USE OF WARRANTIES ON IN-SERVICE PERFORMANCE FOR ROADWAY CONSTRUCTION PROJECTS

Report No. FHWA/MT-98-003/8131

Prepared by

Jerry Stephens and Dave Johnson, Department of Civil Engineering
Mike Wangsmo and Paul Schillings, Department of Mechanical and Industrial Engineering

Montana State University
Bozeman, Montana

Prepared for:

State of Montana
Department of Transportation
Research, Development, and Technology Transfer Program
in cooperation with the
U.S. Department of Transportation
Federal Highway Administration

August 1998

Technical Report Documentation Page

1. Report No. FHWA/MT-98-003/8131	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Use of Warranties on In-Service Performance on Highway Construction Projects		5. Report Date August 1998
		6. Performing Organization Code MSU G+C No. 290323
7. Author(s) Stephens, J. E., Johnson, D. R., Wangsmo, M., and Schillings, P.		8. Performing Organization Report No.
9. Performing Organization Name and Address Department of Civil Engineering, Montana State University Bozeman, Montana 59717		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. 8131
12. Sponsoring Agency Name and Address Montana Department of Transportation 2701 Prospect Avenue Helena, Montana 59620-1001		13. Type of Report and Period Covered Interim January 1996-May 1998
		14. Sponsoring Agency Code 5401

15. Supplementary Notes
Research performed in cooperation with the U.S. D.O.T., Federal Highway Administration

16. Abstract

The objective of this project is to investigate the potential benefits of using in-service warranties on roadway construction projects in Montana. Following this approach to highway contracting, the contract specifications are expressed in terms of the performance of the roadway after it is placed into service, rather than in terms of the construction methods to be used or the final properties to be achieved in building the facility. Perceived benefits of the in-service warranty approach include that a) the contractor is directly motivated to provide a facility that meets the needs of the motoring public (i.e., a smooth, safe roadway) rather than simply to meet prescribed construction standards, and b) competitive market forces will result in the design and construction of innovative and efficient roadway projects. This approach to highway construction contracting differs significantly from the approach currently used in Montana, and thus the results of using this approach are uncertain.

This study has been divided into two phases. Phase I consists of a) identifying the critical issues that must be addressed if in-service warranties are to be used on roadway construction projects, b) reviewing the manner in which these contracts have been implemented in Europe and across the United States, c) determining current perceptions in Montana regarding these contracts, and d) formulating recommendations for demonstration in-service warranty projects to be awarded in Montana. Phase II of the project involves a) developing a formal in-service warranty contract instrument based on the recommendations from Phase I, b) selecting demonstration projects to be constructed using these contracts, c) monitoring their construction and in-service performance, and d) doing a cost-to-benefit analysis of the projects.

Phase I of this study has been completed and the results are presented in this report. Issues that need to be addressed in developing warranty contracts on in-service roadway performance include the aspects of the roadway behavior to be warranted, the duration of the warranty, the payment terms, the bid procedure, etc. Examples on how these issues can be addressed are available from Europe, where the use of in-service warranties appears to be commonplace, and from the United States, where several state departments of transportation have recently researched and awarded demonstration warranty projects. The Montana Department of Transportation, and the Montana construction community and bonding agents have a variety of concerns regarding the use of in-service warranties on roadway construction projects. Many of these concerns can only be definitively answered by awarding and studying demonstration warranty projects. The first conclusion of Phase I is that the demonstration projects should be reconstruction jobs, on moderately traveled highways. Second, the projects should be warranted with respect to ride, rutting, cracking, and skid resistance for a period of 5 to 10 years. Contract awards should be based on securing the best technical quality for the lowest price. Finally, a maintenance bond should be required during the warranty periods.

17. Key Words Warranty, Surety, Bonding, and Montana.		18. Distribution Statement No Restrictions. This document is available to the public through: NTIS, Springfield, Virginia 22161	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 91	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Disclaimer

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the Montana Department of Transportation or the Federal Highway Administration.

Alternate Format Statement

MDT attempts to provide reasonable accommodations for any known disability that may interfere with a person participating in any service, program, or activity of the department. Alternative accessible formats of this document will be provided upon request. For further information, call (406) 444-7693 or TTY (406) 444-7696.

Notice

The authors, the State of Montana, and the Federal Highway Administration do not endorse products or manufacturers. Trade and manufacturers names appear herein solely because they are considered essential to the object of this report.

ABSTRACT

The objective of this project is to investigate the potential benefits of using in-service warranties on roadway construction projects in Montana. Following this approach to highway contracting, the contract specifications are expressed in terms of the performance of the roadway after it is placed into service, rather than in terms of the construction methods to be used or the final properties to be achieved in building the facility. Perceived benefits of the in-service warranty approach include that a) the contractor is directly motivated to provide a facility that meets the needs of the motoring public (i.e., a smooth, safe roadway) rather than simply to meet prescribed construction standards, and b) competitive market forces will result in the design and construction of innovative and efficient roadway projects. This approach to highway construction contracting differs significantly from the approach currently used in Montana, and thus the results of using this approach are uncertain.

This study has been divided into two phases. Phase I consists of a) identifying the critical issues that must be addressed if in-service warranties are to be used on roadway construction projects, b) reviewing the manner in which these contracts have been implemented in Europe and across the United States, c) determining current perceptions in Montana regarding these contracts, and d) formulating recommendations for demonstration in-service warranty projects to be awarded in Montana. Phase II of the project involves a) developing a formal in-service warranty contract instrument based on the recommendations from Phase I, b) selecting demonstration projects to be constructed using these contracts, c) monitoring their construction and in-service performance, and d) doing a cost-to-benefit analysis of the projects.

Phase I of this study has been completed and the results are presented in this report. Issues that need to be addressed in developing warranty contracts on in-service roadway performance include the aspects of the roadway behavior to be warranted, the duration of the warranty, the payment terms, the bid procedure, etc. Examples on how these issues can be addressed are available from Europe, where the use of in-service warranties appears to be commonplace, and from the United States, where several state departments of transportation have recently researched and awarded demonstration warranty projects. The Montana Department of Transportation, and the Montana construction community and bonding agents have a variety of concerns regarding the use of in-service warranties on roadway construction projects. Many of these concerns can only be definitively answered by awarding and studying demonstration warranty projects. The first conclusion of Phase I is that the demonstration projects should be reconstruction jobs, on moderately traveled highways. Second, the projects should be warranted with respect to ride, rutting, cracking, and skid resistance for a period of 5 to 10 years. Contract awards should be based on securing the best technical quality for the lowest price. Finally, a maintenance bond should be required during the warranty periods.

TABLE OF CONTENTS

List of Figures

List of Tables

1. INTRODUCTION

1.1 BACKGROUND

As the world and our nation rapidly change, the future of highway construction may evolve in entirely new and hopefully improved directions. Dynamic changes in highway construction contracting are already underway in some states and in other nations. One such change is a move toward the use of contracts that include warranties on the in-service performance of the roadway. Under this approach, the contract specifications are related to the expectations that the motoring public has for the performance of the roadway once it is in use. At the very least, these expectations include that the roadway provide a safe and comfortable ride over its design life at a reasonable cost. Following the warranty approach, the contractor is given the responsibility of designing, constructing, and maintaining the roadway so that it meets these expectations.

The warranty approach to highway construction contrasts sharply with standard highway contracting practice in Montana and across the country. Roadway construction contracts typically specify construction processes and/or target material properties that the constructed facility must meet rather than specifying long term user related performance criteria. While the majority of these specifications target processes and properties of the materials that are known to be related to long term roadway performance, the actual performance of the roadway over its design life is not considered in the contracting process. Following the in-service warranty approach, these types of contract requirements are eliminated. The contractor is simply expected to provide a useable facility over a pre-determined warranty period using the design and construction approach of his choice. The contractor is expected to step in and repair the roadway if performance falls below some mutually agreed upon level of service during the warranty period.

The warranty approach to contracting highway construction services may result in equal or better quality roadways than are presently being constructed, at lower costs than are presently being incurred. With regard to benefits to the motorist, the contractor is provided with direct incentives to produce a good and useable roadway, rather than being tasked to simply meet

prescriptive standards on construction materials and methods. These incentives and the absence of prescriptive standards should stimulate innovation in the design and construction process, as contractors seek out efficient designs in an effort to maximize their profits. Any cost savings that result from such innovations will eventually be passed on to the motoring public.

Whether or not the above benefits will be realized by using warranty contracts (and the specific level of any benefit to be realized) is uncertain, due to the limited experience in this country with this type of contract for highway construction projects. Much of the risk associated with providing long term serviceability in highways has historically been assumed by the public. This approach has been justified due to the number of variables beyond the control of the contractor on typical highway projects. Uncertainties are often associated with the pre-existing roadway conditions the contractor may be forced to accept and build upon, the conditions of future use the highway will experience (with regard to volume of traffic and environmental conditions), and the level of maintenance the completed roadway will receive. In response to shifting consideration of these risks to the contractor, the initial costs of facilities built under warranty contracts with in-service performance specifications may exceed the cost of building the same facility using traditional contracting procedures. The savings to be realized by using in-service warranties may be over the life of a project or in the form of long term savings associated with the development of improved construction methods and materials.

In using an in-service warranty process, even on a trail basis, a myriad of technical and administrative issues must be addressed. The manner in which these issues are addressed may be critical to accurately assess the feasibility of an in-service warranty contracting approach for roadway construction projects. Issues of concern include: the type of roadway projects appropriate for in-service warranty contracts, the in-service performance parameters to be used in measuring contract compliance, the specific fiscal provisions of the contract agreement, the bonding requirements of such contracts, etc.

1.2 OBJECTIVES AND SCOPE

The objective of this study is to investigate the cost effectiveness of using warranty contracts based on in-service performance on roadway construction projects in Montana. The

study is focusing on the use of such contracts on pavement (roadway) related activities (chip seal, overlay, reconstruction, etc.), in that such work accounts for the majority of the expenditures by the Montana Department of Transportation (MDT) on the highway system. The study has been divided into two phases. Phase I includes 4 tasks that are preparatory to conducting demonstration projects with in-service warranty provisions. These tasks consist of:

1) identifying the manner which in-service warranty contracts differ from current contracts and determining the issues that need to be addressed in implementing such contracts,

2) reviewing current practice with in-service warranty roadway contracts in Europe, the United States, and Canada,

3) soliciting ideas and comments on in-service warranty contracts from those parties in Montana that will be most impacted if these contracts are implemented (MDT, construction companies, bond companies), and

4) formulating specific recommendations on the manner in which Montana might implement in-service warranties on some demonstration roadway construction projects, based on the information collected in tasks 1 through 3.

Phase II of this investigation involves monitoring and analyzing the cost effectiveness of any demonstration in-service warranty roadway projects awarded by MDT as a result of the recommendations issued at the end of Phase I. Specific tasks to be performed in this phase of the investigation (presuming the decision is made to move forward with the project at the end of Phase I) consist of:

1) developing a formal contract instrument to be used on a demonstration project based on the recommendations from Phase I,

2) selecting specific demonstration projects on which to try this contract instrument,

3) collecting cost, in-service performance, and other information from the start of construction through the warranty period for the demonstration projects and attendant control projects constructed with conventional contracts, and

4) performing cost-to-benefit analyses for the demonstration projects and formulating recommendations on the future use of in-service warranties for roadway construction projects in Montana.

This report documents the work completed during Phase I. The intent is to provide the reader with adequate information to determine the direction for Phase II of this project.

2. HIGHWAY CONSTRUCTION PROCESS

2.1 GENERAL REMARKS

The potential benefits and problems associated with using warranties on in-service performance for roadway construction projects can be better understood when discussed in the context of the current roadway construction process employed by MDT. Presented below is an overview of this process, followed by discussions on how each aspect will be affected if in-service warranties are used. Note that the current process MDT uses for roadway construction is similar to that used by many states and municipalities.

2.2 OVERVIEW OF THE CONSTRUCTION PROCESS

2.2.1 Current System - The primary participants in a typical state highway construction project are the contracting agency (MDT), the contractor, and a surety/bond company. A project typically is initiated by MDT when a problem is identified that requires some type of construction activity to resolve. MDT reviews the problem and develops a design solution in-house. A bid package is then assembled that describes: a) the facilities to be constructed, b) any special requirements associated with the project, and c) the specifications upon which judgement of satisfactory performance of work will be made. Public notice is then made of the intention to build the project, and the bid package is made available to any interested party. Contractors interested in working on the project prepare a proposal (bid) that details their prices for all work to be performed. MDT reviews these bids and awards the project to "the lowest...bidder whose bid proposal complies with all of the requirements" prescribed (*MDT, 1995a*). These requirements typically include that the contractor secure bonding for the project in an amount equal to 100 percent of the construction costs. In the event that the contractor is unable to complete the project, the bond is forfeited to the state, and the proceeds are used to finish the project.

Once the project is awarded and the work begins, payment is made to the contractor on some schedule related to the percent of the project completed at any given time. Full payment is typically made shortly after the project is completed and after MDT agrees that it was completed

in conformance with the plans and specifications. In Montana (as in several states), the contractor is subsequently liable for any defects discovered in the finished product related to materials and workmanship for a period of one year after the project is completed. MDT assumes full responsibility for any subsequent maintenance required during the life of the roadway.

2.2.2 Considerations for In-Service Warranty Specifications - Almost every step followed in the current approach to highway construction projects will be altered to some extent if existing construction contracts are replaced with contracts whose specifications are tied to in-service performance of the roadway. These changes will not only be confined to the obvious areas of contract specifications and warranty period, but they may also be made in the manner in which the projects are bid, reviewed, and awarded. Further, changes may also be required in the manner in which these projects are bonded. Therefore, a review in more detail of how these activities are currently performed is an important consideration when evaluating how they may be changed. Such a review is presented below, followed by a discussion of how these activities will be affected by using an in-service warranty approach.

2.3 TECHNICAL SPECIFICATIONS

2.3.1 General Remarks - Several types of technical specifications are used on highway construction projects, and various aspects of a single project may be covered by different types of specifications. On state projects in Montana, independent of the type of specifications used, the contractor is typically hired to execute a design prepared by others (usually MDT engineers). The contract specifications are directly related to the execution of the design, rather than to the use of the constructed facility. Naturally, the features of the project covered by the specifications are those that have been identified from engineering principles and/or experience to correlate with a finished roadway that will serve its intended purpose over its design life. These specifications range in underlying philosophy from dictating the specific manner in which work is to be performed, to stating only the physical characteristics that the final product must possess. The form and content of these specifications has developed over several decades of use

and continues to evolve in response to advances in technology and the accumulation of further experience. The various parties involved in the highway construction process (the contracting agencies, contractors, and the bonding companies) are understandably comfortable with these types of specifications and contracts, as the technical and administrative requirements are known to deliver adequate highways.

2.3.2 Current Contract Specifications - The specifications currently used in highway construction projects can be grouped into three broad categories:

1) **Methods based** - The contract specifies the exact construction procedure to be used in building the roadway. Contract compliance is judged based on properly following those procedures.

2) **Material Properties based** - The contract specifies various properties that the finished product (and/or interim products) must possess. Contract compliance is judged based upon achieving these properties, independent of the construction approach used.

3) **Methods and Material Properties based** - The contract specifies the methods to be used and/or the material properties to be achieved, as appropriate, to practically produce the best possible final product.

Methods based specifications are appropriate in situations where the scientific reason that a particular product performs better than others is uncertain, but it is known from experience that if a specific procedure is followed or that if a specific ingredient is used, the finished product will probably perform as desired. An example of a methods based specification is the specification used by MDT for overlaying bridge decks using silica fume concrete (*MDT, 1995b*). The fundamental intention of the specification is to provide an overlay that will safely carry traffic over a long service life. The specification, however, never mentions the requirement that the overlay needs to provide a long and useful service life. The specification states, among many other things, the specific procedure to be used by the contractor in curing such overlays (impervious curing membrane). Based on experience, this curing procedure is known to be correlated with good overlay performance over the service life of the deck.

Methods based specifications have both advantages and disadvantages relative to other types of specifications. Methods based specifications are attractive from an administrative perspective, in that contract compliance is easily determined and the contract term, limited to the time of construction (with a one year warranty), is relatively short in duration compared to the expected service life of the finished product, which is generally 20 years. These specifications do require that the contracting agency observe construction operations to insure that specified procedures are being followed. The primary disadvantage of methods based specifications is that the contractor has no opportunity or motivation to improve the construction process or the final constructed product. Contractually, the successful completion of a project by a contractor is independent of the subsequent performance of the roadway.

Material property based specifications are appropriate in situations in which the in-service performance of the roadway is known to be correlated with some property of the roadway as measured at the time that it was constructed. Such correlations are generally established based on engineering principles and/or experience. For the running surface on an overlay project, for example, MDT may specify the required density of the completed overlay, without specifying the particular compaction procedure to be used to achieve this density. Once again, the underlying objective of this specification is to obtain an overlay that will satisfactorily carry traffic over its service life. The contract specifications, however, are presented in terms of pavement density (and other parameters of this type) which are known to be related to the subsequent in-service performance of the roadway.

Material property based specifications offer many of the same advantages as methods based specifications. Contract compliance is easily determined, and the duration of the contract is limited to the time of construction (plus a one year warranty). Material property based specifications also offer some opportunities for contractor innovation with respect to the construction processes used to meet the required material specifications. Note, however, that while encouraging innovation with respect to construction practices, these specifications still provide no opportunity or motivation for contractor innovation regarding the nature of the final product, itself.

