year performance criteria shall result in deficient markings and shall require another replacement to bring pavement markings into compliance.

Warranted Durability Performance and Monitoring—The Independent Monitoring Contractor shall monitor the durable pavement marking material for material retention on the pavement annually. This will be a staged inspection with the Engineer designating locations to inspect for material presence remaining on the pavement. Results from the retroreflectivity monitoring may also be used to identify locations that may be losing material. Once these locations are identified the Independent Monitoring Contractor shall evaluate each identified location to determine the amount of material remaining on the roadway for each line per standards found in the National Transportation Product Evaluation Program (NTPEP) Project Work Plan for the Field and Laboratory Evaluation of Pavement Marking Materials.

Durability will be rated as a percent of marking material remaining on the pavement based on testing by the Independent Monitoring Contractor. The Independent Monitoring Contractor shall assign a percentage of marking material remaining (non-exposed substrate) on the 1,000-foot segment. Ten (10)% of this number will be the rating assigned. Thus, a marking with no wear would receive a rating of 10. Three trained evaluators will rate separately and their ratings averaged for a final score. For each marking line, in each 1,000 foot section, the durability will be rated at 100 ft intervals. The average of the ratings per

line will be used to rate that 1,000 foot section line. Lines with averages less than 8 will be failing averages and will require replacement of the entire 1,000 foot section under the warranty terms.

Unacceptable Materials and Work—All work that does not conform to the requirements of these specifications will be considered unacceptable. Non-specification materials, tracking marks, spilled material, materials not within allowable placement tolerances, rain damaged, unauthorized work, or markings applied in non-specified areas shall be considered as unacceptable work.

Unacceptable work placed during installation shall be remedied immediately if it causes a safety problem; otherwise, it shall be remedied prior to initial acceptance. Removal of this unacceptable work shall be accomplished by blasting, grinding, or removing the pavement and replacing it back to grade. Blacking out is not an acceptable method of removal. Removal of unacceptable work, collection of removed material, disposal, and remarking the effected area shall be at the Contractor's expense and the Contractor must receive approval before leaving the area.

The Contractor shall take immediate corrective action to correct pavement markings that do not meet the initial minimum retroreflectivity values found in Table 1 after daily Quality Control testing. The Contractor shall make the necessary adjustments to bring the pavement markings into conformance for retroreflectivity. The Contractor shall submit to and pass verification testing by the State on the pavement markings in the unacceptable area. The Contractor shall then apply a compliant pavement marking to the unacceptable section at no additional cost to the State.

Work and materials that conform to these Specifications shall replace any unacceptable work.

Durable permanent pavement markings applied by any method will be unacceptable if:

- The thickness of the pavement marking is inconsistent or less than specified.
- The top of the pavement marking is not smooth and uniform.
- Any pavement markings are damaged prior to curing.
- Retroreflectivity is too low.
- The material is uncured.
- The substrate is visible in the striped areas.
- The recessed slot is not ground deep enough.
- The recessed slot is not filled to the specified depth.
- Successive spray passes are not aligned over the previous pass.
- The material blackens or is inconsistent in color.
- The marking exhibits poor adhesion.
- The color does not match the approved color chips.
- The top of the pavement marking is cupped.

Removal or Repair of Unacceptable Work—Areas that are unacceptable or fail to meet the specification requirements shall be corrected by the Contractor at no additional cost to the State. Repairs shall not be performed in a "patch-work" manner, meaning repairs shall not be any less than 1,000 feet of one line of material. If one repair is required in a single 1,000 foot section, the entire section shall be required to be removed and replaced. The removed material becomes the property of the Contractor. If traffic control is required for removal of unacceptable material, the Contractor shall provide it at no additional cost to the State.

All materials that fail initial or annual durability and/or retroreflectivity requirements will be completely removed and replaced in kind at no additional expense to the State. The recessed slots will be cleared of all material and reviewed to ensure they are still within specified tolerances for depth. Slots not meeting the depth requirements shall be filled in or ground out to meet the specified tolerances.

Lane Rental Fees—Lane rental fees shall be assessed to the Contractor whenever traffic is impeded by work at each specific location during the duration of the contract period. There will be no assessment of the lane rental fees for the initial installation during the specified working hours and prior to the start of the performance period. The Engineer may determine that the fee will not be charged for lane closures for additional work not covered in the scope of the project or for any work stoppage or extenuating circumstances.

Work zones shall not exceed three miles in length in any one direction with a minimum of three miles between zones. The Contractor shall provide all necessary traffic control devices to provide adequate guidance and safety to the public at no cost to the State. All work will be performed at night between the hours of 10:00 PM and 6:00 AM. All traffic control shall be approved before replacement work begins.

The lane rental fee for all lane closures shall be $750 per hour per mile of lane closed during night work hours. If the lane closure starts prior to 10:00 PM or extends beyond 6:00 AM the lane rental fee shall be $2,000 per hour or portion thereof per mile of lane closed.

The assessed lane rental charge will be deducted from the annual payment due the Contractor after markings are brought into compliance with the performance requirements of the contract. The lane rental charges will be assessed when lane closures are in place rounded up to the next full hour, whether or not work is in progress.

The lane rental assessment rate applies to traffic restrictions in one travel direction. If the Contractor chooses to restrict traffic in both directions at the same time, lane rental assessments will be applied for each direction. The Contractor shall be prohibited from closing two lanes in the same direction on multiple lane roads during any portion of the peak period and shall maintain at least one lane of traffic in each direction during all operations. The Contractor shall maintain at least one lane for traffic and flagger control when performing work on two-lane, two-way roads.

Work accomplished under moving operation lane closures shall be charged the same lane rental assessment rate.

Contractor's Warranty—The Contractor shall furnish a signed Warranty consisting of the following:

- A Warranty that all markings will stay in place and will maintain the minimum retroreflectivity found in Table 1. Lane Line Retroreflectivity Performance Values, through the 4-year Warranty period which will start on the date the work is accepted and initial payment is authorized.

- Annual monitoring of the durable pavement markings retroreflectivity and durability shall be conducted by a third party Independent Monitoring Contractor to determine if the durable pavement markings are performing within the requirements of this specification.

- The Independent Monitoring Contractor shall notify the Engineer before performing monitoring.

- An annual report, including a CD of the data, will be prepared and submitted summarizing the results of the monitoring and the corrective action required by the Contractor.

- The annual payments will be made once the annual durability and retroreflectivity inspection of the durable pavement markings has been completed, the annual report received, and all unacceptable markings have been replaced and accepted.

- The Warranty will state that the Contractor is required to replace all markings that fail bonding or drop below the required minimum retroreflectivity during the Warranty period. Corrective action shall be made within 30 days of written notice.

- When the Engineer makes a written request to the Contractor for repair or replacement, the Warranty period will stop until the requested repairs or replacements are made and accepted.

- For the purpose of the Warranty, the average of the retroreflectivity readings of the pavement marking along a 1,000-foot segment not meeting the minimum retroreflective values will be considered a retroreflectivity failure. The monitoring will be the average of 10 readings per line. Each reading will be the average of a 100 foot interval. The readings will be taken evenly spaced on a running 1,000 foot section. Failing averages will require replacement in kind of the entire 1,000 foot section. The Contractor shall replace the entire 1,000-foot segment of pavement marking under the warranty terms.

- For the purpose of the Warranty, less than 80% of the material remaining along a 1,000-foot segment of markings will be considered a durability failure. Durability will be rated as a percent of marking material remaining on the pavement based on a test by the Independent Monitoring Contractor. This will be a staged inspection with the Engineer designating locations to be inspected. Results from the retroreflectivity monitoring may also be used to identify locations that may be losing material. Once these locations are identified the Independent Monitoring Contractor shall evaluate each identified location to determine the amount of material remaining on the roadway for each line per standards found in the National Transportation Product Evaluation Program (NTPEP) Project Work Plan for the Field and Laboratory Evaluation of Pavement Marking Materials. The Independent Monitoring Contractor shall assign a percentage of marking material remaining (non-exposed substrate) on the 1,000-foot segment. Ten (10)% of this number will be the rating assigned. Thus, a marking with no wear would receive a rating of 10. Three trained evaluators will rate separately and their ratings averaged for a final score. For each marking line, in each 1,000 foot section, the durability will be rated at 100 ft intervals. The average of the ratings per line will be used to rate that 1,000 foot section line. Lines with averages less than 8 will be failing averages and will require replacement in kind of the entire 1,000 foot section. The marking along the entire 1,000-foot segment will be replaced under the warranty terms.

- All materials that fail initial or annual durability and/or retroreflectivity requirements shall be completely removed and replaced in kind at no additional expense to the State. The slots shall be cleared of all material and inspected to ensure they remain within specified tolerances for depth

and width. Slots not meeting the depth or width requirements shall be filled or ground out to meet the specified tolerances. The new pavement marking material shall be identical to the original material and shall be placed in a manner similar to the original installation

- The Warranty shall include that the Contractor shall provide traffic control at Contractor's expense to replace all segments.

- Perform Warranty work when weather permits after coordinating an accepted schedule with the State. At the discretion of the Engineer, until the Warranty work is complete, temporary pavement markings and traffic control shall be required at the Contractor's expense.

The following practices will not be accepted as meeting the requirements of the warranty:

- Placing new, identical material on top of the original failed material.

- Placing paint or other material that is not identical to the original material over the top of the original failed material.

- Covering the original material with paint or another substance and placing new material, identical or not, over blacked out areas.

Warranty Bond—The Contractor shall be required to supply to the State a warranty bond equal to the total contract value. The entire value of the warranty bond shall be maintained for the life of the contract. The Contractor shall submit proof of bond before placing the material.

Method of Measurement. The Recessed Pavement Markings will be measured by the foot of actual pavement markings placed, exclusive of the gaps between skip stripes. The standard application width is considered to be 4 inches. If wider pavement markings are placed, the length of those pavement markings will be adjusted by converting them to an equivalent length of a 4 inch line on a proportionate area basis.

The Monitoring and Reporting will be measured by the line mile of actual pavement markings monitored.

Basis of Payment. Payment for Monitoring and Reporting will be made annually as the monitoring work for each evaluation period is completed and the report is received by the State.

Payment for Recessed Pavement Markings accepted work will be made as a percentage of the bid amount as follows:

Initial (%)	**End of 1st Year (%)**	**End of 2nd Year (%)**	**End of 3rd Year (%)**	**End of 4th Year (%)**
60	5	5	5	25

Initial payment shall be issued after all of the permanent markings included in the pay for performance project have been accepted. The date of this payment shall be the start of the four year performance period. Each annual payment will be made once the annual durability and retroreflectivity inspection of the permanent pavement markings has been completed, the annual report has been received, and all unacceptable markings have been replaced and accepted.

Payment for accepted work will be made as follows:

Pay Item	Pay Unit
S910-05A Monitoring and Reporting	MILE
S911-05A Recessed Pavement Markings	FT

Payment for Monitoring and Reporting will be for furnishing all materials, equipment, labor, and incidentals necessary to complete the work specified, and include annual payment to the Contractor for the following:

- Testing initial and annual retroreflectivity compliance
- Identifying locations that do not meet warranty specifications
- Recording, tabulating, and reporting monitoring and testing to the Engineer and the Contractor

Payment for Recessed Pavement Markings will be for furnishing all materials, equipment, labor, and incidentals, including brooming and material disposal, necessary to complete the work specified, and include payment for the following:

- Laying out the alignment
- Checking dimensional tolerance
- Removing existing pavement markings and other waste materials
- Furnishing a pavement marking schedule
- Placing test strips
- Placing layout guidelines
- Installing recessed pavement markings
- Removing and disposing of unacceptable materials
- Furnishing the Warranty
- Furnishing the Warranty bond

APPENDIX D7

Agency: Illinois Department of Transportation

Attached Example(s) of Warranty Specifications:

Pavement Marking Specification	Period	Remarks
Pavement Striping (SECTION 780): specifications encompass thermoplastic, paint, preformed plastic, epoxy, preformed thermoplastic, and compatible glass beads.	180 days through a winter	The specifications discuss required properties and application requirements for each pavement marking material. The specifications cover lines, words, and symbols. Warranty provisions are discussed in Section 780.10. The winter performance period extends 180 days from Nov. 1st. Contractors, who must be on the list of Approved Contractors, are responsible for fulfilling warranty requirements.
Raised Reflective Pavement Markings (SECTION 781)	180 days through a winter	These specifications cover raised reflective pavement markers, including required properties and installation requirements. The warranty provisions are discussed in Section 781.04. The winter performance period extends 180 days from Nov. 30th. Contractors are the responsible party for fulfilling warranty requirements.

PAVEMENT MARKING

SECTION 780. PAVEMENT STRIPING

780.01 Description. This work shall consist of furnishing and applying pavement marking.

780.02 Materials. Materials shall be according to the following.

Item	Article/Section
(a) Thermoplastic Pavement Markings	1095.01
(b) Paint Pavement Markings	1095.02
(c) Preformed Plastic Pavement Markings	1095.03
(d) Epoxy Pavement Marking	1095.04
(e) Preformed Thermoplastic Pavement Marking	1095.05
(f) Glass Beads for Pavement Markings	1095.07

780.03 Equipment. Equipment shall be according to the following.

Item	Article/Section
(a) Thermoplastic Truck-Mounted (Note 1)	1105.01(a)
(b) Thermoplastic Hand-Operated (Note 1)	1105.01(b)
(c) Epoxy	1105.02

Note 1. A mechanical beader approved by the Engineer shall be used.

CONSTRUCTION REQUIREMENTS

780.04 General. Thermoplastic and epoxy pavement markings shall only be applied by Contractors on the list of Approved Contractors maintained by the Engineer of Operations and in effect on the date of advertisement for bids.

Pavement marking on freeways shall be placed with truck-mounted equipment. Markings on roads other than freeways may be placed with either truck-mounted or hand-operated equipment.

Before applying the pavement marking material, the pavement shall be clean, dry, and free of debris or any other material that would reduce the adhesion of the markings on the pavement.

The edge of a center line or lane line shall be offset a minimum distance of 2 in. (50 mm) from a longitudinal crack or joint. Edge lines shall be approximately 2 in. (50 mm) from the edge of pavement. The finished center and lane lines shall be straight, with the lateral deviation of any 10 ft (3 m) line 1 in. (25 mm) or less.

Pavement marking words and symbols shall conform closely to the dimensions and spacing specified in the MUTCD and the plans. Deviations from the required dimensions and spacing or other departures from reasonable standards of professionalism will be cause for rejection by the Engineer.

The words and symbols shall be as specified in Table 1 in Article 780.12.

780.05 Thermoplastic. Prior to applying the thermoplastic pavement markings, the existing pavement markings shall be removed. The area removed shall be no wider than the width of the existing pavement markings. The new thermoplastic pavement markings shall be applied over the location where the pavement markings were removed.

The Contractor shall notify the Engineer 72 hours prior to the placement of the thermoplastic markings. At the time of this notification, the Contractor shall indicate the manufacturer and lot numbers of thermoplastic and glass beads he/she intends to use.

The compound shall be installed in a molten state at a minimum temperature of 400ºF (205ºC) and maximum temperature of 475ºF (245ºC). Scorching or discoloration of material will be cause for rejection by the Engineer. The machinery shall be constructed so all mixing and conveying parts, up to and including the shaping-die, maintain the material in a molten state.

Thermoplastic shall be applied only when the pavement temperature is 55ºF (13ºC) or greater and no later than November 1 or earlier than April 15. If the thermoplastic markings cannot be placed according to these specifications and the road is to be opened to traffic between November 1 and April 15 and no adequate pavement markings are in place, the Contractor shall, at the direction of the Engineer, place temporary pavement markings according to Section 703. The Contractor shall remove the temporary pavement markings and place the thermoplastic pavement markings on or after April 15 or as agreed upon by the Engineer.

A binder sealer shall be applied on all hot-mix asphalt (HMA) pavements over 60 days old and on all portland cement concrete pavement surfaces where the new thermoplastic material is to be installed. The binder sealer material shall be applied as recommended by the manufacturer of the thermoplastic and in sufficient quantities to entirely cover the surface on which the thermoplastic is to be laid.

The thermoplastic material shall be applied at a thickness of not less than 100 mils (2.50 mm) but no greater than 110 mils (2.75 mm). Finished lines shall be within 1/4 in. (6 mm) of the width specified in the plans.

Thermoplastic markings shall be placed with drop on glass beads according to Article 1095.01, uniformly applied to assure adequate nighttime reflectivity. It shall be the Contractor’s responsibility to use a compatible combination of thermoplastic material and beads to preclude the surface beads from sinking deeply into the thermoplastic.

The thickness of the markings will be measured above the pavement surface at random points as selected by the Engineer, to determine conformance.

(a) If the measurements show less than 100 mils (2.50 mm), the Engineer will “chip” the edges of the markings at random points and measure the thickness of the chips to determine if the overall thickness of the markings is at least 100 mils (2.50 mm). When either the overall thickness or the thickness above the pavement surface is substantially in conformance with the thickness requirements, payment will be made at 100 percent of the contract unit prices involved.

(b) If the thickness at a given location is less than 100 mils (2.50 mm), additional measurements will be taken on each side of the location by the Engineer to determine the extent of the deficient portion of the marking. If the average thickness of the deficient portion is less than 100 mils (2.50 mm) but more than 60 mils (1.50 mm), an adjusted unit price of 50 percent of the contract unit price involved will be used in computing payment for the area which is deficient.

(c) If the measurements show the average thickness to be less than 60 mils (1.50 mm), the Contractor shall remove the surface of the deficient portions of the markings sufficiently to reduce the average thickness to approximately 50 mils (1.25 mm) or less. The Contractor shall then apply additional thermoplastic material and beads to bring the thickness of the markings to at least 100 mils (2.50 mm) and the reflectivity to the minimum required values.

780.06 Paint. Prior to application of the paint pavement marking, the Contractor shall make certain the pavement surface is dry and free of dirt or grease and, if necessary, clean the surface to the satisfaction of the Engineer.

Paint shall not be applied at air temperatures below 50ºF (10ºC), unless approved by the Engineer.

The paint shall be applied at a minimum thickness of 16 mils (406 µm) and beads shall be applied to all painted surfaces at the minimum rate of 6.0 lb/gal (720 g/L) of paint used.

780.07 Preformed Plastic. The markings shall be capable of being applied on either new HMA surfaces by being inlaid into the surface, or on new and existing portland cement concrete and HMA surfaces, by means of a pressure-sensitive, precoated adhesive, or liquid contact cement which shall be applied at the time of installation.

The pavement shall be cleaned as recommended by the manufacturer.

Cleaning operations shall not begin until a minimum of 30 days after the placement of new portland cement concrete pavement.

The cleaning operation shall remove all visible evidence of curing compound on the peaks and valleys of textured concrete surfaces, remove all loose and flaking material, and round any sharp edges and irregularities.

When recommended by the manufacturer, a primer sealer shall be applied on all pavement surfaces where new preformed plastic pavement marking material is to be applied. The primer sealer shall be recommended by the manufacturer of the preformed plastic pavement material and shall be compatible with the material being used. The primer sealer shall be applied in sufficient quantities to entirely cover the pavement surface where the plastic material is to be placed. The Contractor shall not install the preformed plastic pavement markings until the primer sealer dries according to the manufacturer’s recommendations.

The markings placed on the pavement shall be rolled and compacted onto the pavement with a roller or tamper cart approved by the manufacturer. This roller shall be loaded with or weigh at least 200 lb (90 kg). The Contractor shall tamp and roll the material sufficiently to prevent easy removal or peeling. Care shall be taken to cut the material in and around pavement joints or cracks and roll the material into the cracks of joints.

(a) Type B—Inlaid Application. On freshly placed HMA, the inlaid markings shall be applied before final compaction and when the pavement temperature has cooled to approximately 150ºF (65ºC) and when, in the opinion of the Engineer, the pavement is acceptable for vehicular traffic.

The markings shall be applied at a minimum thickness of 60 mils (1.5 mm).

The markings shall be placed on the pavement by means of a mechanical applicator or by a hand method and embedded into the pavement surface with a static compaction roller with minimum water on the roller.

The initial rolling of the markings shall be in the same direction as the application to minimize buckling in front of the roller. The roller shall not be allowed to turn on the markings.

The markings shall be embedded to a depth of approximately 0.04 in. (1.0 mm).

(b) Type B or C—Standard Application. The material shall be applied only when the air temperature is 60ºF (15ºC) or above and rising and the pavement temperature is 70ºF (21ºC) or greater. However, standard application of preformed plastic pavement markings will not be allowed after October 15.

When the preformed plastic markings cannot be placed according to these specifications and the road is to be opened to traffic after October 15 with no adequate pavement markings in place, the Contractor shall place preformed tape for lane lines. All other pavement markings shall be placed according to Article 703.05. The Contractor shall then place the preformed pavement markings on or as soon after April 15 as the requirements of these specifications can be met

780.08 Preformed Thermoplastic. The pavement markings shall be capable of being applied on either HMA or portland cement concrete surfaces by using a propane blowtorch.