The effectiveness of material property based specifications can be compromised by practical considerations regarding which properties of the finished product are most indicative of long term, in-service performance compared to which properties can reasonably be measured during and at the completion of construction. As the understanding of pavement behavior advances, and as instrumentation and other technologies expand, the parameters measured, the manner in which they are measured, and the significance of the measurements continues to change (*Chamberlin, 1995*). These changes, however, tend to be gradual, and the fundamental basis for these types of specifications remains the same. Thus, the historical justification and the level of risk associated with these specifications are recognized by the various parties involved in the construction process.

Some construction activities are specified in terms of both methods and material property based specifications. This approach is used when certain aspects of the behavior are known to be correlated with measurable properties of the material, while other aspects of the behavior are only known to be produced when specific construction procedures are followed. At the current state-of-the-art for several materials, using combined methods and material property based specifications may yield the best end results. Returning to the MDT specification for overlaying bridge decks with silica fume concrete, for example, the specifications describe the procedure to be followed in curing the overlay and also a minimum compressive strength of 7,500 psi at 28 days that the overlay material must achieve.

2.3.3 Considerations for In-Service Warranty Specifications - Under an ideal in-service warranty contract, the contract specifications are expressed directly in terms of the performance the roadway is expected to provide once it is in-service; production methods and intermediate performance requirements are not specified as part of the contract. The specific design, construction procedures, and material properties of the completed roadway are of nominal interest to the contracting agency. Basic expectations of adequate service are that the roadway will provide a smooth, safe ride for an agreed upon period of time for a certain volume of traffic (historically, a 20 year life has been targeted in the design process). It is generally accepted that the level of service provided by a roadway will decline with use, until a condition is reached at

which major rehabilitation is necessary. Based on this consideration, warranty specifications need to define satisfactory in-service performance with respect to ride quality and safety at various times throughout the expected life of the roadway. Issues to be addressed in developing such specifications include:

1) what performance parameters will be used to quantify and measure ride quality and safety for determining warranty compliance, and

2) how will the acceptable values for these parameters at various ages of the roadway be determined?

Ride quality, itself, is difficult to directly and quantitatively assess. Every driver has, to some extent, a different definition of a smooth versus a rough ride, and the specific ride experienced by drivers will be significantly influenced by the characteristics of the vehicle they are traveling in (such as the stiffness of the suspension, the level of road noise that penetrates the passenger compartment, etc.). One commonly used measure of ride quality is the AASHTO Present Serviceability Index (PSI) (*Huang, 1993*). Values of the PSI range from 5.0 for a roadway that provides an excellent ride (e.g, a newly completed roadway), to 2.5 for a roadway that provides a marginally acceptable ride (e.g., a roadway in need of rehabilitation). The traditional PSI value for a particular roadway is established by a ride test, in which a group of trained observers traverse the road and make a judgement of its PSI.

Due to the subjective nature of the PSI, efforts have been made to indirectly measure ride quality using measurements of physical attributes of the roadway that have historically been shown to be correlated with the smoothness of the ride provided and the general condition of the roadway. Parameters considered include the longitudinal profile of the road surface, extent and severity of cracking, and rut depth. These various physical attributes of the roadway can be considered independently or collectively in assessing the serviceability of a roadway. Considerable work has been done on developing the International Roughness Index (IRI) as a measure of pavement condition (*Gillespie, 1992*). This index is calculated by analytically running a standard "vehicle" over the measured longitudinal profile of a roadway and assigning a numerical value to the calculated "ride." IRI values range from 0 to 400 for perfectly smooth to rough surfaces, where rough is referenced to a rough gravel road.

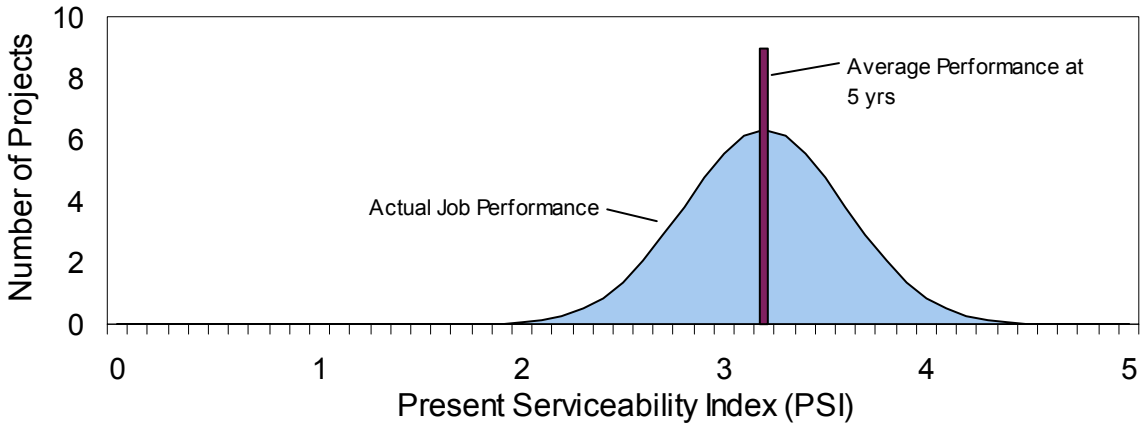
One measure of the safety of roadways from a pavement perspective is the skid resistance (friction) offered by the running surface. Standard tests have been developed to quantify skid resistance (*AASHTO, 1995*), and guidelines are available regarding acceptable skid resistance values for various conditions of vehicle operation (*Kummer and Meyer, 1967*).

Independent of the specific indicators selected for evaluating warranty compliance, acceptable (and achievable) levels for these indicators as a function of pavement age and volume of traffic carried need to be determined. These levels can be determined by reviewing the historical performance of existing pavements. The state of the art in transportation engineering, however, is such that designing a pavement that will meet these specific levels of performance through time is an uncertain task. The relationship between the target design and actual performance of typical pavements is generically illustrated in Figure 1a. Referring to Figure 1a, it is evident that there is some risk that a pavement designed using currently accepted engineering procedures still will not meet the level of performance through time. This risk may be too high for a contractor to accept. The level of risk can be controlled in two ways:

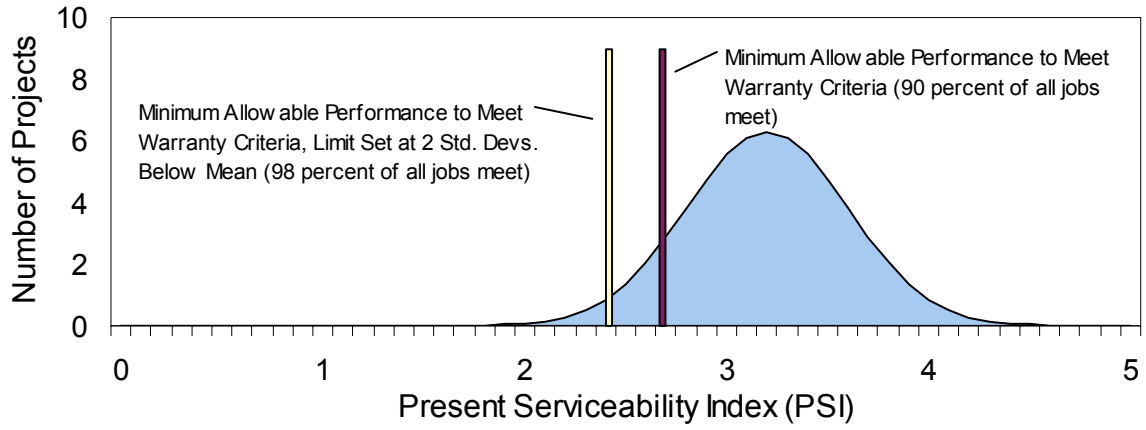
1) the regulatory agency can set the required level of performance sufficiently low that a reasonably designed pavement has a acceptable probability of meeting or exceeding this level (see Figure 1b), or

2) the contractor can set his/her target level of design performance sufficiently high that the risk of not meeting the regulatory agency's required level of performance is acceptable (see Figure 1c)

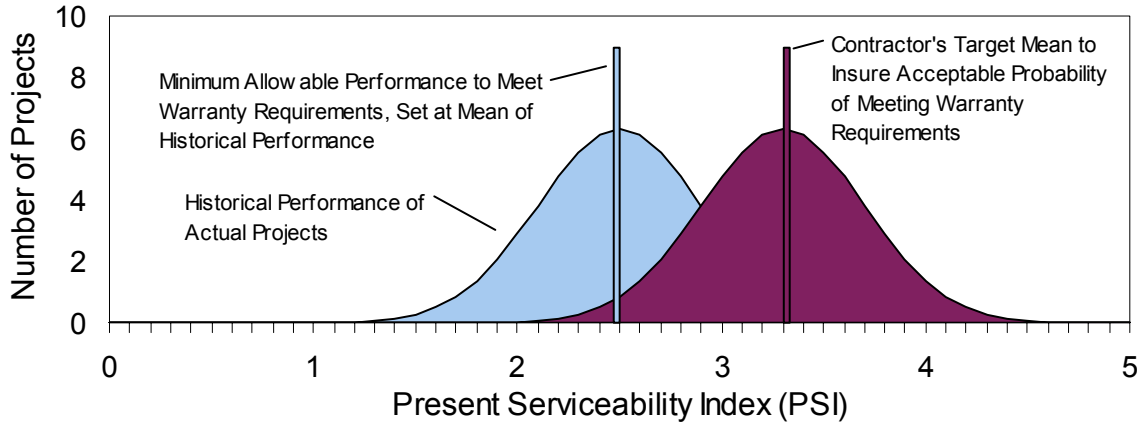
Both of the above strategies have drawbacks. Under the first strategy, little incentive exists to develop new and innovative design solutions for roadway projects, as significantly less than optimum performance is sufficient to meet the performance requirements. At the extreme, efforts might be made to improve the reliability of the design process, so that the lower performance level could be consistently obtained with a less expensive facility. Use of the second strategy will insure that an excellent roadway is constructed. Initial costs, however, may be unacceptably high, as the roadway would be over conservative in its construction.



a) Historical Performance of 5-year old paving projects



b) Possible performance thresholds for warranted paving projects at 5 years



c) Possible contractor response to using mean historical performance as threshold for warranty project

Figure 1. Target levels of pavement performance for warranty purposes

Despite the above concerns, in-service performance specifications potentially offer several advantages over other types of roadway construction specifications. Perhaps the greatest potential benefit is qualitative in nature and consists of a possible change in the manner in which contractors approach project tasks. Under an in-service warranty system, construction tasks will be accomplished with a view toward providing a good and durable roadway, rather than to simply meet prescriptive standards on construction methods and materials as given in the contract. On a warranty overlay project, for example, the contractor should inherently realize and support at least achieving the target compaction level of the running surface, so that the finished facility will perform adequately during the warranty period. This target compaction level will have been set by the contractor, as part of their design of the overlay project.

Following an in-service warranty approach, contractors will have the opportunity and some motivation to employ efficient and innovative design solutions and construction practices in addressing project requirements. Design procedures, construction methodologies, and quality control activities that do not directly contribute to creating quality roadways will, under market forces, be eliminated and/or replaced by more efficient processes.

Under an in-service warranty system, the state will not have to engage in extensive oversight/quality control activities during roadway construction. Density requirements on the running surface of an overlay, for example, will no longer be part of the contract specifications. If the contractor believes as-built density is important to meeting warranty performance requirements, it will be incumbent upon him/her to perform density tests during construction. The state will have to monitor the performance of the roadway during the warranty period to determine contract compliance. Such monitoring may consist of annual inspections during which quantitative data on longitudinal profile, rut depth, extent of cracking, etc. is taken. MDT already performs these types of tasks on at least an annual basis as part of their pavement management program. The intensity of these inspections would need to be increased for warrantied pavements compared to current practice.

The intention of the in-service warranty approach is to only hold the contractor responsible for the occurrence of unacceptable conditions over which he/she has had some control. If, for example, the volume of traffic or composition of the traffic stream changes

significantly over the warranty period with respect to the design requirements originally provided to the contractor, the contractor will not be held responsible for repairing subsequent pavement damage. Thus, the state will have to monitor traffic on warranty projects so that necessary information on volume and type of use is available to determine if, and/or when, the warranty might expire. Once again, MDT already collects this type of information on major state highways (through vehicle classification, static scale, and weigh-in-motion facilities). Once again, the frequency and intensity of the data collection effort may have to be increased on in-service warranty roadways compared to standard practice on conventional roadways.

In situations other than the type described above, definitely establishing the degree to which the contractor's performance is responsible for observed pavement damage may be difficult. Consider, for example, a situation in which rutting problems develop on a warrantied partial reconstruction project. If the scope of the project did not include rehabilitation of the subgrade, and problems with the subgrade were responsible for subsequent rutting problems, the contractor might not be responsible for the damage. The distress in the subgrade, however, could have resulted from an under-designed or poorly constructed base and running surface, which are features of the project within the contractor's control. Establishing both the source(s) of the observed distress and the degree of responsibility of the contractor may require considerable investigatory effort. Some mechanism will be required to allow for the expedient and consensual resolution of differences of opinion regarding warranty compliance between the contractor and the contracting agency.

The consequence of failing to meet the conditions of the warranty may need to be included as part of the contract specifications. If MDT expects the contractor to be prompt and effective in restoring an acceptable level of service to a roadway that is in non-compliance with warranty requirements, these expectations need to be fully stated in the contract provisions.

A distinct disadvantage of in-service warranty specifications is the prolonged nature of the contract agreement. For the agency administering the contract, overhead costs associated with contract administration will be incurred over a relatively long period compared to the present system for roadway construction. For the contractor who was awarded the contract, the possibility of suffering a substantial financial loss will exist throughout the extended warranty

period. Outstanding warranty obligations may affect the ability of contractors to get bonding for new projects (see Section 2.5.2).

2.4 BID PROCESS AND AWARD OF CONTRACTS

2.4.1 Current System - In general, project announcements are publically made, and any contractor can bid on a project whose dollar value is commensurate with the classification of their contractor's license. (Note that on federally-funded project, while a license is not required to bid, the contractor must have a license by start of work, if successful on a bid.) The project is subsequently awarded to the low bidder, presuming various requirements specific to the job are met. One such requirement typically is that the contractor secure a performance bond in an amount equal to the cost of construction. While MDT does not employ a formal pre-qualification process, bidders are pre-qualified by the requirement of bonding (see Section 2.5.1).

2.4.2 Considerations for In-Service Warranty Specifications - In evaluating bids by the above process, it is a fairly simple matter to determine the recipient of a given contract, as the end product is the same, independent of the contractor selected to do the work. Evaluation of the bids submitted under a warranty approach may not be so simple. The proposed physical product could vary significantly among bids, as contractors pursue different strategies in providing a roadway that will meet in-service demands. For example, on a simple reconstruction project, contractor "A" may propose to use a moderately thick base and a thin running surface made with an exotic asphalt concrete, contractor "B" may propose a thick base and a thick asphalt concrete running surface, and contractor "C" may propose a Portland cement concrete pavement. In each case, the contractors may or may not propose to do annual maintenance over the warranty period.

The simple solution to this dilemma is to still take the low bid. The contractor, and bonding company, guarantee the design, and they are obligated to perform remedial work if it becomes necessary. This approach may be somewhat irresponsible, if the design proposed by the low bidder is seriously flawed. If, however, the qualifying low bidder's design is checked by the state, in awarding the bid the state is taking some level of responsibility for the contractor's design. A serious dilemma is created by the approach, as it defeats one of the primary goals of

in-service contracting, which is making the contractor responsible for the performance of the roadway, at least for a portion of its life.

A second solution to this problem is to place constraints on the approach to be followed by the contractor in meeting in-service performance requirements. For example, the stipulation could be made that the running surface on a particular project must be constructed with asphalt concrete. This approach, however, may seriously compromise one of the perceived benefits of the warranty approach. That is, the contractors will not be as free to bid a project using the methodology that they feel is the most appropriate and cost effective methodology to provide the required service of the roadway.

A third solution to this problem is to use a different metric to determine the lowest bid then to simply use the lowest total project cost. Florida let a demonstration design-build project in 1990, for example, in which the contract award was based on the low bid per unit of quality offered (*Merwin, 1990*). A technical panel reviewed the proposals prepared by each contractor and assigned them a score between 0 and 100 based on technical merit. The cost per unit of quality offered was calculated as the total bid cost divided by the numerical technical score of the proposal. The job was awarded to the proposer with the lowest cost per technical quality point. In this specific instance, the low total dollar bid was not the successful bidder on the project.

2.5 BONDING PRACTICES

2.5.1 Current Roadway Construction Bonding Practices - Bonding is used on roadway construction projects to protect the public interest in the event that the contractor is unable to complete a project according to specifications. Note that this form of bonding provides no protection to the public regarding the performance of the roadway over its design life. The bond process simply insures that the roadway will be completed as per design, and that any flaws related to materials and workmanship revealed during the first year of service will be repaired by the contractor. If the contractor is unable to complete the project as specified in the contract, the bond will be forfeited and the proceeds used to finish the project.

In entering into a bond agreement with a contractor, the bonding company implicitly indicates that, in their opinion and within their acceptable level of risk, the contractor will be able to successfully complete the project. Surety companies do thorough evaluations of a contractor's equipment, experience, and outstanding level of bonds before entering into a bond agreement with a contractor on a new job. Thus, as performance bonds are required on all major MDT roadway contracts (in an amount equal to the estimated project cost), the bonding requirement effectively insures only "qualified" contractors can bid on projects. Presuming the governmental agency that solicited the bids concurs with the criteria used by the bonding companies in their screening process, bond companies handle the "pre-qualification process" for the agency.