A primer sealer recommended by the manufacturer of the preformed pavement marking material shall be applied on portland cement concrete surfaces prior to application of the preformed thermoplastic pavement marking material. The primer sealer material shall be applied in sufficient quantities to entirely cover the pavement surface where the pavement marking material is to be placed.

The pavement temperature and the ambient air temperature shall be at or above 32ºF (0ºC) at the time of installation of the pavement markings.

780.09 Epoxy. The pavement shall be cleaned by a method approved by the Engineer to remove all dirt, grease, glaze, or any other material that would reduce the adhesion of the markings with minimum or no damage to the pavement surface. New portland cement concrete pavements shall be blast-cleaned to remove all latents.

Markings shall be applied to the cleaned surface on the same calendar day. If this cannot be accomplished, the surface area shall be recleaned prior to applying the markings. No markings shall be placed until the Engineer approves the cleaning.

Widths, lengths, and shapes of the cleaned surface shall be of sufficient size to include the full area of the specified pavement marking to be placed or removed.

The cleaning operation shall be a continuous moving process with minimum interruption to any traffic.

The material shall be applied to the cleaned road surface at 20 mils ± 1 mil (0.51 mm ±0.03 mm) in thickness, before the glass beads are applied. Glass beads shall be uniformly applied by means of a double drop pressurized bead applicator system. The system shall apply both the first drop glass beads and the second drop glass beads at a rate of 10 lb/gal (1.2 kg/L). Epoxy pavement marking shall be applied only when the air and surface temperatures are a minimum of 35ºF (2ºC) and rising. Where epoxy markings cannot be placed according to these specifications and the road is open to traffic with no adequate pavement markings in place, the Contractor shall place temporary pavement markings according to Article 703.05.

Lane lines shall be applied within four calendar days after removal of any existing lane lines.

The Contractor shall provide the Engineer an accurate temperature measuring device(s) which shall be capable of measuring the pavement temperature prior to the application of the material, the material temperature at the gun tip, and the material temperature prior to mixing.

The Contractor may use preformed plastic pavement marking or thermoplastic pavement marking, meeting the applicable requirements of Sections 1095 and 780, for diagonal lines, stop bars, and letters and symbols in lieu of epoxy at no additional cost to the Department.

780.10 Inspection. The epoxy, thermoplastic, preformed thermoplastic, and preformed plastic Type B or C, pavement markings will be inspected following installation, but no later than October 15 for preformed plastic markings, November 1 for thermoplastic and preformed thermoplastic markings, and December 15 for epoxy markings. In addition, they will be inspected following a winter performance period that extends 180 days from November 1.

Within 15 calendar days after the end of the winter performance period, a final performance inspection will be made. Final acceptance requirements are as follows.

(a) Lane lines: 90 percent intact by area of each individual dashed line segment.

(b) Crosswalks, stop lines, arrows, and words: 90 percent intact by area of each individual line, symbol, or letter.

(c) Center lines, edge lines, gore markings, and channelizing lines: 90 percent intact by area measured over any 10 ft (3 m) length of any individual line regardless of width.

(d) Entire project: measured in its entirety according to (a), (b), and (c) above, the entire project shall be 95 percent intact.

Upon completion of the final performance inspection, or after satisfactory completion of any necessary correction, the Engineer will notify the Contractor, in writing, of the date of such final performance inspection and release him/her from further performance responsibility.

If this inspection discloses any work, in whole or in part, which does not meet the inspection requirements, the Contractor shall, within 30 calendar days, completely repair or replace such work to the satisfaction of the Engineer.

This performance inspection and performance acceptance of the epoxy, thermoplastic, preformed thermoplastic, and preformed plastic Type B and C pavement markings shall not delay acceptance of the entire project and final payment due if the Contractor requires and receives from the subcontractor a third party "performance" bond naming the Department as obligee in the full amount of all pavement marking quantities listed in the contract, multiplied by the contract unit price. The bond shall be executed prior to acceptance and final payment of the nonpavement marking items and shall be in full force and effect until final performance inspection and performance acceptance of the epoxy, thermoplastic, preformed thermoplastic, and preformed plastic pavement markings. Execution of the third party bond shall be the option of the Contractor.

SECTION 781. RAISED REFLECTIVE PAVEMENT MARKERS

781.01 Description. This work shall consist of placing permanent and/or temporary raised reflective pavement markers or replacing the reflective element in a raised reflective pavement marker.

781.02 Materials. Materials shall be according to the following.

Item	Article/Section
(a) Raised Reflective Pavement Markers	1096.01
(b) Temporary Raised Reflective Pavement Markers	1096.02

CONSTRUCTION REQUIREMENTS

781.03 General. The reflector may be attached to the casting prior to or after the placement of the markers. The depression in the web shall be clean and dry. The reflector shall be laminated to an elastomeric pad and adhesively attached to the casting. The protective paper or plastic film covering the adhesive pad shall be removed immediately prior to placing the reflector on the casting. Once the film covering is removed, extreme care shall be taken to avoid contamination of the exposed pad surface. An adhesive meeting the marker manufacturer's specifications shall be used. The adhesive shall be placed either on the reflector or on the web in sufficient quantity so as to ensure complete coverage of the contact area with no voids present and with a slight excess after the reflector is pressed in place.

(a) Permanent. It shall be the Contractor's responsibility to determine the location of any traffic control devices installed in the pavement before beginning work, and shall conduct work to avoid damage to these devices. Any damage to these devices caused by the Contractor's operation shall be repaired.

The pavement shall be cut to match the bottom contour of the marker using a concrete saw fitted with 18 and 10 in. (450 and 250 mm) diameter blades. Diamond blades shall be used on portland cement concrete pavement. The cut shall be clean and completely dry prior to pouring the epoxy. After the cut is cleaned, the configuration shall be checked using a pavement marker. The marker shall fit easily within the cut with the leveling tabs resting on the pavement. If any force is required to place or remove the marker or if the leveling tabs do not rest on the pavement surface, the cut shall be enlarged as necessary. Installations on crowned pavements, super elevations, or ramps shall be cut deeper than those on level pavements if necessary to get proper marker fit. A rapid setting (hard in

one hour) epoxy meeting the requirements of AASHTO M 237 shall be poured into the cut to within 3/8 in. (9 mm) of the pavement surface. The installed height for the reflective pavement markers shall be approximately 0.3 in. (7.5 mm) above the road surface.

The marker shall then be placed into the epoxy-filled cut. The leveling tabs shall rest on the pavement surface and the marker tips shall be slightly below the pavement surface when properly installed. There shall be no epoxy on the reflective lens. The epoxy, when properly mixed, shall be hard cured in 30–45 minutes. If after one hour, a screwdriver or other appointed instrument can be pushed into the epoxy, the marker and the uncured epoxy shall be removed, and the marker shall be cleaned and the unit reinstalled.

The pavement surface temperature and the ambient air temperature shall be at or above 50ºF (10ºC) at the time of installation of the marker for the epoxy adhesive to properly cure.

Unless directed by the Engineer, raised reflective pavement markers shall not be laid directly over a longitudinal crack or joint. The edge of a raised reflective pavement marker shall be offset, toward traffic, a minimum distance of 2 in. (50 mm) from the edge of pavement, a longitudinal crack or joint, or a solid lane line. Raised reflective pavement markers shall be centered in the gap between dashed line segments and the finished line of the markers shall be straight. The lateral deviation on any 10 ft (3 m) line shall not exceed 1 in. (25 mm). Raised reflective pavement markers through tangents of reverse curves which are less than 500 ft (150 m) in length shall be installed at the lesser of the two curve spacings.

The reflectors may be attached to the castings either prior to or after the placement of the markers. The depression in the web shall be clean and dry. The reflector shall be placed on the casting with sufficient pressure to firmly seat it in place, minimum load of 100 lb (45 kg). Adhesive material shall not be permitted on the reflective surface of the prismatic reflector.

(b) Temporary. The pavement surface which the marker shall be bonded to, shall be free of dirt, curing compound, grease, oil, moisture, or any other material which would adversely affect the bond of the adhesive.

The markers shall be placed firmly on the pavement and pressed into place by slowly passing over them with a truck wheel. The pass shall not displace the markers. In lieu of an adhesive pad, an adhesive meeting the marker manufacturer’s specifications may be used. The adhesive shall be placed either on the reflector or on the web in sufficient quantity so as to ensure complete coverage of the contact area with no voids present and with a slight excess after the reflector is pressed in place.

All markers shall be monodirectional. Markers placed to the left of traffic shall be amber and markers placed to the right of traffic shall be crystal.

(c) Replacement. All remaining portions of the existing reflector, and all traces of adhesive, rust, dirt, etc., shall be removed from the marker reflector area by sandblasting or other methods approved by the Engineer.

The Contractor shall be responsible for verifying the model numbers of castings as shown on the plans and shall be responsible for installing the proper replacement reflector in each casting.

The Contractor shall make certain the casting surface is dry and free of dirt and rust prior to placing the reflector on the casting.

The reflector shall be placed on the casting with sufficient pressure to firmly seat it in place, minimum load of 100 lb (45 kg). Adhesive material shall not be permitted on the reflective surface of the prismatic reflector. The pavement surface temperature and the ambient air temperature shall be at or above 50ºF (10ºC) at the time of application of the prismatic reflector.

781.04 Inspection of Raised Reflective Pavement Markers. The permanent raised reflective pavement marker and/or replacement reflector will be inspected following installation, but no later than November 30. In addition, they will be inspected following a winter performance period that will extend 180 days from November 30.

Within 15 calendar days after the end of the winter performance period, a final performance inspection will be made. If this inspection discloses any work which is not visibly intact and serviceable, the Contractor shall, within 30 calendar days, completely repair or replace such work to the satisfaction of the Engineer.

Measured in its entirety, the work shall be 97 percent intact.

Upon completion of the final performance inspection or after satisfactory completion of any necessary corrections, the Engineer shall notify the Contractor in writing of the date of such final performance inspection and release him/her from further performance responsibility.

This delay in performance inspection and performance acceptance of the raised reflective pavement markers shall not delay acceptance of the entire project and final payment due if the Contractor requires and receives from the subcontractor a third party “performance” bond naming the Department as obligee in the full amount of all raised reflective pavement marker quantities listed in the contract, multiplied by the contract unit price. The bond shall be executed prior to acceptance and final pavement of the nonraised reflective pavement marker items and shall be in full force and effect until final performance inspection and performance acceptance of the raised reflective pavement markers. Execution of the third party bond shall be the option of the prime Contractor.

781.05 Basis of Payment. This work will be paid for at the contract unit price per each for RAISED REFLECTIVE PAVEMENT MARKER, RAISED REFLECTIVE PAVEMENT MARKER (BRIDGE), TEMPORARY RAISED REFLECTIVE PAVEMENT MARKER, or REPLACEMENT REFLECTOR.

APPENDIX D8

Agency: Indiana Department of Transportation

Attached Example(s) of Warranty Specifications:

Pavement Marking Material	Period	Remarks
Durable pavement marking materials: thermoplastic, preformed plastic, and epoxy	180 days through a winter	Warranty specifications apply only to durable pavement marking materials, and cover longitudinal lines, transverse lines, and intersection markings. The specifications describe the required characteristics of the pavement markings, application methods, and equipment to be used. Warranty provisions are described in Section 808.09. The contractor is the responsible party for meeting warranty requirements. The 180-day warranty period extends from either the date of final acceptance or November 1st of the calendar year in which the last pavement markings were installed, whichever is later. The practical effect is to have the warranty extend through a winter season.

INDIANA DEPARTMENT OF TRANSPORTATION
SECTION 808—PAVEMENT TRAFFIC MARKINGS

808.01 Description

This work shall consist of furnishing and installing, or removing, pavement traffic markings and snowplowable raised pavement markers in accordance with the MUTCD, these specifications and as shown on the plans. Markings shall be installed as required unless written approval is obtained from the District Traffic Engineer to make modifications at specific locations.

MATERIALS

808.02 Materials

Materials shall be in accordance with the following:

Cones	801.08
Epoxy	921.02(c)

Glass Beads	921.02(e)
Preformed Plastic	921.02(b)
Snowplowable Raised Pavement Markers	921.02(d)1
Thermoplastic	921.02(a)
Traffic Paint	909.05

CONSTRUCTION REQUIREMENTS

808.03 General Requirements

Permanent pavement markings shall be placed on the surface course in a standard pavement marking pattern. Center lines shall be placed on two-way two-lane roads, lane lines shall be placed on multi-lane divided roads, and both center lines and lane lines shall be placed on multi-lane undivided roads. The markings shall be of the same material as the existing pavement markings or any durable pavement marking material.

The pavement shall be cleaned of all dirt, oil, grease, excess sealing material, excess pavement marking material and all other foreign material prior to applying new pavement traffic markings. New paint pavement markings may be placed over sound existing markings of the same color. New thermoplastic, preformed plastic, or epoxy markings may be applied over sound existing markings of the same type if permitted by manufacturer's recommendations, a copy of which shall be supplied to the Engineer prior to placement; otherwise, existing markings shall be removed in accordance with 808.10 prior to placement of the new markings. Removal of pavement marking material shall be in accordance with 808.10. The pavement surface shall be dry prior to applying pavement traffic markings.

Control points required as a guide for pavement traffic markings shall be spotted with paint for the full length of the road to be marked. Control points along tangent sections shall be spaced at a maximum interval of 100 ft (30 m). Control points along curve sections shall be spaced so as to ensure the accurate location of the pavement traffic markings. The location of control points shall be approved prior to the pavement traffic marking application.

808.04 Longitudinal Markings

All longitudinal lines shall be clearly and sharply delineated, straight and true on tangent, and form a smooth curve where required. Lines shall be square at both ends, without mist, drip or spatter.

A solid line shall be continuous. A broken line shall consist of 10 ft (3 m) line segments with 30 ft (9 m) gaps.

All lines shall be gapped at intersections unless otherwise specified or directed.

The actual repainting limits for no-passing zone markings will be determined by the Engineer.

A new broken line placed over an existing broken line shall laterally match the existing broken line, and the new line segments shall not extend longitudinally more than 10% beyond either end of the existing line segments.

(a) Center Lines

Center lines shall be used to separate lanes of traffic moving in opposite directions. All center line markings shall be yellow in color and 4 in. (100 mm) in width. They shall be placed such that the edge of the marking, nearest to the geometric centerline of the roadway, shall be offset 4 in. (100 mm) from the geometric centerline.

The center line of a multi-lane roadway shall be marked with a double solid line.

The two lines forming the double solid line shall be spaced 8 in. (200 mm) apart and shall be equally offset on opposite sides of the geometric centerline.

The center line of a 2-lane, 2-way roadway, where passing is allowed in both directions, shall be marked with a broken line.

The center line of a 2-lane, 2-way roadway, where passing is allowed in one direction only, shall be marked with a double line, consisting of a broken line and a solid line. The broken line and the solid line shall be spaced 8 in. (200 mm) apart and shall be equally offset on opposite sides of the geometric centerline. The solid line shall be offset toward the lane where passing is prohibited. The broken line shall be offset toward the lane where passing is permitted.

(b) Lane Lines

Lane lines shall be used to separate lanes of traffic moving in the same direction. Normal lane line markings shall be white in color and shall be 5 in. (125 mm) wide on freeways, interstates and toll roads, and 4 in. (100 mm) wide on all other roads. They shall be offset 4 in. (100 mm) to the right of longitudinal pavement joints or divisions between traffic lanes. Normal lane lines shall be marked with white broken lines. White solid lines shall be used to mark lane lines only when specified or directed.

(c) Edge lines

Edge lines shall be used to outline and separate the edge of pavement from the shoulder. Edge line markings shall be 4 in. (100 mm) in width and shall be placed such that the edge of the marking nearest the edge of the pavement shall be offset 4 in. (100 mm) from the edge of the pavement except as otherwise directed. Right edge lines shall be marked with a white solid line and left edge lines shall be marked with a yellow solid line.

(d) Barrier Lines

Barrier lines shall be used as specified or directed. Barrier line markings shall be solid lines of the size and color specified or as directed.

808.05 Transverse Markings

(a) Transverse marking lines shall be used as specified or directed to delineate channelizing lines, stop lines, crosswalk lines, and parking limit lines. The markings shall consist of all necessary lines, of the width specified or directed and shall be in accordance with the MUTCD.

(b) Pavement message marking shall be used as specified or directed for railroad crossing approaches, intersection approaches, crosswalk approaches, handicap parking spaces, and other messages applied

to the pavement with pavement marking material. The markings shall consist of all necessary lines, words, and symbols as specified or directed, and shall be in accordance with the MUTCD.

808.06 Curb Markings

Curb markings shall consist of reflectorized paint which shall cover the face and top of the curb. The existing curb and gutter area shall be cleaned of dirt, dust, oil, grease, moisture, curing compound, and unsound layers of other materials before paint is applied to the curb surface.

808.07 Pavement Marking Material Application and Equipment

All double line markings, such as a no passing zone or the center line of an undivided multi-lane roadway, shall be applied in one pass.

Stop lines and crosswalk lines for new or modernized traffic signal installations shall be durable pavement marking material. For this application, preformed plastic may be used on concrete if permitted by manufacturer's recommendations. However, for contract completion dates in winter months when conditions do not permit application of durable markings, traffic paint markings may be substituted with an appropriate unit price adjustment if approved by the Engineer.

(a) Traffic Paint

1. Application

Standard dry and fast dry traffic paint shall be applied only when the pavement temperature is 40°F (5°C) or above. Waterborne traffic paint shall be applied only when the pavement temperature is 50°F (10°C) or above. Standard dry or fast dry traffic paint will only be permitted between October 1 and the following April 30. The wet film thickness of the traffic paint shall be a minimum of 15 mils (380 µm). Painted lines and markings shall be immediately reflectorized by applying glass beads at a uniform minimum rate of 6 lb/gal. (0.7 kg/L) of traffic paint.

Painted markings on newly constructed surfaces shall receive two applications of paint and glass beads. The second application shall be applied as soon as practical after the first application dries.

2. Equipment

Traffic paint shall be applied with a spray type machine capable of applying the traffic paint under pressure through a nozzle directly onto the pavement. The machine shall be equipped with the following: an air blast device for cleaning the pavement ahead of the painting operation; a guide pointer to keep the machine on an accurate line; at least two spray guns which can be operated individually or simultaneously; paint agitator(s); a control device to maintain uniform flow and application; an automatic device which will provide a broken line of the required length; and an automatic glass bead dispenser which is synchronized with the marking application. When fast drying traffic paint or waterborne traffic paint is used, the machine shall be capable of heating the paint to application temperatures in accordance with 909.05.

A brush or small hand propelled machine, designed for that purpose, may be used if approved to apply some painted markings.

(b) Durable Pavement Marking Material

Durable pavement marking material consists of thermoplastic, preformed plastic, or epoxy.

1. Thermoplastic

a. Application

Thermoplastic marking material shall be used on asphalt pavements unless otherwise specified or directed. The pavement surface shall be primed with a binder material in accordance with the manufacturer's recommendations. Thermoplastic marking shall be applied in molten form by spray, extrusion, or ribbon type extrusion airless spray when the pavement temperature is 50°F (10°C) or above. The average thickness of each 36 in. (910 mm) length of thermoplastic marking shall be no less than 3/32 in. (2.5 mm) nor more than 3/16 in. (5 m). Immediately following the application of the thermoplastic markings, additional reflectorization shall be provided by applying glass beads to the surface of the molten material at a uniform minimum rate of 6 lb/100 sq ft (2.9 kg/10 m^2) of marking.

b. Equipment

The machine used for the spray application of thermoplastic markings shall consist of a kettle for melting the material and an applicator for applying the markings. All of the equipment required for preheating and applying the material shall maintain a uniform material temperature within the specified limits, without scorching, discoloring or overheating any portion of the material.

The machine shall be equipped with the following: an air blast device for cleaning the pavement ahead of the marking operation; a guide pointer to keep the machine on an accurate line; at least two spray guns which can be operated individually or simultaneously; agitators; a control device to maintain uniform flow and application; an automatic device which will provide a broken line of the required length; and an automatic glass bead dispenser which is synchronized with the marking application.

2. Preformed Plastic

a. Application

The Contractor shall provide the Department with original copies of all necessary current manufacturer's installation manuals prior to beginning installation work. No installation work shall begin prior to the Department's receipt of these manuals. These manuals will become the property of the Department.

Preformed plastic shall be applied when the air temperature is a minimum of 60°F (16°C) and rising, and the pavement temperature is a minimum of 70°F (21°C). Preformed plastic shall not be applied if the ambient temperature is expected to drop to below 45°F (7°C) within 24 h after application. The pavement surface shall be primed with a binder material in accordance with the manufacturer's recommendations. The pavement surface shall be primed prior to the placement of preformed plastic transverse markings.

If there is a dispute regarding installation, the manufacturer shall provide a properly trained representative to ensure that the installation is performed in accordance with the manufacturer's recommendations.

b. Equipment

The equipment for applying preformed plastic, furnished in rolls, shall be a portable hand-propelled machine capable of carrying and applying at least two rolls of 4 in. (100 mm) to 16 in. (50 mm) widths. The machine shall be equipped with a guide pointer to keep the machine on an accurate line. The machine shall also be equipped with guide rollers and a pressure roller. The pressure roller may be a separate unit.

The machine shall feed the marking material from its original carton through the guide rollers and under the pressure roller onto the pavement. The pressure roller shall be a minimum of 2 in. (50 mm) wider than the width of the marking material and shall weigh a minimum of 200 lb (91 kg). The machine shall also be capable of removing the backing paper from the marking material during the application process. Preformed plastic furnished in strip, symbol, or legend form shall be applied with suitable equipment such as hand rollers.

3. Epoxy

a. Application

Epoxy shall be used on portland cement concrete pavement unless otherwise specified or directed. This material shall be applied only when the pavement temperature is 40°F (5°C) or above. The wet film thickness of the epoxy marking material shall be a minimum of 15 mils (380 μm). Immediately following the application of the epoxy markings, additional reflectorization shall be provided by applying glass beads to the surface of the wet marking at a uniform rate of 20 lb/100 sq ft (9.8 kg/10 m^2) of marking.

b. Equipment

The machine used to apply the epoxy marking material shall precisely meter the two components, produce and maintain the necessary mixing head temperature within the required tolerances, all in accordance with the manufacturer's recommendations. The machine shall be equipped with a high pressure water blast device ahead of a high pressure air blast device, both as an integral part of the gun carriage, for cleaning the pavement ahead of the marking application. The machine shall also be equipped with the following: a guide pointer to keep the machine on an accurate line; at least two spray guns which can be operated individually or simultaneously; an automatic device which will provide a broken line of the required length; and automatic glass bead dispensers which is synchronized with the marking application.

808.08 Marking Protection and Maintenance of Traffic

Protection of the traveling public, of the pavement marking crews, and of the pavement markings shall be provided during the marking operation through the use of proper equipment, traffic control devices, safety devices and proper procedures. Traffic control devices shall be placed in accordance with 107.12. Flaggers shall be provided for traffic control as directed.

(a) Vehicle Signs

Each vehicle in the marking operation shall display the slow moving vehicle emblem when operating at speeds of 25 mph (40 km/h) or less. The slow moving emblems shall be removed when the vehicles are operating at speeds greater than 25 mph (40 km/h). The paint crew signs shall be 24 in. (600 mm) high by 96 in. (2400 mm) wide, with 12 in. (300 mm) series C black letters on an orange encapsulated lens reflective background. Type A and C flashing arrow signs shall be in accordance with 923.04.

(b) Vehicle Warning Lights

All amber flashing warning lights and amber strobe lights mounted on vehicles used in the marking operation shall be in accordance with 801.14(d). All vehicles used in the marking operation shall have a minimum of one flashing amber warning light or amber strobe light which is visible in all directions.

(c) Cones

Cones shall be used to protect marking material which requires more than 60 s drying time. Cones shall remain in place until the marking material is dry or firm enough not to track or deform under traffic. Cones shall be removed as soon as possible and shall never be left in place overnight. Edge lines shall not require protection with cones.

The maximum spacing of cones shall be as follows:

	40 MPH or less	**Over 40 MPH**
Broken Lines	every line segment	every 5th line segment
Solid Lines	20 ft to 30 ft (6 m to 9 m)	

(d) Front Escort Vehicles

A front escort vehicle shall be used if the marking vehicle extends across the center line while operating. This front escort vehicle shall be equipped with a forward facing paint crew sign, a rear facing slow moving vehicle emblem, and a red flag mounted at least 10 ft (3 m) above the pavement.

(e) Marking Application Vehicles

Marking application vehicles such as edge liner or centerliner trucks shall have a rear facing type A or type C flashing arrow sign, an amber flashing warning light mounted near the center of the truck bed and an amber strobe light mounted on each rear corner of the truck bed. The amber flashing warning light and the amber strobe lights shall be mounted on retractable supports and shall be operated at a height of 12 ft (3.7 m) above the pavement unless otherwise directed.

(f) Rear Escort Vehicles

If cones are not required, a rear escort vehicle shall follow a marking application vehicle at a distance of 100 to 500 ft (30 to 150 m). If an additional rear escort vehicle is required due to drying time or heavy traffic volume, it shall follow the first rear escort vehicle at a maximum distance of 1,000 ft (300 m), and may operate in the travel lane or on the paved shoulder.

If cones are required, the cone setting truck shall follow the marking application vehicle and shall be followed by a rear escort vehicle. The cone pick up truck shall be followed by another rear escort vehicle.

All rear escort vehicles shall be equipped with a rear facing type C flashing arrow sign mounted above a rear facing paint crew sign. On two-lane two-way roads, this type C flashing arrow sign shall be operated with the arrowhead turned off. The supply truck may be used as a rear escort vehicle providing it is empty and is equipped with the required traffic control devices.

808.09 Warranty for Durable Pavement Marking Material

Durable pavement marking material shall be warranted against failure resulting from material defects or method of application. The material shall be warranted to retain its color, reflectivity, adherence to the pavement and shall be free of other obvious defects or failures.

All pavement traffic markings which have failed to meet the warranted conditions shall be replaced with no additional payment.

For the terms of the warranty a unit shall be defined as a 1,000 ft (305 m) section of line of specified width in any combination or pattern.

The warranty period shall be 180 days beginning with the last working day for the total contract as defined in the final acceptance letter, but not prior to November 1 of the calendar year in which the last pavement markings were installed. If more than 3% of a unit or 3% of the total of any one intersection or set of transverse markings fails, the failed portion shall be replaced. All pavement markings required to be replaced under the terms of this warranty shall be replaced within 60 days of the notification of failure.

APPENDIX D9

Agency: Maryland State Highway Administration

Attached Example(s) of Warranty Specifications:

Pavement Marking Material	Period	Remarks
Inlaid Pavement Striping Tape (SECTION 562)	180-day observation period, 5-yr warranty period	The specifications discuss materials properties and inlaid application requirements and methods. The specifications cover only longitudinal lines (solid and broken). Materials must be included on a Qualified Products List. A manufacturer's materials certification must be provided. The contractor must install a quality-control test strip. The contractor is responsible for pavement marking performance during the observation period. The materials manufacturer is responsible for performance during the 5-year warranty period. The contractor's observation-period responsibilities are described in Section 562.03.01(i). The manufacturer's warranty-period responsibilities are described in Section 562.03.02.

MARYLAND STATE HIGHWAY ADMINISTRATION

SPECIAL PROVISIONS
CATEGORY 500
PAVING

SECTION 562—INLAID PAVEMENT STRIPING TAPE

562.01 DESCRIPTION. This work shall consist of furnishing and applying inlaid pavement striping tape as specified in the Contract Documents and as directed by the Engineer. The materials used shall perform in accordance with the functional requirements. The Manufacture shall warranty the material for a period of five years.

562.02 MATERIALS.

Inlaid Pavement Striping Tape	Qualified Products List

Manufacturer's Materials Certification shall be provided as specified in TC-1.02.

Environmental Requirements. Materials shall not have more than 100ppm lead and other heavy metals total. "Manufacturers are required to certify material is less than 100ppm." (Please note the NTPEP does not test for heavy metals.)

The pavement stripings shall be tested by The National Transportation Product Evaluation Program (NTPEP) North Deck. The Manufacturer shall certify in writing that the pavement striping tape performs as specified in 562.03.02(a), Functional Requirements, for a period of five years. This five year requirement shall begin at the end of the 180 days observation period.

562.03 CONSTRUCTION.

562.03.01 CONTRACTOR'S RESPONSIBILITIES:

(a) General. The Contractor shall provide a copy of the manufacturer's recommendations to the Engineer. Pavement Striping Tape shall be stored and applied per the manufacturer's recommendations and as directed by the Engineer.

On new hot mix asphalt (HMA) projects, the Pavement Striping Tape shall be inlaid into the final HMA surface of the pavement. The tape shall be applied during the final compaction, and rolled into the HMA by the finish roller. The tape shall be applied while the surface temperature is within the manufacturer's recommended guidelines without disruption to the compaction process. The Engineer will not permit the final course to be placed unless the striping crew and striping materials are at the project site.

Pavement Striping Tape shall conform to pavement contours and be resistant to deformation by traffic and damage from snow removal equipment. Surface preparation, use of solvents and primers, and equipment used in the application of Pavement Striping Tape shall conform to the manufacturer's recommendations and as approved by the Engineer. After striping tape is applied, it shall be immediately ready for traffic.

(b) Quality Control/Quality Assurance. Refer to 549.03.01.

(c) Cleaning Pavement Surfaces. Refer to 549.03.02.

(d) Adherence. Adherence of Pavement Striping Tape shall be randomly checked by using a paint scraper or other tool approved by the Engineer, which shall be held nearly parallel with the highway surface. The edge of the material shall be scraped lightly and there shall be no dislodging of the tape. The Engineer shall be notified in advance so as to witness this procedure. Non-conforming material shall be repaired according to the manufacture's recommendations.

(e) Color. The color of the striping shall match Federal Standard 595 (38907—yellow and 37925—white). The Contractor shall supply the specified color chips for the Engineer's use to visually determine that the striping tapes match the specified color. Striping Tape is discolored when compared visually with the color chips.

(f) Film Loss. No exposed substrate is acceptable.

(g) Retroreflectance. The functional requirements for retroreflectivity are as listed in Table 1 and Table 2.

(h) Quality Control Test Strip. Refer to 549.03.03.

(i) Observation Period. The Contractor shall be responsible for any defects in the striping tape and workmanship of the inlaid striping tape for a period of 180 days from the date the striping tape is applied and under traffic.

The Engineer will not assess time charges during the observation period provided all other work on the Contract is complete. At the end of the 180 days observation period, the Engineer will inspect the pavement striping tapes for durability, color, and retroreflectivity; and inform the Contractor of any pavement striping that failed and requires replacement. The pavement striping will have failed for any of the following conditions:

(1) Film Loss:

(a) Solid Longitudinal Line—more than five percent of the substrate is exposed in any 2000 ft section.
(b) Broken Line—more than five percent of the substrate is exposed in any 2000 ft section or the loss of two consecutive skips.

(2) Retroreflectance—Values for retroreflectivity both initial and throughout the 180 days observation period are as follows:

TABLE 1

MINIMUM RETROREFLECTANCE INITIAL AND THROUGHOUT THE 180 DAYS OBSERVATION PERIOD		
COLOR	**RETROREFLECTIVITY mcd/lux/m²**	**CORRECTIVE ACTION**
White	500 or higher	None
Yellow	350 or higher	
White	499 or below	Removal and Replacement
Yellow	349 or below	

(j) Repairs. The Contractor shall remove and replace all failed inlaid striping tape within 30 days of receiving written notification from the Engineer. The failed material shall be replaced at no additional cost to the Administration. Work shall be in conformance with the manufacturer's recommendations and as approved by the Engineer before the project is accepted. The replacement striping tape shall conform to the same requirements as the original striping tape. If the work is not completed within 30 days, the Engineer will resume time charges until the work is completed and accepted.

At the end of the observation period, when the Engineer is satisfied with the quality of the initial and repaired inlaid striping tape, the Engineer will accept the work and terminate the Contractor's responsibilities.

562.03.02 MANUFACTURER'S RESPONSIBILITIES:

(a) Functional Requirements and Certification. The functional requirements are the performance of the material over the period of five years after the end of the 180 days observation period. The Manufacturer's Certification of Functional Requirements shall begin after the 180 days observation period has ended and the striping is accepted.

The expected performance is as follows:

(1) Retroreflectivity.

TABLE 2

MINIMUM SUBSEQUENT RETROREFLECTANCE (Five Years)			
YEARS	**RETROREFLECTIVITY mcd/lux/m²**		**CORRECTIVE ACTION**
	WHITE	**YELLOW**	
1	400	300	Remove and Replace
2	300	200	
3	200	150	
4	150	125	
5	100	100	Replace or Retrace

(2) Film Loss:

(a) Solid Longitudinal Line—more than five percent of the substrate is exposed in any 2000 ft section.

(b) Broken Line—more than five percent of the substrate is exposed in any 2000 ft section or the loss of two consecutive skips.

(3) Color - Refer to MSMT 729 test procedure.

(b) Warranty. The warranty shall cover the pavement striping materials, the work to replace the striping materials if necessary, and the maintenance of traffic during the reinstallation, all for a period of 5 years.

(c) Corrective Actions. If the material fails to meet the Functional Requirements for the specified period, the manufacturer shall provide the necessary replacement material, labor, and equipment to replace or restore the striping tape. The replacement material shall be equal to or better than the original. The replacement material shall conform to these requirements for the entire 5 year time period.

The manufacturer shall provide maintenance of traffic as required using the current Maryland Manual of Uniform Traffic Control Devices (MdMUTCD) and SHA's Standards and Specifications, or as directed by the District Engineer while performing corrective actions.

(d) Removal. Refer to Section 565.

(e) Response Time. Upon notification of any problems with the stripings, the manufacturer shall have 30 days to respond with a replacement plan and schedule acceptable to the Engineer. Failure to execute the accepted plan within 72 hours will result in a $1,000.00 per day penalty, which will be imposed until compliance. The manufacturer shall provide at his own expense interim stripings until weather is conducive for replacement.

(f) Emergency Repair Factors.

(1) Striping material is not adhering to pavement.

(2) The retroreflectivity is less than acceptable.

When the Administration determines that emergency repairs are necessary, the manufacturer shall perform the repairs within 24 hours of notification. When the manufacturer fails to respond within the 24 hour period, the Administration reserves the right to perform the repairs using Administration or contractual forces. The manufacturer shall ensure that all costs incurred shall be reimbursed.

(g) Retroreflectance Measurement Procedures.

(1) Routine visual inspections will be performed by Administration personnel to monitor the quality of the striping on an annual basis. Areas that appear to be below the minimum retained retroreflectance value will be identified for further investigation in conformance with MSMT 729.

(2) When further investigation is required, the Administration will conduct the investigation in conformance with MSMT 729, Nighttime Visibility Evaluation.

(3) Subject areas will be jointly reviewed by the manufacturer and the Administration visually at night.

(4) When retroreflectivity measurements become necessary to confirm failures, readings will be taken in conformance with MSMT 729. When retroreflectivity is below accepted values as specified in Table 2, the manufacturer shall replace the striping.

562.04 MEASUREMENT AND PAYMENT. Inlaid Pavement Striping Tape lines will be measured and paid for at the Contract unit price per linear foot for the color and width specified.

The payment will be full compensation for all pavement preparation, furnishing and placing of stripes, testing, the Contractor's 180 days observation period, and for all material, labor, equipment, tools, and incidentals necessary to complete the work.

The payment will also be full compensation for the Manufacture's 5 year material warranty period which shall include the furnishing, removing and replacing defective striping; appropriate maintenance of traffic, and for all material, labor, equipment, tools, and incidentals necessary to complete the work.

APPENDIX D10

Agency: Missouri Department of Transportation (Contract through Missouri Highways and Transportation Commission)

Attached Example(s) of Warranty Specifications:

Pavement Marking Material	Period	Remarks
Retroreflective Pavement Marking Tape	4 years	The attached document comprises excerpts from the contract between Missouri and 3M for its 380I-WR tape and 380I-5WR contrast tape. 3M serves as the contractor and the materials manufacturer. The scope of work calls for submittal of a work plan for markings application, and details materials performance requirements. The contract covers longitudinal solid and skip lines. Warranty requirements are in Exhibit I, Section (2)(D).

Pavement Marking Material	Period	Remarks
Durable permanent pavement markings in metropolitan areas that meet defined MoDOT performance criteria through a 4-year warranty period	4 years after installation	This is a true performance specification in that the overall requirement for durable markings does not specify any particular material. The contractor has "full choice on what material to use to meet the performance criteria." The successful bid, from which the attached specifications are excerpted, is based upon "a proven, sophisticated, thermosetting hybrid polymer technology saturated with proven reflective media." The specifications cover longitudinal markings on mainline highway segments, ramps, and turn lanes, and long-line markings within and approaching at-grade crossovers and signalized intersections. Gore markings are included. Intersection markings such as stop bars, turn arrows, and hash marks are not included. The warranted performance is backed by a materials manufacturer that is serving as the prime contractor. The attached documents include relevant excerpts from MoDOT specifications advertised in the bid package, plus modifications contained in the value engineered proposal submitted by the successful materials manufacturing firm acting as prime contractor. Pavement marking performance is expressed in terms of allowable tolerances in marking width and alignment, retroreflectivity, chromaticity, and appearance (covering presence or durability). Performance is evaluated at a minimum following installation (initial evaluation) and annually during years 1 through 4 of the warranty. Payments to the contractor are in 5 steps through the contract period. The contract stipulates maximum percentages of the total contract price to be made for each payment; actual amounts may be adjusted based upon the performance of individual 1.0-mile segments within the contract scope. See contractor's value-engineered proposal for adjustments to the staged payment schedule (i.e., the annual percentage payments). Contractor must provide a bond covering performance of the work through the term of the contract. If more than 10 percent of pavement markings are determined to have failed during any evaluation period, the contractor is considered to be in default and must respond with a written plan to remedy the failures.

MISSOURI DOT PAVEMENT MARKING TAPE SPECIFICATION

MISSOURI HIGHWAYS AND TRANSPORTATION COMMISSION
CONTRACT SERVICES AGREEMENT

THIS AGREEMENT is entered into by 3M Company, a Delaware corporation, acting through its Traffic Safety Systems Division (hereinafter, "Contractor") and the Missouri Highways and Transportation Commission (hereinafter, "Commission").

WITNESSETH:

WHEREAS, the Commission has selected the Contractor to perform non-professional services in the nature of providing and installing retroreflective pavement marking tape services; and

WHEREAS, the Contractor represents that it is qualified in its field of expertise to competently provide such services.

NOW, THEREFORE, in consideration of the mutual promises, covenants, and representations contained herein, the parties agree as follows:

(1) SCOPE OF SERVICES:

(A) The services covered by this Agreement shall include furnishing all personnel and the equipment, material and all other things necessary for installing six (6) inch wide retroreflective pavement marking tape and eight (8) inch retroreflective pavement marking tape as defined below in Section 1 (B).

(B) The specific services to be provided by the Contractor are as follows:

1. Design and layout for placement of markings in accordance with MoDOT plans and requirements.
2. Traffic control at all work locations
3. Surface preparation, including grooving, and installation of marking materials shall be consistent with the marking alignment and groove length specifications attached to the Contract as Exhibit IV. All temporary paint shall be removed before the installation of the tape. If the required removal extends beyond the allowed groove dimensions, bituminous pavement shall be sealed with an approved sealant.
4. Materials used shall conform to the applicable specifications set forth in the Contractor's recommendation for 380I-WR or contrast 380I-5WR series tape, which is defined as 6 inch white tape with 1 inch black tape edges.

5. All applied markings will be recessed either by grooving the surface or by inlay of the marking during the asphalt cement concrete paving operations.
6. Clean up and removal of debris and excess materials at the completion of installation.

(C) The Contractor further warranties that the material used will have the following properties:

1. The initial minimum retroreflectivity for installations of 380I-WR and contrast 380I-5WR will have average minimum initial dry reflectivity of 500 mcd/m^2/lux. Within 30 days after the material is placed, the Contractor shall provide a minimum of 10 regularly spaced initial retroreflectivity readings per direction per project consisting of 5 miles or less of roadway. For projects greater than 5 miles in length, at minimum, an additional 2 initial retroreflectivity readings shall be made per direction per mile over 5 miles. The readings shall be provided in a mutually agreed format.
2. Minimum retroreflectivity for 380I-WR and contrast 380I-5WR of 200 mcd/m^2/lux at 2 years in service.
3. Minimum retroreflectivity for 380I-WR and contrast 380I-5WR of 100 mcd/m^2/lux at 3 or 4 years in service.
4. Physical presence of 95 percent of material. Measurement of the retroreflectivity of the material will be done with a mobile retroreflectometer to identify areas of concern. These areas will then be evaluated for warranty performance in accordance with Contractor's Reflectance Measurement Procedures for Warranty as described in "Market Test Product Bulletin 380I ES May 2004". The remedy for material not meeting the above warranty requirements are set forth in Exhibit I to this Agreement, titled "Scope of Services".