Bond companies have a reasonable idea of the risk associated with their job under the present system of roadway construction contracting. The system has been in-place sufficiently long that the type of work to be performed is well understood, the ability of contractors in-general (and for a particular contractor) to meet the contract specifications has been historically established, and the administrative details of contract process have been practically and comprehensively determined. The period of exposure is limited to one year after physical completion of the project.

2.5.2 Considerations for In-Service Warranty Specifications - Major issues that need to be addressed if bonding is to be used on in-service warranty roadway construction projects include:

1) how can the risk of failure for this type of project be assessed, given that little historical experience with these specifications exists? (Bond companies need to have some idea of the riskiness of the venture they are underwriting.)

2) what action will be required if the warranty specifications are not met, and, if necessary, who will determine what these activities are? (Bond companies need to have some idea of the magnitude of the financial obligation that they and contractor could face.)

3) are the contractors in the state reasonably capable of providing the design and quality control efforts necessary for these projects?

4) as time goes by, will the ability of contractors (and/or the bonding company, itself) to obtain bonding for new warranty jobs be compromised by their accumulated level of outstanding/active warranty bonds?

Obviously these concerns only need to be addressed if the desire still exists on in-service warranty jobs to "protect" the public's investment. Such protection could be provided a) by some form of bonding system similar to the current one used, or b) by withholding some of the payment for the project pending its satisfactory performance during the warranty period. Following either approach, the four issues introduced above need to be addressed.

Historical information collected by MDT on in-service pavement performance should be useful in assessing the level of risk associated with specific in-service warranty performance requirements. As briefly discussed in Section 2.3.3, frequency distributions can be created from past data that show the performance historically delivered by projects of a given type over their service lives. The in-service warranty requirements may well have been purposefully set, after reviewing such distributions, at a level of risk agreed to be mutually acceptable to the public, the contractor, and the bonding company (see Section 2.3.3). The specific requirements selected and the credibility of this entire process are directly tied to the quality of the historical performance data available from MDT. Desirable data on historical projects includes the original project design parameters and the subsequent performance of the as-built project as a function of elapsed time and level of vehicle use.

The level of the financial liability assumed by the surety company and the contractor in entering into an in-service warranty contract is directly related to nature of the remedial action required if the terms of the warranty are not met. The magnitude of this financial commitment can be identified by explicitly stating in the specifications the required remedial actions associated with each element of the in-service warranty (e.g., for cracking, seal pavement; for poor skid resistance, provide a chip seal; etc.) and/or specifying the most extreme action that may be required under the warranty and assigning a cost to this action (e.g., mill off the running surface and place a thin overlay over the entire project). The amount of the bond, or the amount of the contract payment withheld during the warranty period, can be related to this cost.

The ability of a contractor to obtain bonding for roadway construction projects is related to a bonding company's confidence in the contractor's ability to complete the project. Under a warranty approach, in addition to building the facility, the contractor will be responsible for its design as well as for ensuring that it is constructed according to this design. These two functions have been performed almost exclusively by MDT on state road projects, and thus only limited private sector expertise has developed in these areas. Thus, the ability of contractor's to successfully complete these functions is uncertain.

The ability of a contractor to obtain bonding for roadway construction projects is also related to the amount of their outstanding bonded projects. In formulating their rates, bonding companies presume that a contractor's assets will be available to offset any losses they may experience if the contractor defaults on a project. The assets of any given company are finite, and thus there is a limit on the total face value of the bonds (and thus the number of projects) they can be pledged against. This limit on bonding ability can limit the amount of work in which a contractor can engage. Under the present roadway construction system, the obligation of the contractor and bond company on any given project extends for only one year after completion of the project. Thus, the bonding capacity of the contractor is restored in a fairly timely manner as projects are completed. Under in-service warranties, the obligation of the contractor and the bond company can extend throughout the entire warranty period (say, for example, 5 years). Thus, after a few years of work on in-service warranty projects, contractors could accumulate a significant number of projects with active performance bonds. Before any of these projects reached maturity, a contractor could reach his/her bonding capacity, and thus be unable to participate in further jobs.

Possible solutions to the problem of using up the bonding capacity of contractors under an in-service warranty system include:

1) increasing the bonding capacity of contractors, this action would result in an increase in bond costs, as bonding agents would be forced to increase their rates due to the reduced probability of recovering their costs in the event of a default using contractors' assets, and

2) allowing the face amount of the bonds to decrease, as successive years of the warranty period are successfully completed.

2.6 PAYMENT SCHEDULES

A variety of options exist in the issuance of payments for warrantied projects. Consistent with current practice, funds for in-service warranty based contracts could be distributed to the contractors piecemeal as the work is completed and as the stipulations of the warranty are met. Ten percent of the contract amount, for example, could be withheld at the end of construction and subsequently released at the end of the warranty period. Alternatively, a bond could be posted to guarantee any remedial work required during the warranty period was performed.

3. SURVEY OF EXISTING IN-SERVICE WARRANTY CONTRACT PRACTICES

3.1 GENERAL REMARKS

Warrantying the in-service performance of roadway construction projects is not a new idea in the United States. Hancher (*1994*) provides a brief history on the use of such warranties dating back to 1889 in his comprehensive review on roadway warranty practices in the U.S. and Europe. In contemporary times, transportation agencies in various European countries have taken the lead in using in-service warranties. European experience with these types of contracts dates back at least two decades, and their use is now commonplace. Experimentation and adoption of this type of contract has historically been less aggressive in the United States and Canada. Use of in-service warranties has been increasing in the United States since the late 1980's, as innovative contracting procedures have been implemented in a effort to provide the public with better, more economical roads. Thus far, nine states have been identified that are using in-service warranty contracts on demonstration roadway construction projects. Additionally, in-service warranties are offered by at least one major company in the United States on roads that they construct. The majority of the roads involved are typically low volume local and private roads. Finally, information was found on a guide specification developed by FHWA for use with in-service warranties on micro-surfacing projects and on demonstration projects conducted in Canada using a modified version of this guide.

3.2 EUROPEAN PRACTICE WITH IN-SERVICE WARRANTIES

3.2.1 General Remarks - Representatives of the highway construction industry in the United States toured Europe in 1990 (*AASHTO, 1991*) and 1992 (*U.S. TECH, 1993*) to observe their roadway construction procedures with respect to their technical approaches and business practices for both flexible and rigid pavements. A summary of their findings with respect to contracting practices from these tours is found in Table 3.1. The countries visited by the tour included Austria, Denmark, France, Germany, Norway, Sweden, and the United Kingdom. A number of European practices, including warranties, were identified by the tours' participants as potential sources of the observed higher quality of European roadways compared to those in the United States. The political, social, and economic climate, in addition to the transportation

Table 3.1 - European Warranty Practices

Country	Structural Design	QA/QC	Warranty Period	Warranty Terms
Austria	State Approved	Contractor	2-5 years	Warranty Bond
Denmark	State	Contractor	5 years min.	5% Retention
France	Contractor	Contractor	10 years	Failures paid by contractor
Germany	Contractor (within state established limits)	QA - State QC - Contractor	4-5 years	5% Retention
Norway	State (usually)	Contractor	3 years	15% Warranty Bond
Sweden	Joint	Contractor	3-5 years	Failures paid by contractor
United Kingdom	State	State	Do not use in-service warranties	

network, itself, are different in Europe and the United States. Therefore, adoption of the European warranty model may not be appropriate in the United States. Differences in the construction situation in the United States and Europe (*Hancher, 1994*) include:

1) in Europe, government and industry closely cooperate in the pursuit of quality, and any increase in net construction costs associated with this collaboration are accepted,

2) the construction industry in Europe is much more actively involved in research and development than in the United States,

3) while contracts are awarded competitively in European countries, governments are able to restrict these awards to well qualified contractors,

4) in many European countries, the government is able to negotiate the price and scope of effort on construction work during the warranty period, and

5) contract disputes in Europe appear to be settled by negotiation rather than litigation, as might be the case in the United States.

All the European countries listed above, with the exception of the United Kingdom, offer in-service warranties on roadway construction projects. Typical warranty periods range from 2 years for an unbound base course without a wearing surface in Austria, to 10 years for roadway projects in France. During the 1990 tour of asphalt concrete highways in the afore mentioned countries, the observations below (*Hancher, 1994*) were made for each country.

3.2.2 Austria - Austria uses in-service warranties on roadway projects. Similar to the U.S., the project specifications are approved by the government, and a construction bond is required. An additional warranty bond is required for all highway projects in the form of cash deposit, or deposit of domestic trustee security. Warranty periods vary in Austria depending on the type of work to be performed. For example, a hot mix asphalt pavement with a unit weight of less than 45 kg/m^2 (9.2 lb/ft^2) will be covered by a 2-year warranty period, while a hot mix asphalt pavement with a unit weight of greater than 110 kg/m^2 (22.5 lb/ft^2) will require a 5-year warranty. QA/QC items are the responsibility of the contractor, with the results reported to the government. Conflicts over the results of testing are performed by an independent laboratory, paid by the party which disputes the results. Any defects are to be repaired by the contractor "immediately."

3.2.3 Denmark - Denmark advertises road work in a fashion similar to standard practice in the United States. Contract award, however, is based on the lowest life-cycle cost offered in the bid proposals. Structural design is the responsibility of the Danish Road Directorate (DRD). Therefore, the government sets items such as the structural number for a given section of roadway. The contractor selects the mix design and may choose to extend the minimum warranty period to strengthen their bid. Quality testing is done by the contractor, and reviewed by the government. Repairs are made to defective sections by the liable party. Binding arbitration is used to resolve all disputes. Standard warranty periods are 5 years for highway pavement, 2 years for the subbase, and 1 year for the earthwork. Five percent of the contract price is held in retainer during the warranty period. The DRD has found that less than 2 percent of its projects have warranty related problems.

3.2.4 France - The road system analogous to our interstates in France is unique in its operation. The system is run by private and quasi-public concessionaires. The concessionaires handle all aspects of the facility. Within this system, when a contractor seeks to be awarded a project, they submit a bid package that includes a technical proposal, a price, a quality control plan, information on the personnel that will work on the project, and a statement on the financial condition of the company (the latter two items are used to pre-qualify a contractor). Proposals from qualified bidders are evaluated for technical merit, with the contract awarded to the lowest bidder with a technically sound proposal. Innovation on the part of the contractors is encouraged. All of the contracts awarded by the concessionaires include a 10-year warranty. Failures during the first year of operation are completely paid for by the contractor, with a negotiated sharing of the costs of repairs thereafter, on a case-by-case basis.

3.2.5 Germany - Under the German system, the government and contractors have clearly defined roles in the construction process. The government has developed typical structural sections and mix designs based on the various facilities found in Germany, the level of traffic they are required to carry, and the materials available for their construction. Quality assurance is also the responsibility of the government, although they typically sub-contract this duty to a private company. The contractor is responsible for the mix design of an individual project under the confines of the recognized government limits, and handles the quality control for a project. Contracts are awarded to the low bidder based on the cost of construction. A 4-year warranty is required for all highway projects; a 5-year warranty, for all bridge projects. These warranty periods are set by law. Five percent of the project costs are retained during the warranty period. This amount may be reduced to 3 percent if the job is "proceeding smoothly." All defects that occur in the warranty period are the responsibility of the contractor. This work is then rewarranted for a minimum of 2 years. The contractor may negotiate additional compensation if the warranty repair work significantly improves the quality of the road.

3.2.6 Norway - During the 1990 tour, it was found that approximately 50 percent of the dollars spent on highway construction in Norway was on larger projects awarded to private contractors.

The remainder of the highway construction work was generally handled by the Norwegian Public Roads Administration (NPRA) using private machinery and its own 1,600 employees. While design-build contracts have been experimented with in Norway (with mixed results), most contracts are awarded on a unit price basis to the contractor that provided the "best bid" and not necessarily the lowest price. Interwoven in this evaluation are the quality and maintenance items included with the bid. Warranty periods run for 3 years beginning on the date of project completion. A 15 percent surety bond, based on the contract price, is held during construction. This amount is reduced after transference of the facility to the NPRA to 3, 2, and 1 percent for the first, second, and third years of operation of the facility, respectively.

3.2.7 Sweden - An innovative contracting procedure has been developed in Sweden called "functional contracting." The functional contracting methodology was developed in the 1980's and includes design-build and maintenance specifications, but it is not used for all road projects. Included in the contract specifications are maximum allowable rut depths, smoothness, and friction requirements for the roadway. Under the guidelines of functional contracting, no defects are allowed during a 5-year warranty period.

Most contracts in Sweden are issued under a quality assurance process that includes a warranty of 2 years for road construction, 3 years for the pavement, and 5 years for bridge projects. All failures during the warranty period are repaired by the contractor the first time. If a subsequent failure occurs, the contractor must replace and re-warrant the entire project. The one exclusion to this requirement is if the problem is found to be in an underlying layer on a resurfacing project. In this case, the contractor is not held responsible. A dispute resolution team handles all questions of responsibility for failures.

3.2.8 United Kingdom - The 1990 European Tour found that the United Kingdom does not use warranties. The British do, however, use a 40-year design period, with planned overlaying at the 20-year mark. While no formal warranty is used in the United Kingdom, they do retain 1.5 percent of the contract cost for the first year of service. During this time, the contractor is

required to maintain the facility. There was much interest expressed in the United Kingdom in utilizing warranties on future projects during the 1990 visit.

3.3 EXPERIENCE IN THE UNITED STATES WITH IN-SERVICE WARRANTIES

3.3.1 General Remarks - The use of in-service warranties on roadway construction projects is much less prevalent in the United States than in Europe. The various participants in the highway construction process (from the state DOTs, to contractors, to bonding companies) have been reluctant to change the existing process for contracting such projects, which is known from long experience to generally produce an adequate product. The broadening of Federal Highway Administration (FHWA), Special Experimental Program Number 14 (SEP 14) in 1991 to cover in-service warranty projects resulted in increased interest and activity in the United States regarding the use of such contracts on roadway construction projects. SEP 14 was initiated in 1988 with the intention of stimulating innovation and experimentation with highway contracting practices in the United States (*FHWA, 1995*). Contracts that included in-service warranty provisions originally were ineligible for the program, as such projects potentially would incorporate in-service maintenance activities, which cannot be paid for using federal funds. The Intermodal Surface Transportation Efficiency Act of 1991 allowed federal aid projects to be warrantied for the first time, with SEP 14 as the means of implementing contracts incorporating such warranties.

In-service warranty roadway construction projects have been tried by at least nine states since 1991 under SEP14. A summary of these activities is presented in Table 3.2. Items that have been subjected to warranties include pavement markings, chip seals, micro-surfacing, asphalt concrete overlays, and new asphalt concrete construction. The number of projects with in-service warranties appears to be increasing each year. Presented below are descriptions of some of the warranty projects initiated since 1991.

Warranties on the in-service performance of roadway construction projects are also being offered by at lease one company in the United States, Koch Materials (*Walters, 1998*). These warranties have been offered on roads constructed by the company for private entities and local governments on private sector projects, generally on low volume roads.

Table 3.2 - Current Pavement Warranty Activities in the United States

State	Type of Project	Year Began	Warrantied Behavior	Warranty Period	Warranty Terms
California	AC Overlay on a PCC Pavement	1992	rutting raveling flushing delamination	3-5 years	Monetary Retainment + Bond
	Chip Seal	1991	chip loss	2 years	Unknown
Colorado	Hot Bituminous Pavement	1997	unknown	3 years	Unknown
Indiana	AC Overlay on a PCC Pavement	1995	ride quality rutting skid resist cracking	5 years	Bond
Michigan	AC Overlay on a PCC Pavement	1997	ride quality surf. distress rutting	5 years	Monetary Retainment + Bond
Missouri	Rubberized AC Overlay	1991	unknown	3 years	Unknown
New Mexico	Partial Reconstruction + New Construction	1997	rutting friction ride quality distress	5-20 years	Bond
Wisconsin	Partial Reconstruction (AC Overlay on Granular Base)	1995	rutting friction longevity (pavement distress)	5 years	Bond

3.3.2 California - The California Department of Transportation (Caltrans) let one of the early warranty projects under FHWA's SEP 14 program in 1991. This project involved warrantying chip seal projects with respect to chip retention under traffic loads (*Huckabay, 1997*). California has not responded to requests for information on the specific provisions of this project. Caltrans' second warranty venture, initiated in 1993, also under FHWA's SEP 14 program, involved three

separate rehabilitation projects in the Redding, San Diego, and San Francisco districts (*Huckabay, 1997*). Note that the project in the San Francisco district subsequently was not awarded as a warrantied project, as all of the bids received on the project were judged to be unacceptably high.

The project in the Redding district, also know as the Sims Project, was an asphalt concrete overlay of a 2-mile "cracked and seated" Portland cement concrete (PCC) section on Interstate 5 (*Vallerga, 1995*). The project was to have a 10-year design life, with the first 5 years of in-service performance covered by a warranty on rutting, raveling, flushing, delamination, and cracking (*Caltrans, 1993*). Ten million, 80-kN (18-kip) ESALs were projected for the 5-year warranty period. The duration of the warranty period was selected at 5 years "because there have been pavement failures in the vicinity of this project in the first four years."