(D) The Contractor shall also complete all work covered by this agreement by December 31, 2011. An allowance will be made on meeting this completion date if climatic conditions restrict the application of the material. If the Contractor is not able to complete all work by May 31, 2012, liquidated damages of $7,300 per day will be assessed until the work is completed. The amount of work to be completed and additional terms are set forth in Exhibit I to this Agreement, titled "Scope of Services," which is attached hereto and made a part of this Agreement. In addition, the Contractor shall comply with Exhibit II to this Agreement, titled "General Terms and Conditions and Special Terms and Conditions," which is attached hereto and made part of this Agreement.

(2) ADDITIONAL SERVICES: The Commission reserves the right to direct additional services not described in Exhibit I as changed or unforeseen conditions may require. Such direction by the Commission shall not be a breach of this Agreement. In this event, a supplemental agreement will be negotiated and executed prior to the Contractor performing the additional or changed services, or incurring any additional cost therefore.

[NOTE: Subsequent legal items are excluded from this excerpt. Technical specifications continue in Exhibit I on next page.]

EXHIBIT I

SECTION (1):
GENERAL DESCRIPTION AND BACKGROUND

(A) Background: The scope of this contract is to provide for the installation of six (6) inch wide retroreflective pavement marking tape and eight (8) inch contrast pavement marking tape on divided highways as specified by the Commission.

(B) Contract Period: This contract covers work to be completed by December 31, 2011.

SECTION (2)
SCOPE OF WORK

(A) Services: The contractor shall provide the following services:

3M will perform the following services to install the pavement markings within MoDOT's jurisdiction that are listed in the end of this Exhibit hereof (collectively referred to as "the Services"):

a) Design and layout for placement of markings in accordance with MoDOT plans and requirements.
b) Tra ffic control at all work locations.
c) Surface preparation, including grooving, and installation of marking materials shall be consistent with the marking alignment and groove length specifications attached to the Contract as Exhibit IV. All temporary paint shall be removed before the installation of the tape. If the required removal extends beyond the allowed groove dimensions, bituminous pavement shall be sealed with an approved sealant.
d) Materials use d shall conform to the applicable specifications set forth in the Contractor's recommendation for 380I-WR or contrast 380I-5WR series tape.
e) All applied markings will be recessed either by grooving the surface or by inlay of the marking during asphalt cement concrete paving operations.
f) Clean up and removal of debris and excess materials at the completion of installation.

(B) 3M Responsibilities:

3M will provide MoDOT a work plan to perform Services in a timely fashion that allows for efficient and cost effective installation of markings. At 3M's option fixed or moving lane closures may be used in the work plan. Traffic control in the contractor work zone shall be in accordance with the figures included in Exhibit V.

The contractor will complete the application of pavement markings within 5 days of the confirmed roadway availability by the district Resident Engineer. This includes pavement markings for specific portions of roadway not less than five miles in length, as requested by the Commission as portions of resurfacing projects are completed and require pavement markings. If tape installation is not able to begin within this time frame or when climatic conditions restrict the application of tape markings, the contractor will apply, at its expense, temporary paint striping, four inches wide, which may remain in place for up to six months. The temporary paint striping shall have a minimum initial retroreflectivity of 150 mcd/m^2/lux. The temporary paint shall be maintained with a minimum retroreflectivity of 100 mcd/m^2/lux and at a 95 percent physical presence as defined in Exhibit I section (2) (D) paragraph 3. Should the contractor be notified to apply temporary pavement markings more than once to a specific job number, a mobilization fee of $1500 shall apply, not to exceed a maximum of two mobilization fees per job number. Mobilization charges will not apply on two-directional job numbers until after the second mobilization has been requested. Mobilization charges will not apply if the contractor has to reapply temporary paint markings that fall below the minimum criteria described above. The contractor agrees to remove MoDOT type 1 temporary raised pavement markers when located in proximity to where the tape is being installed at no charge to the Commission. The contractor agrees to remove MoDOT type 2 temporary raised pavement markers when located in proximity to where the tape is being installed at a unit cost as indicated in Exhibit III.

3M will provide MoDOT evidence of completion of Services for each project listed in this Exhibit.

(C) MoDOT Responsibilities

MoDOT will ensure that 3M has timely access to work sites. In addition MoDOT will allow use of temporary markings on projects listed in this Exhibit until such time as 3M can provide Services according to the submitted work plan per this agreement.

MoDOT will process and settle all 3M invoices by their due dates. MoDOT will respond promptly, and in any case, within five business days, to any 3M request for direction, information, approval, authorization or other decision reasonably necessary for 3M to perform the Services.

MoDOT will allow 3M to perform Services during daytime and nighttime hours consistent with existing MoDOT policy.

(D) Warranty and Remedy

3M warrants that the Services will be performed in a safe, professional and workmanlike manner consistent with the applicable industry standards. Materials warranty shall conform to the specification and added provisions listed herein. Remedy for failure to meet warranty conditions will be according to the following:

If 380I-WR or contrast 380I-5WR fails to meet initial retroreflectivity of 500 mcd/m^2/lux, material will be replaced in kind.

		Warranty Resolution at Retained Retroreflectivity Levels		
		> 200 mcd/lux²	**100-199 mcd/lux²**	**< 100 mcd/lux²**
Age of Tape	0-2 years	Meets Performance Level	Replacement of material "in-kind"	
	3-4 years	Meets Performance Level		Replacement of material "in-kind"

		Warranty Resolution at Physical Presence Levels	
		> 95% presence	**< 95% presence**
Age of Tape	0-2 years	Meets Performance Level	Replacement of material "in-kind"
	3-4 years	Meets Performance Level	Replacement of material "in-kind"

Physical presence is defined as "Physical failure of more than 5 percent of the tape in a section will require warranty replacement of the tape in that section. Failure of a lane line is defined as 50 percent or more of a ten (10) foot lane line missing."

(E) General Provisions

3M is expressly allowed to subcontract some or all of the services to be performed by under this Agreement, but such subcontracting shall not relieve 3M of responsibility for performance and quality of the services.

3M will not be responsible for the delay in its performance of any obligation under this Agreement caused by acts of God, legal restrictions, or any other conditions beyond the control of 3M.

MISSOURI DOT PERFORMANCE SPECIFICATION

MISSOURI DEPARTMENT OF TRANSPORTATION
JEFFERSON CITY, MISSOURI
Striping and Striping Warranty

Request No. 2-080717CB

1. Introduction:

1.1 This solicitation seeks bids from qualified organizations to provide Striping and Striping Warranty throughout the state of Missouri with an effective contract period from the Notice to Proceed through June 30, 2012, to the Missouri Highways and Transportation Commission (MHTC) and Missouri Department of Transportation (MoDOT), hereinafter referred to as MoDOT.

2. Scope of Work

2.1 **General Requirements**

Services: The Offeror shall provide the following professional services:

Contractor to provide and install durable permanent pavement markings on various route in the St. Louis and Kansas City metropolitan areas that meet MoDOT defined performance criteria. The contractor will also warranty their product for a period of 4 years after the installation. Existing pavement markings will be removed and the contractor will install their system according to the guidelines described in the following. This includes mainline and ramp markings, mainline turn lanes and crossovers on the mainline. Outer roads and crossroads at interchanges are not included.

a. MoDOT will establish defined performance criteria for retroreflectivity, presence and color.
b. MoDOT will evaluate the pavement markings on the various routes from April 1 – June 1 during the contract period, for a total of 4 warranty evaluations.
c. An initial evaluation will be done before the end of 2008 to determine if the initial performance criteria are met.
d. Pavement markings will be evaluated in 1.0-mile segments.
e. The total contract price will be divided into 5 potential payments. The payment for the initial evaluation will be twelve (12) percent of the total contract cost. There will be four (4) warranty evaluations which will each be eligible for a maximum of twenty-two (22) percent of the total contract cost.
f. Contractor payment will be based on the number of segments meeting or exceeding performance criteria.
g. Contractor will provide per foot unit costs for replacement due to maintenance activities.
h. The various routes to be covered by this contract are listed in attachment A.
i. Estimated quantities of pavement markings to be installed are listed in attachment B.
j. The contractor will provide wet reflective pavement markings unless the existing markings are in a milled rumble.
k. The contractor will complete installation of their pavement marking system on all of the various routes by October 31, 2008.
l. The contractor will be allowed only one application of their pavement marking system. This excludes any restriping due to maintenance damage.

MISSOURI DEPARTMENT OF TRANSPORTATION
JEFFERSON CITY, MISSOURI
Striping and Striping Warranty

Request No. 2-080717CB

m. The contractor will be allowed to restripe up to 2.5 percent of the total pavement marking applied in a calendar year without effecting payment.
n. Intersection markings, such as stop bars, turn arrows and hash marks are not part of this contract and will be maintained by MoDOT forces.
o. The contractor will be responsible for the following marking at interchanges and intersections.
    - Interchanges – the contractor is expected to stripe the ramps to the ramp terminus. Normally this is where the ramp intersects the crossroad. For directional interchanges, the contractor will stripe the ramps to where they terminate on the other freeway.
    - At Grade Crossovers or signalized intersections – the contractor will be responsible for all long line markings within and approaching the intersection. Pavement markings on the side street approaches will not be the contractor's responsibility.

2.2 **Specific Requirements:**

PERFORMANCE CRITERIA

Performance criteria will be based on what MoDOT considers the minimum acceptable level.

Width and Alignment

- All white markings 6 inches wide.
- All yellow markings 6 inches wide.
- Gore markings will be 12 inches wide.
- Any skip markings or solid lines inside of the edgelines on concrete surfaces will be contrast marking according to the attached job special provision.

Marking Width Tolerance

Marking Width	Requirement
4 inch	± 1/4 inch
6 inch	± 1/4 inch
10 inches and above	± 1/2 inch

- Lateral deviation shall not exceed one inch in 100 feet.
- Length of ten-foot skip markings shall not deviate more than 3 inches.

Retroreflectivity

- Initial retroreflectivity measured after 7 days but no more than 45 days after the installation of the pavement markings shall meet the following table:

MISSOURI DEPARTMENT OF TRANSPORTATION
JEFFERSON CITY, MISSOURI
Striping and Striping Warranty

Request No. 2-080717CB

Initial Performance Retroreflectivity Criteria mcd/m²/lux 30 meter Laserlux	
White	**Yellow**
450	300

- The long term warranted retroreflectivity shall meet the following table:

Performance Retroreflectivity Criteria mcd/m²/lux 30 meter Laserlux	
White	**Yellow**
250	175

Chromaticity

- Chromaticity shall be within the following FHWA approved color boxes for the life of the marking material.

Daytime Color Specification Limits for Retroreflective Pavement Marking Material With CIE 2° Standard Observer and 45/0 (0/45) Geometry and CIE Standard Illuminant D_{65}

Color	Chromaticity Coordinates (Corner Points)							
	1		2		3		4	
	x	y	x	y	x	y	x	y
White	0.355	0.355	0.305	0.305	0.285	0.325	0.335	0.375
Yellow	0.560	0.440	0.490	0.510	0.420	0.440	0.460	0.400

Appearance

- Ninety-five percent (95%) of the total pavement marking material in a 1.0 mile segment shall remain in place.
- More than fifty-five percent (50%) of any individual skip shall be in place.

2.3 **Performance Evaluation**

MISSOURI DEPARTMENT OF TRANSPORTATION
JEFFERSON CITY, MISSOURI
Striping and Striping Warranty

Request No. 2-080717CB

MoDOT along with contractor representatives will do measurements of the performance criteria. The evaluations will be done by:

- Width and Alignment – during the collection of the retroreflectivity data. If the evaluation team is concerned about the width or alignment of a segment, field measurements will be taken by the team to verify performance.
- Retroreflectivity – primarily with a Laserlux van, handheld retroreflectometers may also be used for spot checks. Retroreflectivity will be strictly based on the retroreflectometer results for each segment.
- Chromaticity – by the MoDOT Chemical Lab at designated test sections using a handheld instrument. Chromaticity readings will be taken when the evaluation team is concerned that the color of a segment may be outside of the allowed coordinate box.
- Appearance – based on subjectivity ratings made during the collection of the retroreflectivity data. If the evaluation team is concerned about the appearance performance of a segment, field evaluations will be taken by the team to verify performance.

Retroreflectometer Calibration

The Laserlux van will be calibrated according to manufacturer's recommendations. The contractor is invited to participate in the calibration process to assure agreement with the calibration. If handheld retroreflectometers are used, they also will be calibrated to manufacturer's recommendations.

Evaluation Periods

There will be five (5) evaluation periods, one initial evaluation and four warranty evaluations.

The initial evaluation period will be conducted between seven and forty-five days after the pavement markings have been placed. This evaluation period will focus on meeting the initial retroreflectivity requirements as well as alignment, width and color.

Warranty evaluation of pavement markings on the various routes will be conducted from April 1 – June 1 prior to each payment period.

The contractor will be notified 1 week before evaluations are to begin to send a representative. The contractor will be supplied a full report at the end of each evaluation period.

In addition, MoDOT will reserve the right to randomly inspect any of the pavement markings on the various routes outside of the payment evaluation periods. These inspections will be part of quality assurance (QA) auditing. The contractor will be notified of the results of these QA auditing inspections.

MISSOURI DEPARTMENT OF TRANSPORTATION
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Contractor Payments

Payments to the contractor will be based on performance evaluations. Payments will be based on the following:

- The contract will be bid as one complete total cost to provide and install warranted pavement markings on the various routes for the duration of the contract period.
- This total bid price will be divided into 5 potential payment amounts based on the following table.

Payment Percentages Table

Evaluation Period	Maximum Percent of Total Contract price Available
Initial Performance	12
Warranty Performance 1	22
Warranty Performance 2	22
Warranty Performance 3	22
Warranty Performance 4	22

- Each of these amounts will be the maximum payment available to the contractor per payment period.
- Payment will be based on the performance of individual 1.0 mile segments.
- The total payment available for the performance period will be divided by the available number of 1.0 mile segments available during that payment period.
- Each line on the various routes will be evaluated individually.
- Payment will be based on those segments per line that meet or exceed the performance criteria.
- Failure to meet the performance criteria on any 1.0 mile segment of a line will result in no payment for that segment.
- All repairs shall be completed by Memorial Day.
- Contractor payments will be made according to the following schedule;

MISSOURI DEPARTMENT OF TRANSPORTATION
JEFFERSON CITY, MISSOURI
Striping and Striping Warranty

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Payment Schedule	
When	**Pay Period**
December 31, 2008	1
June 30, 2009	2
June 30, 2010	3
June 30, 2011	4
June 30, 2012	5

The contractor will be allowed to repair up to 2.5 percent of the total pavement markings applied in a year and still receive full payment for the next warranty payment period. Failure of more than 2.5 percent of the total pavement markings will deducted for the amount of payment due for that warranty pay period.

Dispute Resolution

If there are irreconcilable disagreements on the retroreflectivity results, the contractor may hire, at their expense, a third party, approved by MoDOT, to take retroreflectivity readings. These readings will be the final numbers used in determining payment.

Material

The contractor has full choice on what material to use to meet the performance criteria, with the following considerations. The contractor has the option of deciding the amount and type of yellow pigment for yellow material. The contractor shall certify that all yellow materials using lead chromate pigments shall meet the criteria of non-hazardous waste as defined by 40 CFR 261.24 when tested in accordance with EPA Method 1311, Toxicity Characteristics Leaching Procedures (TCLP). The striping and marking material, upon preparation and installation, shall not exude fumes that are toxic, or detrimental to persons or property. All material using lead free pigments shall not contain either lead or other Resource Conservation and Recovery Act (RCRA) materials, in excess of the standard defined by EPA Method 3050 and 6010.

Traffic Control

The contractor shall be responsible for providing all traffic control during the pavement marking operations. Traffic control shall be in accordance with the MoDOT *Traffic Control for Field Operations* manual. The contractor shall notify the appropriate Work Zone Coordinator at a MoDOT District Office two (2) MoDOT working days in advance of any work being performed.

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Unless the material is track free at the end of the contractor's application train, traffic channelizers shall be used to protect the markings from traffic. Any claims resulting from vehicles tracking the freshly applied material will be the responsibility of the contractor.

There may be some time restrictions applied as needed, or due to incidents, planned events that generate increased traffic, or to coordinate with other roadway work going on. Due to traffic volumes, the majority of work in the St. Louis and Kansas City areas will be done at night. The District Work Zone Coordinator will advise the contractor if any of the work will be allowed during daylight hours.

Removal of Existing Markings

When removing existing pavement marking, the method of surface preparation or removal shall not cause structural damage to the pavement. Current acceptable methods are water blasting, shot blasting or grinding.

The contractor is expected to have neat, crisp lines. When existing markings are being removed for the application of the contractor's markings, the contractor will completely remove those markings that will impact the appearance of their markings. As an example, skips that have become too wide or too long due to multiple stripings, will be totally removed before the contractor installs their markings.

Layout of New Markings

Prior to installing any permanent pavement markings, the contractor shall notify the Traffic Section at the appropriate District Office. MoDOT forces will work with the contractor to locate the type, color and width of markings prior to placement. Failure of the contractor to contact MoDOT prior to the installation of permanent markings will cause any markings done not in accordance with MoDOT pavement marking guidelines to be considered failed and not available for payment.

Maintenance Activities

During the course of this contract there will be locations where maintenance of the surface or shoulders will be required. If the maintenance activities degrade or destroy the pavement markings, the contractor will not be held responsible. The contractor will provide MoDOT with a unit price, per foot, for replacing permanent pavement markings damaged by maintenance activities.

When either 500 feet or more of continuous line is missing or when 1000 feet or more within a 1-mile stretch are missing, the contractor will begin repair activities. MoDOT will notify the contractor when and where repairs need to be made.

Damage by Others

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Striping and Striping Warranty

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If other contractors working on the various routes damage existing contractor installed lines, repair will be handled the same as for maintenance activities.

Damage to Pavement

The pavement markings used by the contractor shall not cause any noticeable damage to the pavement over the life of the contract.

Grooved Installation

The contractor will be allowed to install the permanent markings in a groove, if the installation is in accordance with manufacturer's recommendations. The groove area shall meet the following tolerances:

- Not more than 1 inch wider than the pavement marking
- Not more than 2 foot longer than the pavement marking
- Not deviate laterally more than 3/8 inch in 10 feet
- Depth in accordance with manufacturer's recommendations
- The entire area of the groove shall be sealed with either the permanent pavement marking or other approved sealer.

Failure to meet the above tolerances will result in failure of the markings and no payment will be made.

Warranty

The contractor shall warrant that all pavement markings are in accordance with the performance criteria as defined in this contract. Any pavement markings failing to meet the performance criteria will not be eligible for payment. Failure of the pavement markings due to, but not necessarily limited to, damage by traffic, anti-skid materials, studded tires, tire chains, chemical deicers, snowplowing or other loss of material will be considered cause for no payment. If the markings are damaged by pavement failure or MoDOT surface maintenance operations, the contractor shall replace the damaged markings at the agreed unit price. Evaluation of performance criteria will be done as previously described.

Default

If during any evaluation period, more than ten (10) percent of the pavement markings on the various routes are determined to have failed to meet the performance criteria, the contractor shall be considered in default. The contractor will provide, in writing, to MoDOT a plan to remedy the failures. The contractor will not implement their plan without prior approval from MoDOT. If MoDOT rejects the remediation plan, this contract will be cancelled with no further payment due the contractor.

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Exclusions

Some of the sections currently have Type 2 tape installed on the lane lines. Removing and replacing this tape is not part of the contract. Any tape that is damaged by the contractor's activities shall be replaced by the contractor at no cost to the Commission.

Comparison

As a comparison for determining the pricing of the warranty system, MoDOT is providing the following estimate of the current pavement marking system. The example uses one direction of a divided highway, one mile in length. The estimate is based on the following materials:

Skips are type 2 tape installed once.
Edgelines are contractor installed wet reflective paint installed the first year and restriped by MoDOT forces with high build wet reflective paint in years 2, 3 and 4.

Our estimated costs, per mile of a two lane, one direction divided highway are:

Asphalt	$13,851.02 per mile
Concrete	$14,775.02 per mile

The contractor, as part of their submittal, will provide a breakdown of costs per one mile of divided highway similar to the above.

3. Bid Submission

3.1 Each bid must be mailed or hand-delivered in a sealed package to the RFB Coordinator at the General Services Procurement Office. All questions regarding the RFB shall be submitted to the RFB Coordinator. All bids must be received at the General Services Procurement Office located at 830 MoDOT Drive, no later than **10:00 AM, CDT, July 17, 2008**.

RFB Coordinator:

Ms. Cheryl Bonner
Missouri Department of Transportation
830 MoDOT Drive; Jefferson City, MO 65109
P.O. Box 270; Jefferson City, MO 65102
PHONE: (573) 526-8194; FAX: (573) 526-1218

All bids must be received in a sealed package clearly marked **"Striping and Striping Warranty"**.

MISSOURI DEPARTMENT OF TRANSPORTATION
JEFFERSON CITY, MISSOURI
Striping and Striping Warranty

Request No. 2-080717CB

3.2 **Bid Guaranty/Contract Bond:**

The Contractor shall provide to the Commission and maintain at all times during the term of the Contract security for performance of the Work as described below (or other assurance satisfactory to the Commission in its sole discretion). Each bond required hereunder shall be provided by a Surety licensed as surety, and qualified to do business in the State of Missouri. The Surety shall be listed in the current United States Department of the Treasury, Fiscal Service, Department Circular 570, *Companies Holding Certificates of Authority as Acceptable Sureties on Federal Bonds and as Acceptable Reinsuring Companies.* The Contract bonds may not be in excess of the underwriting limitation listed in the circular. All bonds shall survive until all work bonded is completed and accepted.

Each bid shall be accompanied by a Bid Bond, Certified Check, Cashier's Check or Bank Money Order payable to the Director of Revenue—Credit State Road Fund for an amount equal to Five (5) Per Cent of the amount of the BID submitted, as a guarantee that the bidder, if awarded the contract, shall annually provide an acceptable performance and payment (Contract bond) or a cashier's check, a bank money order or a certified check made payable to "Director of Revenue—Credit State Road Fund" in an amount of the contract price of all the work eligible for payment that year.

If a BID BOND is used (in lieu of a certified check, cashier's check, or bank money order), it must be in the form provided and executed by the bidder as principal and by a surety company authorized to do business in the State of Missouri as surety. The agent executing the same on behalf of the surety company must attach a current Power of Attorney setting forth his authority to execute the bond involved.

3.3 Bids will be reviewed to determine if it complies with the mandatory requirements and to determine the lowest and responsive bid.

3.4 **Cost Determination** – The low bid shall be determined by the lowest cost submitted on the pricing page.

3.5 **Contract Award** – The contract will be awarded to the lowest responsive bidder determined as specified above.

a. Award of this bid will be made on an "All or None" basis after reviewing all options, and by using the "lowest and best" principle of award, providing the prices are acceptable to the Commission. In the event of tie low bids, the Commission reserves the right to establish the method to be used in determining the award.

3.6 **Open Competition/Request for Bid Document**

MISSOURI DEPARTMENT OF TRANSPORTATION
JEFFERSON CITY, MISSOURI
Striping and Striping Warranty

Request No. 2-080717CB

a. It shall be the bidder's responsibility to ask questions, request changes or clarification, or otherwise advise MoDOT if any language, specifications or requirements of an RFB appear to be ambiguous, contradictory, and/or arbitrary, or appear to inadvertently restrict or limit the requirements stated in the RFB to a single source. Any and all communication from bidders regarding specifications, requirements, competitive bid process, etc., must be directed to the buyer from the MoDOT, unless the RFB specifically refers the bidder to another contact. Such communication should be received at least five (5) working days prior to the official bid opening date.

MISSOURI DEPARTMENT OF TRANSPORTATION
JEFFERSON CITY, MISSOURI
Striping and Striping Warranty

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PRICE PAGE

(A) **FEE SCHEDULE:** The Offeror shall indicate below all fees for providing services in accordance with the provisions and requirements stated herein.

A. 5 Year Performance Striping $ 7,166,400.00 (see page 13A)

B. Per foot cost for striping due to maintenance activities. $ 27.00*

* Assuming 500 linear feet per instance.

Award will be based on the prices submitted in item A above.

Pavement Marking System

Offerer to describe the pavement marking system(s) proposed for this contract. The proposed pavement marking system(s) will not be part of the bid evaluation but is for informational purposes only.

The system consists of a proven, sophisticated, thermosetting hybrid polymer technology saturated with proven reflective media to deliver expected performance criteria mentioned herein.

Willard Hudgar — Signature

Controller — Title

POLY-CARB
Creative Chemistry for Infrastructure

August 21, 2008

Exhibit I

Mr. Kevin Keith
Chief Engineer
Missouri Department of Transportation
105 West Capitol, PO Box 270
Jefferson City, MO 65102

Re: *Striping and Striping Warranty RFB 2-080717CB*

Dear **Mr. Keith**:

In response to your RFB for *Striping and Striping Warranty*, the following is **POLY-CARB's** value-engineered proposal.

1. Project completion date of July 1, 2009.
2. Work allowed during day and night except rush-hours. District coordination and consent is required.
3. The following retro-reflectivity requirements:

Retro-reflectivity: mcd/m²/lux	White	Yellow
Initial RR Performance	450	300
Warranted (4 years)	**200**	**150**

Rumble stripes are exempt from retro-reflectivity requirements.

4. All edge-line and skip-dash markings will contain wet-reflective media. Gore markings will not.
5. Contractual payment terms of 60% upon completion and 4 payments of 10% each. Bi-weekly progress estimates shall be submitted. Work performed and completed will have warranty evaluations in 2009.
6. **POLY-CARB** will be able to correct any pavement markings installation prior to MODOT's initial acceptance/payment.
7. **POLY-CARB's** Value-Engineered proposal:

As bid POLY-CARB Proposal	$ 7,166,400
Value-Engineered Savings	***($ 600,427)***
Value-Engineered Proposal	**$ 6,565,973**

Thank you for your consideration. We look forward to serving you.

Warmest regards,
POLY-CARB, Inc.

Puneet Singh

Cc: Dan Patacca, Raymond Somich II, File

POLY-CARB, INC.
33095 Bainbridge Road
Cleveland, Ohio 44139
Tel: 440.248.1223
Fax: 440.248.1513
866.POLY-CARB (765-9227)
www.poly-carb.com

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POLY-CARB
Creative Chemistry for Infrastructure

Addendum: August 21, 2008 letter regarding *Striping and Striping Warranty RFB 2-080717CB*

August 25, 2008
Mr. Kevin Keith
Missouri Department of Transportation

Exhibit II

The following should clarify these points to our previous communication.

Item 3

The rumble stripes will be installed to meet initial retroreflectivity requirements, but they will not be held to the warranty requirements over the long term.

Item 4

a) Skip-dash markings will be contrast. Edgelines and gores will not be contrast.
b) Gore markings will contain wet-reflective media similar to the rest of the lines.

Item 5

a) POLY-CARB understands no lump sum payment will be made.
b) Payment is directed as 60% upon location completion (per section of road) and meeting initial performance requirements. Balance of 4 payments at 10% each will be paid upon passing each annual requirement.
c) Work completed in 2008 will adhere to the payment date plan as bid. 2009 completed work will have its first inspection no later than November 1, 2009.
d) Bi-weekly estimate reports will be submitted for progress planning and update purposes.

Thank you for the opportunity to clarify these matters. Please contact me should you have further questions.

Respectfully submitted,

POLY-CARB, Inc.

Puneet Singh

Cc: Dan Patacca, Raymond Somich II, File
PS/rcs

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Addendum B: In Follow-up from August 21, 2008 letter regarding *Striping and Striping Warranty RFB 2-080717CB* and August 25, 2008 Addendum.

August 29, 2008

Mr. Kevin Keith

Missouri Department of Transportation

The following is presented in lieu of the previous Item 5(c).

Work completed in 2008 will adhere to the payment date plan as bid.

For pavement markings completed during calendar year 2009 and before July 1, 2009, the following payment schedule will be used.

Payment Schedule		
When	**Pay Period**	**Payment Type**
August 30, 2009	1	Initial
June 30, 2010	2	Warranty
June 30, 2011	3	Warranty
June 30, 2012	4	Warranty
June 30, 2013	5	Warranty

Thank you for the opportunity to further clarify this matter.
Please contact me should you have further questions.

Respectfully submitted,

POLY-CARB, Inc.

Puneet Singh

Cc: Dan Patacca, Raymond Somich II, File

PS/rcs

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APPENDIX D11

Agency: Nevada Department of Transportation

Attached Example(s) of Warranty Specifications:

Pavement Marking Specification	Period	Remarks
General Warranty Requirement Covering Specified Materials	2 years	The attached warranty, Section 102.13, is a general material guaranty of performance for the pavement marking materials that are specified for a particular project. (This example is taken from Nevada DOT District One.) The contractor is the party responsible for fulfilling warranty requirements. The warranty is written generally to cover any pavement markings that are included in the project.

NEVADA DEPARTMENT OF TRANSPORTATION

102.13 Material Guaranty The successful bidder shall provide a warranty on all pavement marking materials provided under this agreement for a 2-year period from the date of the final acceptance by the Engineer. The successful bidder will maintain the performance bond throughout the installation and warranty period. The day-time and night-time color of the retro-reflective pavement markings materials applied shall be as per ASTM D6628-03, and shall continue to conform with this Specification throughout the 2-year warranty period. The Pavement Markings material shall provide a minimum reflectivity reading of 200 mcd/(m^2 lx) for white pavement markings and 200 mcd/(m^2 lx) for yellow pavement markings throughout the 2-year warranty period. The successful bidder will replace any pavement markings installed under this agreement that do not meet the above specifications and/or become damaged, discolored, loses either day-time or night-time visibility throughout the life of the warranty period, at no cost to the Nevada Department of Transportation. The contractor shall replace any defective pavement markings within 30-calendar days, as directed by the State of Nevada Department of Transportation District One Engineer. Failure to meet the above specification within 30 calendar days will result in the Department commencing procedures to utilize the performance bond to pay for the replacement of the defective markings.

The Engineer will be responsible for the final decision regarding questions concerning the performance of the pavement markings during the warranty period and as to the acceptable fulfillment of the warranty.

APPENDIX D12

Agency: Northwest Territories—Transportation

Attached Example(s) of Warranty Specifications:

Pavement Marking Material	Period	Remarks
Paint with Reflecting Beads	1 year	The warranty for materials and workmanship derives from general conditions that govern all government-sponsored construction work in the Northwest Territories. GC32, Warranty and Rectification of Defects in Work, is excerpted in the attached document. GC32 provides for correction of defects or faults in work that become evident within 12 months of acceptance. Given the harsh winter conditions that realistically limit the expected life of pavement markings, the warranty is rarely invoked. It is viewed as protection to the Government to ensure that work and materials are up to standard and not deficient. Pavement markings are placed on paved roads and chip-seal surfaces, and include single and double lines, solid and broken directional dividing lines, edge lines, lane lines, continuity lines, arrows, gore areas, stop lines, crosswalk areas, railroad crossings, and lines and legends at ferry approaches. The specified painting period is limited to 20-25 days in August. The contractor is the responsible party in fulfilling this warranty. The contractor is not responsible for damage due to normal wear and tear that can be reasonably expected. In this context, winter maintenance operations are considered part of normal wear and tear. Contract documents (not included in the attachment) provide for several quality control mechanisms; for example, a pre-construction meeting, required contractor site visits, a list of Approved Paint Materials, and government-provided storage areas.

GOVERNMENT OF THE NORTHWEST TERRITORIES (GNWT) TRANSPORTATION

Excerpt from contract General Conditions

GC32 WARRANTY AND RECTIFICATION OF DEFECTS IN WORK

32.1 Without restricting any warranty or guarantee implied or imposed by law or contained in the Contract Documents, the Contractor shall, at his own expense, rectify and make good any defect or fault that appears in the Work or comes to the attention of the GNWT within 12 months from the date of the Final Certificate of Completion referred to in GC44.1.

32.2 The Engineer may direct the Contractor to rectify and make good any defect or fault referred to in GC32.1 or covered by any other expressed or implied warranty or guarantee.

32.3 A direction referred to in GC32.2 shall be in writing, may include a stipulation in respect of the time within which a defect or fault is required to be rectified and made good by the Contractor, and shall be given to the Contractor in accordance with GC11.3.

32.4 The Contractor shall rectify and make good any defect or fault described in a direction given pursuant to GC32.2 within the time stipulated therein.

APPENDIX D13

Agency: Oregon Department of Transportation

Attached Example(s) of Warranty Specifications:

Pavement Marking Specification	Period	Remarks
General Language (SECTION 00850)	All warranty periods below begin after acceptance of the pavement marking.	This section describes general requirements for the range of pavement marking materials used: high-performance markings, methyl methacrylate (MMA), pavement markers, marking paint, marking tape, and thermoplastic. Associated adhesives and reflective elements are also discussed. Pavement marking materials must be selected from the Qualified Products List (QPL). The specifications cover general labor, equipment, materials, and methods requirements. They describe the role and responsibility of a manufacturer's representative when called for to be onsite during pavement marking installation. They describe manufacturer's certification of installers when called for in the specific sections below. A pre-striping conference will be held prior to work. A 150-ft test section is required for approval prior to installation of longitudinal markings. Section 00850.75 describes the general warranty requirements. The manufacturer is the party responsible for fulfilling warranty requirements when called for in the sections below.

Pavement Marking Specification	Period	Remarks
Durable Warranty Requirements, Long Lines (SECTION 00865.75)	3 years: 4 years:	For surface-mounted thermoplastic. For other materials and methods in this section. Pavement markings covered by this section require an onsite manufacturer's representative, manufacturer-certified installers, and a manufacturer's warranty to meet the specified performance criteria. Methods and materials in this section include the following: Method—Profile: MMA, thermoplastic, 90 or 120 mils; Method—Non-Profile: MMA, thermoplastic, 90 or 120 mils; Method—Inlaid: MMA, thermoplastic, different patterns specified; Method—Profile Wet Weather: thermoplastic, MMA; Method—Non-Profile Wet Weather: thermoplastic, MMA; Method—Spray: MMA, thermoplastic, 90 or 120 mils; Material—Pavement Marking Tape: hot-laid or grooved, different patterns specified.
High Performance Marking Warranty Requirements, Long Lines (SECTION 00866.75)	1 year	For modified urethane, sprayed (25 mils) or protected inlaid. Pavement markings covered by this section require an onsite manufacturer's representative, manufacturer-certified installers, and a manufacturer's warranty to meet the specified performance criteria.
Durable Warranty Requirements, Legends, Stop Bars, and Crosswalk Bars (SECTION 00867.75)	18 months	For the following materials and methods: liquid, hot-laid thermoplastic; preformed, fused thermoplastic film; cold-applied plastic film (tape); and methyl methacrylate. Pavement markings covered by this section require an onsite manufacturer's representative and a manufacturer's warranty to meet the specified performance criteria.

OREGON DEPARTMENT OF TRANSPORTATION

Section 00850—Common Provisions for Pavement Markings

Description

00850.00 Scope—This work consists of furnishing, preparing, and installing all forms of pavement markings.

Materials

00850.10 Materials—Furnish the following materials from the QPL:

- Adhesive for Pavement Markers
- High Performance Pavement Markings
- Methyl Methacrylate
- Pavement Markers
- Reflective Elements*
- Marking Paint
- Marking Tape
- Thermoplastic

* Reflective elements used with materials other than marking paint are not required to be from the QPL. Use reflective elements according to the manufacturer's recommendations.

Equipment

00850.20 Equipment—Use equipment acceptable by the marking material manufacturer for the method specified and the following:

(a) Equipment for Pavement Legends and Bars—Use manual or automatic application equipment.

(b) Equipment for Longitudinal Lines—Use applicators, sprayers or extruders made specifically for applying the specified pavement marking material at a uniform width and thickness on the roadway surface.

Except for tape applications, use automatic bead applicators that place a uniform layer of beads on the line.

Use equipment capable of placing two parallel lines simultaneously with variable spacing between the two lines and capable of placing the entire width of a line in one pass.

Use a three-gun system for applying sprayed markings.

Hand units are allowed for tape applications only.

(c) Equipment for Inlaid/Grooved Markings—Use grinding equipment with diamond grinding heads and shot-blasting equipment to create a smooth, flat-bottomed cut of uniform depth.

Labor

00850.30 Manufacture's Representative—For Sections referencing 00850.30, provide the services of a manufacturer's representative on-site during the installation, authorized to sign a warranty on behalf of the manufacturer.

00850.31 Manufacturer-Certified Installers—For Sections referencing 00850.31, provide installers certified by the marking materials manufacturer for the specified marking material and method. Do not begin installation prior to receiving the Engineer's approval.

Construction

00850.40 Projects Without Striping Plans—For projects without striping Supplemental Drawings, replace striping to match existing pavement markings in-kind. Document existing striping by survey according to Special Provision 00305. Submit survey documentation to the Engineer seven calendar days prior to loss of existing pavement markings.

00850.41 Projects With Striping Plans—For projects with striping Supplemental Drawings, install striping as shown.

00850.42 Pre-Striping Conference—Meet with the Engineer and striping subcontractor, if striping is done by a subcontractor, two weeks prior to beginning striping work to discuss methods and practices of accomplishing all required striping work. Submit the following in writing five calendar days before the pre-striping conference for approval:

- A striping schedule showing areas and timing of work, and placing of material.
- A list of materials proposed for use and the application method.
- A copy of the manufacturer's installation instructions and Material Safety Data Sheets (MSDS).
- Proof of installer's certification for those Sections referencing 00850.31.
- Equipment specifications.
- A spill recovery plan including:
  - Name, address, and phone number of the Contractor's contact with the DEQ.
  - Name, address, and phone number of the persons certified and on-call to do clean-up.

00850.43 Prepare and Prime Pavement—Prepare pavement surfaces according to the following:

- **Existing Pavement Surfaces—**When required by the pavement marking manufacturer, remove pavement markings from existing pavement surfaces that will adversely affect the bond of new pavement marking material to the roadway surface according to Section 00851.

  Remove all other contaminants from existing pavement surfaces that may adversely affect the installation of new pavement markings by sandblasting, shot-blasting, or sweeping. Air blast the pavement with a high-pressure system to remove extraneous or loose material.

- New Asphalt Concrete Surfaces—Remove contaminants from new AC surfaces that may adversely affect the installation of the pavement markings by sandblasting, shot-blasting, or sweeping. Air blast the pavement with a high-pressure system to remove extraneous or loose material. Apply materials to new asphalt concrete that is sufficiently cured according to the manufacturer's recommendations.

- New Portland Cement Concrete Surfaces—Remove curing compounds and laitance by an approved mechanical means. Air blast the pavement with a high-pressure system to remove extraneous or loose material. Apply materials to concrete that has reached a minimum compressive strength of 3,000 psi and that is sufficiently cured according to the manufacturer's recommendations.

After the pavement surface is clean and dry, apply primer as recommended by the manufacturer to the area receiving the pavement markings. Apply the primer in a continuous, solid film according to the recommendations of the primer manufacturer and the pavement markings manufacturer.

00850.44 Alignment Layout—Place control points for lines every 50 feet on tangent and every 25 feet on a curve. Using these control points, layout a continuous narrow guideline for each line, along one edge of, or uniformly offset from the intended permanent line location. Do not proceed with installation until the guidelines are approved by the Engineer.

For inlaid/grooved markings, indicate the exact grind-out location with a 4 inch wide line as the guideline. For broken lines, lane drop lines, and dotted lines, use 10 feet, 3 feet, and 2 feet long sections respectively, at the cycle length shown. For solid lines, use a continuous line. Use marking paint from the QPL applied at a thickness of 6 mils. Reflective elements are not required.

00850.45 Installation—Apply pavement marking materials to clean dry pavement surfaces and according the following:

- Place material according to the manufacture's recommendations.
- Place parallel double lines in one pass.
- Place the specified width of lines in one pass.
- The pavement surface shall not be visible in the striped areas.
- The top of pavement marking shall be smooth and uniform.
- Skip line ends shall be square and clean.
- Place pavement marking lines parallel and true to line.
- Place skip lines so that they are in cycle with at least one end of any adjacent project.
- Place markings in proper alignment with existing markings.
- Immediately clean up marking material dribbled beyond the cutoff.

For inlaid/grooved markings, grind the slot as shown. For each grinder operator and piece of equipment, obtain the Engineer's and manufacturer representative's approval of the slot within the first 150 feet for solid lines and within the first 300 feet for skip lines. Do not proceed with grinding until the slot is approved. Repeat this process for each new grinder operator or new piece of equipment used.

After grinding, obtain the Engineer's and manufacturer representative's approval before placing marking material. Clean the slot by shot blasting. Remove metal shot-blasting residue by magnetic sweeping, and clean the area with high pressure air immediately before placing the marking material.

00850.46 Placement Tolerance—Allowable tolerances for installation are:

- **Lateral location on roadway:** 1/2 inch on tangents; 1 inch on curves
- **40 foot skip cycle length:** ±2 inches for skip length, ±2 inches for gap length
- **12 foot skip cycle length:** ± 3/4inch for skip length, ±1 inches for gap length
- **8 foot skip cycle length:** ±1/2 inch for skip length, ±3/4 inches for gap length
- **Skip Cycle:** A tolerance of 1/10 of the skip line length on the first skip line of a run, but it shall be on cycle within one skip
- **Double lines:** Parallel, with a gap tolerance of ±1/2 inch
- **Width of lines:** +3/8 inch, –1/16 inch
- **Thickness of lines:** +5 mils, –3 mils
- **Divergence of parallel double lines:** ±3/8 inch

00850.47 Quality Control—Record the following readings for each type and color of marking material and the locations where they were taken. Submit the results to the Agency within one day of taking the readings.