Two Redding California contractors (W. Jaxon Backer, Inc. and J. F. Shea Co.) bid the project jointly. One contractor took responsibility for the northbound lanes; the other, the southbound lanes. The contractors were given considerable latitude in the roadway design. Caltrans did specify the maximum aggregate size, the number and thickness of asphalt concrete lifts (two 4.5 cm (0.15 foot) lifts), and the asphalt grades for each lift. The first lift involved the use of a densely graded asphalt concrete (Pacific Coast User-Produced Performance Based Asphalt Grade 6 (PBA-6) and maximum aggregate size of 26 mm (1-inch)). The second lift was a gap graded rubberized asphalt concrete (an 85:15 to an 80:20 blend of Asphalt Rubber (AR) 1000, AR 2000, or AR 4000 and a re-plasticized granular rubber from tires and a maximum aggregate size of 26 mm (1-inch)). The two contractors selected different mix designs and separate aggregate and asphalt sources. The contractors were required to verify the acceptability of the mix designs using an independent party. Quality control testing during construction was the responsibility of the contractors, but they were required, at a minimum, to follow Caltrans quality control procedures.

Items warrantied under the contract included rutting, raveling, flushing, delamination, and cracking. Definitions of each of these distresses were written into the contract, with threshold levels of acceptable performance established by Caltrans. For example, during the 5-year warranty period, rut depths were not to exceed 13 mm (0.5 inch) under an expected loading

of 10 million 80-kN (18-kip) ESALs (*Harvey, et.al., 1995*). Unless otherwise stated in the contract documents, the required repair for warranty problems was stated to be removal of the affected material to a depth of 4.5 cm (0.15 feet) and replacement with rubberized asphalt concrete. Warranty work was to be done annually, following surveys of the roadway by Caltrans personnel. Conflict resolution was to be accomplished by the standard Caltrans operating procedure. This procedure involves a grievance board comprised solely of Caltrans personnel; if the findings of the board are disputed, arbitration or judicial action are employed.

A 5-year performance bond was required of the contractors performing the work, and Caltrans retained 10 percent of the contract bid price to assure the commitment of the contractors to meeting the warranty requirements. The retained funds were disbursed to the contractors by Caltrans in the amounts of up to 10, 25, 45, and 70 percent of the total amount retained after the first, second, third, and forth years of the warranty period, respectively. These distributions were only to be made if the contractor fulfilled their obligations under the warranty specifications.

The other project performed by Caltrans under SEP 14 was the San Diego project (*Huckabay, 1997*). This project incorporated a 3-year warranty period, with special provisions that closely mirrored those of the Sims Project. No additional information was provided for this project by Caltrans.

3.3.3 Wisconsin - The Wisconsin Department of Transportation (WisDOT), in conjunction with the Wisconsin Asphalt Paving Association (WAPA) and the FHWA, began working on warranties for in-service performance in 1994 under SEP 14. In 1995, WisDOT let three warranty projects to three different contractors. WisDOT indicated that the groundwork for this action was laid over the previous ten years, during which WisDOT moved away from the state specifying mix designs and construction procedures on roadway construction projects to a system in which contractors develop mixes and perform quality control testing under WisDOT supervision and approval (*Shober, Whited, and McMullen, 1995*). WisDOT was motivated to move in this direction in an effort to produce better highways at a reduced cost while encouraging innovation in both design and construction methodologies.

The basic warranty contract instrument, and the projects it was used on in Wisconsin, represent a compromise between the ideal provisions for a warranty job (in which the contractor is allowed total freedom in construction of the project, with contract compliance based simply on in-service performance), used on the ideal type of project (total reconstruction), and a contract that can be practically executed in the existing construction and administrative environment. A brief description of the Wisconsin projects, as described by Shober and his colleagues (*1995*) at WisDOT, is presented below.

The initial demonstration projects were chosen so as to have a high likelihood of success. It was decided that the most suitable projects involved the use of asphalt concrete reconstruction over a granular base on 2-lane highways carrying medium traffic (2500 to 4500 ADT). The projects involved milling off the existing pavement to a maximum size of 26 mm (1-inch), placing this material on an existing granular base to form a new base, and then applying a running surface. To help minimize project variables, all the roadways had a good foundation with existing distress levels similar at all points along their respective lengths. Thus, while the jobs were not total reconstructions as might be preferred, initial conditions were both uniform and good. While the contractors were allowed extensive freedom on mix design and construction methods (in keeping with the philosophy of only being concerned with in-service performance), the pavement thickness (from 75 mm to 125 mm (3-5 inches)) and type of base (granular) were specified in the contract documents (contrary to the philosophy of allowing complete freedom in facility design). These items were specified to simplify comparison of bid proposals. Other items specified by WisDOT were the location of the projects and the schedule for completion of each project. In keeping with the principals of warranty based contracting, quality assurance was left to the contractor's discretion.

The in-service warranty specifications for these projects were jointly established by WisDOT, FHWA, and WAPA. A 5-year warranty period was established because five years was believed to be an acceptable evaluation period to assure a quality product, without overburdening the contractors. The contractors were held liable for attributes of in-service performance over which it was believed that they had control. These attributes were chosen to be rutting, friction, and longevity, where longevity encompasses 11 measures of pavement

distress. These measures of pavement distress, and the threshold values that will trigger warranty repairs, are summarized in Table 3.3. Items considered for inclusion in the specifications that were eliminated from the final contract include roughness, appearance, noise, maintenance minimization, and delineation (the use of different colored material for the mainline and shoulder sections). Reasons for omitting these items ranged from the absence of proven, standard techniques for their measurement to a lack of a sufficient historical data to confidently establish performance expectations for them.

The expected levels of in-service performance of the roadway throughout the warranty period was established by investigating the actual performance of approximately 200 miles of AC pavements placed over granular bases in each of 1987 and 1988. Threshold levels for friction resistance, rutting, and longevity were established so that, in general, 90 percent of the pavements investigated would meet the criteria. The contractors were not liable for factors beyond their control, as previously mentioned. Examples of factors beyond the control of the contractors include settlement over culverts and the accumulation of axle loadings (ESALs) 50 percent higher than predicted for the 5 year period.

Remedial actions were specified by WisDOT in the event that any threshold level of performance was not met (see Table 3.3). Included in the specification was the requirement that if 30 percent or more of the total project were requiring or had received a remedial action, the entire project would thus receive the corrective action. All remedial work in the primary service lanes was to also be performed on the shoulders.

With regard to execution of the contract, a bond was required to insure that any remedial work necessary during the warranty period would be completed. The amount of the bond was set at the highest "reasonable" expenditures expected during the warranty period. In this case, repair by thin overlay (38 mm (1.5 in.), compacted) was expected to be the most severe remedial action that would reasonably be undertaken, and the bond amount was based on performing this task. An A.M. Best rating of "A-" or better was required of the bonding company. A Conflict Resolution Team was established to mediate any disputes that might occur during the warranty period.

Table 3.3 - Wisconsin Warranty Provisions

Distress Type	Threshold Levels	Remedial Action
Alligator Cracking	10% of the area in a segment.	Remove and replace distressed layer(s).
Block Cracking	10% of the area in a segment.	Remove and replace distressed layer(s).
Edge Raveling	10% of the segment length.	Remove and replace distressed layer(s).
Flushing	20% of the segment length.	Remove and replace distressed surface mixture full depth.
Longitudinal Cracking	305 linear meters (1000 linear feet) for cracks which average 13 mm (0.5 in.) or less.	Rout and seal all cracks.
	152 linear meters (500 linear feet) for cracks which average greater than 13 mm (0.5 in.).	Rout and seal all cracks.
Longitudinal Distortion	1% of the segment length.	Remove and replace distressed layer(s).
Rutting	6 mm (0.25 in.).	Mill surface with fine-toothed mill, overlay or micro-surface.
Surface Raveling	"Slight rating."	Apply a chip seal.
Transverse cracking.	25 cracks per segment.	Rout and seal all cracks.
	25 cracks per segment with 25% of the linear meters (feet) of cracking having band cracking or dislodgement.	Remove and replace distressed layer(s) to a depth not to exceed the warranted pavement.
Transverse Distortion	1% of the segment length.	Remove and replace distressed layer(s).
Patching	46 linear meters (150 linear feet) of patching per segment.	Remove and replace the surface layer or place a 30 mm (1-1/4 in.) overlay.
Potholes, slippage areas and other disintegrated areas.	Existence	Remove and replace distressed area(s).

The team consists of two members each representing WisDOT and the contractors. The fifth member is an individual mutually agreed upon by WisDOT and the contractor.

A system of annual evaluations of pavement conditions was established as part of the contract under the warranty system. This evaluation is conducted by WisDOT between April 15 and May 15. The survey consists of evaluating two 0.16 km (one-tenth mile) sections within each mile of each project. One of the 0.16 km sections is chosen at random, and one is to be the 0. 48 - 0.64 km (0.3 - 0.4 mile) section from the start of each mile. The contractor is given the opportunity to contest the validity of any survey to the Conflict Resolution Team. If the predetermined thresholds given in the contract are found to be exceeded, warranty work will be done by the contractor, as coordinated with WisDOT.

The number of contractors that bid on these projects was judged by WisDOT to be "limited." Bids were received, however, from competent contractors, one of whom was awarded each project. Elective maintenance was included by some contractors in their bids. Overall, WisDOT estimated that the contract costs were 5 to 10 percent higher than a conventional contracting approach. Thus, these projects must offer a benefit of this order of magnitude to be cost effective.

These projects reportedly have produced an increased awareness in the contracting community on providing long term roadway performance as opposed to meeting short term construction requirements. While concerns have been raised regarding the potential inability of small contractors to compete on these projects, it is generally held (*Shober, et.al., 1995*) that they will not be left out of the warranty process. Small contractors with innovative and efficient ideas may have the opportunity to implement these ideas and thus better compete with larger contractors than under the current system. Thus far (third year of warranty), no major problems have occurred with these projects (*Shober, 1998*).

Wisconsin has recently developed in-service warranty specifications for Portland cement concrete pavements (*Shober, 1998*). Wisconsin plans to award three demonstration projects that use these specifications early in 1998. An industry representative indicated that a primary motivation for industry moving forward with these demonstration projects is WisDOT's obvious interest in this approach (*McMullen, 1998*). However, the concrete paving contractors in

Wisconsin are concerned that these projects will have increased costs with no improvements in the quality of the job done.

3.3.4 Indiana - Indiana has also experimented with warranty roadway construction projects under FHWA's SEP 14. Many similarities exist between Indiana's approach in implementing warranties to that used by Wisconsin. The special provisions for the Indiana contract were developed through a joint committee of the Asphalt Pavement Association of Indiana (APAI), the Indiana Department of Transportation (InDOT), and FHWA. Representatives from this group met with individuals from WisDOT and WAPA to learn from their experiences. The following summary of Indiana's work was prepared from information presented by InDOT in "Innovative Contracting Procedures: A+B+C Bidding and Performance/Warranty Specifications for Hot Mix Asphalt," 1995a and "Specifications for Warranted Asphalt Pavement," 1995b, McDaniel in "Performance/Warranty Specifications for Hot Mix Asphalt," 1995, and by Avera in *Asphalt Contractor*, 1996.

Indiana's first demonstration project, unlike the projects selected by Wisconsin, is on a heavily traveled (35,000 ADT) section of interstate highway. The project consisted of rehabilitating 4 miles of pavement by milling off an existing overlay, cracking and seating the underlying concrete pavement, and placing a new asphalt concrete overlay. While the contractor was given the responsibility of specifying the overlay mix design, InDOT did specify that at least a PG 64-28 asphalt cement be used and the aggregate meet Superpave specifications (responsibility for transverse cracking was retained by InDOT due to this stipulation). Bidders were free to use the mix design procedure of their choice (Marshall, Hveem, Superpave, etc.). InDOT also required that the contractor perform basic quality control testing on the project and to submit a quality control plan to InDOT for approval. Only the mainline pavement is subject to the warranty requirements (shoulders, ramps, and acceleration and deceleration lanes are not included).

InDOT's objective in using an in-service warranty is to insure that the motoring public is provided with a safe, smooth ride over the design life of the pavement. To accomplish this objective, the contractor was required to warranty the performance of the roadway for a 5-year

period with respect to ride quality (as quantified using the IRI), rut depth, skid resistance, and the amount of longitudinal cracking. Note that Indiana is using significantly fewer types of distress in evaluating pavement performance during the warranty period than were used by Wisconsin. Indiana believes that ride quality, as measured by the IRI, reasonably reflects the effects on performance of several of the distresses explicitly mentioned by Wisconsin.

Acceptable levels of ride quality (IRI), rut depth, skid resistance, and the amount of longitudinal cracking at any time during the 5-year warranty period were established after an extensive examination of numerous 5-year old AC pavements that were judged to be delivering acceptable performance. Similar to WisDOT, InDOT took contractors on a tour of several stretches of pavement so that they could relate numerical distresses to physical pavement condition. In general, the levels that trigger remedial action were set two standard deviations below the observed mean performance for existing pavements. Threshold values for the warranty parameters are given in Table 3.4.

Annual surveys of pavement condition will be conducted by InDOT. The contractor can dispute the results of these distress surveys. If excessive distress is identified during the surveys, it must be remediated by the contractor in the year in which it is detected. The threshold levels of performance, however, are to be waived if Class 5 truck traffic exceed estimates by more than 50 percent (a weigh-in-motion device was installed in the vicinity of the project), the base thickness is at least 50 mm less than the given design thickness, or if the subgrade density is less than 90 percent of optimum. Reflection cracking and stripping were specifically excluded as distresses covered under the warranty.

The contract documents specify the minimum remedial actions that must be taken based on the nature of the observed distress, as indicated in Table 3.4. The contractor does not have to follow the remedial actions listed above. However, the contractor is expected to develop a suitable remediation plan for the specific situation encountered and to submit this plan to InDOT for approval.

Table 3.4 - Indiana Warranty Provisions

Distress Type	Threshold Levels*	Remedial Action
International Roughness Index (IRI)	2.1 m/km (133 in/mi)	Based on cause of failure
Alligator Cracks**		Remove and replace the distressed surface layer(s)
Block Cracks**		Remove and replace the distressed surface layer(s)
Transverse Cracks**		Rout and seal all cracks
Flushing**		Remove and replace the distressed surface layer, full lane width
Longitudinal Distortion**		Remove and replace the distressed surface layer, full lane width
Longitudinal Cracks	0 m	Rout and seal all cracks
Rutting	9.0 mm (0.35 in.)	Mill surface with a fine-toothed mill to remove rut, overlay
Friction	Friction Number of 25 or less	Micro-surface distressed area, full lane width
Potholes, slippage areas, raveling, segregation, and other disintegrated areas	Any occurrence	Remove and replace the distressed area(s)

*For Each 100 m (328 ft.) Section
** Measured within the IRI.

Similar to the Wisconsin approach, a bond was required to insure that any remedial work necessary during the warranty period will be completed. The amount of the bond was set at 500,000 dollars, which is approximately 20 percent of the initial value of the warrantied work. This bond was believed to be on the order of magnitude of the cost to remove and replace the running surface. While this liability could exceed the value of the required performance bond, no limit was placed on the liability the contractor may have to assume. A Conflict Resolution Team was established with same membership as specified by WisDOT.

Indiana used an "A+B+C" bidding process for this demonstration warranty project. Following this process, the bid is divided into three components:

A - consideration of labor and materials to complete the project (appears to include any warranty related costs)

B - consideration of cost to consumers of disruption of traffic (in this case, lane closures)

C - consideration of long term performance by warrantying in-service performance.

Part A of the bid most resembles the type of bid submitted on a traditional roadway construction project; parts B and C are both new types of contract provisions being experimented with by InDOT. An incentive and penalty clause was included with the "B" portion of the bid to encourage timely completion of the project. Therefore, it was the sum of A+B that was used to determine the low bidder for the project. Consequently, under this system, a contractor that was not the low bidder under a traditional contracting system may still win the contract by estimating fewer disruptions to traffic to complete the required tasks.

3.3.5 Michigan - The Michigan Department of Transportation (MIDOT) began work on a demonstration warranty roadway construction project in December of 1995 (*MIDOT, 1996*; *Scherocman and Van Deusen 1997*). The project consisted of rehabilitating a 9.8 km (6.1 mile) segment of Portland cement concrete, rural freeway to provide a 20-year design life with a 5-year warranty on certain aspects of pavement performance. A contract for the project was let in summer of 1996, and the roadway was expected to be opened to traffic in the fall of 1997. The project incorporated features of both the California and Indiana approaches to in-service warranties, with:

1) fewer DOT imposed, front end constraints on the contractor's design solution, and

2) a new approach to evaluating bid proposals.

In the Michigan project, all aspects of the design and construction apparently were left to the contractor's discretion (except for the 20-year design life and the 5-year warranty). MIDOT

did not specify the method of base preparation, materials, pavement type, or pavement thickness to be used. Five contractors bid the project. As part of the bid process, the contractors had to prepare a technical proposal that outlined their design, indicated the manner in which the required ride quality would be achieved, and described the quality control program they would use during construction. A price proposal was subsequently submitted by each contractor. The successful bidder was determined by dividing the score MIDOT assigned to each technical proposal by the corresponding bid price. Thus, the basis for bid award was the lowest cost per unit of technical quality, rather than simply the lowest lump sum bid (see Section 2.4.2). The technical evaluation criteria used by MIDOT to score the proposals is given in Table 3.5.