(a) Placement Tolerances—Measure the following at the time of installation or application:

- For inlaid/grooved markings, measure the depth of the slot every 300 feet.
- For surface applied markings, except paint and tape applications, measure the thickness of the lines, at 300 foot intervals. Thickness is measured from the top of the pavement marking to the top of the wearing surface. Marking material placed in a depression left by pavement line removal will not be included in measuring the thickness of the line.

(b) Curing of Material—Rate the line, markings, and pavement marker adhesive at the time of installation and 14 calendar days after placement to determine if the material has properly cured. Note any soft spots, abnormally darkened areas, or other indications that the line has not properly cured.

(c) Retroreflectivity—Use a retroreflectometer to measure the retroreflectivity within 48 hours of curing and 14 calendar days after placement, except for paint applications:

- At 300 foot intervals for longitudinal lines.
- At each pavement legend/bar. Take ten individual readings per pavement legend/bar. If the Project has more than ten pavement legend/bars, measure a minimum of ten legends/bars or 10% of the total number of legends/bars, whichever is greater. The legends to be measured will be selected by the Engineer.
- Estimate the bead embedment depth for longitudinal lines and pavement legends/bars at the same location as the retroreflectivity reading.

Temporary

00850.50 General—Protect all applied markings from traffic until sufficiently cured so as not to be damaged or tracked by traffic movements.

Finishing and Clean-up

00850.70 Disposal of Waste—Waste material becomes the property of the Contractor at the point or origin. This includes all grindings and all removed marking material. Dispose of waste according to 00290.20.

00850.71 Removal and Repair of Unacceptable Work—Remove unacceptable materials according to Section 00851. If more than one repair is required in a single 300 foot section, grind and repair the entire 300 foot section.

00850.75 Manufacturer's Warranty—For Sections referencing 00850.75, furnish a Warranty from the manufacture signed by the manufacture's representative.

The Warranty period will start on the date the Engineer accepts the work and authorizes final payment [i.e., payment for this Specific Bid Item, not necessarily for the entire project] (clarification provided by Oregon DOT on 12-02-2008, not yet incorporated formally in specification).

The Warranty shall recite that the manufacturer will repair or replace, at the discretion of the Engineer and at no additional cost to the Agency, all pavement markings that drop below the minimum required retroreflectivity, show insufficient color stability, or fail to bond, within 6 months of the Agency's request to do so.

Perform Warranty repair work when weather permits. At the discretion of the Agency, temporary pavement markings may be required, at the manufacturer's expense, to protect traffic until repairs can be made.

When the Agency makes a written request to the manufacturer for repair or replacement, the Warranty period will stop until the required repairs or replacements are made and accepted.

APPENDIX D14

Agency: Texas Department of Transportation

Attached Example(s) of Warranty Specifications:

Pavement Marking	Period	Remarks
Longitudinal Prefabricated Pavement Markings (PPM) (SPECIAL SPECIFICATION 6986)	6 years after acceptance	Specifications describe the scope of work, materials and equipment requirements, application and performance evaluation methods, and pavement marking performance requirements. Specifications require a 6-year manufacturer's warranty bond, under which the manufacturer is responsible for meeting warranty performance requirements. Alternately, the contractor may provide a warranty bond that meets all requirements, in which case the contractor is the warrantor. Extreme wear at intersections, damage due to snow and ice removal, and premature pavement failure are considered examples of "outside causes." If the TxDOT Engineer determines that outside causes are responsible for pavement marking damage, such damage is not subject to the warranty's replacement provisions.
Multipolymer Pavement Markings (MPM) (SPECIAL SPECIFICATION 6153)	3 years after acceptance	Specifications describe the scope of work, materials and equipment requirements, application and performance evaluation methods, and pavement marking performance requirements. Specifications require a 3-year manufacturer's warranty bond, under which the manufacturer is responsible for meeting warranty performance requirements. Alternately, the contractor may provide a warranty bond that meets all requirements, in which case the contractor is the warrantor. Warranty provisions apply to longitudinal lines only. Transverse and gore markings, symbols, and words/ legends are excluded from warranty coverage. The TxDOT Engineer may exclude MPM from the warranty's replacement provisions if damage is determined to be from outside causes; for example, extreme wear at intersections, damage due to snow and ice removal, and premature pavement failure.

Pavement Marking	Period	Remarks
Raised Pavement Markers (RPMs) (SPECIAL SPECIFICATION 6152)	1 year	Specifications describe the scope of work, materials and equipment requirements, application and performance evaluation methods, and pavement marking performance requirements. Specifications require a 1-year manufacturer's warranty bond, under which the manufacturer is responsible for meeting warranty performance requirements. Alternately, the contractor may provide a warranty bond that meets all requirements, in which case the contractor is the warrantor. The evaluation of RPM performance proceeds in the following stages: Initial acceptance, as of the end of each month, of all passing RPMs installed that month, and at final job acceptance; A 60-day performance period; and A 1-year warranty period. During the performance period, RPM performance is evaluated visually in terms of retroreflectivity and missing markers. During the warranty period, RPM performance is evaluated visually in terms of retroreflectivity. The warranty does not cover replacement of missing markers. The TxDOT Engineer may exclude RPMs from the replacement provisions of the warranty or performance periods if damage is determined to be from outside causes; for example, extreme wear at intersections, damage due to snow and ice removal, and premature pavement failure.

2004 Specifications

SPECIAL SPECIFICATION
6986
Longitudinal Prefabricated Pavement Markings (PPM) with Warranty

1. Description. Furnish and place longitudinal PPM as shown on the plans. Provide a manufacturer's warranty bond for a 6 year period. The Department will allow a Contractor provided warranty bond in lieu of the manufacturer's bond if all conditions of the manufacturer's warranty including the requirements of this Item are met. In such case, the Contractor is responsible for meeting the warranty requirements. Use the form provided by the Department. The Department will allow substitution of a contractor's bond with a manufacturer's bond after execution of the Contract prior to final acceptance.

2. Materials. Use pavement markings that meet the requirements of Type B in DMS-8240, "Permanent Prefabricated Pavement Markings," and that are shown on the Material Producer List (MPL) entitled "Pavement Markings (Permanent, Prefabricated)"maintained by the Department.

3. Equipment. Provide equipment as required or directed according to the following (The provider of the warranty bond is responsible for providing equipment during the warranty period unless otherwise shown on the plans.):

A. Preparation and Application. Use equipment designed for the pavement preparation and application of the type of PPM material selected.

B. Colorimeter. Provide a colorimeter using 45°/0° geometry CIE, D65 Illuminant, 2° standard observation angle meeting the requirements of ASTM E 1347, E 1348, or E1349.

C. Retroreflectometer. Unless otherwise shown on the plans, provide a portable or mobile retroreflectometer meeting the following requirements.

1. **Portable Retroreflectometer.** Provide a portable retroreflectometer that meets the requirements of ASTM E 1710.
2. **Mobile Retroreflectometer.** Provide a mobile retroreflectometer that:

- is approved by the Construction Division (CST) and certified by the Texas Transportation Institute Mobile Retroreflectometer Certification Program for project evaluation of retroreflectivity
- is calibrated daily, before measuring retroreflectivity on any pavement stripe, with a portable retroreflectometer meeting the following requirements: ASTM E 1710, entrance angle of 88.76°, observation angle of 1.05°, and an accuracy of ±15%;
- requires no traffic control when retroreflectivity measurements are taken and is capable of taking continuous readings at or near posted speeds

Furnish mobile retroreflectivity measurements in compliance with Special Specification 6629 "Mobile Retroreflectivity Data Collection for Pavement Markings" unless otherwise approved by the Engineer. The Engineer may require an occasional field comparison check with a portable retroreflectometer meeting the requirements listed above to insure accuracy.

4. Construction.

A. General. Prepare the pavement surface using controlled techniques that minimize pavement damage and hazards to the traveling public. Apply the PPM materials, according to the manufacturer's recommendations, using widths, colors, shapes, and at locations as shown on the plans.

Obtain approval for the sequence of work and estimated daily production. Use traffic control as shown on the plans or as approved. Establish guides to mark the lateral location of pavement markings as shown on the plans or as directed, and have guide locations verified. Use material for guides that will not leave a permanent mark on the roadway. Apply markings in alignment with the guides and without deviating for the alignment more than 1 in. per 200 ft. of roadway or more than 2 in. maximum. Remove all applied markings that are not in alignment or sequence as stated in the plans or as stated in the specifications at the Contractor's expense and in accordance with Item 677, "Eliminating Existing Pavement Markings and Markers," except for measurement and payment.

B. Initial Performance Requirements. Meet Article 5, "Performance Requirements" initially, after installation. The Engineer will conduct visual performance evaluations of PPM**.** For markings that do not meet the Engineer's visual performance evaluation, the Contractor may present test results for color (using a colorimeter), retroreflectivity (using a retroreflectometer in accordance with this Item), and durability (in accordance with ASTM D 913) for the Engineer's use in making acceptance or rejection decisions.

For PPM not meeting performance requirements, repair or replace until reevaluation shows the PPM meet the performance requirements as approved by the Engineer.

C. Written Acceptance. The Department will provide written acceptance after the Contractor meets the initial performance requirements. This written acceptance (see attached sample form) will include the date, location, length, and type of PPM.

5. Performance Requirements.

A. Color. Provide PPM consisting of pigments blended to provide color conforming to highway colors as shown in Table 1.

Table 1
Color Requirements

Federal 595 Color		Chromaticity Coordinates								Brightness (Y)
		1		2		3		4		
		x	y	x	y	x	y	x	y	
White	17855	.290	.315	.310	.295	.350	.340	.330	.360	60 min
Yellow	33538	.470	.455	.510	.489	.490	.432	.537	.462	30 min
Black										5 max

B. Retroreflectivity. Provide PPM for longitudinal markings meeting the minimum retroreflectivity values listed in Table 2.

Table 2
Minimum Retroreflectivity Requirements

Color	Retroreflectivity, $mcd/m^2/lx$, Min
White	120
Yellow	120

C. Durability. Provide PPM that do not lose more than 5% of the striping material in a 1,000-ft section of continuous stripe or broken stripe (25 broken stripes). Pavement markings must remain in the proper alignment and location.

D. Performance Evaluation Procedures. Provide traffic control and conduct evaluations of color, retroreflectivity, and durability as required or directed.

1. **Color.** Measure color using 45°/0° geometry CIE, D65 Illuminant, 2° standard observation angle in accordance with ASTM E 1347, E 1348, or E 1349.
2. **Retroreflectivity.** Unless otherwise shown on the plans, conduct retroreflectivity evaluations of pavement markings with either a portable or mobile retroreflectometer. Make all measurements in the direction of traffic flow, except for broken centerline on 2-way roadways, where measurements will be made in both directions.

   If using a portable retroreflectometer, take a minimum of 1 measurement every mile on each series of markings (i.e., edge line, center skipline, each line of a double line, etc.), at locations approved by the Engineer. If more than 1 measurement is taken, average the measurements. For all markings measured in both directions, take a minimum of 1 measurement in each direction. If the measurement taken on a specific series of markings within each mile segment falls below the minimum retroreflectivity values, take a minimum of 5 more measurements at locations determined by the Engineer within that mile segment for that series of marking. If the average of these 5 measurements falls below the minimum retroreflectivity requirements, that mile segment of the applied markings does not meet the performance requirement.

   If using a mobile retroreflectometer, review the results to determine deficient sections and deficient areas of interest. These areas do not meet the performance requirements.
3. **Durability.** Measure durability in accordance with ASTM D 913 for marking material loss and visual inspection for alignment and location. Conduct evaluations at locations approved by the Engineer.

6. Warranty Requirements.

Each warranty period is for 6 yr. and starts the day after written acceptance.

The marking warrantor is responsible for meeting Article 5, “Performance Requirements” for the duration of the warranty period.

During the warranty period, the Engineer will conduct periodic visual performance evaluations of PPM. For retroreflectivity the Engineer will use Tex-828-B, “Determining Functional Characteristics of Pavement Markings.” The warrantor may be present during these evaluations. For areas, which, in the opinion of the Engineer, have a questionable visual evaluation, the warrantor may replace the PPM or may conduct a performance evaluation for the performance requirement in question, according to

Section 5.D, “Performance Evaluation Procedures.” Conduct retroreflectivity evaluations according to Section 5.D.2, “Retroreflectivity,” using either portable or mobile retroreflectometer unless otherwise shown on the plans. The warrantor is responsible for traffic control when conducting performance evaluations.

The warrantor will replace PPM that fails to meet the color, retroreflectivity, or durability performance requirements during the warranty period. Replace PPM that fails to meet the performance requirements within 30 days of notification.

All replacement PPM must meet the materials and performance requirements of this specification, under the following conditions to complete the warranty period:

If the longitudinal PPM fails to meet the performance requirements in Article 5 in Years 1 through 4, use materials meeting Type B requirements of specification DMS-8240.

If the longitudinal PPM fails to meet the performance requirements in Article 5 in Years 5 or 6, use materials that meet DMS-8240 (Type A or B) or on the MPL entitled “Pavement Markings (Multipolymer),” to meet the performance requirements of Article 5.

The end of the warranty period does not relieve the warrantor from the performance deficiencies requiring corrective action identified during the warranty period.

The Engineer may exclude PPM from the replacement provisions of the warranty period, provided the Engineer determines that the failure is a result of outside causes rather than defective material. Examples of outside causes are extreme wear at intersections, damage by snow or ice removal, and premature pavement failure.

Provide a contact person, address and telephone number for notification of needed PPM replacement.

7. Measurement. This Item will be measured by the foot or by any other unit shown on the plans. Each stripe will be measured separately.

This is a plans quantity measurement Item. The quantity to be paid is the quantity shown in the proposal unless modified by Article 9.2, “Plans Quantity Measurement.” Additional measurements or calculations will be made if adjustments of quantities are required.

8. Payment. The work performed and materials furnished in accordance with this Item and measured as provided under “Measurement” will be paid for at the unit price bid for “Longitudinal Prefabricated Pavement Markings (PPM) with Warranty” of the color, shape and width, specified as applicable, at the time of project acceptance. This price is full compensation for materials, application of longitudinal PPM, testing, warranty work, equipment, labor, tools, and incidentals.

2004 Specifications

SPECIAL SPECIFICATION
6153
Multipolymer Pavement Markings (MPM) with Warranty

1. Description. Furnish and place MPM as shown on the plans. Provide a manufacturer's warranty bond for longitudinal lines for a 3 year period. The Department will allow a Contractor provided warranty bond in lieu of the manufacturer's bond if all conditions of the manufacturer's warranty including the requirements of this Item are met. In such case, the Contractor is responsible for the meeting the warranty requirements. Use the form provided by the Department.

2. Materials.

A. Multipolymer Pavement Marking Materials. Use materials that produce an adherent, retroreflective pavement marking system that meets all of the performance requirements of this Item. Use materials that do not result in the generation of any hazardous materials/wastes, as defined in Article 1.58, "Hazardous Materials or Waste," during application or removal. If requested, provide a laboratory report from a commercial laboratory indicating material used does not result in the generation of any hazardous materials/wastes, as defined in Article 1.58, during application or removal.

Use a multipolymer resin material, which is:

- 2-component (a predominantly multipolymer pigmented resin component with a curing agent component);
- 100% solids, producing no toxic fumes when heated to application temperature;
- track-free in less than 40 min.; and
- formulated and tested to perform as a pavement marking material with glass spheres applied to the surface.

Before work begins, provide a laboratory report from an independent testing laboratory showing that the initial color of each material selected for use conforms to the color limits set forth in Table 1, measured by 45°/0° geometry CIE, D65 Illuminant, 2° standard observation angle in accordance with ASTM E 1347, E 1348, or E 1349.

B. Non-Reflectorized Contrast or Shadow Markings. The marking material used for the contrast or shadow marking must conform to the same formulation, material, prequalification and sampling requirements with the exception of the following items:

- color pigment used;
- glass spheres must be replaced with a black, color-fast, anti-skid material.

Before work begins, provide a laboratory report from an independent testing laboratory showing that the initial color of each material selected for use conforms to the color limits set forth in

Table 1, measured by 45°/0° geometry CIE, D65 Illuminant, 2° standard observation angle in accordance with ASTM E 1347, E 1348, or E 1349.

3. Equipment. Provide equipment as required or directed according to the following (The provider of the warranty bond is responsible for providing equipment during the warranty period unless otherwise shown on the plans.):

A. Preparation and Application. Use equipment designed for the pavement preparation and application of the type of MPM material selected.

B. Colorimeter. Provide a colorimeter using 45°/0° geometry CIE, D65 Illuminant, 2° standard observation angle meeting the requirements of ASTM E 1347, E 1348, or E 1349.

C. Retroreflectometer. Unless otherwise shown on the plans, provide a portable or mobile retroreflectometer meeting the following requirements.

1. Portable Retroreflectometer. Provide a portable retroreflectometer that meets the requirements of ASTM E 1710.

2. Mobile Retroreflectometer. Provide a mobile retroreflectometer that:

- is approved by the Construction Division (CST) for project evaluation of retroreflectivity, which will include taking a set of readings on stripes designated by CST and comparing them with the readings of a portable retroreflectometer provided by CST;
- is calibrated daily, before measuring retroreflectivity on any pavement stripe, with a portable retroreflectometer meeting the following requirements: ASTM E 1710, entrance angle of 88.76°, observation angle of 1.05°, and an accuracy of ±15%;
- requires no traffic control when retroreflectivity measurements are taken and is capable of taking continuous readings at or near posted speeds; and
- documents mobile retroreflectometer evaluations, showing average retroreflectivity values for each 0.25 mi. section, or the area of concern if it is less than 0.25 mi., with all deficient sections clearly marked.

4. Construction.

A. General. Prepare the pavement surface using controlled techniques that minimize pavement damage and hazards to the traveling public. Apply the MPM materials, according to the manufacturer's recommendations, using widths, colors, shapes, and at locations as shown on the plans.

Obtain approval for the sequence of work and estimated daily production. Use traffic control as shown on the plans or as approved. Establish guides to mark the lateral location of pavement markings as shown on the plans or as directed, and have guide locations verified. Use material for guides that will not leave a permanent mark on the roadway. Apply markings in alignment with the guides and without deviating for the alignment more than 1 in. per 200 ft. of roadway or more than 2 in. maximum. Remove all applied markings that are not in alignment or sequence as stated in the plans or as stated in the specifications at the Contractor's expense and in accordance with Item 677, "Eliminating Existing Pavement Markings and Markers," except for measurement and payment.

B. Initial Performance Requirements. Meet Article 5, "Performance Requirements" initially, after installation. Perform an initial performance evaluation after **7** and before **15** days after MPM are installed to verify that the MPM meet the performance requirements in Article 5 for retroreflectivity. Conduct initial retroreflectivity evaluations of placed pavement markings with either a portable or mobile retroreflectometer, unless otherwise shown on the plans, according to Section 5.D.2, "Retroreflectivity." The Contractor is responsible for traffic control when conducting performance evaluations.

For color and durability, the Engineer will conduct a visual evaluation and require Contractor testing only if MPM do not appear to meet the performance requirements in Article 5.

For MPM not meeting performance requirements, repair or replace until reevaluation shows the MPM meet the performance requirements as approved by the Engineer.

C. Written Acceptance. The Department will provide written acceptance after the Contractor meets the initial performance requirements. This written acceptance (see attached sample form) will include the date, location, length, and type of MPM.

5. Performance Requirements.

A. Color. Provide MPM consisting of pigments blended to provide color conforming to standard highway colors as shown in Table 1.

Table 1
Color Requirements

Federal 595 Color		Chromaticity Coordinates								Brightness (Y)
		1		2		3		4		
		x	y	x	y	x	y	x	y	
White	17855	.290	.315	.310	.295	.350	.340	.330	.360	60 min
Yellow	33538	.470	.455	.510	.489	.490	.432	.537	.462	30 min
Black										5 max

B. Retroreflectivity. Provide MPM meeting the minimum retroreflectivity values listed in Table 2.

Table 2
Minimum Retroreflectivity Requirements

Color	Retroreflectivity, $mcd/m^2/lx$, Min
White	175
Yellow	125

C. Durability. Provide MPM that do not lose more than 5% of the striping material in a 1,000-ft section of continuous stripe or broken stripe (25 broken stripes). Pavement markings must remain in the proper alignment and location.

D. Performance Evaluation Procedures. Provide traffic control and conduct evaluations of color, retroreflectivity, and durability as required or directed.

1. Color. Measure color using 45°/0° geometry CIE, D65 Illuminant, 2° standard observation angle in accordance with ASTM E 1347, E 1348, or E 1349.

2. Retroreflectivity. Unless otherwise shown on the plans, conduct retroreflectivity evaluations of pavement markings with either a portable or mobile retroreflectometer. Make all measurements in the direction of traffic flow, except for broken centerline on 2-way roadways, where measurements will be made in both directions.