Performance during the warranty period is being measured using ride quality, surface distress parameters (transverse, longitudinal, block, and alligator cracking), and rutting. Similar to California, 10 percent of the contract price (in this case, $760,000) is being withheld, pending acceptable performance of the pavement during the warranty period. This amount is returned to the contractor at annual intervals in a back-ended manner in the amounts of none after the first year; 1 percent after the second year; 2 percent after the third year; 3 percent after the fourth year; and 4 percent after the fifth year.

Table 3.5 - Michigan's Proposal Evaluation Criteria

Item	Potential Points
Technical Criteria	**30 Maximum**
Maintaining Traffic	10
Application of Design	10
Innovation of Design/Constructability	10
Management Criteria	**25 Maximum**
Team's Quality Control Plan	10
Applicable Experience of Design Team	5
Applicable Experience of Const. Eng and Inspection Team	10
Project Schedule	**15 Maximum**
Completed by Nov. 15, 1996	15
Open to Traffic by Nov. 15, 1996 and Completed by Aug. 31, 1997	10
Other	0
Proposed Pavement Fix	**30 Maximum**
Adequacy of 20-year Maintenance Schedule	10
Best Optimal Design to Achieve Minimum 20-year Design Life	20
Maximum Potential Score	**100**

3.3.6 Colorado - The approach being followed by Colorado with respect to in-service warranties on roadway construction projects mirrors that followed by other states as described above. An interesting feature of the situation in Colorado is that the state legislature passed a law that requires the Colorado DOT to investigate this approach to roadway construction. The pilot program was to begin by July 1, 1997 and is scheduled to end July 1, 2002. The warranty period was limited to 3 years for "qualified hot bituminous pavement projects."

3.3.7 New Mexico - One of the most ambitious attempts at the use of warranties in the United States thus far, is New Mexico's Corridor 44 Project. This project involves New Mexico

Highway 44, in northwest New Mexico, from Bernalillo (near Albuquerque) to Bloomfield. Impetus for this ambitious project stemmed from "economic and safety concerns." The scope of work consists of widening those areas, of the approximately 190 km (120-mile) section, from 2-lane to 4-lane, where they are currently only 2-lane. (This is approximately 175 km (110 miles) of the described reach.) Quoting from the Request For Proposals (RFP) issued by the New Mexico State Highway and Transportation Department (NMSHTD), the "developer" will be responsible for (*NMSHTD, 1997*):

1) obtaining financing for the Corridor 44 Project,

2) providing the final design of the improvements for the Project,

3) providing construction management services in overseeing the construction of the improvements to in the Project, and

4) providing a warranty and preventive maintenance services for the Project following its substantial completion and opening to traffic.

The NMSHTD is responsible for (*NMSHTD, 1997*) (quoting):

> The Corridor 44 Project shall be managed on behalf of the (NM)SHTD by an Engineer in Responsible Charge. The (NM)SHTD shall participate in the oversight in the design and construction of the Project consistent with the responsibilities of the Project Development Contractor for such activities as provided in this RFP.

The bonding requirements for this project involves three phases. New Mexico required an A.M. Best rating of not less than "A" for the issuing bonding company. The initial bonding phase is a 10 million dollar proposal guarantee. This amount shall be returned to the "offerors" of proposals not selected within 30 days of the final execution of the agreement between the state and the selected proposer. The state is to return this bond to the selected proposer at the same time, provided all required documentation and subsequent bonds have been submitted. The second required bond is a performance and payment bond to cover the design and construction management phases of the Corridor 44 Project. The amount of this bond is to be equal to the amount negotiated between the chosen developer and the state for these items. The third and final bond called for by NMSHTD is a performance warranty bond. The amount of this bond will be negotiated with the developer.

All aspects of design, except for the environmental and right-of-way design (approximately 30 percent of the total design), are the responsibility of the developer. The remaining items are the responsibility of the state. Bidders have been given considerable latitude in developing their own designs, with NMSHTD setting only some minimum acceptable standards. For example, the pavement design life was to be 20 years and to be consistent with AASHTO design standards. No limits were placed on the pavement type, aggregate, binder, etc. Developers were required to incorporate into their proposal submission of a QA/QC and a preventive maintenance plan. These items will be reviewed by NMSHTD and weighted in the selection process.

As ambitious as the design freedom offered to developers on the Corridor 44 Project are, the warranty components are equally, if not more so, ambitious. It is felt that the market will determine the overall length of the warranty period. The minimum required warranty is to encompass an initial mandatory 5-year period. Following this base warranty, the state can choose to extend the period an additional 5 years, and then further for 10 consecutive 1-year extensions. Therefore, the warranty may extend throughout the total 20-year design life. The previously mentioned warranty bond would follow an identical path, with the bond durations corresponding to the warranty lengths.

The warranty and maintenance activities which are the developer's responsibility are divided into 3 categories. The first category of items covered by warranty provisions are related to the pavement and its performance. Included in this are pavement distresses, as described in SHRP-P-338 (*NRC, 1993*); the roughness and rutting, reported in IRI units; and the surface friction, based on ASTM E274-90 "Standard Test Method for Skid Resistance of Paved Surfaces Using a Full-Scale Tire" (*ASTM, 1997*). The roughness and distress indices are to be combined into a Pavement Serviceability Rating (PSR), based on the pavement management system of the NMSHTD. Minimum threshold values are established by NMSHTD for this item, with the value decreasing as the pavement ages. Individual distresses recognized by SHRP-P-338 have also been given their own individual thresholds, with distinctions made for flexible and rigid pavements. Along with the threshold levels, remedial actions are specified for the individual distresses, again with lessening threshold levels as the pavement ages.

The second major category of warranted items are the major structures. In general, this classification includes bridges and their associated components. Items that the developer shall cover under the warranty provisions include: settlement, design or material deficiencies, spalling, fatigue cracking, rideability, delaminations and patched areas, expansion joints, drainage, and painting.

The third, and final, warranty category is erosion control. Erosion warranty requirements are for the embankments and erosion control structures. These structures are to be designed to provide protection from a 50-year event with freeboard for a 100-year event. Therefore, a 500-year flood, for example, would be considered an act-of-God.

Items covered by the warranty are to be evaluated jointly by NMSHTD and developer personnel annually, generally with equipment provided by the developer. Note that exceptions to the warranty of the pavement and the major structures are provided for based on the level of traffic carried by the facility once it is in-service. If the number of Class 4 of greater commercial vehicles exceeds the projections provided by NMSHTD, the developer will not be responsible for the distressed associated with the excessive loadings. To obtain accurate traffic data, NMSHTD is contractually obligated to install weigh-in-motion devices along the route.

In the event that a dispute(s) arises between the state and the developer, a two step process is provided to resolve the dispute(s). The first phase consists of negotiations between the state and the developer. If these negotiations prove to be futile, the disagreement is heard by a dispute resolution board. This board shall consist of one member each from the NMSHTD and the developer, and a third person, mutually agreed upon by both parties. The powers of this board are similar to those of Wisconsin and Indiana.

The method used to evaluate, select and award the contract for the Corridor 44 Project are clearly defined in the RFP. A summary of the evaluation criteria is presented in Table 3.6, with a total of 520 available points.

Table 3.6 - New Mexico's Proposal Evaluation Criteria

Item	Potential Points
Design	**160 Maximum**
Roadway	50
Bridge Structures	30
Maintenance of Traffic	30
Project Development/Design Qualifications	50
Construction Management	**160 Maximum**
Management/Organizational Capabilities	40
Quality Management Program	40
Work Plan/Schedule	20
Coordination with Agencies/Utilities	20
Community Relations/Public Information	20
Safety/Maintenance During Construction	20
Warranty	**100 Maximum**
Basic Warranty Service Plan and Optional Warranty Plans	10
Duration of Optional Warranty Extensions	10
Preventative Maintenance	10
Cost	50
Approach to Securing a Performance Guarantee for the Warranty	10
Experience and Capabilities with Warranties	10
Financing	**100 Maximum**
Offeror's Financing Method(s) or Techniques(s) for the Entire Project	25
Method and Cost of Financing of Construction	25
Offeror's Financial Capability to Finance the Project	20
Offeror's Proposed Method(s) for Securing its Performance of all Financial Aspects of the Project	15
Offeror's Proposed Duration for Repayment of all Financing of the Project	10
NMSHTD Involvement in the Achievement of Financing	5
Maximum Potential Score	**520**

New Mexico is currently negotiating the final details of the contract for the Corridor 44 Project with a consortium consisting of Flat Iron, CH_2M Hill, and Koch Materials. It is felt that the contract should be finalized by mid-February. The remainder of 1998 is to be used to complete the design of the project, with construction to begin in 1999, and an expected completion no later than July 1, 2001.

3.3.8 Initiatives of Private Companies - Koch Materials (Wichita, Kansas) recently began offering warranties on the in-service performance of roadway projects they construct (*Walters, 1998*). Koch offers design, build, and maintenance services as requested by the client through their "Performance Roads" program. The market for these services ranges from private subdivision developers to state departments of transportation. The warranties offered on these roadways are tailored to the needs of the client and cover bleeding, rutting, cracking, potholes, and delaminations. Major warranty projects Koch is currently involved with include the 400 million dollar San Miquel Mountain Parkway in California that has a 15-year warranty, and the Corridor 44 Project in New Mexico (see Section 3.3.7) which has up to a 20-year warranty.

3.4 IN-SERVICE WARRANTIES FOR MICRO-SURFACING

3.4.1 FHWA Guide Specifications - FHWA has developed a guide for in-service warranty specifications for micro-surfacing (*FHWA, 1991*). The guide recommends the materials to be used and the properties to be achieved of the micro-surfacing mixture, with the suggestion that deviations from these recommendations be documented by the contractor. The guide specifications include minimum criteria that the surface must meet at the completion of construction (maximum number of tear marks, maximum ripple size, maximum change in elevation across transverse and longitudinal seams, minimum skid resistance, etc.) and warranty provisions. The suggested warranty period in the guide specifications is 2 years. Surfaces that have lasted 2 years apparently have been found to provide long service lives (*Moulthrop and Dunn, 1996*). The recommended performance bond during the warranty period ranges from 50 to 100 percent of the contract amount. Warrantied performance includes skid resistance, bleeding and flushing, surface loss, weathering and raveling, and ruts. Compliance with the

warranty is determined by the contracting agency. Warranty repairs are expected to be done within 30 days of notification of the contractor by the contract agency.

3.4.2 Canada - In-service warranties for micro-surfacing projects have been experimented with by the Ontario Ministry of Transportation (*Bradbury and Kazmierowski, 1995*). The Ministry used the FHWA guidelines described above in developing their in-service warranty specifications. Ontario selected a 2-year duration for the warranties based on a) an industry expressed preference regarding warranty duration, b) the measured performance of existing micro-surfaces in Ontario, and c) the FHWA guidelines for these projects. The contract specifications covered two types of surface distress during the warranty period, namely, aggregate loss/raveling and flushing. The specified repair in the event these distresses exceeded allowable levels typically consisted of resurfacing the distressed area over a minimum of one lane width. If the micro-surfacing is found to be responsible for any safety problems with the roadway, repairs must be made within two weeks of notification of the problem. A performance bond was required during the warranty period in an amount equal to 10 percent of the total contract price. Ontario believed that the bond amount of 50 to 100 percent of the contract price suggested by FHWA was too large.

All contractors that bid on the warranty projects had to be pre-qualified based on their record of proven performance with micro-surfacing projects. New contractors with an interest in micro-surfacing projects were required to demonstrate the effectiveness of their product and/or placement procedure by installing a 500 m (1640 ft.) test surface on a two-lane section of freeway. All costs of the test installations were borne by the demonstrating contractors.

The mix design for the micro-surfacing material was left to the discretion of the contractor. However, the designed mix had to meet the properties specified in the FHWA guidelines, and a trial area had to be placed for inspection by Ministry personnel prior to the commencement of large-scale operations.

4. EXISTING PERCEPTIONS IN MONTANA OF IN-SERVICE WARRANTIES

4.1 GENERAL REMARKS

An investigation of the potential benefits and liabilities of using in-service warranties on roadway construction projects can best move forward with the willing cooperation of the various entities involved in the highway construction process, namely, MDT, roadway contractors, and bonding companies. Therefore, each of these groups was contacted during the first phase of this project to obtain their input on the over-all concept of warranty contracting and on the plan of action being pursued at Montana State University regarding its evaluation in Montana. In general, while all three groups voiced concerns regarding the use of in-service warranty contracts on roadway construction projects, they all indicated a willingness to investigate the approach.

4.2 MONTANA DEPARTMENT OF TRANSPORTATION

4.2.1 General Remarks - Discussions have been held with two groups of MDT personnel regarding the use of warranties on in-service performance on roadway construction projects, namely, the technical panel assembled for this research project and the attendees at the annual MDT maintenance conference held in Helena in the spring of 1996. MDT also has two active warranty projects for striping, initiated in 1993 and 1994 under the FHWA SEP 14 program. While obviously not a roadway project, this warranty experience may still offer some valuable perspectives for this study to consider.

4.2.2 Project Technical Panel - Several discussions have occurred with the MDT technical panel on the general features of in-service warranty projects, the advantages and disadvantages this type of contract may offer for roadway construction projects, the types of projects in-service warranties may be most appropriate for, and the manner in which demonstration projects should be implemented. Membership on the technical panel is given in Appendix A. The substance of the general discussions of the committee on the concept of using in-service warranties for roadway construction projects have been included in Section 2 of this report. With respect to the

types of projects that may be appropriate for in-service warranties, the committee's attention initially focused on maintenance overlays. Reasons for considering this type of project for demonstration purposes included:

1) these projects are less costly than full reconstruction projects. Thus, the magnitude of the financial risk to all the parties involved with a demonstration project (contractor, bonding company, MDT) would inherently be limited.

2) these projects by definition are done for preventative maintenance reasons. Thus, these overlays are typically done on roadways that are in reasonable condition with respect to cracking and rutting. In-service performance of the overlay would therefore be expected to reflect the quality of the overlay, itself, rather than any significant pre-existing conditions in the original road.

During further discussion of this idea by the committee, significant concerns were raised regarding a) the degree to which the contractor could be realistically held responsible for the behavior of the overlay, independent of the condition of the underlying material, and b) the high costs anticipated for repairing the overlay if the warranty requirements were not met. The cost of the remedial measures envisioned for most excessive distress scenarios were equal to the cost of the original overlay.

In light of the above concerns, the committee revisited the issue of the type of roadway construction activity that should be considered for demonstration in-service warranty projects. The committee was attracted to full reconstruction projects for demonstration purposes, as such projects would give the contractor complete control over all aspects of the finished facility from the subgrade to the finished running surface. In this situation, the contractor could reasonably be held responsible for the in-service performance of the entire facility. The primary disadvantages voiced for total reconstruction were that such projects are very complex and expensive compared to other roadway construction activities.

At the other end of the construction spectrum from total reconstruction are chip seal projects. The committee specifically focused their attention on the chip seals done as the last step when new pavement is laid down. It was believed that in using these projects, problems with pre-existing conditions affecting subsequent project performance would be avoided, since

these particular chip seals are applied to new pavement. Also, such projects are of modest cost (relative to overlay and reconstruction projects) and can be easily repaired if performance criteria are not met during the warranty period. Two aspects of chip seal performance were considered for warranty, namely, chip retention as a function of time and skid resistance as a function of time. The basic behavior of interest is skid resistance (and its deterioration through time), which is expensive to measure. This aspect of chip seal performance, however, may be reasonably reflected by chip retention, and some preliminary work was done at MSU on chip retention as a warranty parameter.

Before investing significant resources in developing an in-service warranty contract for chip seals, the technical panel decided that the Montana contracting community should be consulted regarding their thoughts on in-service warranties for roadway construction projects. Input from the construction community was considered essential for any investigation of warranty practices to be complete and for any subsequent demonstration projects to be constructed. The results of a survey of contractor ideas on using in-service warranties on roadway construction projects is presented in Section 4.3 of this report.

4.2.3 Presentation to MDT Annual Maintenance Seminar - A presentation on the concept of using warranty specifications on in-service performance on highway construction projects was made to a group of MDT personnel at the annual maintenance meeting in Helena in March of 1996. The greatest concern of the audience was the impact that this approach to roadway construction projects might have on MDT staffing requirements. Some of the employees at the presentation felt their jobs were threatened by this program. Warranty projects were perceived as requiring only nominal state involvement during their design and construction phases compared to traditional projects. Therefore, it was perceived that the state workforce, from construction inspectors to design engineers, would be substantially reduced if warranty contracts were used on a broad scale. This perception prevailed despite statements made during the presentation that:

1) warranty contracts may only be found to be appropriate for a limited range of MDT construction activities,

2) reductions in personnel required to support the construction phase of projects will be offset, to some extent, by increased personnel required to monitor roadway performance during the warranty period, and
3) if warranty contracts are found to be a more efficient method for constructing roads, funds will become available to do more projects, which will again increase some state oversight activities.

Many of the design and construction functions presently performed by state personnel will still need to be done on warranty projects, responsibility for these functions will simply shift from the state to the contractor. Thus, while not explicitly stated during the presentation, as state personnel requirements diminish, private sector employment opportunities should increase.

4.2.4 Montana Experience with In-service Warranties on Highway Striping - As previously stated, MDT participated in SEP 14 program with two warranted pavement stripping contracts (*Stevenson, 1997*). Both projects utilized a 3-year performance period. At least one of the projects required the contractor to return to the project location to repair sections that were failing to meet the warranty requirements. No other concerns have been raised over the performance of the sections included in these contracts.

4.3 MONTANA CONTRACTING COMMUNITY

4.3.1 General Remarks - Obviously, the Montana construction industry will be affected by changes in contracting practices for roadway construction projects. As the entity that actually performs the work on such projects, their opinions and ideas on a) the overall concept of using warranty contracts for roadway construction projects and b) the manner in which the concept is being investigated in this study, were deemed to be important. Furthermore, the cooperation of the construction industry was judged to be essential to the ultimate success of the study.

The construction industry in the state was first introduced to the study through a presentation made by MSU to the members of the Highway Committee of the Montana Contractors' Association (MCA) at their monthly meeting in April, 1996. MCA is the Montana Chapter of the Associated General Contractors (AGC). The presentation began with a broad overview of the in-service warranty concept followed by a discussion of the perceived benefits

and drawbacks of this approach to roadway construction projects. The presentation concluded with comments on the specific type of project being considered for demonstration purposes (at that time, chip seals on new pavements).

Following the presentation, the contractors voiced several concerns and raised many issues regarding the use of warranties on roadway construction projects in general, and on chip seal projects, in particular. Based on this input and the general level of interest displayed by industry at the meeting, the decision was made to more formally and comprehensively solicit comments from the Montana construction industry on in-service warranties. Note that only limited information of this kind is available in reports (*Hancher, 1994*) and from conference presentations on demonstration projects conducted in other areas of the country using in-service warranty contracts, specifically in Wisconsin (*Shober, et.al. 1996*) and Indiana (*InDOT, 1995b*). Highway construction conditions may be different in Montana compared to these locations. Notably, the market for highway construction services is limited in Montana due to the low population, large geographic size, and rural character of the state. From the results of a survey conducted by the Asphalt Institute, for example, it can be inferred (with respect to a gross order of magnitude) that Montana constructed approximately one-half of the volume of asphalt paving done in Wisconsin in 1996. Thus, it was believed that contractors operating in Montana's construction environment might have new insights to offer regarding the use of in-service warranty contracts in such markets.

The mechanism selected for collecting contractor input on in-service warranties was a mail survey sent out to all the members of the Highway and Heavy Construction divisions of MCA. The results of this survey, presented at the 1998 Annual Meeting of the Transportation Research Board (*Stephens, et.al., 1998*), are summarized below.

4.3.2 Survey Description - The survey was designed to obtain information about contractors':

- experience and present knowledge on in-service warranty work in road construction,
- opinions on the types of specifications they feel are appropriate for road construction,

- ideas on the types of work for which warranty contracts may be appropriate,
- suggestions on the types of roads appropriate for demonstration projects,
- thoughts on the payment terms to be used in warranty contracts,
- ideas on specific attributes to be used in measuring in-service performance,
- willingness to consider bidding on warranty jobs and ideas on the bidding process, and
- opinions on the effect of warranty contracts on quality and contractor/owner relations.

After reviewing the available literature, making a presentation to the highway committee of MCA, and discussing the situation with MDT, these issues emerged as of major interest to either the contractors (MCA) or the contracting agency (MDT).

The survey, reproduced in Appendix B, consisted of 12 questions with either "Yes/No" or "multiple choice" answers. For most of the questions, respondents were given the opportunity to reply "Other" and were also provided space for additional comments. Space for "Other Comments" was provided at the end of the question section. The questions were prefaced by a "Background" section requesting information on the respondent's participation in highway construction. Information was requested about whether highway construction was a major activity engaged in by the company, the estimated dollar volume of highway work engaged in each year, and the number of years that the company has been involved with highway construction. Respondents were also given the opportunity to identify themselves, if they wished to be contacted for more detailed discussion of warranty contracts. Such respondents were guaranteed confidentiality for their survey answers.

To insure that the respondents understood the fundamental issue addressed by the survey, an explanation of in-service warranty contracts was given in the cover letter sent with the survey, and terminology and definitions were provided for the types of specifications currently used in highway construction contracts (similar to the definitions presented in Section 2.3.2 of this report).

4.3.3 Survey Response and Analysis Procedure - Twenty-nine surveys were returned out of the 99 surveys sent out. Complete survey results are available from Stephens, et.al. (*1996*). The backgrounds of the respondents are given in Table 4.1. Surveys were sent out to all members of MCA, as identified in a mailing list provided to MSU by MCA. Note that of the 99 companies that received surveys, 75 were listed in the directory of MCA contractors as engaging in highway construction activities, and 33 of these companies were further listed as "heavy" contractors (*MCA, 1996*).

Table 4.1 Summary of Respondents, Contractor Survey

Characteristic of Respondent	Number of Respondents	Percent of Total Respondents
Returned survey	29	100
Indicated highway construction was a major area of work	22	76
Indicated an annual dollar volume of work of:		
- less than 0.5 million dollars	6	21
- 0.5 to 2 million dollars	3	10
- 2 to 5 million dollars	6	21
- more than 5 million dollars	14	48
Listed experience in highway construction as:		
- less than 5 years	1	3
- 5 to 15 years	9	31
- more than 15 years	18	62

With regard to evaluating the survey response, the decision was made to divide the respondents into two broad categories based on their apparent level of involvement in highway construction. Respondents that indicated highway construction was a major area of work for their company and/or respondents that indicated their company engaged in more than 0.5 million dollars per year of highway work were placed in one category and were considered to be

highway contractors. A total of 23 respondents fell into this category (22 of whom indicated that they both did 0.5 million dollars per year in highway work and that highway construction was a major area in which their company worked). The second category of respondents consisted of those individuals that indicated highway construction was not a major area in which their company worked and that estimated the dollar volume of highway work engaged in by their company was less than 0.5 million dollars per year. These respondents, six in number, were considered to be non-highway contractors.

Analysis of the survey response focused on the 23 surveys received from highway contractors. The responses from these surveys were viewed both collectively and for two sub-groupings, namely, small dollar volume contractors (0.5 to 5 million dollars of highway work annually, 9 in number) and large dollar volume contractors (greater than 5 million dollars of highway work annually, 14 in number). Survey responses from non-highway contractors were thought to possibly offer a slightly different perspective on the warranty issue as compared to those from highway contractors. Therefore, these results were reviewed separately (not presented herein).

Problems were encountered in analyzing the results of questions that offered the respondents the opportunity to rank their responses. Many respondents selected a single choice or ranked only their top one or two choices out of the four or five choices offered. In light of this situation, the results presented for this type of question consider only the first choice indicated by each respondent.

The "Other" category, which is included in the tabulated results for several questions, incorporates answers (including missing answers) outside of the offered choices for each question. Respondents that left “yes” or “no” questions unanswered were considered to be uncertain of their opinions on these questions (as opposed to necessarily having no opinion on these questions).

4.3.4 Summary of the Results of the Survey Questions - Presented on the following pages are summaries of the responses received on each survey question from the 23 respondents engaged annually in more than 0.5 million dollars of highway construction work. From the general tone

of the remarks made in the "Comments" section of each question, and in the "Other Comments" section at the end of the survey, the respondents treated the survey seriously, filled them out independently, and spent some time formulating their responses. A summary of the results for each question (from 23 respondents) is presented in Table 4.2. Unless otherwise noted in the discussion below, the responses for small and large dollar volume contractors were similar in nature.

4.3.4.1 Existing Knowledge of Warranty Contracts - While the highway construction community in Montana has little experience with warranty contracts for road construction (only 17 percent indicated any substantial direct experience with these contracts), a majority of the community (70 percent) is generally aware of the concept.

4.3.4.2 Type of Specifications Appropriate for Roadway Construction - Material property based specifications were selected by the most respondents (39 percent) as appropriate for roadway construction work. Note that a few respondents (13 percent) strongly felt that a combination of methods and material property based specifications was the best option for highway construction projects. When the responses for material property based specifications are collectively considered with the combined material property based/methods based responses, 52 percent of the respondents endorsed at least in part the use of material property based specifications. The responses to this question differed significantly between large and small dollar volume contractors. Small dollar volume contractors predominantly favored methods based contracts (44 percent), while large dollar volume contractors predominantly favored material property based contracts (43 percent, 64 percent when materials/methods based responses are considered collectively with the combined responses of methods and material property based specifications). Only 13 percent of all of the responses indicated that warranty specifications were the most appropriate type of specification for highway projects.

Table 4.2 - Summary of Results, Contractor Survey

Information Solicited	Choices of Responses Provided in the Survey, and Percent of Respondents (out of 23) that Selected Each Response					
Past experience with warranty contracts in highway construction	Extensive	Some	Little	None		
	0	17	22	61		
Aware of the concept of using warranties on in-service performance for roadway construction projects	Yes		No		No Answer	
	70		30		0	
Appropriate type of specifications for roadway construction work	Methods	Material	Both	Warranty	Other	
	17	39	13	13	8	
Type of construction activities appropriate for in-service warranty contracts (first choice)	Crack seal	Chip seal	Overlay	Reconstruct	Other	
	9	9	0	39	43	
Type of roadway appropriate for a demonstrating warranty project	Interstate	Primary	Secondary	Local	Other	
	35	9	22	17	17	
Payment terms	100% at completion		90% at completion		Other	
	78		9		13	
Bonus payments for extraordinary performance	Yes		No Answer		No Answer	
	74		13		13	
Measures appropriate to evaluate in-service performance	Cracking	Rutting	Rough/ride	Skid Resist	Appear	Other
	21	25	26	7	11	10
Would consider bidding on a demonstration project that used a warranty contract	Yes		No		No Answer	
	61		22		17	
Pre-qualification is an appropriate bidding procedure for warranty projects	Yes		No		No Answer	
	65		26		9	
Award warranty project to lowest bidder with an approved program of work	Yes		No		No Answer	
	61		26		13	
Use of in-service warranties will have a positive effect on the quality of the job done	Yes		No		No Answer	
	48		43		9	
Use of warranty contracts will result in improved relationships between MDT and the contractor	Yes		No		No Answer	
	30		57		13	

Contractor comments on this survey question were a) that a combination of methods and material property based specifications is the best approach for highway projects (this comment was made by several respondents), and b) that the present type of contract specifications is adequate (typically a mixture of methods and material property based specifications) for roadway construction projects, if MDT would simply enforce them.

4.3.4.3 Type of Construction Activity Appropriate for In-service Warranty Specifications - Of the construction activity choices listed in the survey (see Table 4.2), total reconstruction was selected by 39 percent of the respondents as the most appropriate type of project for use with warranty contracts. The comment was made that for anything less than total reconstruction, too many variables are beyond the contractor's control to reasonably evaluate the contractor's performance based on subsequent in-service performance. Support for total reconstruction was strongest among large dollar volume contractors (50 percent of whom selected total reconstruction as their first choice for type of demonstration project). No clear choice for type of construction was evident in the responses from small dollar volume contractors. Total reconstruction did receive the most support of any construction type from small dollar volume contractors, although only 22 percent of this group of respondents favored this type of construction.

Forty-three percent of the respondents passed over the list of activities provided in the question statement (all paving/roadway related) and provided their own answer to this question. Thirty-three percent of the respondents stated that none of the listed activities were appropriate for warranty work. The other 10 percent of the respondents suggested construction projects secondary to providing a running surface for vehicles (striping, seeding, structures, etc.), implying that road surface related activities are less desirable for in-service warranty contracts.

None of the respondents selected overlays as the most appropriate type of project for an in-service warranty. Crack sealing and chip sealing projects were each selected by 9 percent of the respondents as most appropriate for warranty contracts.

4.3.4.4 Type of Roadway Appropriate for Demonstration Projects - The first choice for the type of roadway (interstate, primary, secondary, local) upon which to demonstrate warranty projects was widely split between the types offered. The dominant choice was an interstate route (selected by 35 percent of all respondents); the least favored system was a primary route (selected by only 9 percent of the respondents). While small dollar volume contractors clearly favored using an interstate route (44 percent) and felt that a local route was inappropriate (0 percent), first choices for the large dollar volume contractors were evenly split between these same two systems (both at 29 percent).

These results offer no clear choice of system for demonstration projects. One respondent indicated that the most appropriate roadway for a demonstration project was "any project where no federal dollars were involved". One problem cited with using local roads was that such roads frequently were poorly constructed initially. Thus, unless such a road was fully reconstructed, it would be impossible to agree on the source and responsibility for any surfacing problems that might develop after a project was complete. A final comment was made that the ability to control high axle loads should be a criteria in project selection.

4.3.4.5 Payment Terms of the Contract - The majority of the respondents (78 percent) indicated a preference for 100% payment upon completion of construction with a surety bond for the warranty period. The responses were very similar from both small and large dollar volume contractors. A majority of the respondents (74 percent) indicated that warranty contracts should include bonus payments for extraordinary performance of the roadway during the warranty period. Support for bonus payments was greater for small dollar volume contractors (89 percent) than for large dollar volume contractors (64 percent). A concern mentioned with bonus payments was the manner in which extraordinary performance would be defined and measured.

4.3.4.6 Measures of Roadway Performance Used to Evaluate Warranty Contract Compliance - Of the parameters listed in the survey question (see Table 4.2), cracking, rut depth, and roughness/ride received approximately equal support (20 to 25 percent range) as performance parameters to be used with warranty contracts for roadway construction. These

parameters clearly received more support than the other parameters included in the survey, namely skid resistance and appearance (5 to 10 percent range). Responses were similar for small and large dollar volume contractors. Note that on this question, respondents were asked to indicate all of the performance measures they believed to be appropriate for in-service warranty contracts. The indicated breakdown of the responses is simply the number of times a particular parameter was selected divided by the total number of selections made.

With regard to the parameters used to evaluate in-service performance, concerns were expressed that in using any of the listed parameters, the contractor would be held responsible for factors beyond the contractors control. Such factors might include: weather, properties of the asphalt available from local refineries, properties of the aggregate available from local pits, preexisting roadway conditions, use of tire chains, style of snowplowing, level of maintenance, etc.

4.3.4.7 Interest in Bidding on a Demonstration Project that Uses a Warranty Contract - A majority of the respondents (61 percent) indicated that they would be willing to consider bidding on demonstration projects that use warranty contracts. A slightly greater percentage of small dollar volume contractors responded affirmatively to this question (66 percent) than large dollar volume contractors (57 percent). Twenty-two percent of the respondents indicated that they would not bid on this type of project.

Many of the respondents qualified their response to this question with comments related to resolving the uncertainties associated with the bidding process, the measures of performance to be used in evaluating contract compliance, etc. The majority of the respondents that did not provide a "yes" or "no" answer to this question indicated that there were too many unresolved issues regarding these contracts to offer a definitive answer to this question. One comment was that traffic loads cannot be sufficiently controlled to accept the consequences of the warranty. Taken in context, this comment appeared to address the magnitude of the applied loads (i.e., overweight vehicles) rather than simply the volume of traffic. One respondent that replied affirmatively to the question stipulated that this response was contingent upon the company's bonding agent approving and supporting the process.

4.3.4.8 Bid Process and Award of Contract - The majority of the respondents (65 percent) answered affirmatively to pre-qualifying contractors for bidding on warranty contracts. This sentiment was shared, to a large extent, by both small and large dollar volume contractors. Concerns were mentioned regarding the criteria to be used in the pre-qualification process and the entity that would evaluate contractor's compliance with these criteria. The comment was made that bonding requirements might serve as a pre-qualification tool, and that small contractors and new contractors might have difficulty obtaining bonding for these projects.

Most of the respondents (61 percent) indicated that warranty contracts could be awarded to the contractor with the lowest bid from a pool of contractors with approved programs of work. Support for this approach was stronger from the small dollar volume contractors (78 percent) than from the large dollar volume contractors (50 percent). The observation was made that the concept of an "approved" program of work was inconsistent with a pure in-service warranty approach, in that in the approval process, judgements would be made on the design and construction methodologies to be used, rather than simply on the performance of the finished product. One respondent recommended simply awarding the project to the lowest bidder, as under an in-service warranty contract, the contractor assumes all the risk. The idea of allowing the bidder to specify the terms of the warranty was also mentioned. Contract award would be based on a cost-to-benefit analysis of the specific warranty offered in the contractor's proposal.

4.3.4.9 Expected Effect of Warranty Contracts on the Quality of the Job Done - Opinion was almost evenly split on whether the use of warranty contracts would have a positive effect on the quality of the job done. Forty-eight percent of the respondents were of the opinion that the quality of the product would improve if warranty contracts were used. While 43 percent of the respondents stated the opposite opinion that warranty contracts will not improve the quality of the job done. Of all the questions asked, this question produced one of the greatest differences in response between small and large dollar volume contractors. The small dollar volume contractors were optimistic about warranty contracts improving quality, with 67 percent of the respondents indicating that improvements in quality should be expected. Conversely, only 36

percent of the large dollar volume contractors believed warranty contracts would improve the quality of the job done.

Comments were made that any improvement in the quality of the constructed project will occur over the long term, as unqualified contractors are eliminated from the field. One respondent stated that unless new and cost-effective materials are developed, product quality will be the same using warranty contracts as is produced under the present contract system. A few respondents indicated that competition will be reduced, and initial costs will significantly increase, if contracts based on in-service warranties are used.

4.3.4.10 Effect of Warranty Contracts on the Relationship Between MDT and Contractors - The majority of the respondents (56 percent) believe that warranty contracts will not improve the relationship between MDT and the contractors. The response of small and large dollar volume contractors differed considerably on this question. The majority of the small dollar volume contractors (56 percent) believe that the relationship between MDT and contractors will improve with the use of warranty contracts. Conversely, the majority of the large dollar volume contractors (64 percent) are of the opinion that the use of warranty contracts will not improve the relationship between MDT and contractors.