If using a portable retroreflectometer, take a minimum of 1 measurement every mile on each series of markings (i.e., edge line, center skipline, each line of a double line, etc.), at locations approved by the Engineer. If more than 1 measurement is taken, average the measurements. For all markings measured in both directions, take a minimum of 1 measurement in each direction. If the measurement taken on a specific series of markings within each mile segment falls below the minimum retroreflectivity values, take a minimum of 5 more measurements within that mile segment for that series of marking. If the average of these 5 measurements falls below the minimum retroreflectivity requirements, that mile segment of the applied markings does not meet the performance requirement.

If using a mobile retroreflectometer, review the results to determine deficient sections and deficient areas of interest. These areas do not meet the performance requirements.

3. Durability. Measure durability in accordance with ASTM D 913 for marking material loss and visual inspection for alignment and location. Conduct evaluations at locations approved by the Engineer.

6. Warranty Requirements. The warranty requirements apply to the longitudinal lines only. Transverse and gore markings, symbols, words, etc. will not require warranty.

Each warranty period is for 3 yr. and starts the day after written acceptance.

The warrantor is responsible for meeting Article 5, “Performance Requirements” for the duration of the warranty period.

During the warranty period, the Engineer will conduct periodic visual performance evaluations of MPM. For retroreflectivity, the Engineer will use Tex-828-B, “Determining Functional Characteristics of Pavement Markings.” The warrantor may be present during these evaluations. For areas, which, in the opinion of the Engineer, have a questionable visual evaluation, the warrantor may replace the MPM or may conduct a performance evaluation for the performance requirement in question, according to Section 5.D, “Performance Evaluation Procedures.” Conduct retroreflectivity evaluations according to Section 5.D.2, “Retroreflectivity,” using either portable or mobile retroreflectometer unless otherwise shown on the plans. The warrantor is responsible for traffic control when conducting performance evaluations.

The warrantor will replace MPM that fails to meet the color, retroreflectivity, or durability performance requirements during the warranty period. Within 15 days after notification place new markings in accordance with Article 4, “Construction.”

All replacement MPM must meet the materials and performance requirements of this specification.

The end of the warranty period does not relieve the warrantor from the performance deficiencies requiring corrective action identified during the warranty period.

The Engineer may exclude MPM from the replacement provisions of the warranty period, provided the Engineer determines that the failure is a result of outside causes rather than defective material. Examples of outside causes are extreme wear at intersections, damage by snow or ice removal, and premature pavement failure.

Provide a contact name, address and telephone number for notification of needed MPM replacement.

7. Measurement. This Item will be measured by the foot; by each word, symbol, or shape; or by any other unit shown on the plans. Each stripe will be measured separately.

This is a plans quantity measurement Item. The quantity to be paid is the quantity shown in the proposal unless modified by Article 9.2, "Plans Quantity Measurement." Additional measurements or calculations will be made if adjustments of quantities are required.

8. Payment. The work performed and materials furnished in accordance with this Item and measured as provided under "Measurement" will be paid for at the unit price bid for "Multipolymer Pavement Markings (MPM) with Warranty" of the type and color specified and the shape, width, and size specified as applicable, at the time of project acceptance. This price is full compensation for materials, application of MPM, equipment, labor, tools, and incidentals.

SPECIAL SPECIFICATION
6152
Raised Pavement Markers (RPMs) with Warranty

1. **Description.** Furnish and place RPMs as shown on the plans. Provide a manufacturer's warranty bond for RPMs for a 1 year period. The Department will allow a Contractor provided warranty bond in lieu of the manufacturer's bond if all conditions of the manufacturer's warranty including the requirements of this Item are met. In such case, the Contractor is responsible for the meeting the warranty requirements. Use the form provided by the Department.

2. **Materials.** Furnish RPMs that meet DMS-4200, "Pavement Markers (Reflectorized)," and are on the Material Producer List. Furnish the same model RPMs for each type from the same manufacturer.

   Use adhesive approved by the RPM manufacturer.

3. **Construction.** Remove existing RPMs in accordance with Item 677, "Eliminating Existing Pavement Markings and Markers," except for measurement and payment.

   Install RPMs in accordance with RPM manufacturer's recommendations.

   Place RPMs on new asphalt concrete or surface treatment only after the new surface has aged at least 14 days.

   Establish pavement marking guides to mark the lateral location of RPMs as shown on the plans and as directed. Do not make permanent marks on the roadway for the guides. Place the RPMs in proper alignment with the guides. Acceptable placement deviations are shown on the plans.

   Remove RPMs placed out of alignment or sequence as shown on the plans or stated in this Specification at the Contractor's expense, in accordance with Item 677, except for measurement and payment.

   Remove and replace all RPMs failing to meet the visual evaluations as determined by the Engineer. Install each replacement RPM in front of and in alignment with the original RPM. Patch each hole left by the missing original RPM with an approved material at the time of RPM replacement.

   The Department will provide written acceptance as of the last calendar day of each month for RPMs installed that month and at final job acceptance for any remaining installed RPMs. This written acceptance (see attached sample form) will include the date, location, and quantity of markers accepted each month.

4. **Visual Evaluations.** The Department will use the following visual evaluations to measure the performance of installed RPMs:

   A. **Retroreflectivity of RPMs.** The Department will perform night retroreflectivity evaluations using a passenger vehicle with the headlights set on low beam. The RPMs within the range of the headlights must appear reflective.

      For RPMs initially installed at:

- 80-ft. spacing, a minimum of 4 RPMs must be retroreflective and
- 40-ft. spacing, a minimum of 8 RPMs must be retroreflective.

The Engineer may make exceptions where road geometry affects RPM visibility. The evaluation may include a videotape recording to be used for additional review and documentation of performance. Upon request, the Engineer will allow a Contractor or manufacturer representative to accompany the Engineer on subsequent evaluations when RPMs do not appear to meet the retroreflectivity requirements.

B. Missing RPMs. The Department will perform visual evaluations to determine if RPMs are missing. Upon request, the Engineer will allow a Contractor representative to accompany the Engineer on subsequent evaluations for missing RPMs.

The Engineer may exclude RPMs from the replacement provisions of the performance or warranty periods, provided the Engineer determines that the failure is a result of outside causes rather than defective material. Examples of outside causes are extreme wear at intersections, damage by snow or ice removal, and premature pavement failure.

5. Performance Period. Provide a 60-day performance period that begins the day following written acceptance.

Replace all RPMs failing to meet Article 4, “Visual Evaluations” during the performance period and within 15 days after notification following the procedures in Article 3, “Construction.” The end of the performance period does not relieve the Contractor from the performance deficiencies requiring corrective action identified during the performance period.

Provide a contact name, address and phone number for notification of needed RPM replacement.

6. Warranty Period. The warrantor must provide a warranty bond on the form provided and approved by the Department. (See the attached bond form.)

The warrantor warranty period is for 1-yr. and starts the day after the performance period ends. The warrantor will replace any RPMs that fail to meet Section 4. A, “Retroreflectivity of RPMs” during the warranty period and within 15 days after notification following the procedures in Article 3, “Construction.”

The end of the warranty period does not relieve the warrantor from the performance deficiencies requiring corrective action identified during the warranty period.

Each manufacturer’s warranty does not include replacement of missing RPMs.

Provide a contact name, address and phone number for notification of needed RPM replacement.

7. Measurement. This Item will be measured by each RPM. This is a plans quantity measurement Item.

The quantity to be paid is the quantity shown in the proposal, unless modified by Section 9.2, “Plans Quantity Measurement.” Additional measurements or calculations will be made if adjustments are required.

8. **Payment.** The work performed and materials furnished in accordance with this Specification and measured as provided under "Measurement" will be paid for at the unit price bid for "Raised Pavement Markers (RPMs) with Warranty" of the types specified. This price is full compensation for removing existing markers; furnishing and installing warranted RPMs and meeting the performance period requirements; providing a warranty bond; and equipment, materials, labor, tools, and incidentals. Payment for "Raised Pavement Markers (RPMs) with Warranty" will be handled in the following manner:

   A. Initial Payment. When RPM installations receive written acceptance, 80% of the bid price for RPMs of the type specified for that installation will be paid.

   B. Final Payment. At the completion of all performance periods and the replacement of all RPMs identified during the performance periods that failed to meet the visual evaluations, an additional 20% of the bid price for RPMs of the type specified will be paid.

APPENDIX D15

Agency: West Virginia Department of Transportation

Attached Example(s) of Warranty Specifications:

Pavement Marking	Period	Remarks
Medium-Life Pavement Marking System	1 year	The attached document is a sample contract containing specifications for "medium-life" pavement markings capable of providing at least one year of continuous performance. Short-duration products including solvent-borne paint, methyl methacrylate, and chlorinated rubber will not be approved. This is a true performance specification in that the overall requirement for a medium-life pavement marking system does not specify any particular material. Required aspects of marking application, materials properties, equipment capabilities, and so forth are specified. Pavement marking performance criteria include retroreflectivity, durability, and color retention. The required period of performance is delimited by specific calendar dates in the contract. Snowplow damage is considered normal wear and tear within the contract; thus, contractors would normally be responsible for repairs under the warranty. However, a discussion with WVDOT staff indicates that in exceptionally bad winters, the contractor may not be held responsible for resulting damage to pavement markings. Quality control mechanisms include a Pre-Construction Conference, letters of certification from the materials manufacturer and the contractor regarding suitability of the proposed materials, manufacturer certification of the contractor as installer, and appointment of a contractor's Project Control Coordinator (PCC) to oversee quality control. Contractor's failure to complete repairs of deficient markings within the specified period will cause the contractor to be subject to liquidated damages.

WEST VIRGINIA DOT

GOVERNING SPECIFICATIONS:

The West Virginia Division of Highway's Standard Specifications for Roads and Bridges, adopted 2000, Supplemental Specifications dated January 1, 2003, Standard Details Book, Volume 2, dated January 1, 1994, the Contract documents and the Contract Plans are the governing provisions applicable to this project.

MATERIALS:

The pavement marking material shall be formulated as a medium-life pavement marking system capable of providing a minimum of one year of continuous performance. Solvent born paint, methyl methacrylate, chlorinated rubber, or other short duration products will not be approved.

The successful Contractor may employ only one (1) paint scheme per Contract unless otherwise directed by the Director of the WVDOH Traffic Engineering Division (a paint scheme consisting of one particular binder, bead type(s), application rate and associated tolerances as specified by the manufacturer). However, the Contractor may utilize any paint scheme on call backs associated with failed pavement markings. There shall be no materials lab testing associated with the warranted pavement marking scheme, but the binder and bead type(s), application rate, and all other particulars shall be provided to the Engineer at the Pre-Construction Conference and a letter of certification from the manufacturer and contractor stating the materials to be used meet the materials specifications set forth in this contract. **The Contractor shall not place any pavement markings prior to April 15, 2008. The contract inception date shall be April 15, 2008 for calculating liquated damages**.

The Contractor shall provide a pavement marking system to meet the following performance requirements:

Color determination will be made at any point in time within the contract date. If not a visual match, the diffused day color of the marking shall conform to the following CIE Chromaticity coordinates limits:

Table 1

CIE CHROMATICITY COORDINATE LIMITS

Color	Reflectance Limits									
	1		2		3		4		Y (%)	
	x	y	x	y	x	y	x	y	min	max
White	0.480	0.410	0.430	0.380	0.405	0.405	0.455	0.435	80.0	—
Yellow	0.575	0.425	0.508	0.415	0.473	0.453	0.510	0.490	50.0	60.0

The color shall show no appreciable discoloration due to aging during the life of this contract. Pavement markings shall be visually checked by the Engineer at any time during the life of this contract. Additionally, the Engineer may at any time during the life of this contract use a portable color meter to determine if the markings have faded or darkened beyond the CIE Chromaticity Coordinate Limits.

RETROREFLECTIVITY/CONSTRUCTION:

The pavement marking system installed shall at all times during the life of this contract maintain a minimum reflectance value of 200 MCD/M^2/LX for white pavement markings and 150 MCD/M^2/LX for yellow pavement markings when measured with a LTL-2000 retroreflectometer or equal 30 meter device approved by the Traffic Engineering Division (TED). The Contractor will also be required to take and record a minimum of five (5) readings per day, per color, per pavement marking crew. These readings shall be recorded on the daily report and should be taken throughout the day. The contractor shall provide the printout tape from the LTL readings with the daily Centerline reports. The tapes should have the date, color and route on the LTL Log ID.

During the pavement marking contract, the pavement marking materials furnished and installed under this project shall show no signs of failure greater than five (5) percent loss due to blistering, excessive cracking, bleeding, staining, discoloration, smearing or spreading under heat, deterioration due to contact with oil or gasoline, chipping, scaling, spalling, poor adhesion to the pavement, damage from traffic and normal wear. Snowplow damage shall be considered as normal wear within this contract.

Retroreflectivity values shall be maintained until October 15, 2008. Loss due to pavement failure, unless caused by the marking material, will not be considered as a material failure and will not be included in the loss calculations and/or retroreflectivity readings.

PAVEMENT MARKING REVIEW:

There may be periodic pavement marking reviews throughout the project. These reviews will occur at any time after the markings have been placed. These reviews will evaluate the pavement marking material within the project limits for either day and night acceptability considering all requirements listed above. The following method will be used to measure the retroreflectivity acceptance of the pavement marking material:

- Locate and identify a starting point for measuring retroreflectivity pavement markings for a roadway. Obtain five (5) readings per line that are to be taken over a 1,000 foot section of roadway. Additional test measurements to be taken in one (1) mile intervals, with five (5) readings to be recorded in a 1,000 foot section.

- At each check point, readings are to be averaged to determine failed areas.

- If a section has failed, then testing measurements will be taken at one-half mile mark before and after the failed check point. Each of these check points will be defined as 1,000 foot sections prior and after the one-half mark. The readings before and after the failed check point shall be averaged to determine the direction of failed markings.

- If the initial check point fails, along with both one-half mark check points, then that entire one mile length of pavement markings would be considered to be failed.

- Roadways that are less than one (1) mile in length shall have ten (10) readings measured throughout the length of the project for each color line the average of these readings shall determine whether or not these pavement markings fail.

During the life of this contract if any markings along a 1,000 feet or more section of pavement are found to be deficient for any reason, the Contractor will be given notification stating the locations and the type of deficiency. These notifications will be given at any time during the life of the contract, but no later than October 15, 2008. The Contractor shall completely replace the deficient markings, as directed

by the Engineer within twenty (20) calendar days of the written notification. The retroreflectivity may be checked after re-application to meet the minimum value of that period.

If the Contractor *does not* complete the replacement of all of the deficient pavement markings by the end of the twenty (20) calendar day replacement period, the Contractor shall be subject to liquidated damages as described within Section 108.7 of the West Virginia Division of Highway's Standard Specifications until replacement is completed. These liquidated damages shall not stop during the winter shut-down period and shall be in combination with any other liquidated damages incurred. No direct payment shall be made for the replacement of any deficient pavement marking during the one year warranty period as such work shall be considered as incidental to the work as paid for by the various pavement marking items in the contract.

APPROVAL OF CONTRACTOR'S EQUIPMENT AND PERSONNEL:

The Contractor (prior to commencement of the project) shall submit to the Engineer a detailed list of all equipment and the resumes of all personnel within the confines of this project. The Contractor shall also provide certification from the binder manufacturer that the Contractor is qualified to apply the manufacturer's material in conformance with these specifications. Drivers and operators with less than one year of experience shall not be used on this project.

The Contractor is responsible for quality control, and to that end, shall employ a Project Control Coordinator (PCC) at the Contractor's expense. The PCC shall be designated and in attendance at the Pre-Construction Conference. This PCC shall be a member of the District Pavement Marking Crew. The PCC shall be responsible for all communication between the District Pavement Marking Crew and District Personnel. Communications shall be provided to the District, and shall be employed between the PCC and the District in the form of cellular phone technology, two-way radio, or other form of communication during working hours (communications shall be at the Contractor's expense and shall be integral to the contract cost).

The PCC shall be required to fill out all Daily Centerline Report(s) and provide these completed forms to the Engineer. The Contractor shall provide the District all collective daily centerline reports on a weekly basis. The Contractor's weekly centerline reports shall be delivered to the Engineer the first work day of the following week. Failure to deliver centerline reports to the Engineer shall invoke daily liquidated damages as described in Section 108.7 of the West Virginia Division of Highway's Standard Specifications for each calendar day that the Contractor fails in delivering these centerline reports. The Engineer will randomly check the accuracy of these reports. If a discrepancy of more than 2% is found, the Contractor will be required to have an independent consultant, approved by the Division, to verify all pay items on this contract. The cost of the consultant will be the responsibility of the Contractor—the Contractor will not be reimbursed by the Division for consultant services.

The Contractor's striper shall be equipped with electrical foot counters. The counters shall individually tabulate the amount of footage applied by each striping gun whether solid or dashed. The counters shall be six digit types with a reset feature. The Contractor shall determine the accuracy of the foot counters and establish an adjustment factor as required to determine the pay item quantities. The foot counters shall be periodically checked to assure accurate measurements. No paint shall be applied without the accurate operation of the foot counters. The Contractor shall provide the Engineer with a certified document on these calibrations. The Contractor shall employ a mechanical sweeper-blower unit powerful enough to remove normal highway dirt and debris. This unit shall not be part of the pavement marking truck and this shall be incidental to each respective bid item.

The Contractor shall use an accurate dashing mechanism, capable of being adjusted to retrace existing lane or center line markings.

APPLICATION OF PAVEMENT MARKING MATERIAL:

The pavement marking material shall be mixed uniformly throughout and shall have a homogeneous disbursement of color and beads when applied to the pavement.

Pavement marking lines shall be straight or of uniform curvature and shall conform with the tangents, curves, and transitions as specified in the pavement marking standards and/or as directed by the Engineer.

The finished lines shall have well-defined edges and be free of horizontal fluctuations. The lateral deviation shall not exceed 1.5 inch from the proposed location alignment as specified in the Standards and /or directed by the Engineer. When striping interchanges, material will be applied for the full length of all ramps, including all wraps around all islands and curbs, gore areas, etc.

The Contractor shall be responsible for removing all pavement marking materials spilled upon the roadway surface or adjoining area. The Contractor shall use methods acceptable to the Engineer for removing the spilled material.

Any pavement marking which is crossed by a vehicle and tracked shall be replaced and any subsequent marking made by the vehicle shall be removed by methods acceptable to the Engineer and at no additional cost to the Department.

The Department will be responsible for coding and spotting where old markings cannot be determined or if the Department desires to make changes in existing markings. The Department must be given notification of twelve (12) days prior to commencement of work in area.

Prior to commencement of work, and only if required by the binder manufacturer, all existing edge, lane or center lines will be fully eradicated in accordance with Section 636.7—Eradication of Pavement Markings. When eradicating lane or center lines, the Contractor shall replace the lines within twenty-four hours from the start of eradication. The eradication shall be incidental to Pay Items 663001-004“#” and 663002-005“#.”

The Contractor shall be responsible for cleaning and/or replacing any Raised Pavement Markers (RPMs) that are painted. The Contractor, when painting center lines, shall either offset or retard pavement marking lines to avoid painting the RPM reflectors.

RESURFACING PROJECTS AND PRIORITY PAINTING:

At the Pre-Construction Conference the Contractor will be provided with county maps and tables showing roadways to be painted. The contractor shall paint the centerline and or lane line on all routes by July 1, 2008. The centerline and or lane line shall be designated as priority painting. The Contractor shall be assessed liquidated damages for failure to meet this Priority Pavement Marking Date (PPMD) as shown in Schedule “A” per day, for each calendar day, that any of the routes are not marked with center line or lane line. The Contractor may begin painting on or after April 15, 2008.

Schedule A—Priority Pavement Marking Date (*PPMD*) =

$$\frac{\text{(Contract Bid Price/Total Days in Contract)}}{\text{(Total Days within Priority Period/\%of Priority Markings Completed)}} * \text{Delinquent Days}$$

EXAMPLE:

GIVEN:
Contract inception date April 15, 2008
Total days in contract = 107
Required Priority completion date July 1, 2008
Contractor's Priority completion date July 15, 2008
Percentage Priority route completed as of completion date = 90%
Contract bid price $500,000
Delinquent period = July 1, 2008 until July 15, 2008
(Calendar days which exceed the July 1st deadline, which include permitted weather days. Delinquent days not to exceed 107 calendar days.)

$\frac{(\$500{,}000/107) * 15 \text{ days}}{(77*0.9)}$ = $1011 per day/per delinquent period
= $16,515 Total liquidated damages

Once the Contractor begins, he shall continue the pavement marking contract until all of the scheduled routes are completed. All pavement markings on all scheduled routes shall be completed by August 1, 2008. The contractor shall be assessed liquidated damages as described in Schedule "B" for each calendar day that the Contractor exceeds the contract completion date. The Contractor may be called back after this date to do additional painting; however, no call-backs shall be issued after October 15, 2008.

Schedule B—Project Completion Liquidated Damages (*PCLD*) =

$$\frac{\text{Bid Price} * \text{Estimated Roadway Marking Uncompleted (\%)}}{\text{Total Number of Days in Contract}}$$

EXAMPLE:

GIVEN:
Contract inception date April 15, 2008
Completion date August 1, 2008
Percentage of roadway marking uncompleted 20%
Total bid price $500,000
Actual completion date August 16, 2008
Delinquent period = Aug. 1, 2008 until Aug. 15, 2008 (Calendar days which exceed the August 1st deadline which include permitted weather days).

$\frac{(\$500{,}000*0.20)}{107}$ = $935.00 per day/ per delinquent period
= $935.00 * 15 days
= $14,025 Total liquidated damages

REPLACEMENT (CALL-BACK) PAVEMENT MARKINGS:

The Engineer will try to provide the Contractor with a schedule of resurfacing projects and their anticipated completion dates. However, the Contractor will not be allowed to perform any additional pavement markings not allowed for in the contract during the priority phase of this contract 4/15/2008–7/1/2008).

After the Contractor has completed the priority phase of this contract, the Engineer shall have as his/her option the judgment to utilize the District Pavement Marking Contract 'OR' the District Recall Pavement Marking Contract to perform additional pavement markings not designated in this contract. This call-back shall be at the Engineer's discretion and the appointed Contractor shall be required to begin pavement markings for additional routes or for completed roadway projects upon notification within ten (10) working days.

Priority call-back may be required to begin within 24 hours but shall not be any later than three (3) working days. The Contractor will be required to place full compliance pavement markings, meaning the center line or lane line and edge line within the ten (10) working days, or three (3) working days for the priority call-back.

The Engineer may add or eliminate any route to or from the schedule, if, because of low traffic volumes or other reasons, if the Engineer determines the route does or does not require pavement markings.

The Contractor will be paid one unit of the Bid Item—204003-000 "Mobilization, Per Job Order" for each time the Contractor is called back to a District.

The Contractor shall be paid "Mobilization Per Priority Job order—Bid Item 204001-000" for each time he is called back to the District for priority Call-Back.

The Contractor will also be paid "Mobilization, Per Mile"—Bid Item 204002-000 to compensate for the mileage between the District Headquarters and the County Headquarters if the Call-Back requires the Contractor to place pavement markings outside the District Headquarters County.

The Contractor will also be paid "Mobilization, Per Mile" if the Engineer directs the Contractor for pavement marking which would require the Contractor to move outside the county he is working in.

The Contractor will not be paid "Mobilization, Per Job Order" if he/she is already in the District.

The Contractor will not be paid "Mobilization, Per Mile" if the approved weekly schedule requires the Contractor to be in the county of the route to be painted.

LIQUIDATED DAMAGES:

If the Contractor does not begin pavement marking within a notifications specified time, he shall be assessed liquidated damages as described in Section 108.7 of the West Virginia Division of Highway's Standard Specifications for each calendar working day after the respective notifications time constraints placed on the Contractor until painting begins.

TRAFFIC CONTROL:

Maintenance of Traffic shall be in accordance with Section 636 of the West Virginia Division of Highways Standard Specifications Roads and Bridges, adopted 2000, as amended by the West Virginia Division of Highways Supplemental Specifications, dated January 1, 2003, the Contract Documents and the Contract Plans. These are the governing provisions applicable to the project, and the manual, Traffic Control for Street and Highway Construction and Maintenance Operations, May 2006; which is made a part of this contract and the traffic plan for individual segments as described below:

Reflective sheeting used on temporary traffic control devices within the scope of this project shall be of new condition and meet the requirements of the WVDOH Approved Products Listing (APL). Night visibility and legibility shall be maintained for all temporary traffic control devices.

Traffic control shall be in accordance with Case D4 of the manual, Traffic Control for Street and Highway Construction and Maintenance Operations, May 2006, with the exception that the trail vehicle shall be protected with a Type VII (Truck Mounted Attenuator) impact attenuation device when painting ex- pressways, Cost for all traffic control, including truck mounted attenuators (TMAs), electric arrows, flagging, signs, flashers, etc., shall be incidental to Items 663001-005(#) or 663002-004(#).

The Contractor is prohibited from placing pavement markings on US and WV Routes within City Limits or other high ADT areas during peak hour periods (7:00 AM–9:00 AM, 4:00 PM–6:00 PM) unless otherwise directed by the Engineer, or at any other peak time as designated by the Engineer.

METHOD OF MEASUREMENT/PAYMENT:

The quantity of pavement marking lines to be paid for shall be the actual number of linear miles of pavement markings which have been satisfactorily placed. The quantities for lane lines show the approximate equivalent 4-inch solid lane miles. The Contractor will be paid for actual 4-inch solid miles applied as determined by the Engineer.

When applying 6-inch lines, the Contractor will be paid 1.5 times the rate for a 4-inch line and when applying an 8-inch line, the Contractor will be paid 2 times the rate of a 4-inch line.

PAY ITEMS:

The paint pay items for this contract shall be as follows:

Item 204001-000	Mobilization	LS
Item 204002-000	Mobilization, Per Mile	MI
Item 204003-000	Mobilization, Per Priority Job Order	EA
Item 204003-000	Mobilization, Per Job Order	EA
Item 663001-005	Edge line, Type II, White	MI
Item 663001-005	Edge line, Type II, Yellow	MI
Item 663002-004	Lane Line or Centerline, Type II, White	MI
Item 663002-004	Lane Line or Centerline, Type II, Yellow	MI

COMPLETION OF WORK:

All work shall be completed by August 1, 2008. The Contractor shall be assessed liquidated damages as described in Table 2, Schedule B, per calendar day for each day after August 1, 2008 that work is not completed. There shall be no stoppage of the penalty due to winter shut-down.

PERFORMANCE BOND:

The Contractor's performance bond may be retained until February 1, 2009.

APPENDIX E

European Warranty Experience

U.S. REVIEWS OF EUROPEAN WARRANTY PRACTICE

European experience in road construction warranties has a long history. This experience has been addressed in several studies and international scans by U.S. agencies. While many of these fact-finding missions are not necessarily focused on pavement marking warranties specifically, they do establish differences in legal and institutional approaches between European and U.S. practice that likely influence the success of warranty use. The following sources have been consulted for this synthesis study:

- *NCHRP Synthesis 195, Use of Warranties in Road Construction* (Hancher 1994), which reviewed U.S. and European practices on road construction warranties.
- A Federal Highway Administration scan, in cooperation with AASHTO, of asphalt pavement warranty practice and technology in Denmark, Germany, Spain, Sweden, and the United Kingdom (D'Angelo et al. Nov. 2003).
- A FHWA scan, in cooperation with AASHTO and NCHRP, of construction management practices in Canada and Europe (*Common Ground* . . . Summer 2005; DeWitt et al. May 2005).
- A description of laboratory turntables in Germany and Spain for accelerated testing of pavement markings ("Superior Materials . . . " Summer 2004).
- A white paper submitted to this synthesis study by a representative of the American Traffic Safety Services Association, ATSSA ("Pavement Marking Material . . ." n.d.), which gives U.S. industry perspectives on pavement marking product evaluation and the proposed use of European-style pavement marking turntables for accelerated product evaluation.

NCHRP Synthesis 195

The review of road construction warranties presented in *NCHRP Synthesis 195* includes a section on European warranty practices as of the early 1990s, with a focus on pavements. This review consolidated the findings of several international scans, fact-finding visits to Europe by FHWA staff, and knowledge of the *Synthesis 195* author. Findings were presented for Austria, Denmark, France, Germany, Norway, Sweden, and the United Kingdom. The *Synthesis 195* author noted that road construction warranties were already widely accepted in Europe, and contractors there were afforded a greater role in design and construction method input than their U.S. counterparts. While it might be concluded that transfer of contracting and construction management methods would result in corresponding advances in the United States, the *Synthesis 195* author cautioned that institutional differences between the European and U.S. road construction environments might inhibit the effectiveness of such a transfer. These differences included a less litigious relationship between agencies and contractors in Europe, differences in the structure of the respective construction industries, and greater European use of bid alternatives, contractor testing, and end-result (or performance-based) specifications rather than method-based (or prescriptive) specifications.

Common Ground Report

The *Common Ground* report provides a succinct statement of key characteristics of the European and Canadian road construction environment. Central to this environment are changing public and private sector roles that are adapting to alternative methods of project delivery.

> Critical components of these new methods include the evolving relationships among public agencies, contractors, and private engineering firms, which are transforming risk allocation processes, quality control/quality assurance, and general contract administration procedures. Emerging delivery methods include the use of non-traditional procedures such as design-build contracts, public-private arrangements, maintenance and warranty requirements, and use of third-party consultants to perform contract management.
>
> . . . The scan team discovered a more spirited effort of long-term partnership and collaboration between public and private sectors and witnessed heightened customer awareness among industry members.
>
> Canadian and European agencies have developed construction management systems that promote the alignment of team goals through the use of integrated risk analysis techniques that support the strategic application of alternative delivery methods. These concepts thread through the project life cycle, from procurement systems that set the framework for success to contract payment systems that reinforce trust.
>
> *Source: Common Ground* . . . Summer 2005.

The recommendations of the *Common Ground* report were characterized as motivating change within U.S. transportation agencies "to promote teamwork and more collegial relationships" between public and private sector groups. "This change should occur in collaboration with industry and should benefit both large and small engineering firms, contractors, and suppliers" (*Common Ground* . . . Summer 2005, p. 3). Warranties are addressed specifically in one of this report's recommendations. Moreover, the broad changes in U.S. construction management proposed in the other recommendations envision practices and contracting environments that could accommo-

date new types of warranty provisions and new approaches to their administration. The recommendations include the following:

- **To align team goals to customer goals:** Procurement practices, contract provisions, and construction management methods should align goals of the customer, agency, and contractor. The industry should form teams early in the process to integrate these goals and maintain this alignment through project development and construction.
- **To develop risk assessment and allocation techniques:** Improved risk assessment processes should extend from project scope development through construction management. These processes should identify risks and assign them to the party best able to manage them.
- **To strategically apply alternative delivery mechanisms:** Consider alternative delivery mechanisms that can best align goals and allocate risk. Work toward early industry involvement and more effective life-cycle design solutions.
- **To enhance qualification rating processes:** Processes for quality-based rating and contractor selection are key to successful projects. All international parties who participated in this scan cited accurate and timely rating processes as critical to successful construction management.
- **To use qualifications in procurement:** The recommendation is to increase the use of best value procurement, which considers price, contractor qualifications, proposed project schedule, and proposed technical approach, and encourages long-term partnership and work efficiency.
- **To pilot early contractor involvement:** A proposed qualification-based process of contractor rating and selection should be pilot-tested using a target-price contract. The pilot should be formulated and conducted with industry support. Early involvement of the contractor represents a fundamental change in how highway construction is conducted in the United States.
- **To apply alternative designs and bids in procurement:** The recommendation is to increase the use of alternate bids in the traditional low-bid environment. A bid evaluation process that is perceived as fair and transparent is critical to success, and can achieve better value-for-money.
- **To conduct preproposal meetings:** When considering alternate designs, confidential preproposal meetings allow prospective contractors to validate the acceptability of innovative designs. This approach, now used on design-build projects, could be extended to other methods of project delivery.
- **To apply more contractor quality management:** Contractor quality management systems can complement agency QA processes. Contractor quality plans can be part of procurement competition and written into the project contract. Quality-management-process certifications can be used when appropriate.
- **To use appropriate alternative payment methods:** An agency can assess the feasibility of structuring contractor payments differently when they can serve particular types of projects and customer goals; for example, milestone payments and lump-sum payments.
- **To consider alternative application of life-cycle responsibility:** When it is appropriate to give the contractor responsibility for maintaining project quality through a period of its life-cycle, long-term warranties can deliver better products, promote innovation, and eliminate redundancy in QA processes between the agency and the contractor.

Note that several themes that run through these recommendations—e.g., early contractor involvement in the project development process, integration of the contractor's role within a partnering approach to meet a customer's goals, a recognized contractor role in promoting quality during the project life-cycle, and a willingness to consider alternative processes and methods—can also work for innovative approaches to warranties. For example, an agency could use a prequalification process in lieu of requiring warranty bonds.

Scan: European Asphalt Pavement Warranties

An international scan team organized through the FHWA and AASHTO in November 2002 visited five European nations—Denmark, Germany, Spain, Sweden, and the United Kingdom—to review short- and long-term warranties for asphalt paving projects (D'Angelo et al. Nov. 2003). Topics of interest included risk assessment for agencies and contractors, administration of warranty contracts, and performance indicators and practices related to pavements specifically. Findings and recommendations applied to material and workmanship warranties, performance warranties, best-value procurement, and alternative contracting methods. Since the scope of the current synthesis study is on pavement markings, the review of this international scan focuses more on the concepts and implementations of European warranties and how they compare with U.S. practice, rather than its specific pavement-related findings. In this context, the experiences of these five European nations with respect to asphalt pavement warranties are as follows (D'Angelo et al. Nov. 2003):

- Materials and workmanship warranties of various durations have been used for 30 to 40 years. These countries are continuing to move toward pavement performance warranties and other methods to engage the contractor into assuring the quality of pavement performance through its full life cycle.
- Among these quality-oriented practices are the development of partnership relationships among agencies and industry participants, the use of best-value procurement techniques, and the application of alternative contract methods including warranties, performance-based contracts, and design-build-finance-operate (DBFO)

concessions. The motivations for these contracting innovations include:
  – Opportunity for contractor innovation;
  – Need for private sector financing assistance; and
  – Desire to improve quality and efficiency.
- All of the countries visited use materials and workmanship warranties on their traditional road construction projects. Warranty periods vary from 1 year (Spain) to 4 years (Germany). Denmark and Sweden use performance warranties in their traditional contracts, while the UK employs performance warranties in design-build contracts, which have become its preferred method of pavement construction contracting. All three of these countries use a 5-year performance warranty, which balances an assurance of satisfactory pavement performance without undue burden on the contractor to maintain the warranty through the full service life of the pavement.
- All five countries visited use best-value rather than low-bid procurement. Criteria for contractor selection include safety, innovation, and environmental impact. Denmark adds the bidding of additional years of warranty protection as a best-value criterion. In some cases contractor prequalification is also used as part of the best-value process. All countries reinforced the importance of a best-value approach to the warranty approach, since it promotes trust and confidence among the parties.
- Much longer warranty periods (e.g., up to 35 years) are being explored in alternative types of contracts such as DBFO and Pavement Performance Contracts (PPCs, which have warranty periods of 11–20 years among the host countries). These longer warranty periods reflect the fact that contractors have responsibility for pavement design, construction, and maintenance according to performance criteria established by the owner agency. These alternative arrangements are developed in collaboration with industry.

The scan report recommended actions at the federal, state, and local governmental levels in the United States to promote greater use of warranties, including short-term (e.g., up to 5 years) materials and workmanship warranties leading to long-term performance warranties in the future. Legislation enabling wider use of best-value procurement processes and contractor prequalification should be sought where needed. The report also recommended that the federal government take the lead in establishing a warranty resource center for use by the federal, state, and local governments. State and local governments should take practical steps toward developing and implementing materials and workmanship warranties and, when it is appropriate to engage contractors in design, short-term performance warranties. Best-value and contractor-prequalification processes should also be implemented. The report recommended roles for industry in education, participation in roundtable discussions and pilot projects, and strengthening of knowledge and capabilities regarding construction and maintenance methods and products to support warranty use.

Scan: European Programs in Superior Materials and Advanced Testing

An international scan team on Superior Materials, Advanced Test Methods, and Specifications toured four European countries—the United Kingdom, Denmark, Germany, and the Netherlands—in July 2003 to learn about European practices in the subject topics. A particular focus concerned ways to accelerate identification, evaluation, approval, and acceptance of new products, and to incorporate the products within project specifications. The investigation also included processes that yielded superior materials—i.e., materials that could improve facility performance significantly, cost-effectively, with improved safety or reduced construction time. The European environment for innovative materials development and testing was found to comprise several processes ("Superior Materials . . ." Summer 2004), of which the following are most relevant to this synthesis study:

- European Union standardization of highway specifications, common testing and evaluation protocols that were integrated into binding specifications across the EU, and a structuring of specifications toward function and performance rather than method. This approach allowed greater innovation by private industry while protecting the confidentiality of the production methods.
- The UK's Highway Authorities Product Approval Scheme (HAPAS). Under HAPAS, the Highways Agency (HA) and industry jointly develop functional specifications to replace method specifications. Once the HA approves these new specifications, the private sector is able to develop products that meet these functional requirements. Prior to use, the HA subjects the products to independent third-party review, evaluation, and certification through a program managed by the British Board of Agrément (BBA). After certification, a product may be used on HA-funded projects. HAPAS also enforces a requirement that manufacturers of new products train and certify installation contractors and provide evidence of such to the HA before construction.
- The countries visited engage in performance contracting and use of warranties as routine practice. The duration of warranties is negotiable between agency and contractor; new products that are perceived as riskier might be subject to a longer warranty period. A combination of price and quality forms the basis of bid award, where quality includes a credit for innovation.
- The Netherlands is conducting a pilot program to encourage long-range, visionary solutions to highway problems. For example, concepts were developed to provide a prefabricated road surface that could be applied or removed quickly, and that would generate less vehicle-pavement noise than existing paved surfaces.
- Germany has built a laboratory turntable on which to conduct accelerated performance tests of selected pavement markings: tape, temporary paint, and permanent paint. Marking samples are mounted on plates on the turntable. When rotated, the turntable causes the sam-

ples to pass under tire assemblies that simulate passage of traffic. The test protocol describes the number of cycles (rotations) and laboratory environmental conditions (environmental controls were being added by Germany). Spain has a similar facility, although it was not visited during this scan tour. The scan team believed that this turntable concept should be considered for application in the United States by AASHTO's NTPEP.

ATSSA WHITE PAPER

The ATSSA white paper responded to the recommendation of the scan team regarding consideration of a U.S. pavement marking test facility, incorporating results of a follow-up visit to the laboratory turntable facility in Spain. The background section of the paper summarized a joint ATSSA–SASHTO (Southeast Region of the American Association of State Highway and Transportation Officials) effort begun in the 1980s. This effort involved a public-private partnership to test and evaluate new road safety devices on a test deck in the Southeastern U.S. The items tested included raised pavement markers and adhesives, snowplowable markers, durable and nondurable pavement markings, as well as other items not related to pavement markings. The paper noted that the single most challenging obstacle to overcome in this program was the relative lack of acceptance of program results by the state DOTs. Few states were willing to accept the NTPEP results as the sole determinant for including the product on their Qualified Product Lists. Pavement markings were among those products that received relatively weaker acceptance of test results.

Given this history, the paper considered the implications of NTPEP's pursuing the idea of an accelerated testing turntable for pavement markings. The paper made the following observations ("Pavement Marking Material . . ." n.d.):

- While the Spanish and German turntables have been used for many years, they are not without controversy regarding validation of laboratory data versus actual conditions and performance in the field.
- It is not clear how the turntable would accommodate the climatic and topographic variability throughout the United States. Moreover, it was felt that the goals of the laboratory facility and proposed use of the test results had not been articulated.
- The ATSSA members felt that while the facility itself was impressive, the value of its data would be primarily for research and development rather than for evaluation of potential performance of pavement markings or for product approval.
- The paper identified four areas of technical concern in which it was felt that a laboratory turntable would not yield valid results:
  - Lack of exposure to ultraviolet light;
  - Laboratory preparation of pavement marking samples that does not mimic actual installation or application methods in the field;
  - Standardized, constant laboratory environmental conditions that reflect neither the full degree of variability in conditions throughout the United States nor the short-term cycles of fluctuation that stress highways in the field; and
  - Differences between the substrate material on the turntable plates that is used to simulate the pavement surface versus the actual pavement substrate properties in the field, including variability in materials (e.g., asphalt vs. concrete) and variations in these material properties among states.
- The institutional framework and construction industry and culture in the United States is much different from those in Europe. It is not clear that the technological transfer of the laboratory turntable from Europe to the United States will ensure that the effective use of test results from the facility can likewise be successfully transferred to the U.S. legal and business environment.
- The paper closes with several questions to which the industries represented by ATSSA are seeking answers:
  - What is the goal of the turntable and what is proposed to be accomplished?
  - Why is the turntable the answer?
  - Why not study and develop models of programs that are successfully working in the United States?
  - Is the turntable a replacement for NTPEP? Is it in addition to NTPEP?
  - Will there be broader acceptance of this facility and the data it generates?
  - Is this the first step in the development of a mechanism to establish a National Performance Standard for Pavement Markings?

Abbreviations used without definitions in TRB publications:

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