Several contractors observed that disagreements will always arise between the contracting agency and the contractor. Use of warranty contracts may simply change when this conflict occurs from during construction to the post-construction warranty period. Other concerns mentioned on this issue included that use of these contracts will open a whole new area of conflict between MDT and the contractors, and that more opportunities for conflict will occur on these projects due to their increased costs. The increase in initial costs for these projects was also seen as an issue that might upset the public.

4.3.5 Summary of Respondents' General Comments - Recognizing that the survey questions might not fully address all the opinions and ideas that contractors had on the topic of using in-service warranty contracts for roadway construction projects, the opportunity was provided for respondents to make additional comments. Ten respondents (7 large dollar volume contractors

and 3 small dollar volume contractors) offered additional comments at this time. Concerns were repeatedly voiced in these comments on the ability of small to medium sized construction companies (often family owned) to survive in a warranty based market. A major concern was that the bonding capacity of these companies would be rapidly used up as the number of projects they completed with overlapping warranties accumulated over successive construction seasons. The dollar volume of work engaged in by many of these firms significantly exceeds the net realizable value of their worth.

Concern was also expressed that small to medium size contractors in this state have little in-house design and material testing capability or experience, as these functions have traditionally been performed by the state. These contractors may over design warranty based projects (and thus drive up their bid costs) to compensate for their lack of familiarity with design and material testing activities.

One respondent, familiar with the warranty contract process used in European countries for roadway construction, indicated that most roadway construction companies in Europe were large, that all projects were bid by invitation, and that performance bonds were not required. These conditions contrast sharply with those in Montana.

The benefits of using warranty contracts on projects compared to the present type of contracts was also questioned by several of the respondents in their general comments. They indicated that the present problems with in-service performance of highways may not be completely solved simply by using warranty contracts. In many instances, contractors and state agencies are already working together to build the best roads possible within current budgetary constraints. If this is the case, why is any different performance expected from the same project built using a warranty contract? Use of warranty contracts will simply shift the risk of poor in-service performance of these projects from the state to the contractor, who in turn will increase their prices in response to assuming the risks. Improved roadway performance will only result from the development of inexpensive, long lasting roadway materials.

Some respondents were also concerned that MDT in-house costs may remain unchanged by the adoption of in-service warranty contracts. While one potential benefit of the use of warranty contracts is reduced involvement of MDT in the construction process (contract

compliance is not evaluated during construction), MDT will be involved in a variety of new activities during the warranty period.

4.3.6 Discussion of Survey Results - All of the questions raised by the contractors regarding how in-service warranties can be implemented on roadway construction projects and what (if any) benefits will be realized using this contracting approach are valid. Further, note that the contractor's questions are very similar to the concerns of MDT and the surety companies. In general, definitive answers to these various questions are not available. The absence of such information was, in part, the impetus for this study. This study thus far has revealed that specific and well developed methodologies are available to address some of the contractors' concerns regarding in-service warranties. Issues ranging from the bid proposal evaluation process to the choice of in-service warranty parameters have been dealt with in different ways by various states that are in the process of investigating in-service warranties (see Section 3.3). While most of these methodologies are still unproven (insufficient time has passed since the associated demonstration projects began to fully validate their performance), they can never-the-less be evaluated based on their potential for success in Montana, and included in any demonstration projects let by Montana, as appropriate.

Definitive answers to some of the questions with in-service warranty projects, such as the effect of in-service warranties on a) the quality of the job done and b) the relationship between MDT and the contracting community, can only be found by conducting demonstration projects. Contractor opinion on these issues is presently split between opposite viewpoints, with compelling arguments made on both sides of each issue.

Many of the features preferred by contractors for in-service warranty projects, as identified in this survey, were used in the warranty projects constructed in California, Wisconsin, and Indiana by their respective state departments of transportation. In each case, the basic warranty contract instrument, and the projects it was used on, represent a compromise between the ideal provisions for a warranty job (in which the contractor is allowed total construction freedom, with contract compliance based simply on in-service performance), used on the ideal

type of project (total reconstruction), and a contract that can be practically executed in the existing construction and administrative environment.

4.3.7 Summary and Conclusions from Survey of Montana Contractors - Based on the results of this survey, the Montana contracting community is open to investigating the use of in-service warranty contracts on roadway construction projects, although contracts that use traditional methods and material property based specifications are believed to be more appropriate for these types of projects. The contractors believe that the potential benefits of using in-service warranty contracts compared to the present type of contract are uncertain. The contractors expect that initial project costs will significantly increase for projects with in-service warranties, in response to the shift in responsibility for a failed project from the state to the contractor. They believe that this increase in initial cost may occur without substantial improvements in the quality of the constructed project or reductions in overall state operating costs. Further concerns were expressed with respect to the ability of small and medium sized companies to survive in a warranty market, due, in part, to their financial/bonding situation. (Note that the objective of this study is to investigate many of these concerns.)

Despite the above stated concerns, the majority of the contractors indicated they would consider bidding on demonstration projects that used in-service warranty contracts. The contractors indicated that the most favorable type of job for such projects was total reconstruction. Measures of in-service performance selected for evaluating contract compliance were cracking, rutting, and ride. With regard to contract terms, the contractors believed 100 percent payment at the completion of construction with some form of bond during the warranty period was appropriate. They supported pre-qualifying bidders and awarding the contract to the lowest bidder with an approved program of work.

4.4 MONTANA BONDING COMPANIES

A representative of a major construction bonding company in the state of Montana, USF&G, was contacted regarding the use of in-service warranties on highway construction projects (*Sears, 1996*). This agent expressed concern with the long term nature of the bond

commitment on warranty projects. Surety companies already are uncomfortable with bonding even prolonged construction projects, without the specter of long term, in-service warranties. The problem faced by the surety is estimating the financial condition of the contractor several years in the future. Construction companies apparently have the second highest rate of bankruptcy of any type of business. The surety agent indicated that contractors may be able to find bonding for these projects, but the bond companies, themselves, may go bankrupt in the long term.

The bonding agent indicated that retaining some of the contractors' fees provides them more incentive to do a good job than simply paying for bond coverage. The agent indicated that contractors will probably increase their fees on in-service warranty projects to offset any retained funds (depending on the duration of the retention). The agent recommended consideration of both bonds and retention of part of the fee on in-service warranty roadway construction projects.

Concern was also voiced by the agent regarding the ability of small contractors to compete on in-service warranty projects. This concern may be related to the problem of small contractors using up their bonding capacity as they accumulate active, in-service warranty projects across several construction seasons.

Additional and more substantial contact needs to be made with the bonding companies in the state of Montana regarding their ideas on, and participation in, demonstration in-service warranty projects. One avenue for making and maintaining such contact is to invite a member(s) of this industry to join the technical panel for this study.

5. FUTURE DEMONSTRATION PROJECT ACTIVITIES

5.1 RECOMMENDATIONS FOR THE IMPLEMENTATION OF MONTANA DEMONSTRATION PROJECTS

5.1.1 General Remarks - Presented below are specific recommendations on the types of roadway construction projects MDT should consider for demonstration, in-service warranty projects and features that should be included in the associated contracts. These recommendations were developed with due consideration of:

1) the philosophical objectives of using in-service warranties on roadway construction projects,

2) current practices regarding in-service warranties on roadway construction projects, particularly those developed and being tried by other state DOTs, and

3) the concerns and interests of MDT, the Montana construction community, and Montana bonding agents.

These recommendations should be reviewed by the technical panel for this project. Consideration should also be given toward expanding membership on this panel to more actively and formally include representative(s) of the Montana highway construction community (possibly nominated by MCA) and of the Montana construction bonding industry. This committee should work toward a consensus contract document to be used on demonstration in-service warranty projects.

Throughout discussions of any demonstration projects, it is important to remember that in-service warranty contracts represent a radical departure from current practice in Montana for roadway construction projects. In addition to their unfamiliarity with the in-service warranty aspects of these projects, contractors in Montana will also be involved for the first time with the design and quality control aspects of a project. The type of projects recommended below for demonstration purposes were selected with due consideration of this situation. Both MDT and the bonding companies will need to be convinced of the contractors' ability (possibly enhanced through partnerships with consulting engineering firms in the state) to engage in both design and

quality control activities. The bid review process recommended below was formulated to insure that contractors interested in such projects investigate these activities, and that MDT has the opportunity to evaluate the contractors design process and quality control plan.

5.1.2 Type of Project - Any demonstration projects should involve total reconstruction of the roadway. In anything less than a total reconstruction project, it may be difficult to determine if the contractor is responsible for any excessive distress that might appear during the warranty period, or if such distress is the result of pre-existing conditions beyond the contractor's control. Total reconstruction projects admittedly are more complex and expensive than other types of roadway construction projects; they are, however, more appropriate for a warranty approach.

Early demonstration projects should be at locations that have good in situ subgrade materials and high quality, locally available aggregates (for use in the base and running surface). The roadways should carry a volume of traffic and mixture of vehicle types representative of average conditions across the state system. (Note that some mechanism should be available to closely monitor the traffic using the roadway, as such measurements may be critical in establishing the period the warranty is in effect.) No constraints should be placed upon the designs proposed by bidders. Traditional (and familiar) design techniques should yield successful pavements under these conditions. Under these circumstances, similar design solutions would be expected from various bidders, which should simplify bid evaluation and contract award.

The above type of project has a high probability of being successful (that is, the project will provide satisfactory service throughout the warranty period). It is important to recognize, however, that this type of project may not fully demonstrate the benefits and problems that could be encountered on warranty projects. Over the long term, in-service warranties may offer the greatest benefit on projects with unusual circumstances, in which innovative designs and extraordinary workmanship are essential to acceptable long term performance. Note that at least one of California's early warranty projects apparently was at a problem location, in that the roadway being repaired had failed after only 4 years of service. All of the other states that have experimented with warranties appear to have selected "routine" projects that have a high

likelihood of success. If early demonstration project are successful, and as the parties involved become more comfortable with the warranty approach, consideration should be given to using warranties on unusual projects.

Each demonstration project should be split into two parts. One part of the project should be constructed using a traditional contracting process; the second part, using a warranty approach. Ideally, the sections will be of similar lengths, have similar geometric features, and they will be founded on the same subgrade material. Design of the section of roadway to be constructed using a traditional contracting process will be accomplished by MDT. This design should be made available to contractors bidding on the in-service warrantied portion of the roadway. The contractors should be clearly informed that this design is being made available for informational purposes only and that they are required to obtain an independent design as part of the contract requirements. The eligibility of the projects for FHWA's SEP 14 program should be carefully considered.

5.1.3 Warranty Specifications - Aspects of the roadway performance to be monitored during the warranty period should be the IRI, rut depth, skid resistance, surface raveling, and cracking. These aspects of in-service performance adequately describe the quality and safety of the ride provided by the roadway and reflect its expected longevity. The acceptable level of performance for each of these parameters at the end of the warranty period needs to be determined by MDT personnel. Historical distress data should be available from MDT to establish acceptable and achievable levels of these parameters. If data are not available for these parameters, alternate parameters of a similar nature should be selected for which historical data are available. WisDOT and INDOT set their levels of acceptable performance such that approximately 90 percent of the historical projects they studied would have met the requirements of the warranty. A more appropriate approach to this problem may be to establish the desired level of performance at the end of the warranty period, and to then observe the historical probability of achieving this level of performance. The contractor should also be expected to warranty the roadway against severe localized distress, such as potholes.

The warranty should expire at the end of a preset period of time or when a preset volume of traffic has traveled over the road. While most states have used a 5-year warranty period, such a period may be too short for conditions in Montana. The database of historical pavement performance should be searched to see if any accelerated periods of pavement deterioration occur in poorly performing projects at later ages. If such periods are noted, the warranty period should be extended to cover such periods. Problems of this kind can occur, for example, if a harsh mix used to reduce rutting during the early life of a pavement becomes brittle after a few years and cracks extensively. The warranty should expire if the volume of traffic (either AADT or ESALs) exceeds the volume of traffic predicted at the time of design by 50 percent.

Warranty inspections should be made by the state in the spring of each year (beginning at the completion of construction). Inspections should be made at both regular and randomly spaced intervals along the length of the project. Following the approach used by other states, every mile of a project should be sampled a) at a specific, repeated location and b) at a randomly selected location along its length. If these inspections reveal unsatisfactory performance with respect to warrantied behaviors, the contractor should be expected to repair the roadway in the same year. The contractor should also be expected to immediately repair certain types of local distress, such as potholes, and any unsafe situations (e.g., dramatic loss of skid resistance). The contract should specify the minimal remedial actions associated with each distress, with the expectation that a contractor would prepare a plan appropriate for each situation encountered. The required default repair should be the removal of the surface and replacement with a minimum of a 9.1 cm (0.3 ft) thick overlay. A conflict resolution team should be established to mediate disputes between the contractor and the state regarding such things as warranty compliance and required warranty repairs. This team should consist of five members, with two members from the contractor, two members from the state, and one independent member mutually selected by the contractor and the state.

5.1.4 Bonding Requirements - Demonstration projects should include a traditional performance bond on the initial construction phase of the project to insure the roadway is built as proposed by the successful bidder. A second bond should be required once the roadway is placed in service,

to insure that any work required during the warranty period will be completed by the contractor. The amount of this bond should be based on the worst reasonable repair scenario that may confront the contractor, which generally would be considered to be a thin overlay for the entire project. The minimum recommended overlay on Montana roadways, independent of traffic volume, is 9.1 cm (0.3 ft) thick. In general, repaired areas would expect to be covered under the same conditions as the original pavement until the end of the original warranty period.

For warranty periods in excess of 5 years, consideration should be given to reducing the contractor's liability in the event that the warranty provisions of the contract are not met each year. This idea is consistent with the common practice of reducing the value of warranties over time on products that are "consumed" by their use. Germany uses this approach on their roadway construction projects, in which responsibility for repairs made after the first year of service are negotiated based on the value such repairs offer to the roadway user.

In any event, the proposed bonding requirements should be directly discussed with representatives of the surety industry in Montana to insure that these requirements are practical, and that the bonding companies will be willing to participate in these projects.

5.1.5 Bid Evaluation and Award - The bids submitted on any given job could cover a wide range of design solutions if prescriptive design requirements are kept to a minimum in the contract documents. Comparing bids may be a difficult task under these circumstances. One process that is sufficiently robust to handle this situation is to identify the best bid using the cost per unit of technical quality offered in the proposal rather than simply using lump sum cost. Contractors should be required to submit a technical proposal with their bid that outlines their design, indicates the manner in which the warrantied performance will be achieved, and describes the quality control program they will use during construction. Sufficient detail should be presented to allow for technical review and scoring of these activities by an MDT bid evaluation team. The bid evaluation methodologies used by Michigan and New Mexico should be reviewed and used, as appropriate, in developing a methodology for Montana. The criteria upon which the technical proposals will be evaluated (and any format requirements for these proposals) should be provided to all potential bidders. A minimum technical score should be

established below which a bid will be considered technically non-responsive to the project requirements.

While the contractors indicated that pre-qualification of bidders was desirable, such pre-qualification should not be required. Unqualified bidders will be eliminated from consideration by the bond requirements and/or during the technical review of the proposals by MDT. Letters of intent to bid on the project should be required so that MDT is aware of the level of possible participation on a given project.

5.2 SEQUENCE OF ACTIVITIES

The following sequence of activities is anticipated for early demonstration projects (adapted from Clark, 1996):

1)	Informational Meeting:	Hand out informational package Presentation on new contracting procedure Respond to questions
2)	Pre-Bid Meeting:	Respond to questions Tour of existing roadways representative of expectations
3)	Receive Letters of Interest:	Provide formal bid package to interested contractors
4)	Receive Proposals:	
5)	Evaluate Proposals:	Proposals scored by evaluation team
6)	Award Project:	Award based on lowest cost per unit of quality offered
7)	Construction:	MDT functions as observer
8)	Warranty Period:	MDT conducts annual inspection to determine compliance with warranty requirements, coordinates repairs with contractor as necessary

9) Cost-to-Benefit Analysis: A cost-to-benefit analysis is performed of the in-service warranty versus the traditional approach to roadway construction projects

One demonstration project should be followed through to at least the completion of construction before a second project is started.

A significant, pro-active educational effort may be necessary during early demonstration projects to insure an adequate number of qualified bids are submitted. The intent of this effort would be to insure that no contractor refrained from bidding on such a project due to insufficient or incorrect information about the project. At least two pre-bid conferences should be held. A basic informational package would be handed out at the first meeting. A presentation would be made at the meeting on the overall concept of in-service warranties, the specific details of the demonstration project and the associated contract specifications, and the sequence of project activities from the pre-bid conference to end of the warranty period. This presentation would include a review of current practice with such contracts in other states, and, if possible, contacts from these projects. A second meeting would be held approximately one month later to entertain contractor questions concerning the project. This meeting would include a tour of existing roadways that illustrate those pavement behaviors covered by the in-service warranty provisions of the demonstration project. Contractors interested in bidding on the project would be formally identified after these meetings and provided with a formal bid package. The remaining project activities would then proceed as outlined above.

6. SUMMARY AND CONCLUSIONS

The objective of this investigation is to determine the cost effectiveness of using warranties on in-service performance on roadway construction projects in Montana. Work on the project has been divided into two phases. Phase I consists of identifying the issues that must be addressed in implementing in-service warranties, reviewing current practice with this type of contract in other countries and across the United States, determining current perceptions in Montana regarding this type of contract, and, finally, formulating recommendations for demonstration warranty projects for Montana. Phase II of the project consists of finalizing a contract instrument to be used on the demonstration projects, monitoring the performance of the projects subsequently constructed using this instrument, and based on these observations, performing a cost-to-benefit analysis for the use of in-service warranties.

Phase I of this investigation has been completed (with the results presented herein), and decisions now need to be made regarding the future direction of this project. The first decision that has to be made is whether to proceed with Phase II of the investigation at this time. If the choice is made to go forward, further decisions need to be made regarding the specific provisions and administrative procedures to be used for the demonstration warranty projects. The information and recommendations presented in this report should facilitate this process.

The decision on whether to move forward with this investigation should be made based on an assessment of the potential net benefits to be realized by using in-service warranties on roadway construction projects. Philosophically, this approach to roadway construction projects is expected to improve quality and reduce costs because a) the contractor is directly motivated to provide a facility that offers a safe and smooth ride once it is in-service, b) market forces will force the contractor to focus on activities that directly contribute to a smooth and safe ride, and c) the contractor will have the opportunity to explore new and innovative design solutions and construction procedures. Recall that under an ideal in-service warranty approach, contract requirements are simply expressed in terms of the performance to be provided by the roadway once it is placed into service. The nature of the facility required to provide this service and the manner in which it is constructed are completely at the contractor's discretion. This approach to

roadway construction projects contrasts sharply with current practice. The intent of current contract specifications is simply to insure that at the time of its completion, the roadway has been physically constructed according to MDT's design.

The information collected in Phase I of this project is inconclusive with regard to whether the use of contracts with in-service warranty specifications will result in better quality roads than are currently being constructed at lower costs than are presently being incurred. Such contracts are commonly used in European countries, reportedly with excellent success. The social, economic, and political conditions in Europe, however, are different from those in the United States. European governments appear to work collaboratively with contractors in the pursuit of high quality roads, and they seem to be willing, in general, to pay extra initial costs in the interest of improved, long term roadway performance. Whether the European warranty model will work in the United States, where government agencies and contractors tend to function as separate entities and lowest cost is traditionally the primary criteria for bid award, is uncertain. Use of in-service warranties on roadway construction projects has been less aggressively pursued in the United States compared to Europe. Contemporary demonstration projects were first let in 1991 in the United States, with a significant increase in the number of demonstration projects begun after 1994. Thus, the majority of these projects have only been in place for two to three years, and meaningful conclusions regarding their net benefit or liability cannot be drawn.

In Montana, the opinion of the contracting community is almost evenly split regarding the potential improvement in the quality of roadway projects if in-service warranty contracts are used. Small firms are more optimistic than large firms regarding possible improvements in quality. Opinion on the costs of these projects is more unanimous, with both small and large firms stating that these projects will be more expensive than traditional projects. The construction industry is thus concerned that if in-service warranty contracts are used on roadway construction projects, costs will increase without improvements in quality. A 5 to 10 percent increase in project costs was estimated for the demonstration warranty projects in Wisconsin, and thus a commensurate improvement in quality/performance will be necessary for the warranty approach to be cost effective. The comment was also made by a Montana contractor that many contractors are already doing a good job using the available materials and construction methods.

In this situation, why will in-service warranties result in any better product than they are presently providing? An additional business related concern, shared by MDT, the contracting community, and the bonding companies in the state, is the ability of small and medium sized contractors to obtain bonding and compete in an in-service warranty environment.

Despite the several concerns mentioned above, this project should move forward. Almost all of the information presented above, with respect to both the potential benefits and problems with using in-service warranties on roadway construction projects, is subjective in nature rather than based on demonstrable fact, and only moderate consensus of opinion is observed on many of the issues discussed. The specific intention of Phase II of this project is to gather the information necessary to make a decision regarding the usefulness of in-service warranties based on fact rather than supposition. Phase II of the project cannot move forward, however, without the cooperation of the construction and bonding industries in Montana. Based on a survey of the construction industry in the state, many contractors are willing to consider bidding on demonstration contracts with in-service warranty provisions. Thus far, only limited contact has been made with the bonding companies in the state. Additional input needs to be solicited from the bonding companies regarding in-service warranties, and these companies need to be integrated into the project planning process.

In moving forward with in-service warranties, it is important to recognize that the roles played by the contractor and the state are dramatically different using this contracting approach compared to those using traditional approaches. Design and quality control functions historically performed by the state will now be the responsibility of the contractor. To accomplish this change in job responsibilities without a period of transition may be a challenging task.

Specific recommendations were made at the end of Phase I of this investigation regarding the implementation of demonstration projects for Phase II. These recommendations were made with due consideration of the philosophical objectives of using in-service warranties on roadway construction projects, current practice in Europe and across the United States with this type of project, and the concerns with this approach to highway contracting expressed by MDT, the Montana contracting community, and a bonding company in Montana. The demonstration

projects should be reconstruction jobs on two-lane rural highways that carry moderate traffic. Maximum freedom should be given to the contractors bidding on the project with respect to design and construction, with project award based on an evaluation of the best value offered per unit of technical quality. Performance to be covered by the warranty should include ride, skid resistance, and surface raveling and cracking. The warranty period should be 10 years. The contractor should be required to obtain a maintenance bond for this period in an amount equal to the cost of overlaying the project. MSU will do a cost-to-benefit analysis at the end of the warranty period to determine the value of using in-service warranties on roadway construction projects in Montana.

The type of project described above was selected for demonstration purposes partially because the use of traditional design and construction methods on this type of project are expected to result in successful warranty performance. Under these familiar circumstances, MDT, the Montana contracting community, and Montana bonding companies should be more likely to attempt these projects. In the long term, however, the greatest benefit of using in-service warranties may be realized on projects that require innovative design and construction solutions and/or outstanding workmanship to provide good in-service performance.

7.0 REFERENCES

American Association of State Highway and Transportation Officials, (1995), Standard Specifications for Transportation Materials and Methods of Sampling and Testing, 17th Edition, AASHTO T242-92, "Frictional Properties of Paved Surfaces Using a Full-Scale Tire," American Association of State Highway and Transportation Officials, Washington, D.C.

American Association of State Highway and Transportation Officials, (1991), "1990 European Asphalt Study Tour," American Association of State Highway and Transportation Officials, Washington D.C.

American Society for Testing and Materials, (1997), Volume 4.03, Road and Paving Materials; Vehicle-Pavement Systems, ASTM E 274-90 "Standard Method for Skid Resistance of Paved Surfaces Using a Full-Scale Tire," American Society for Testing and Materials, West Conshohocken, Pennsylvania.

Avera, L., (1996), "Indiana marks a warranty milestone." Asphalt Contractor, November, 1996, pp. 44-45.

Bradbury, A., and Kazmierowski, T. J., (1995), Implementation of Micro-Surfacing Warranty Specifications in Ontario, Ministry of Transportation, Downsview, Ontario.

California Department of Transportation, (1993), Notice to Contractors and Special Provisions for Construction on State Highway, Sacramento, California.

Chamberlin, W. P., (1995), Performance-Related Specifications for Highway Construction and Rehabilitation. National Cooperative Highway Research Program, Synthesis of Highway Practice 212, TRB, National Research Council, Washington, D.C.

Clark, D., (1996), Personal Communication, Montana Department of Transportation, Helena, Montana.

Federal Highway Administration, (1991), Guide Warranty Specifications for Micro-Surfacing, Federal Highway Administration, Washington, D.C.

Federal Highway Administration, (1995), Rebuilding America: Partnership for Investment, Innovative Contracting Practices, Federal Highway Administration, Washington, D.C.

Gillespie, T. D. (1992), "Everything You Always Wanted to Know About the IRI, But Were Afraid to Ask." Road Profile Users Group Meeting, September 1992, Lincoln, Nebraska.

Hancher, D. (1994), "Use of Warranties in Road Construction," National Cooperative Highway Research Program, Synthesis of Highway Practice 195, TRB, National Research Council, Washington, D.C.

Harvey, J., Vallerga, B. A., and Monismith, C. L. (1995), Transportation Research Record 1492, Transportation Research Board, Washington, D.C.

Huang, Y. H. (1993), Pavement Design and Maintenance, Prentice Hall, Englewood Cliffs, New Jersey. pp. 426-435.

Huckabay, T. (1997), Personal Communication, California Department of Transportation, Redding, California.

Indiana Department of Transportation (1995a), "Innovative Contract Procedures: A+B+C Bidding and Performance/Warranty Specifications for Hot Mix Asphalt." Indianapolis, Indiana.

Indiana Department of Transportation (1995b), "Specifications for Warranted Asphalt Pavement." Pavement Warranty Working Group, Indianapolis, Indiana.

Kummer, H. W., and Meyer, W. E., (1967), "Tentative Skid-Resistance Requirements for Main Rural Highways," *National Cooperative Highway Research Program Report No. 37*, National Cooperative Highway Research Council, Washington, D.C.

McDaniel, R. S, (1995), Proposal - "Performance/Warranty Specifications for Hot Mix Asphalt (Special Experiment Project No. 14)." West Lafayette, Indiana.

McMullen, K, (1998), "Development and Implementation of PCC Pavement Warranty Specifications in Wisconsin", 77th Annual Meeting, Transportation Research Board, Washington, D.C., January 1998.

Merwin, D. P. (1990), "Design/Build Public Projects: Has Their Time Come?", Highway & Heavy Construction, October, 1990. pp. 20-21.

Michigan Department of Transportation (1996), Special Provisions Federal Aid Project No. NH 9681 (007), Lansing, Michigan.

Montana Contractors' Association Inc. (1996), Membership Directory. Helena, Montana

Montana Department of Transportation (1995a), Standard Specification for Road and Bridge Construction, Helena, Montana.

Montana Department of Transportation (1995b), Special Provisions Federal Aid Project No. IM 0002 (50), Helena, Montana.

Moulthrop, J. S., and Dunn, B. H. (1996), "Developments with Warranty Specifications for Microsurfacing," 75th Annual Meeting, Transportation Research Board, Washington, D.C., January 1996.

New Mexico State Highway & Transportation Department, (1997), Request for Proposals Corridor 44 Project, New Mexico State Highway & Transportation Department, Albuquerque, New Mexico.

Scherocman, J. A., and Van Deusen, C. H. (1997), "Thinking outside the windrow." Asphalt Contractor, October, 1997. pp. 50-58.

Sears, W. (1996), Personal Communication, USF&G, Helena, Montana.

Shober, S. F., Whited, G. C., and McMullen, K. W. (1995), Wisconsin's Department of Transportation's Asphaltic Pavement Warranties. Wisconsin Department of Transportation, Madison, Wisconsin.

Shober, S. F., Whited, G. C., and McMullen, K. W., (1996) "Wisconsin grabs the warranty rung." Asphalt Contractor, November, 1996. pp. 36-43.

Shober, S. F. (1998), Personal Communication, Wisconsin Department of Transportation, Madison, Wisconsin.

Stephens, J.E., Wangsmo, M., and Schillings, P., (1996) Preliminary Survey Results, Warranty-Based Contracting in Highway Construction. Prepared for the Montana Department of Transportation by the Civil Engineering Department, Montana State University, Bozeman, Montana.

Stephens, J., et.al. (1998), "Survey of the Montana Construction Industry Regarding the Use of In-service Warranties in Roadway Construction Projects", Proceedings, Transportation Research Board Annual Meeting, January, 1998.

Stevenson, J. (1997), Personal Communication, Montana Department of Transportation, Helena Montana.

Strategic Highway Research Program, National Research Council, (1993), "Distress Identification Manual for Long-Term Pavement Performance Studies," SHRP-P-338, Federal Highway Administration, Washington, D.C.

U.S. TECH, (1993), "Report on the 1992 U.S. Tour of European Concrete Highways," Federal Highway Administration, Washington, D.C.

Vallerga, B. A. (1995), "Warrantied Pavement on an Interstate Highway in California," Conference Proceedings 7:Third International Conference on Managing Pavements, Transportation Research Board, Washington, D.C.

Walters, B. (1998), Personal Communication, Koch Materials, Wichita, Kansas.

APPENDIX A

Technical Panel Members

The members of the technical panel for this project are:

Mark Baum, Construction Bureau, MDT
Richard B. Clark, PMS, MDT
Ed Larson, Road Design, MDT
Dwayne Rehbein, Riverside Contracting
Tim Sauer, SHRP, MDT
Mike Sears, FHWA
Kent Sheperd, NDT, MDT
Dan Williams, Maintenance, MDT
Sue Sillick, Research, MDT

APPENDIX B

Survey Questions on In-service Warranties
Montana Contractors' Association

This appendix contains the questions sent to the members of the Montana Contractors' Association in a survey conducted to obtain their opinions on the use of in-service warranties for roadway construction projects.

WARRANTY-BASED CONTRACTING
IN
HIGHWAY CONSTRUCTION
October 1996
Montana State University

Thank you for participating in this survey. While your opinions and ideas are important to us, we also know that your time is valuable. Therefore, this survey was designed to require only a few minutes to complete. The survey consists of a series of statements/questions on warranty contracting along with a range of responses.

- Please place a check in the box opposite the response that **best** represents your own response.
- If no response is appropriate, please check "Other" and provide your own response.
- Space is provided at the end of each statement for additional comment. Extra sheets of paper may also be used.
- Please answer every question.
- Background information is optional. Your name and company will be kept confidential. Please provide this information if you would like to be contacted for more detailed discussion or commentary on these matters.
- Please return the survey (self addressed, stamped envelope enclosed) by Nov. 15, 1996.
- Call Jerry Stephens (406-994-6113) or Paul Schillings (406-994-5939) at MSU if you have any questions

BACKGROUND

Contact Name (Optional)

Organization (Optional)

Telephone Number (Optional)

Would you consider highway construction to be a major area your company does work in?

- ❑ **Yes**
- ❑ **No**

Estimated gross dollar volume of highway work per year

- ❑ **Less than 0.5 million dollars**
- ❑ **0.5 to 2 million dollars**
- ❑ **2 to 5 million dollars**
- ❑ **More than 5 million dollars**

Number of years that company has worked in highway construction

- ❑ **Less than 5 years**
- ❑ **5 to 15 years**
- ❑ **More than 15 years**

SURVEY QUESTIONS

1. **Has your company had experience with highway contracts that include explicit warranty provisions that extend more than one year past completion of construction?**
   - ❑ **Extensive**
   - ❑ **Some**
   - ❑ **Little**
   - ❑ **None**

   Comments

2. **Are you aware of, or have you previously thought about, the idea of contractors issuing long term warranties on roadway construction projects?**
   - ❑ **Yes**
   - ❑ **No**

   Comments

3. **What type of contract do you generally feel is appropriate for roadway construction work?**
   - ❑ **Methods based -** contract specifies exact construction procedure to be used in building the roadway; contract compliance is judged based on following those procedures
   - ❑ **Materials based -** contract specifies materials and material properties to be achieved in building the roadway; contract compliance is judged based on meeting material specifications, independent of construction procedure used
   - ❑ **Warranty based-** contract specifies in-service performance criteria roadway must meet for a given period of time after it is placed in service, independent of the material or construction procedures used
   - ❑ **Other**

   Comments

4. **What type(s) of roadway construction projects do you think warranty contracts may be useful for? (if multiple selections are made, rank numerically, beginning with '1' as best)**
   - ___ **Crack sealing**
   - ___ **Chip sealing**
   - ___ **Thin overlay**
   - ___ **Thick overlay**
   - ___ **Total reconstruction**

   Other Candidates:

5. If a demonstration project using a warranty contract is to be performed, what type of roadway would be most appropriate? (if multiple selections are made, rank numerically, beginning with 1 as best)

___ Interstate
___ Primary
___ Secondary
___ City/County/Local
Other types:

6. In what manner would you implement payment terms in a warranty contract?

- ❑ **100 % upon completion of construction with surety bond for warranty period**
- ❑ **90 % upon completion of construction, remainder during warranty period (no surety bond during warranty period)**
- ❑ **Other**

Comments

7. Should a warranty contract include bonus payments for extraordinary performance of the roadway during the warranty period?

- ❑ **Yes**
- ❑ **No**

Comments

8. What measures of roadway performance do you feel would be acceptable to evaluate contract compliance during the warranty period (for overlay and/or reconstruction)?

- ❑ **Amount of cracking (with due consideration of temperature and load effects)**
- ❑ **Rut depth**
- ❑ **Roughness/ride**
- ❑ **Skid resistance**
- ❑ **Appearance**
- ❑ **Other**

Comments

9. Would you consider bidding on a demonstration project that uses a warranty type contract, if new terms are developed for this type of contract that attempt to address such things as uncertainties in traffic loads during the warranty period and that attempt to establish such things as reasonable levels and measures of performance to evaluate contract compliance coupled with bonding/payment schedules.

- ❑ **Yes**
- ❑ **No**

Comments

10. What bidding process might be appropriate for a warranty-based contract?

(a) Prequalification before receipt of invitation to bid?

- ❑ **Yes**
- ❑ **No**

Comments

(b) Review and approval of proposed work, with contract award to the lowest bidder with approved program of work?

- ❑ **Yes**
- ❑ **No**

Comments

11. Will the use of warranty based contracts in highway construction have a positive effect on the quality of the job done?

- ❑ **Yes**
- ❑ **No**

Comments

12. Will the use of warranty based contracts improve the relationship between the owner (the motoring public, as represented by MDT) and the contractor?

- ❑ **Yes**
- ❑ **No**

Comments

Other Comments (use additional sheets if necessary)